MODELLING EXPORT ACTIVITY OF ELEVEN APEC COUNTRIES, 1978-97

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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. The new approach is based on a panel data framework (instead of a simple cross sectional or time series approach) where the additional information available from using both types of data (i.e. cross sectional and time series) is utilised to properly model all the specific effects. The model is applied to a panel of APEC countries.

JEL classification: C23, F17
Key words: Gravity model, Panel data, Fixed effects model, Export flows, APEC countries.

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1. Introduction

Modelling and predicting foreign trade flows has long been an important task in international economics. For well defined areas, or trading blocks, such as the European Union (EU), the Southern Cove Common Market (MERCOSUR) or the Asia-Pacific Economic Cooperation (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,

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etc.) of the exporting and importing countries, and possibly the business cycle as well.

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 success in explaining and predicting different types of flows. In the case of modelling trade flows, they consistently exhibit high statistical explanatory power, but have been criticized during early applications for their apparent lack of theoretical foundations (Tinbergen (1962) and Pöyhönen (1963)). Later Linnemann (1966) and Aitken (1973) justified such 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. Thursby 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 justified by the underlying theoretical model. Anderson (1979) and Oguledo and MacPhee (1994) used a (linear) expenditure system to derive their models while Bergstrand (1985) 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, such models were estimated using data from 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 (Thursby 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 the business cycle 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, and indeed to separate these two effects at all. For example, if X is the export volume of country i to country j and Z is the export volume of country j to country i in the sample and important explanatory variables are the growth rates in X, say a, and in Z, say b, it is hard to separate the effect that a and b have on X from what they have on Z.

In this paper we use a generalised gravity model, allowing for proper representation of local and target country effects and also the business cycle.[1] This approach is based on a panel data framework (instead of simple cross sectional, time 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 apply this model to a panel of 11 APEC countries.

2. The Model

We use here the basic form of the gravity model, where no prices appear in the equation. It is, however, augmented by some financial variables.

$$\begin{aligned}\ln EXP_{ijt} = {} & a_i + g_j + l_t + b_1 \ln GDP_{it} + b_2 \ln GDP_{jt} + b_3 \ln POP_{it} + b_4 \ln POP_{jt} \\ & + b_5 \ln FCR_{jt} + b_6 \ln RER_{ijt} + b_7 \ln DIS_{ij} + u_{ijt}\end{aligned} \quad (1)$$

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

GDP_{it} is the GDP in country i at time t, and the same for GDP_{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;
DIS_{ij} is the distance between countries i and j;

[1] Some of the theoretical results are presented in Mátyás (1997) and (1998).

i = 1,..., N, j = 1,..., i - 1, i + 1,..., N + 1, where the N + 1-th element here is the rest of the world, t = 1,..., T; a_i is the local country effect; g_j is the target country effect; l_t is the time (business cycle) effect, and; u_{ijt} is a white noise disturbance term.

From an econometric point of view the a, g and l specific effects can be treated as random variables (an error components approach) or fixed parameters (a 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

$$y = D_N\alpha + D_J\gamma + D_T\lambda + Z\beta + u \quad (2)$$

where **y** is the vector of observations of the dependent variable *EXP*

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

Z is the matrix of observations of the explanatory variables in (1), organised in a similar way to y, D_N and D_T are dummy variable matrices ($\mathbf{D}_N = \mathbf{I}_N \otimes ?_{NT}$, $\mathbf{D}_T = ?_{N^2} \otimes \mathbf{I}_T$, where ι is the vector of ones with its size in the index), α is an (N × 1), λ is a (T × 1), γ is an ((N + 1) × 1), ß is a (K × 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 × T) × (N + 1)) matrix is a bit more complex:

$$\mathbf{D}_J = \begin{bmatrix} \tilde{\mathbf{I}}^{(1)} \\ \vdots \\ \tilde{\mathbf{I}}^{(N)} \end{bmatrix}$$

where

$$\mathbf{I}^{(1)} = \begin{bmatrix} \mathbf{0} & \mathbf{I}_N \end{bmatrix} \quad \text{and} \quad \tilde{\mathbf{I}}^{(1)} = \mathbf{I}^{(1)} \otimes \mathbf{?}_T$$

$$\mathbf{I}^{(2)} = \begin{bmatrix} \mathbf{1} & & \\ & \mathbf{0} & \mathbf{I}_{N-1} \end{bmatrix} \quad \text{and} \quad \tilde{\mathbf{I}}^{(2)} = \mathbf{I}^{(2)} \otimes \mathbf{?}_T$$

$$\vdots$$

$$\mathbf{I}^{(N)} = \begin{bmatrix} \mathbf{I}_{N-1} & \mathbf{0} & \\ & & \mathbf{1} \end{bmatrix} \quad \text{and} \quad \tilde{\mathbf{I}}^{(N)} = \mathbf{I}^{(N)} \otimes \mathbf{?}_T$$

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 that $l_{t=1} = 0$ is imposed on the model. When time series data is used $N = 1$ and the restriction $a_{i=1} = 0$ is imposed, while when panel data is used there are no such necessary restrictions. Unfortunately, none of the previous applications of this model took into account the local, target and time effects, thus implicitly imposing the unnecessary restrictions that $a_i = g_j = l_t = 0$ for all i, j and t. These are unlikely to be correct and moreover can be easily tested for in the general specification of (1).

3. The data

The Asia-Pacific Economic Cooperation (APEC) was established in 1989 by the following 12 countries: Australia, Brunei, Canada, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand and the United States. Since then 9 other countries have joined this group: China, Taipei and Hong Kong in 1991, Mexico and Papua New Guinea in 1993, Chile in 1994, and Peru, Russia and Vietnam in 1998. In this study, however, we focus on the original members who, presumably, had relatively stronger economic ties over the whole sample period, 1978 to 1997. The only exception is Brunei, for which most of the necessary international trade data is unavailable. All data except DIS_{ij}, come from two types of International Monetary Fund (IMF) publications: the yearbooks of International Financial Statistics (IFS) for 1995, 1996 and 1998, respectively and the yearbooks of Direction of Trade Statistics (DOTS) for 1982, 1987, 1989, 1995 and 1998. As for definitions, country composition and classification in general, these publications are consistent with each other. The data comprise annual measures for 1978-1997 of the following variables:

EXP_{ij} : Export from country i to country j in terms of millions of 1995 US dollars. It is calculated from export in current US dollars on the free-on-board (f.o.b.) basis, that is by the value of the goods at the border of the exporting country, deflated by the export (goods and services) deflator. 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.
GDP_i : Gross Domestic Product of country i in millions of 1995 US dollars.
POP_i : Population of country i in thousands of people.
FCR_i : Foreign currency reserves (foreign exchange) of country i in millions of SDR.
RER_{ij} : Real exchange rate between countries i and j, calculated as the annual average of the national currency unit of country j per US dollar divided by the annual average of the national currency unit of country i per US dollar.
DIS_{ij} : Distance between countries i and j in nautical miles, measured as the average length of the shipping routes between the major ports.[2]

Besides the APEC countries the European Economic Area (EEA) and Switzerland are also involved in the analysis.[3] Being the most significant economic trading block of the world, EEA is used as a

[2] Source: http://www.ports.com.

[3] For the sake of simplicity we shall refer to this group of countries as EEA.

proxy for the "rest of the world". Although EEA was established only in 1994, we consider the "rest of the world" over the whole sample period as the group of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. For this block of countries we computed *GDP*, *POP* and *FCR* as the sum of the individual countries' observations. The exchange rate is with respect to the ECU.

4. Empirical results

Table 1 contains the simple OLS results for the fully restricted model - no local or target country effects, and no time effects (*Model A*). Table 2, augments the model by also including local effects (*Model B*). The results of including local and target effects are presented in Table 3 (*Model C*). Finally, the results of the fully unrestricted model with local, target and time effects are presented in Table 4 (*Model D*).

The Effect of Explanatory Variables

Crudely speaking, domestic only variables (indexed by *it*) correspond to the *supply* of exports, whilst target only variables (*jt*'s) apply to the *demand* for exports. Variables varying by local and target country (*ijt*'s) are a hybrid of both supply and demand factors.

Model A

In the simplest restricted gravity model, Table 1, both domestic and target country GDP are significant and positive, with the former effect dominating. Target country GDP is a measure of the extent that exports are "sucked in" as the foreign economy grows. Local country GDP is simply a measure of the size of the (domestic) economy in terms of available goods - one would expect larger economies to export more. Similarly, with population, with now domestic levels helping to define production possibility frontiers, and foreign levels, potential overseas markets/demand. However, in this specification, these population effects appear to perversely signed, indicating that larger domestic economies and larger potential markets, actually decrease export flows.

The level of foreign currency reserves of the importing country, in this specification, appears to exert a strong positive effect on export flows. However, the other financial variable, the exchange rate, appears surprisingly insignificant. Being defined in terms of foreign currency per unit of domestic currency, it is correctly signed (that is, a domestic currency appreciation is represented by a rise in the real exchange rate), but its apparent insignificance may seem puzzling. It is, however, a sure sign of some kind of specification error, as we are going to show that this model is underspecified. Finally, as expected, distance exerts a strong negative impact on export flows. The (adjusted) explanatory power of this model is at around 50%.

Table 1. *Model A*
Estimation results for the fully restricted model
$a_i = g_j = l_t = 0$ for all i, j and t

Variable	Coefficient	Standard Error		*t*-statistic
Constant	5.5667	0.4232		13.154
ln GDP_{it}	0.8947	0.0275		32.558
ln GDP_{jt}	0.1440	0.0362		3.983
ln POP_{it}	-0.4792	0.0332		-14.453
ln POP_{jt}	-0.4541	0.0336		-13.496
ln FCR_{jt}	0.5561	0.0303		18.354
ln RER_{ijt}	-0.0054	0.0102		-0.532
ln DIS_{ij}	-0.8452	0.0440		-19.190
Observations	2420			
RSS	5611.481			
adj. R^2	0.50294			
F-tests[#]	*F*-statistic	df_1	df_2	*F*-crit
A vs *B*	355.181	10	24022	1.83
A vs *C*	533.038	21	39123	1.57
A vs *D*	291.883	40	72	1.39

[#]: *Model X* vs *Model Y.*

Model B

When exporting country effects are additionally included, Table 2, we immediately observe that there is indeed, unobserved country heterogeneity. That is, some countries quite clearly have differing propensities to export, even once we have conditioned on identified observed heterogeneity of both the local and target country. Individually, all of the exporting country effects are strongly significant, with the possible exception of Malaysia. Moreover, the *F*-test clearly rejects the null hypothesis that these local country effects are jointly zero (see Table 1).

Table 2. *Model B*

Estimation results allowing for local effects, $g_j = l_t = 0$ for all j and t

Variable	Coefficient	Standard Error		*t*-statistic
Constant	10.9884	0.2780		39.526
ln GDP_{it}	-1.96E-07	6.55E-08		-2.999
ln GDP_{jt}	8.07E-07	1.99E-08		40.518
ln POP_{it}	7.79E-05	3.16E-06		24.668
ln POP_{jt}	-5.68E-06	4.47E-07		-12.710
ln FCR_{jt}	-3.23E-06	5.34E-07		-6.045
ln RER_{ijt}	5.97E-04	8.65E-05		6.895
ln DIS_{ij}	-0.8244	0.0292		-28.255
Australia	0.8125	0.0984		8.255
Indonesia	-12.8383	0.4777		-26.876
Japan	-4.3005	0.2889		-14.885
Korea	-1.4306	0.1117		-12.813
Malaysia	-0.1054	0.1025		-1.029
New Zealand	0.3562	0.1134		3.142
Philippines	-5.1805	0.1538		-33.678
Singapore	1.7970	0.1197		15.011
Thailand	-3.5261	0.1390		-25.359
USA	-13.3497	0.5927		-22.525
Observations	2420			
RSS	2263.891			
adj. R^2	0.79863			
F-tests[#]	*F*-statistic	df_1	df_2	*F*-crit
B vs *C*	280.877	11	23912372	1.79
B vs *D*	109.842	30		1.46

Note: Since this model includes an intercept term one dummy variable (Canada) has been omitted.[#]: *Model X* vs *Model Y*.

Of these effects, the U.S.A. and Indonesia appear to have the lowest propensities to export to the APEC region (relative to the omitted country of Canada), and Singapore then Australia, the highest. Including local country effects, does however, appear to cause local country GDP, the exchange rate and target country population and foreign currency reserves, to have superficially perversely signed effects. The addition of these effects though, quite significantly increases the explanatory power of the model.

Model C

The perverse signs on these explanatory coefficients are reversed however, when we additionally include target country effects (Table 3). Moreover, the explanatory variables are now "correctly" signed and strongly significant. All of the local country effects are now strongly significant, but now Indonesia, Japan, the Philippines and the U.S.A. appear to have the lowest (relative) propensities to export, and Singapore and New Zealand the highest.

In terms of the additional target country effects, they are again all highly significant (with the possible exception of Thailand). Moreover, their inclusion raises the explanatory power of the model to a very high 91%, and one clearly rejects the null hypothesis that they are jointly equal to zero (see Table 2).

Those countries that appear to have a low (relative to the omitted country of Canada) propensity to import from exporters in the APEC region are the large trading "countries" of the European Union and U.S.A. Those with a high propensity to import are Singapore and New Zealand.

Note: Since this model includes an intercept term two dummy variables (Canada as local and target country) have been omitted.[#]:

Model X vs *Model Y*.

Table 3. *Model C*
Estimation results allowing for local and target effects, $l_t = 0$ for all t

Variable	Coefficient	Standard Error		t-statistic
Constant	-47.1178	2.4201		-19.469
$\ln GDP_{it}$	0.9100	0.0892		10.205
$\ln GDP_{jt}$	0.7579	0.0783		9.685
$\ln POP_{it}$	1.7903	0.3414		5.244
$\ln POP_{jt}$	2.0465	0.1807		11.327
$\ln FCR_{jt}$	0.0760	0.0324		2.347
$\ln RER_{ijt}$	-0.4573	0.0435		-10.512
$\ln DIS_{ij}$	-0.8752	0.0245		-35.686
Australia	1.3755	0.1591		8.645
Indonesia	-6.8533	0.6625		-10.345
Japan	-4.7570	0.4014		-11.850
Korea	-3.4963	0.2808		-12.451
Malaysia	1.6042	0.1860		8.624
New Zealand	4.1009	0.6201		6.613
Philippines	-3.5879	0.3839		-9.346
Singapore	5.9859	0.7048		8.493
Thailand	-2.6736	0.3292		-8.122
USA	-3.6098	0.6517		-5.539
Australia	1.0996	0.1249		8.806
Indonesia	-1.0459	0.1557		-6.719
Japan	-1.1937	0.2451		-4.870
Korea	2.1290	0.2202		9.667
Malaysia	1.8409	0.2291		8.035
New Zealand	4.1932	0.4281		9.795
Philippines	-0.5902	0.1520		-3.883
Singapore	6.1121	0.5125		11.926
Thailand	-0.1574	0.1355		-1.162
USA	-3.9391	0.4575		-8.610
EEA	-5.5324	0.5172		-10.696
Obs. 2420		RSS =987.651		adj. $R^{2=}$ 0.91175
F-tests[#]	F-statistic	df_1	df_2	F-crit
C vs D	5.285	19	2372	1.57

Model D

Finally, Table 4 contains the results of the fully unrestricted model, where we additionally include time (business cycle) effects. Although the explanatory power of the model is only marginally increased from *Model C*, all of the time effects are individually significant, and moreover one would clearly reject the null hypothesis that they are jointly equal to zero (see Table 3). All of the time effects are positive, relative to the omitted year of 1978. These effects are plotted in Figure 1. The shaded areas represent approximate periods of growth recessions in the Pacific Region. As expected, the downturns in export flows are generally associated with economic growth downturns in the region.

Local and target GDP and population continue to exert a strongly significant positive impact on export flows, with the former having a larger effect in the local country, and the latter in the target country. That is, the capacity effect of domestic GDP outweighs the demand pull effect of target country GDP, and the production possibility frontier effect of domestic population is outweighed by the potential market effect of foreign population. Due to price effects, the exchange rate adversely affects exports flows, as does the distance between countries. Both of these effects are strongly statistically significant. Finally, of the explanatory variables, only the foreign currency reserves of the importing country do not appear to be strongly significant. However, this may be because this variable simply represents the sum of past trade flows, and has little bearing on contemporaneous ones.

The countries which appear to exhibit the lowest (relative) conditional propensity to export are: Indonesia, Japan, Korea and the Philippines. Those with the highest are Singapore and New Zealand. Those countries with the lowest (relative) conditional propensity to import are EEA and U.S.A., those with the highest are Singapore, New Zealand and Korea.

Table 4. *Model D*
Estimation results for the unrestricted model

Variable	Coefficient	Standard Error	*t*-statistic
Constant	-43.0310	3.9800	-10.812
ln GDP_{it}	0.8383	0.0949	8.836
ln GDP_{jt}	0.6888	0.0876	7.860
ln POP_{it}	1.5804	0.3838	4.121
ln POP_{jt}	2.0072	0.1804	11.124
ln FCR_{jt}	0.0555	0.0341	1.625
ln RER_{ijt}	-0.4626	0.0428	-10.790
ln DIS_{ij}	-0.8756	0.0241	-36.301
Australia	1.2334	0.1913	6.448
Indonesia	-6.6040	0.7094	-9.309
Japan	-4.3113	0.5221	-8.257
Korea	-3.4845	0.2803	-12.431
Malaysia	1.3402	0.2473	5.419
New Zealand	3.5008	0.7653	4.574
Philippines	-3.5861	0.3853	-9.308
Singapore	5.3257	0.8621	6.178
Thailand	-2.6681	0.3309	-8.063
USA	-2.9669	0.8084	-3.670
Australia	1.0472	0.1280	8.182
Indonesia	-1.0348	0.1535	-6.741
Japan	-0.9162	0.2934	-3.122
Korea	2.1379	0.2168	9.862
Malaysia	1.6761	0.2487	6.739
New Zealand	3.9333	0.4539	8.666
Philippines	-0.7099	0.1641	-4.327
Singapore	5.8855	0.5287	11.132
Thailand	-0.2312	0.1403	-1.648
USA	-3.6568	0.4861	-7.523
EEA	-5.1637	0.5594	-9.231
1979	0.3454	0.0817	4.227
1980	0.5979	0.0827	7.226
1981	0.6082	0.0848	7.173
1982	0.5460	0.0867	6.299
1983	0.4750	0.0899	5.283
1984	0.4683	0.0938	4.994

Table 4. *(cont.)*			
Variable	Coefficient	Standard Error	*t*-statistic
1985	0.3817	0.0963	3.965
1986	0.5543	0.1209	4.584
1987	0.5592	0.1269	4.408
1988	0.5262	0.1325	3.971
1989	0.5237	0.1381	3.792
1990	0.5024	0.1449	3.467
1991	0.5289	0.1519	3.481
1992	0.6463	0.1593	4.056
1993	0.5900	0.1675	3.523
1994	0.5952	0.1720	3.460
1995	0.2180	0.1008	2.163
1996	0.3766	0.1058	3.560
1997	0.4868	0.1134	4.291
Observations	2420		
RSS	947.541		
adj. R^2	0.91465		

Note: Since this model includes an intercept term three dummy variables (Canada as local and target country and also 1978) have been omitted.

Thus Singapore and New Zealand appear to have the more open economies, having high propensities to both import and export, once we have conditioned on business cycle effects and local and target country related fundamentals. On the other hand, EEA and U.S.A. appear to have a somewhat closed economy, especially with regard to APEC exports.

5. Concluding Remarks

From the above *F*-tests and the individual significance of most of the dummy variables, it is quite clear that *Model D* is the preferred specification. It is superior both from a statistical and an economic point of view, as it affords a better understanding of the data. Using this model, we are able to identify those countries with strong (and conversely weak) propensities to both import and export. This is extremely important for policy setting both by, and within, the trading bloc. For example, APEC members wanting to pursue export led expansionary policies, would do well to look to Singapore and New Zealand as potential markets. Moreover, superficially closed economies may not be so (c.f. Japan), once one has correctly taken into account business cycle effects and local and target country fundamentals. It is only by specifying the fully unrestricted gravity model, that one can adequately answer such questions. Policy could well be misdirected if such effects are ignored, that is, based upon traditional Gravity models. In terms of explanatory variables, if we were to (erroneously) focus on the restricted (traditional) Gravity model, the effect of foreign GDP would be vastly under estimated. We would also have wrongly concluded that local and target population has a detrimental affect on exports. The effect of foreign currency reserves on export flows would have been over emphasized and we would have wrongly concluded that the exchange rate did not affect export flows.In summary, it is imperative that policy is set in accordance not only with the correct response parameters (based upon the fully specified model), but also that the various member states' propensities to import and export are sufficiently, and adequately, taken into account.

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