Production profile compatibility in a dynamic gravity model of trade*

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Abstract

The extent to which what countries produce makes them ‘compatible’ to trade is an issue that has so far eluded the popular Gravity framework of international exchange. Efforts to account for exogenous sources of comparative advantage, via regressors such as per capita GDP, do not seem to adequately capture either differential technologies or differential factor endowments across countries (see Melitz, European Econ. Review, 2007). At the same time, the recent findings of Debaere (Journal of Intern. Econ., 2005) suggest that reliance on a new trade theory justification for the model does not itself justify the presumption that the degree of specialization across countries is sufficiently uniform or pronounced to render them, ceteris paribus, equally trade compatible. To address this long-standing weakness of the Gravity model we introduce a dynamic specification that relies on trade reciprocity to account for the extent to which the production profiles of different countries are trade compatible. The model is estimated using an APEC panel of data for the years 1973 to 2000. Our results provide strong support for the view that the neglected measure of production profile compatibility plays a important role in the Gravity setting.

JEL Classification: C33, F14, F15

Keywords: Dynamic gravity model, production compatibility, specialization, cone of diversification.

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Abstract

The extent to which what countries produce makes them ‘compatible’ to trade is an issue that has so far eluded the popular Gravity framework of international exchange. Efforts to account for exogenous sources of comparative advantage, via regressors such as per capita GDP, do not seem to adequately capture either differential technologies or differential factor endowments across countries (see Melitz, *European Econ. Review*, 2007.) At the same time, the recent findings of Debaere (*Journal of Intern. Econ.*, 2005) suggest that reliance on a new trade theory justification for the model does not itself justify the presumption that the degree of specialization across countries is sufficiently uniform or pronounced to render them, *ceteris paribus*, equally trade compatible. To address this long-standing weakness of the Gravity model we introduce a dynamic specification that relies on trade reciprocity to account for the extent to which the production profiles of different countries are trade compatible. The model is estimated using an APEC panel of data for the years 1973 to 2000. Our results provide strong support for the view that the neglected measure of production profile compatibility plays an important role in the Gravity setting.

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1 Introduction

The Gravity model arguably represents the workhorse of empirical investigations in international trade. Its modern application transcends the traditional use of examining international flows in final commodities (see, for example, Anderson and Wincoop 2003, and Rose 2005) and includes the study of foreign direct investment (see, amongst others, Buch and Piazolo 2001, and Mauro 2000) as well as labour migration (Karemera, Oguledo, and Davis 2000.) The rising popularity of the Gravity approach may be attributed to a number of factors and perhaps most importantly to the widespread recognition that it has become sufficiently developed over time. On the theoretical front the framework now relies on well-considered foundations (Anderson 1978, Helpman 1987, Deardorf 1995, and Evenett and Keller 2002), and the latest model specifications are in line with the current econometric literature (see, for example, Matyas 1997, 1998 and Egger 2000 .)

Still, recent work by Debaere (2005) suggests that the model can benefit from further refinement. This already well known contribution finds that the impact of relative country size on trade flows depends critically on the level of development of the countries considered. In particular, similar country size is found to be positively related to trade volumes across industrialized countries, but negatively related to the flow of trade across developing nations. This result highlights a key weakness of standard formulations of the Gravity approach. As explained by Helpman (1987), such formulations rely on the assumption of complete specialization, with each country producing differentiated products. Reliance of the Gravity approach on this assumption is intuitive. Given the absence of exogenous factors of comparative advantage from this framework,¹ ‘love of variety’ is by default a key driver of international trade (see for example Krugman 1979, 1980.) In this light, relative country size assumes a particularly prominent role in the analysis. It captures the scope of potential trade between any two countries, and is expected to relate positively to the volume of trade. Put simply, large countries are expected to trade high volumes with other large countries, while the volume of trade between large and small countries is expected to be small (at least as compared to their cumulative GDP.) Debaere’s (2005) findings contradict this premise suggesting that there is more to the story of what makes

¹Notwithstanding the fact that, at least indirectly, relative factor endowments are captured by measures of per capital GDP (see Serlenga and Shin 2004) as well as by distance (see Melitz 2007).
the production profiles of different countries ‘trade compatible’.

One possible explanation, recently advocated by Feenstra (2004, p. 149), relies on the notion that the extent of a country’s specialization in differentiated products relates to its level of development. According to this author, the process of industrialization increases any given country’s capacity to specialize and results in developed nations producing uniquely identifiable commodities while developing nations supply, more-or-less, easily substitutable low-skill products and raw material. This hypothesis is not easy to investigate empirically given that seemingly identical raw material and resources such as, say, crude oil, often differ substantially in their characteristics and uses depending on origin (Kohli and Morey 1990.) However, to the extent that Feenstra’s (2004) view might describe the link between industrialization and product differentiation accurately, it has the potential to explain how production profile compatibility can vary from any one pair of countries to another in a manner that is independent of their relative size or other explanatory variables commonly used in Gravity equations. Of course, there might be other explanations for Debaere’s (2005) results. For example, it may very well be the case that, rather than levels of industrialization, production profile compatibility depends critically on exogenous sources of comparative advantage that are not explicitly considered by the Gravity approach as recently argued by Melitz (2007). In addition, it must be the case that the extent to which countries specialize in particular sets of commodities partly depends on their adopted trade policies (see for example Tombazos 2003b.) This is yet another important element of the trade flow puzzle that is typically neglected in the Gravity framework.

Whatever its key determinants, production profile compatibility is an important issue that has so far eluded the Gravity approach, often leading to misspecified implementations of this framework. This contribution represents an effort to ameliorate this deficiency. Our approach relies on the notion that irrespective of what drives the production profiles of different countries to be ‘trade compatible’ (levels of industrialization, endowments, trade policies, and perhaps other factors not considered here) the extent of this compatibility will manifest itself in the form of high reciprocal trade flows. In this light, we use a measure of this reciprocity to capture the effects of matching production patterns while addressing the econometric complexities that have previously hindered this approach. In
recognition of the fact that the extent to which production profiles are compatible is likely to have important repercussions on future trade volumes, we also allow our model to be dynamic and to account for partial adjustments to disequilibria. Incorporating dynamics in such a model has the benefit of not only improving understanding of the temporal evolution of trade flows but also contributing to its forecasting properties, both of which have important policy implications.

2 The Model

2.1 Reciprocity

The extent of cross country specialization has been the subject of much research in recent years (see for example Davis and Weinstein 2001 and Schott 2003.) Relevant findings suggest that traditional product categorizations hide fundamental and profound cross-country specific product differences. They further demonstrate the existence of multiple diversification cones that partition clusters of countries specializing in largely exclusive subsets of commodities (see in particular Schott 2003.) Such results provide strong to the ‘love of variety’ justification of the Gravity approach that relies heavily on the assumption of cross-country specialization. However, they also emphasize the need to explicitly take into account the extent to which specialization profiles of the trading nations considered by any given implementation of the Gravity approach fall into different cones of diversification or are ‘trade compatible’.

To illustrate how our approach of accounting for production profile compatibility fits in the relevant literature, consider the standard formulation of a typical Gravity equation given by

\[ y_{ijt} = \mathbf{x}'_{ijt} \mathbf{\beta} + \alpha_i + \gamma_j + \lambda_t + u_{ijt} \quad i,j = 1, \ldots, N, \ i \neq j, \ t = 1, \ldots, T \] (1)

where: \( y_{ijt} \) represents the volume of trade exports from country \( i \) to \( j \) at time \( t \); \( \mathbf{x}_{ijt} \) is the vector of structural explanatory variables (such as GDP, population, and the exchange rate), which may or may not vary in the complete \( ijt \) index space; \( \alpha_i, \gamma_j \) and \( \lambda_t \) are the

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\(^2\)Of course, in models that, unlike the the Gravity framework, rely explicitly on exogenous sources of comparative advantage that prevail in the context of perfect (rather than monopolistic) competition, specialisation is not a requirement for trade.
unobserved specific effects (such as unobserved supply, demand, and time effects); $\beta$ is the unknown parameter vector - the item of interest; $N$ and $T$ correspond to the number of countries and time periods, respectively; and $u_{ijt}$ is the disturbance term. The unobserved effects ($\alpha_i$, $\gamma_j$, and $\lambda_t$) can be considered fixed (to be estimated) or random (part of the disturbance term of the model).\textsuperscript{3}

To account for interaction effects in the standard formulation of the Gravity equation, Wall and Cheng (1999) and Egger and Pfaffermayr (2003) have argued for the inclusion of boolean variables. In particular, Wall and Cheng (1999) propose the addition of a country-pair coefficient $\alpha_{ij}$ in equation (1) requiring the estimation of a total of $(N - 1)^2$ country-pair specific parameters. This may be viewed as a comprehensive approach of accounting for cross-country interactions. However, the number of additional parameters that require estimation often becomes unreasonably large (in their case to more than 800!), rendering econometric estimation intractable. By contrast, Egger and Pfaffermayr (2003) favour the inclusion of a small number of interaction parameters to capture elements such as ‘common border’ and ‘common language’ which generally results in a better fitting model.

In what follows we propose a model that is sufficiently more parsimonious than Wall and Cheng (1999) to be econometrically tractable, yet adequately more general than Egger and Pfaffermayr (2003) to capture trade compatibility accurately. To gain a handle on trade compatibility we consider that it is perhaps best reflected in the high correlation between reciprocal trade flows. Countries typically exhibit larger export flows to those countries from which they import relatively more. This is reflected in Figure 1 where we plot these reciprocal export flows (in constant $\$/US) for each country pair from a sample of APEC countries over the years 1973 - 2000 (see Section 3.1.) Our model relies on this reciprocity to measure varying degrees of trade compatibility. In the interest of a comprehensive treatment of reciprocal trade we also recognize that the volume of exports from any one country to another must depend on how much that country exports in total to all other countries. However, the direction of this relationship may not always be easy to infer \textit{a priori}. On the one hand, total exports represent an ‘activity’ (or income) variable in the implicit demand schedule setting; hence, as ‘total’ exports increase as a result of,

\textsuperscript{3}It should be noted that almost all empirical applications in the literature have relied on the fixed effects specification; an exception is Harris and Matyas (2001).
Figure 1: "Trade Compatibility" as Measured by the (Log of) Bilateral Export Flows

say, an export-led drive, exports to individual countries should also rise (although to avoid formulating identities, exports to the country in question are not included in this sum.) On the other, for any given year the total export potential of any given country may be viewed as limited (recall that these models are typically static in their structure and as such represent equilibrium levels.) Hence, for a fixed amount of exports, as total exports to all but one of the countries considered increase, exports to the remaining country must necessarily decrease. These considerations provide strong support for augmenting the Gravity equation with a \textit{quasi}-total exports variable.

Of course, in light of the issues outlined above, it is clear that the resulting model is a highly interrelated simultaneous system. If all these direct and indirect effects are taken into account, a near accounting-type identity results. Such a model would fit well the data, but would provide little insight regarding the behavior of the economy.

What we propose here instead is to incorporate these direct and indirect interaction effects in the econometric specification in a parsimonious way. The standard econometric specification (1) is consequently augmented with two additional variables, $y_{jit}$ and $y_{ij^*t}$, where the former is the reciprocity interaction variable that accounts for trade compatibility and the latter corresponds to \textit{quasi}-total exports. A formal characterization of these
variables in the context of the adopted model is provided below:

\[ y_{ijt} = y_{ijt} + y_{ij} + y_{i} + y_{j} + u_{ijt}, \]  

\[ y_{ij^*t} = \sum_{j} y_{ijt}, \quad j = 1, \ldots, j-1, j+1, \ldots, N, \quad j \neq i, \]

where \( \delta \) and \( \delta^* \) correspond to the parameters associated with \( y_{ijt} \) and \( y_{ij^*t} \), respectively. Parameter \( \delta \) reflects the importance of reciprocity or trade compatibility and is expected to be positive.\(^4\) It should be noted that \( \delta \) and \( \delta^* \) could also have \( i \) and \( j \) indexes, but this would contravene the objective of a parsimonious approach.

It is interesting to note that incorporating trade compatibility in the analysis extends the Gravity literature closer to that of demand systems. In fact, writing equation (2) in multiplicative form and restricting \( \delta^* \) to unity renders the model in the form of a (pseudo-) share equation.

Of course, given that variables \( y_{ijt} \) and \( y_{ij^*t} \) are likely to be correlated with the stochastic elements of the model, the specification outlined in (2) is a quasi-simultaneous system. Moreover, due to national accounting identities, exports and national income flows will be jointly determined. In this light, the common estimation methods of least squares and maximum likelihood are generally expected to lead to biased and inconsistent results. This is especially likely to be the case if the unobserved effects of equation (2) are assumed to be random. Under the circumstances we opt for a Generalized Method of Moments (GMM) estimation that facilitates consistent estimation without the explicit use of appropriate instruments which, at any rate, are always notoriously difficult to identify.

### 2.2 Dynamics

It is surprising that almost all empirical applications of the Gravity model rely on a static perspective, implicitly imposing the assumption that trade flows are in perpetual equilibrium. There is much evidence to suggest that important trade partnerships, as often reflected in Preferential Trade Agreements (PTAs), Custom Unions, and the like, have knock-on effects on future trade flows (see, for example, Krugman 1993, Baldwin

\(^4\)A negative sign would imply a bilaterally unbalanced system, reflecting the type of unlikely scenario that would prevail in the presence of trade restrictions that do not elicit retaliation.
For this reason it is desirable to allow for the system to be temporarily out of equilibrium and to follow a partial adjustment path towards it.

At the same time, it is well known that the volume of trade between any two countries in any given year correlates with the previous year’s volume due to the relative stability of the factors that facilitate trade compatible production profiles (including exogenous sources of comparative advantage, levels of industrialization and so on.) Typically, in standard formulations such as (1), this issue is addressed using the usual ad hoc corrections (see for example Egger 2002.) However, it is well known that autocorrelated disturbances are frequently the result of misspecified dynamics in the structural specification of the model, which calls for a more comprehensive treatment of this issue.

Knock-on effects on the one hand, and classic sources of autocorrelation on the other, argue for the inclusion of lagged trade flows in the model. In this light, we extend earlier work in this area (Harris and Matyas 2001) by proposing a simple econometric specification that augments (2) in an effort to account for the role of dynamic reciprocity, on the one hand, and convergence to equilibrium, on the other. In particular, we propose the addition of three variables to (2): a lagged dependent variable, a lagged reciprocity variable, and a lagged quasi-total exports variable. The resulting model is

\[ y_{ijt} = y_{i;jt-1}\delta_1 + x_{ijt} \beta + y_{ijt}\delta + y_{ij;+t}\delta^* + y_{ij,t-1}\delta_2 + y_{ij;+t-1}\delta^*_3 + v_{ijt} \]

\[ v_{ijt} = \alpha_i + \gamma_j + \lambda_t + u_{ijt} \]

where the \( \delta_1, \delta_2 \) and \( \delta^*_3 \), parameters relate to the dynamic components.\(^5\)

In addition to the simultaneity issues that also pertain to (2), the complexity of estimating (4) is further exacerbated by the presence of lagged (endogenous) variables. There is much in the literature on panel data econometrics in the context of dynamic models (see, inter alia, Arellano and Bond 1991, Arellano and Bover 1995, Kiviet 1995, and Harris and Mátýás 2004.) However, the literature on dynamic Gravity models is much less developed.

In standard dynamic panel cases empiricists typically transform the model, generally by taking first differences, and applying a (linearized) implementation of the GMM after a suitable set of instruments is selected (see, for example, Arellano and Bond 1991.) The extent of simultaneity prevalent in our model complicates the implementation of such an approach.\(^5\)

As \( y_{ij,t-1} \) and \( y_{ij;+t-1} \) turned out to be exceedingly collinear in our data, only the latter was used in estimations of both the ‘static’ and ‘dynamic’ versions of the model.
approach, and argues in favour of a nonlinear GMM estimation. By contrast to the linear GMM approach, its non-linear counterpart does not require specification of appropriate instruments (although, asymptotic efficiency is increased if such instruments are in fact used.) So long as the number of moment conditions exceeds the number of parameters to be estimated, estimation can be based on the conditions that the variance of $u_{ijt}$ is constant and that all stochastic elements of equation (4) are independent.

It should be noted that given the structure of the model, there is a greater number of moment conditions available than in the case of the usual dynamic panel approach. This seems to facilitate asymptotic efficiency arguments that suggest using as many moment conditions as possible. However, as we explain elsewhere (Harris, Matyas, and Sevestre 2008), using an excessive number of such conditions in the context of finite samples is subject to a number of pitfalls. Here, the moment conditions used in the empirical application are, conditional on all of the explanatory variables of the model, that:

\[ E(v_{it}) = 0 \]  \hspace{1cm} (5)

and

\[ E(v'v) = \sigma_v^2 I + \sigma_\gamma^2 I + \sigma_\lambda^2 I + \sigma_u^2 I. \]  \hspace{1cm} (6)

It should be noted that conditions (5) and (6) yield a significant number of over-identifying restrictions.

The nonlinear GMM approach is in many ways ideal in the case of the Gravity model for the reason that it does not require use of orthogonality conditions concerning the strict exogeneity of the explanatory variables, or even the need for instrumental variables. After all, many of the explanatory variables of even the most basic formulations of the Gravity model cannot be considered strictly exogenous due to the various accounting identities implicit in the analysis (for example exports are part of GDP.) Note that a non-linear GMM approach does not appear to lend itself to a fixed effects treatment of equation (4) as there is the usual problem of incidental parameters in consistently estimating each of the separate sets of unobserved effects.
3 Empirical Application

3.1 The Data

For the empirical application, we closely follow the broad specifications and datasets of Harris and Matyas (2001) and Egger and Pfaffermayr (2003). The variables used are:

- **Dependent variable:**
  - (one plus) export flows from country \(i\) to country \(j\) in period \(t\), \(y_{ijt} = (1 + y_{ijt})\);
  - source: *IMF Direction of Trade Yearbook*.

- **Explanatory variables (*i.e.* those variables chosen to enter \(x_{it}\) in the basic specification):**
  - Real Gross Domestic Products of exporter and importer \((GDP_{it} \text{ and } GDP_{jt}, \text{ respectively})\); source: *World Bank World Tables*.
  - Local and target populations \((POP_{it} \text{ and } POP_{jt})\); source: *World Bank World Tables*.
  - Target country’s foreign currency reserves \((FCR_{jt})\); source: *IMF International Financial Statistics*.
  - The real exchange rate between the two countries \((RER_{ijt})\), defined as units of foreign currency per unit of domestic currency; source: *World Bank World Tables*.
  - Distance between the two countries in nautical miles \((DIS_{ij})\); the average length of the shipping routes between the major ports; source: http://www.ports.com.
  - Whether the countries share a common border \((BOR_{ij})\).
  - Whether the countries share a common language \((LAN_{ij})\).
  - Differences in relative factor endowments, proxied by differences in *per capita* GDPs \((RLF_{ijt})\). This variable is defined as in Serlenga and Shin (2004):
    \[
    RLF_{ijt} = |PCGDP_{jt} - PCGDP_{it}|
    \]
    where \(PCGDP\) corresponds to *per capita* real GDP.
Table 1: (Natural Log of) Total Exports by Country

<table>
<thead>
<tr>
<th></th>
<th>Australia</th>
<th>Canada</th>
<th>Indonesia</th>
<th>Japan</th>
<th>Korea</th>
<th>Malaysia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>7.24</td>
<td>6.66</td>
<td>6.93</td>
<td>8.49</td>
<td>7.06</td>
<td>6.66</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>1.15</td>
<td>2.16</td>
<td>1.92</td>
<td>1.41</td>
<td>1.75</td>
<td>1.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>New Zealand</th>
<th>Philippines</th>
<th>Singapore</th>
<th>Thailand</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>5.76</td>
<td>5.91</td>
<td>7.37</td>
<td>6.13</td>
<td>8.84</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>1.32</td>
<td>1.80</td>
<td>1.33</td>
<td>1.81</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Similarity in relative size of trading countries in terms of GDP ($SIM_{ijt}$), defined as in Serlenega and Shin (2004):

$$SIM_{ijt} = 1 - \left( \frac{GDP_{it}}{GDP_{it} + GDP_{jt}} \right)^2 - \left( \frac{GDP_{jt}}{GDP_{jt} + GDP_{it}} \right)^2$$

As per the discussion of earlier sections we include the trade reciprocity variable and its lag ($y_{jit}$ and $y_{ji,t-1}$); and the (lagged) quasi-total exports of country $i$ variable ($y_{ij,t-1}$).

All non-boolean variables are entered in natural logarithm form (including the dependent variable) and all monetary variables are measured in constant $US$.

Our dataset represents 11 countries of the APEC trading bloc (Australia, Canada, Indonesia, Japan, Korea, Malaysia, New Zealand, the Philippines, Singapore, Thailand, and the United States) over the years 1973 to 2000. As we argue elsewhere (Tombazos 2003a), international trade data that has not benefited from more than 6, or so, years of revisions lacks accuracy, so we decided to avoid data for years after 2000. The European Union, EU, trading bloc was used as a proxy for the ‘rest of the world’ such that $i = 1, \ldots, N = 11$ and $j = 1, \ldots, J = EU$. Table 1 presents (one plus the natural logarithm of real) export flows from each country over the sample period. Not surprisingly, Japan and the US are the two major exporters in the region, followed by Singapore and Australia. Smaller exporters are the Philippines and New Zealand, with those from Canada being the most volatile.

Selected summary statistics for key variables utilized in the analysis are presented in Table 2. The average distance between trading partners is just under some 4,000 nautical miles, and only 7% of the countries share a common border. However, of more interest, are the sample correlations between the (potential) explanatory variables, and export flows.
As per our earlier discussion, there is a strong bivariate correlation between exports flows and reciprocal export flows ($\rho = 0.88$). There are also strong bivariate correlations, but of a lesser extent and of an approximately equal magnitude ($\rho \approx 0.5$) between export flows and: $y_{ij \cdot t}$; $GDP_{it}$; $GDP_{jt}$; and $FCR_{jt}$. Bilateral population correlations are much weaker, and there appears to be very little bivariate correlation between export flows and either of $DIST_{ij}$ and $RER_{ijt}$.

### 3.2 Results

Table 3 presents a series of estimation results corresponding to competing specifications of the framework that we propose. The first four models are estimated using OLS. Model 1 is the standard Gravity model with no unobserved effects; Model 2 is the same with the additional variables $y_{jit}$ and $y_{ij \cdot t-1}$; Model 3 is similar to Model 2 but includes all three sets of unobserved (fixed) effects; Model 4 builds on Model 3 by additionally including $y_{ij,t-1}$ and $y_{ji,t-1}$, but has no unobserved effects; whilst Model 5 is the fully specified model, with all variables and unobserved (random) effects and is estimated by GMM.\(^6\)

\(^6\)As noted earlier, due to the well known problem of incidental parameters, a fixed effects treatment is not possible in the context of a non-linear GMM framework.
Table 3: Gravity Model Estimation Results, Absolute t-statistics in Parentheses, Model Size is 3,388

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.578**</td>
<td>-1.710**</td>
<td>2.599</td>
<td>-0.139</td>
<td>0.699</td>
</tr>
<tr>
<td>GDP$_{it}$</td>
<td>0.772**</td>
<td>0.242**</td>
<td>0.738**</td>
<td>0.035**</td>
<td>0.147**</td>
</tr>
<tr>
<td></td>
<td>(6.62)</td>
<td>(8.22)</td>
<td>(9.33)</td>
<td>(3.96)</td>
<td>(3.65)</td>
</tr>
<tr>
<td>GDP$_{jt}$</td>
<td>0.817**</td>
<td>0.468**</td>
<td>0.310**</td>
<td>0.061**</td>
<td>0.211**</td>
</tr>
<tr>
<td></td>
<td>(47.76)</td>
<td>(26.42)</td>
<td>(3.98)</td>
<td>(6.57)</td>
<td>(4.62)</td>
</tr>
<tr>
<td>POP$_{it}$</td>
<td>-0.246**</td>
<td>-0.178**</td>
<td>-1.503**</td>
<td>-0.028*</td>
<td>-0.331**</td>
</tr>
<tr>
<td></td>
<td>(14.44)</td>
<td>(12.37)</td>
<td>(6.14)</td>
<td>(3.91)</td>
<td>(5.56)</td>
</tr>
<tr>
<td>POP$_{jt}$</td>
<td>-0.164**</td>
<td>-0.052**</td>
<td>0.497*</td>
<td>-0.005</td>
<td>-0.253**</td>
</tr>
<tr>
<td></td>
<td>(9.45)</td>
<td>(3.59)</td>
<td>(2.08)</td>
<td>(0.70)</td>
<td>(3.71)</td>
</tr>
<tr>
<td>FCR$_{jt}$</td>
<td>0.034**</td>
<td>-0.017*</td>
<td>0.021</td>
<td>-0.011*</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>(2.90)</td>
<td>(1.73)</td>
<td>(1.33)</td>
<td>(2.26)</td>
<td>(0.94)</td>
</tr>
<tr>
<td>RER$_{ijt}$</td>
<td>-0.015**</td>
<td>-0.021**</td>
<td>0.382**</td>
<td>-0.004*</td>
<td>-0.015</td>
</tr>
<tr>
<td></td>
<td>(2.85)</td>
<td>(5.01)</td>
<td>(12.12)</td>
<td>(1.86)</td>
<td>(1.21)</td>
</tr>
<tr>
<td>DIST$_{ij}$</td>
<td>-0.916**</td>
<td>-0.513**</td>
<td>-0.484**</td>
<td>-0.068**</td>
<td>-0.118*</td>
</tr>
<tr>
<td></td>
<td>(37.07)</td>
<td>(21.14)</td>
<td>(15.34)</td>
<td>(5.50)</td>
<td>(1.97)</td>
</tr>
<tr>
<td>RFL$_{ijt}$</td>
<td>0.040**</td>
<td>0.032**</td>
<td>0.064**</td>
<td>0.003</td>
<td>-0.033</td>
</tr>
<tr>
<td></td>
<td>(2.78)</td>
<td>(2.68)</td>
<td>(6.01)</td>
<td>(0.48)</td>
<td>(1.36)</td>
</tr>
<tr>
<td>SIM$_{ijt}$</td>
<td>-0.146**</td>
<td>-0.073**</td>
<td>0.031*</td>
<td>-0.014*</td>
<td>-0.461**</td>
</tr>
<tr>
<td></td>
<td>(9.31)</td>
<td>(5.52)</td>
<td>(2.31)</td>
<td>(2.23)</td>
<td>(6.44)</td>
</tr>
<tr>
<td>BOR$_{ij}$</td>
<td>0.954**</td>
<td>0.458**</td>
<td>0.293**</td>
<td>0.076**</td>
<td>1.158**</td>
</tr>
<tr>
<td></td>
<td>(13.65)</td>
<td>(7.74)</td>
<td>(4.64)</td>
<td>(2.68)</td>
<td>(4.61)</td>
</tr>
<tr>
<td>LAN$_{ij}$</td>
<td>-0.128**</td>
<td>-0.040</td>
<td>0.113*</td>
<td>-0.051*</td>
<td>2.113**</td>
</tr>
<tr>
<td></td>
<td>(2.99)</td>
<td>(1.13)</td>
<td>(2.23)</td>
<td>(2.98)</td>
<td>(16.21)</td>
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<tr>
<td>$y_{ijit}$</td>
<td>0.484**</td>
<td>0.419**</td>
<td>0.201**</td>
<td>0.073**</td>
<td>0.723**</td>
</tr>
<tr>
<td></td>
<td>(34.35)</td>
<td>(27.46)</td>
<td>(11.96)</td>
<td>(36.01)</td>
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</tr>
<tr>
<td>$y_{ij,t-1}$</td>
<td>0.294**</td>
<td>0.120**</td>
<td>0.045**</td>
<td>0.182**</td>
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</tr>
<tr>
<td></td>
<td>(15.54)</td>
<td>(3.50)</td>
<td>(4.81)</td>
<td>(5.36)</td>
<td></td>
</tr>
<tr>
<td>$y_{ij,t-1}$</td>
<td>0.852**</td>
<td>0.637**</td>
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</tr>
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<td></td>
<td></td>
<td>(106.74)</td>
<td>(32.03)</td>
<td></td>
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</tr>
<tr>
<td>$y_{ji,t-1}$</td>
<td>-0.125**</td>
<td>-0.567**</td>
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<tr>
<td></td>
<td></td>
<td>(7.56)</td>
<td>(27.40)</td>
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</tr>
</tbody>
</table>

Unobserved Effects | No | No | Yes | No | Yes

**Hausman** 0.6377

**Significant at 1% level; *Significant at 10% level.

**Hausman** to the $p$-value of the Hausman test of valid over-identifying restrictions, $H_0$ is that the moment conditions are valid.
The results of Model 1 form the basis of traditional Gravity model analysis. All variables are significant at the 1% level and most have the expected signs. There are however, two exceptions pertaining to language \((LAN)\), and, as in the case of the study by Debaere (2005), the variable corresponding to the relative size of the trading countries \((SIM_{ijt})\). The largest and statistically most robust effects appear to be afforded by GDP, distance \((DIS_{ij})\), and the sharing of a common border \((BOR_{ij})\).

Including the variables that measure trade reciprocity and quasi-total exports in Model 2 has the effect of switching the sign of foreign currency reserves of the target country \((FCR_{jt})\), and rendering the variable indicating the sharing of a common language \((LAN_{ij})\) statistically insignificant. However, the two new variables that are now added to the equation are both statistically significant, most strikingly the measure of trade reciprocity. More importantly, even though the role of the trading nations’ relative size \((SIM_{ijt})\) remains, perversely, negative, it now decreases in magnitude by about 50%. This suggests that, as expected, inclusion of a measure of trade reciprocity in the analysis disentangles (at least in part) the role of production profile compatibility from that corresponding to relative size. As a result, \(SIM_{ijt}\) can now capture more accurately the extent to which economies of similar size experience greater scope for trade. Model 3 further insulates relative size from the issue of trade compatibility by accounting for fixed unobserved effects. This further enhancement is successful in facilitating a switch in the sign of relative size from negative to positive as prescribed by theory (see Helpman 1987.) Interestingly, accounting for production profile compatibility also restores the correct role of common language \((LAN_{ij})\) to that of promoting, rather than undermining, greater trade. However, Model 3 also causes a perverse switch of the impact that an increase in the real exchange rate will have on trade flows from negative to positive.

Econometric issues aside, the changes in the coefficient of the trading nations’ relative size \((SIM_{ijt})\) that are observed as we advance the analysis from estimation of Model 1, to Model 2, and finally to Model 3 are in accordance with expectations and our results provide strong support for our earlier explanation of Debaere’s (2005) troubling findings. However, while the paper may be partly motivated by Debaere (2005) its scope transcends an effort to provide an explanation for this author’s puzzling results. As argued in earlier sections, our objective is to account for production profile compatibility in the context
of an appropriate dynamic setting, on the one hand, and an estimation procedure that does not neglect to address the issue of endogenous regressors, on the other. Accounting for trade compatibility is addressed by Model 3, but the estimation approach employed in the case of this and the first two models fails to account for the endogeneity of right hand side variables. Casual examination of Table (3) reinforces this view. As it may be noted from this Table, the first three models exhibit extremely large $t$-statistics; for example, in Model 1 the coefficient of local GDP is over 55 strongly suggesting the presence of endogeneity in these equations. Interestingly, this apparent endogeneity is reduced somewhat when the unobserved effects are treated as fixed constants (Model 3.) For example, the $t$-statistic of $GDP_{it}$ falls from 26 to 4 and that of $y_{jit}$ from 34 to 27. This suggests that portion of the endogeneity arises from the fact that explanatory variables are correlated with the (composite) error term (recalling that a fully specified model has a composite stochastic term of $v_{ijt} = \alpha_i + \gamma_j + \lambda_t + u_{ijt}$) and that by treating these unobserved effects as fixed, lessens such correlations. In the panel data literature this result is well-known (see for example Wooldridge 2002.) Due to this apparent endogeneity bias, the results of the first three models should be interpreted with care. However, as explained in an earlier section, GMM estimation yields consistent parameter estimates as long as the moment conditions utilized are valid. Model 5 that relies on this estimation approach clearly passes the Hausman test for over-identifying restrictions, which confirms the validity of the moment conditions utilized. Reference to relevant $t$-statistics provides further evidence in support of the view that the endogeneity problem of the first four models is alleviated in the specification of Model 5. Interestingly, the sign of $SIM_{ijt}$ switches back to negative in the final model suggesting that there is perhaps a natural trade-off between the significance of incorporating a measure of trade compatibility in the analysis and the importance of alleviating the problems of endogenous regressors.

Still, examination of the consistent parameter estimates of the final model strongly endorses our all-inclusive specification of Model 5. Naturally, we rely on this specification to shed light on the extent to which accounting for production profile compatibility in a dynamic setting contributes to the Gravity approach. With regard to the additional variables advocated for inclusion in this paper, we first note that the contemporaneous reciprocal variable is positive and strongly statistically significant. That is, trade compat-
ibility plays an important role in the analysis which, in the context of our dataset, may be interpreted as suggesting that APEC countries have ‘preferred’ trading partners. Lagged reciprocal export flows are significantly negative, but of a smaller absolute magnitude than contemporaneous ones. The combination of these two effects suggests a dynamic, cyclical adjustment to preferred trading partners. Not surprising, quasi-total exports relate positively to export flows across all countries. This is of a smaller magnitude than the reciprocal effect: as quasi-total exports increase, exports to the omitted country from this total increase. Finally, lagged export flows, capturing an amalgamation of effects ranging from relative factor endowments, to level of development, to historical and political ties, to transport costs, to preferred trade partner effects, and so on, are strongly significant and of a magnitude on a par with that of contemporaneous reciprocal export flows.

Turning our attention to variables included in virtually all standard Gravity equations, we note that the addition of quasi-total, reciprocal, and lagged trade flows significantly decreases the economic and statistical significance of ‘traditional’ Gravity parameters. For example, in Model 1, the elasticity of export flows with respect to local GDP was 0.772, with an associated $t$-statistic of over 55, whereas in Model 5 this elasticity falls to 0.147 with a $t$-statistic of 3.65. This suggests that, to a large extent, these traditional variables generally act as proxies for the quasi-total, reciprocal, and lagged trade flow variables. Interestingly, the perverse sign associated with the sharing of common language in the ‘miss-specified’ Model 1, is corrected and statistically significant in the fully specified, consistently estimated, Model 5.

It should be noted that both target and domestic GDP exert significantly positive effects, as expected and in line with previous literature, on export flows. However, taking into account the additional variables nominated in this article decreases their estimated effects. For example, elasticities in excess of unity are not uncommon (see, for example, Egger and Pfaffermayr 2003, Cheng and Wall 2002 and Serlenga and Shin 2004.) At the same time we find the foreign GDP coefficient to be larger, suggesting that the demand-side ‘pull’ effects of foreign output dominate the supply-side ‘push’ effects of domestic output. In relation to the target and domestic population variables we should point out that their role in the Gravity setting is generally considered to be ambiguous (see, for example, Berstran 1989 and Oguledo and MacPhee 1994.) As it may be noted
from Table (3) our estimations suggest significant negative population effects which are not uncommon in the Gravity literature (see Harris and Matyas 2001 and Serlenega and Shin 2004.)

Although not always included in typical implementations of the Gravity approach, the foreign currency reserves of the target country are typically positive and significant (see, for example, Harris and Matyas 2001 and Egger and Pfaffermayr 2003.) However, here, once the model is fully specified, they are no longer significant. The reason could well be that these simply represent the accumulation of current and previous trade flows, combined with past exchange rate policies, rendering their effect on contemporaneous export flows somewhat ambiguous.

Being defined as units of foreign currency per unit of domestic currency, adjusted for relative prices, the exchange rate is akin to a price variable in the exports demand schedule.\(^7\) Again, unlike previous evidence (see, for example, Harris and Matyas 2001, Egger and Pfaffermayr 2003, and Serlenega and Shin 2004) once the model is fully specified, we find here that this price variable is insignificant.

Furthermore, we find that countries that share a common border appear to trade more heavily than others that do not, as do countries that share a common language. The distance variable is intended as a proxy for transportation costs. Although we find a statistically significant negative effect here, the magnitude of both the economic and statistical effect is drastically reduced from that typically found in the literature. For example, Rose (2005) estimates elasticities well in excess of (minus) unity, compared to the \(-0.118\) found here. Presumably this variable was previously measuring production profile compatibility effects not attributable to distance, but instead to exogenous sources of comparative advantage, degree of specialization, level of industrialization and the like.

\section{Conclusion}

Gravity models proposed in the literature have so far sidestepped the issue of including an explicit specification of either exogenous sources of comparative advantage, advocated by factor endowment and Ricardian frameworks, or the ‘acquired’ drivers of trade upon which new trade theory relies. Characterizations of the model based on the former, argue

\(^7\)Although there may be secondary effects of the lower price of input prices.
that a crude measure of relative factors is reflected in per-capita GDP. However, recent findings by Melitz (2007) cast serious doubt on the extent to which such a measure has much potential of representing comparative advantage in the analysis. The new trade theory drivers of trade appear to be equally absent from the typical Gravity equation. This is strongly supported by the recent results of Debaere (2005) that suggest that the degree of specialization of different countries that would be required to make them ‘trade compatible’ depends on factors not considered by the Gravity approach.

This contribution represents an effort to ameliorate this important deficiency of the Gravity framework. Our approach relies on the notion that irrespective of what determines the extent to which the production profiles of different countries are ‘trade compatible’, the degree of this compatibility will manifest itself in the form of high reciprocal trade flows. This reciprocity is combined with total exports (that measure ‘income’ or economic ‘activity’) and their lags to construct a dynamic Gravity model that accounts for income-adjusted production profile compatibility.

Our results strongly endorse the importance of including ‘trade compatibility’ effects in Gravity formulations, as well as the view that such effects are dynamic: export flows do not move immediately in response to exogenous shocks to the system.
References


