An Econometric View on the Estimation of Gravity Models and the Calculation of Trade Potentials

Peter Egger

1. INTRODUCTION

In the last decade, the application of gravity models enjoyed a big revival. This was not so much driven by its more rigorous theoretical foundation (Anderson, 1979; Bergstrand, 1985, 1989 and 1990; Helpman and Krugman, 1985; and Helpman, 1987, etc.) but by the opportunity to project bilateral trade relations (see Wang and Winters, 1991; Hamilton and Winters, 1992; Baldwin, 1994; and successors). The first applications were undertaken within the context of the Fall of the Iron Curtain and the new potential integration effects between the EU (OECD) and the former COMECON member states. According to the traditional concept of the gravity equation, bilateral trade can be explained by GDP and GDP per capita figures and both trade impediment (distance) and preference factors (common border, common language, etc.). The economic framework in most cases was cross-section analysis (Wang and Winters, 1991; Hamilton and Winters, 1992; Brulhart and Kelly, 1999; and Nilsson, 2000, etc.). Only a few authors made use of (random effects) panel econometric methods (Baldwin, 1994; Gros and Gonciarz, 1996; Mátyás, 1997; and Egger, 2000).¹

Two conceptually different approaches were followed. First, some authors argued that in the initial stage of the systemic and economic transformation, e.g. of the Central and Eastern European countries (CEEC), these countries behaved differently from developed countries such as the EU or OECD members. A gravity model was estimated for EU or OECD countries and the parameters were used to project ‘natural’ trade relations between these countries and the CEEC.

¹ Mátyás (1997 and 1998) provides insights in the question of proper econometric specification without dealing with the issue of trading potentials.
The difference between the observed and the ‘predicted’ trade flows was then interpreted as the un-exhausted trade potential. I think that this was a valuable experiment, especially at the early stage of transformation of the CEEC. This technique was used by Wang and Winters (1991), Hamilton and Winters (1992) and Brulhart and Kelly (1999), and I refer to it as the out-of-sample projection approach. Second, and more recently, authors have included the transformation countries under consideration already in the regression analysis. Then, the residual of the estimated equation was interpreted as the difference between potential and actual bilateral trade relations (Baldwin, 1994; and Nilsson, 2000). I call this the in-sample projection approach.

This paper intends to provide insights into the choice of the adequate estimation technique and into the problems related to in-sample projections of trade potentials. In general, the estimator choice is an important issue for the interpretation of the gravity coefficients, which depends on the underlying interests. For future research, three important econometric problems should be considered:

1. The traditional cross-section approach is probably affected by a severe problem of misspecification. Mátyás (1997) notes that the most natural representation of bilateral trade flows is a three-way specification. Then, eliminating one of the three dimensions (time) implies that the natural representation of a time-averaged gravity model is a two-way panel with (fixed or random) exporter and importer effects. Since these are the most important dimensions of variation, convenient OLS estimates are very likely to result in inconsistent estimates. This renders conclusions on OLS-based trade potentials as problematic and affects both the in-sample and the out-of-sample prediction concept.

2. We should care about the association of different estimators with short-term and long-term time-horizons when comparing results (see Pirotte, 1999). Whereas fixed effects (and consistent random effects) model estimates reflect short-run parameters, between model estimates are closer to long-run parameters.

3. Finally, from a consistent and efficient estimator we should expect white-noise residuals, which do not have any more systematic variation. If an estimator reveals large systematic differences between observed and in-sample predicted values (such as large un-exhausted East-West trade potentials), this should be interpreted as an indication for misspecification and parameter inconsistency.²

² The application of the random effects approach is problematic because of the likelihood of its inconsistency due to correlation between some of the explanatory variables and the unobserved individual effects.
I focus on panel estimators. In my application, the previously used estimators result in large unused trade potentials at least for intra-CEEC trade. I demonstrate that the large in-sample actual-to-potential trade ratios stem from two sources. First, the correlation of the explanatory variables with the unobserved effects leading to inconsistent parameter estimates for the random effects model (REM) as used by Baldwin (1994) and Gros and Gonciarz (1996). Second, from serial correlation of the residuals. The consistent and efficient estimator in the application is an AR(1) model in the spirit of Hausman and Taylor (1981), which has not been used previously either in trade or in other fields of economic research. This estimator eliminates the systematic difference between observed and in-sample predicted trade flows. However, the in-sample approach to the calculation of trade potentials is misleading since properly specified econometric models cannot obtain systematic variations in residuals at all.

The paper is organised as follows. Section 2 briefly introduces the specification. Section 3 presents the estimation results and in-sample projections of export potentials of the EU member states (EU15), Hungary, Poland, and the Czech Republic (henceforth CEEC3) in 10 CEEC (CEEC10). Section 4 concludes.

2. THE ECONOMETRIC SPECIFICATION

According to the endowment-based new trade model with Dixit and Stiglitz (1977) preferences, bilateral trade is an increasing function of bilateral sum of factor income $G$, relative country size $S$, and the difference in relative factor endowments ($R$; compare Helpman and Krugman, 1985; Helpman 1987; and others). Accordingly, bilateral exports can be estimated by

$$Y_{ijt} = \beta_0 + \beta_1 G_{ijt} + \beta_2 S_{ijt} + \beta_3 R_{ijt} + \beta_4 V_{ii} + \beta_5 V_{ij} + \beta_6 RL_{iit} + \beta_7 RL_{jit}$$
$$+ \beta_8 E_{ijt} + \beta_9 D_{ij} + \beta_{10} B_{ij} + \beta_{11} L_{ij} + \lambda_t + u_{ijt},$$

where all variables are real figures and expressed in logs, and the error term can be written as:

$$u_{ijt} = \mu_{ij} + v_{ijt},$$

with $\mu_{ij}$ as the (fixed or random) unobserved bilateral effect and $v_{ijt}$ as the remaining error. In line with Helpman (1987) the Heckscher-Ohlin determinants can be formulated in the following way:

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3 The 10 CEEC are: Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, and Slovakia.
\[ G_{ijt} = \log(GDP_{it} + GDP_{jt}) \]
\[ S_{ijt} = \log \left( 1 - \left( \frac{GDP_{it}}{GDP_{it} + GDP_{jt}} \right)^2 - \left( \frac{GDP_{jt}}{GDP_{it} + GDP_{jt}} \right)^2 \right) \]
\[ R_{ijt} = \log \left( \frac{GDP_{it}}{N_{it}} \right) - \log \left( \frac{GDP_{jt}}{N_{jt}} \right) \]

where \( N \) denotes a country’s population and GDP per capita is as commonly used as a proxy for a country’s capital-labour ratio. Moreover, I use four variables, which reflect a country’s freedom with respect to international exchange and therefore transport costs in a broad sense.\(^4\) These are exporter (importer) viability of contracts \( (V_{it}^{(+)}, V_{jt}^{(+)})) \) and exporter (importer) rule of law \( (RL_{it}^{(+)}, RL_{jt}^{(+)})) \). They influence an exporter’s (importer’s) costs of international exchange, since a higher level of contract viability reduces a firm’s risk (i.e. of bankruptcy) and a higher level of rule of law also reduces the probability of losing money, since contract breakers have to take their responsibility and are more likely to lose their case. Additionally, bilateral trade is affected by more traditional measures of transport costs, which are commonly in use. These are the real bilateral exchange rate \( (E_{ijt}^{(+)})) \), distance \( (D_{ij}^{(-)})) \), common borders \( (B_{ij}^{(+)})) \) and common language \( (L_{ij}^{(+)})) \), where the latter two are dummy variables.\(^5\)

For the panel econometric projection of potential bilateral trade, researchers have concentrated on the random effects model (REM), which requires that \( \mu_{ij} \sim (0, \sigma^2_{\mu}), v_{ijt} \sim (0, \sigma^2_{v}) \), and the \( \mu_{ij} \) are independent of the \( v_{ijt} \). Moreover, the \( X_{ijt} \) (i.e. the explanatory variables) have to be independent of the \( \mu_{ij} \) and \( v_{ijt} \) for all cross-sections \( (ij) \) and time periods \( (t) \). Whereas the fixed effects model (FEM) is always consistent in the absence of endogeneity or errors in variables, the REM is only consistent if the above-mentioned orthogonality conditions are fulfilled. Then, the REM has the advantage of more efficiency as compared to the FEM. If these conditions do not hold, only the FEM is consistent since it wipes out all the time-invariant effects \( (\mu_{ij}) \). The decision between FEM and REM can be based on a Hausman (1978) test. However, in the FEM time-variant variables cannot be estimated any longer and it wastes a lot of degrees of freedom, since the \( \mu_{ij} \) may be correlated only with a few explanatory variables. Therefore, Hausman and Taylor (1981) provide an alternative which makes use of the several dimensions of panel data in order to overcome this correlation without any variables from outside the model. The appropriateness of the latter can be based on a Hausman and Taylor test for over-identifying restrictions. Finally, the mentioned models assume that there is no serial correlation of the error term \( v_{ijt} \) and the only

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\(^4\) See the next section for more details on data sources.

\(^5\) Note that the econometric arguments below are fully independent of the underlying theoretical context and also hold for the traditional set-up à la Linnemann (1966).
correlation over time is due to equicorrelation (i.e. the presence of the same individuals over time). If $v_{ijt}$ follows an autoregressive process and this is ignored, it results in consistent but inefficient parameter estimates and standard errors also rendering the Hausman (1978) and Hausman and Taylor (1981) tests inappropriate, since they require to use the efficient estimator under the null.

When trade potentials are projected, researchers usually focus on residuals rather than parameters. This paper demonstrates, that the choice of the econometric set-up is of great relevance for the calculation of bilateral trade potentials (especially, in the in-sample prediction approach). I estimate the following models: an FEM, an REM, the corresponding Hausman and Taylor model (HTM), and a Between model all assuming no autocorrelation of the error term. According to Pirotte (1999) the consistent FEM (and consequently also the REM or the HTM) can be associated with short-term parameter estimates, whereas the Between estimator gives parameter estimates, which reflect the long run. Since I find autocorrelation of the residuals, an REM and HTM for the case of first-order autocorrelation (AR(1)) are estimates in addition (see the Appendix for a derivation of the latter).

3. DATA, ESTIMATION RESULTS AND PROJECTIONS

I estimate a panel of exports of OECD countries to other OECD members and the 10 Central and Eastern European countries over the period 1986–1997. I use real exports, GDP, and exchange rates with 1995 as the base year. Nominal exports in current USD are from OECD (Monthly Statistics of International Trade), IMF (Direction of Foreign Trade), and the Vienna Institute of Comparative Economic Studies (hereafter WIIW). Nominal GDP in USD and GDP deflators are from OECD (Economic Outlook and National Accounts Volume 1), IMF (International Financial Statistics), and WIIW. Exchange rate indices are collected from IMF (International Financial Statistics) and WIIW. Population numbers are available from OECD (Economic Outlook and National Accounts Volume 1), IMF (International Financial Statistics) and WIIW. The economic freedom variables are provided by Economic Freedom Network (Economic Freedom of the World) and account for legal structure and property rights (Area V of the database) and international exchange (part of Area VI of the respective database). Transport costs in a narrow sense are proxied by distance between two countries’ capitals in miles.

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6 Baltagi (1995) and Mátys (1996) provide an overview of the literature on autocorrelation in panel data.

7 Noteworthy, if one finds systematic country or country-pair specific differences between observed and predicted trade flows this automatically implies the presence of autocorrelation in the residuals.
<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Fixed Effects</th>
<th>Random Effects</th>
<th>Hausman-Taylor</th>
<th>Between</th>
<th>First-Order Autocorrelation – AR(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
<td>Random Effects</td>
</tr>
<tr>
<td>Bilateral Sum of GDP</td>
<td>2.470***</td>
<td>1.817***</td>
<td>2.454***</td>
<td>1.757***</td>
<td>1.815***</td>
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<tr>
<td></td>
<td>(0.114)</td>
<td>(0.027)</td>
<td>(0.109)</td>
<td>(0.030)</td>
<td>(0.027)</td>
</tr>
<tr>
<td>Similarity in Country Size</td>
<td>0.504***</td>
<td>0.853***</td>
<td>0.498***</td>
<td>0.918***</td>
<td>0.879***</td>
</tr>
<tr>
<td></td>
<td>(0.087)</td>
<td>(0.031)</td>
<td>(0.084)</td>
<td>(0.034)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>Difference in Relative Factor Endowments</td>
<td>0.377***</td>
<td>-0.055*</td>
<td>0.383***</td>
<td>0.606***</td>
<td>-0.138***</td>
</tr>
<tr>
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<td>(0.062)</td>
<td>(0.031)</td>
<td>(0.059)</td>
<td>(0.129)</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Exporter Viability of Contracts</td>
<td>0.039</td>
<td>0.290***</td>
<td>0.028</td>
<td>2.499***</td>
<td>0.331***</td>
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<tr>
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<td>(0.045)</td>
<td>(0.043)</td>
<td>(0.050)</td>
<td>(0.297)</td>
<td>(0.053)</td>
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<tr>
<td>Importer Viability of Contracts</td>
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<td>0.653***</td>
<td>0.688***</td>
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<td>(0.038)</td>
<td>(0.038)</td>
<td>(0.037)</td>
<td>(0.255)</td>
<td>(0.043)</td>
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<tr>
<td>Exporter Rule of Law</td>
<td>-0.091**</td>
<td>-0.081*</td>
<td>0.001</td>
<td>-0.242</td>
<td>-0.104**</td>
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<tr>
<td></td>
<td>(0.045)</td>
<td>(0.043)</td>
<td>(0.025)</td>
<td>(0.230)</td>
<td>(0.051)</td>
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<tr>
<td>Importer Rule of Law</td>
<td>0.175***</td>
<td>0.152***</td>
<td>0.176***</td>
<td>-0.236*</td>
<td>0.098***</td>
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<td>(0.028)</td>
<td>(0.028)</td>
<td>(0.027)</td>
<td>(0.140)</td>
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<tr>
<td>Real Exchange Rate</td>
<td>0.023***</td>
<td>-0.005</td>
<td>0.025***</td>
<td>-0.263***</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.006)</td>
<td>(0.091)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Distance</td>
<td>–</td>
<td>-0.915***</td>
<td>0.783</td>
<td>-0.178***</td>
<td>-0.914***</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>(0.027)</td>
<td>(17.079)</td>
<td>(0.046)</td>
<td>(0.027)</td>
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</tr>
<tr>
<td>Common Border</td>
<td>–</td>
<td>0.308</td>
<td>17.375</td>
<td>–0.931</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>(0.123)</td>
<td>(119.945)</td>
<td>(0.029)</td>
<td>(0.122)</td>
</tr>
<tr>
<td>Common Language</td>
<td>–</td>
<td>0.731</td>
<td>–0.367</td>
<td>0.291</td>
<td>0.698</td>
</tr>
<tr>
<td></td>
<td>–</td>
<td>(0.130)</td>
<td>(66.611)</td>
<td>(0.121)</td>
<td>(0.129)</td>
</tr>
<tr>
<td></td>
<td>(3.063)</td>
<td>(0.723)</td>
<td>(134.058)</td>
<td>(1.964)</td>
<td>(0.735)</td>
</tr>
</tbody>
</table>

Number of Observations  9375  9375  9375  9375  9375  9375
Number of Bilateral Relations  837  837  837  837  837  837
$R^2$    0.9994  0.9966  0.9992  0.9988  0.9978  0.9996
Average $\theta_i$     –     0.857  0.9972  –     –     0.772  0.984
Time Effects: $F(11, 8520)$  5.39***  92.91***  6.01***  5.92***  82.71***  2.86***
Bilateral Effects: $F(836, 8520)$  49.20***  –     –     –     –     –
Hausman Test: $\chi^2(18)$  –     328.17***  –     –     5213.36***  –
Honda Lagrange Multiplier Test$^2$  –     170.53***  –     –     –     –
Hausman Over-identification Test: $\chi^2(3)$  –     –     0.59  –     –     0.88
Canonical Correlations$^3$  –     –     0.30  –     –     0.37
Durbin-Watson$^4$  –     –     –     –     0.82  0.85
Baltagi-Wu LBI$^5$  –     –     –     –     1.11  1.13

Notes:
1 Standard errors in parentheses.
2 One-sided test statistic based on square root figures of the traditional Breusch-Pagan test statistics; asymptotically following a standard normal distribution.
3 Geometric mean of canonical correlation coefficients.
4 According to Bhargava et al. (1982).
5 Locally best invariant test statistic according to Baltagi and Wu (1999).
*** Signiﬁcant at 1 per cent.
** Signiﬁcant at 5 per cent.
* Signiﬁcant at 10 per cent.
Table 1 presents the estimation results for six different panel estimators. Note that the Between model should reflect long-term influences. All other estimators reflect short-run impacts if the parameters can be consistently estimated (see Pirotte, 1999). According to the test statistics we should not ignore cycle effects ($F$-tests for time effects) and the presence of heteroscedasticity in the cross-section ($F$-test and Honda test). However, the Hausman test statistic reveals that the REM suffers from correlation and gives inconsistent parameter estimates (which are closer to the Between estimates). The HTM seems most appropriate as is indicated by the over-identification test. It comes close to the FEM in terms of parameter estimates and it seems efficient. The time-invariant variables cannot be estimated significantly, which is due to the explanatory variables at hand. Testing for autocorrelation reveals that the HTM is not efficient and both the Hausman test statistic and the Hausman and Taylor test for over-identification are inappropriate. Due to large differences in the parameters between the FEM and the REM, the Hausman test also rejects the appropriateness of the REM AR(1). In our application, the HTM AR(1) is consistent and efficient among the short-term estimators. It additionally allows us to estimate the impact of common borders with more success.

In order to underpin the relevance of the model choice for the in-sample projection of bilateral trade potentials, I calculate trade potentials of EU15 countries and three Central and Eastern European economies (CEEC3) in the CEEC10. Usually, the exponent of minus one times the bilateral residual is interpreted as the bilateral trade potential and, for the moment, it is interpreted in the traditional manner.

Obviously, in terms of actual-to-potential trade ratios the REM lies in between the HTM and the Between model. As compared to the HTM, the REM overestimates the trade potential of the CEEC3 in the CEEC10 by more than 210 per cent. In contrast, it underestimates the potential of the EU15 by about six per cent. This is even more pronounced if autocorrelation is accounted for. As compared to the HTM AR(1) approach, the REM AR(1) overestimates the EU15 trade potential in the CEEC10 by about 49 per cent and that of the CEEC3 by about 367 per cent. According to the HTM AR(1) model there is no export
<table>
<thead>
<tr>
<th>Exporting Country</th>
<th>Random Effects</th>
<th>Hausman-Taylor</th>
<th>Between</th>
<th>First-Order Autocorrelation – AR(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Random Effects</td>
</tr>
<tr>
<td>Belgium-Luxembourg</td>
<td>0.61</td>
<td>0.88</td>
<td>0.74</td>
<td>0.59</td>
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<tr>
<td>Denmark</td>
<td>0.94</td>
<td>0.88</td>
<td>1.15</td>
<td>0.89</td>
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<tr>
<td>Germany</td>
<td>0.63</td>
<td>0.95</td>
<td>0.63</td>
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<td>Finland</td>
<td>0.59</td>
<td>0.83</td>
<td>0.87</td>
<td>0.58</td>
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<td>1.44</td>
<td>0.90</td>
<td>1.43</td>
<td>1.33</td>
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<tr>
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<td>0.75</td>
<td>0.79</td>
<td>0.55</td>
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<td>1.14</td>
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<td>1.09</td>
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<td>Ireland</td>
<td>0.73</td>
<td>0.83</td>
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<tr>
<td>Italy</td>
<td>0.85</td>
<td>0.83</td>
<td>1.03</td>
<td>0.82</td>
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<td>Netherlands</td>
<td>0.57</td>
<td>0.93</td>
<td>0.64</td>
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<td>Austria</td>
<td>0.73</td>
<td>0.96</td>
<td>0.90</td>
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<td>Portugal</td>
<td>2.59</td>
<td>0.75</td>
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<td>Spain</td>
<td>1.40</td>
<td>0.75</td>
<td>1.82</td>
<td>1.39</td>
</tr>
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<td>0.98</td>
<td>0.92</td>
<td>1.24</td>
<td>0.72</td>
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<tr>
<td>Hungary</td>
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<td>0.98</td>
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<tr>
<td>Poland</td>
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<td>0.95</td>
<td>0.34</td>
<td>0.48</td>
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<tr>
<td>Czech Republic</td>
<td>0.12</td>
<td>1.04</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>CEEC3</td>
<td>0.32</td>
<td>1.00</td>
<td>0.29</td>
<td>0.27</td>
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</table>
potential to CEEC10 left for both the EU15 and the three CEEC. The EU15 export potential to CEEC10 is about 34 per cent (16 per cent) higher in the HTM (the HTM AR(1)) approach than in the Between set-up, where the former can be associated with the short-run and the latter with the long-run. The opposite holds true for export potentials of the CEEC3, which are 71 per cent (76 per cent for AR(1)) smaller in the short-run than in the long-run.

Unfortunately, from a pure econometric point of view such in-sample prediction experiments of thought are inappropriate, since proper specification should always result in white-noise residuals, which is the case for the HTM AR(1). This reveals the difficulty of the in-sample prediction approach to trade potentials as it is commonly in use. I propose to interpret in-sample evidence for a large overlap of predicted over observed trade relations as an indication of misspecification rather than of unused trade potentials. In the above example the REM, the REM AR(1), and the Between model exhibit non-white-noise residuals indicating specification and consistency/efficiency problems.

The above arguments raise the question about a possible guide for practitioners on ‘how to do it right?’ and how to proceed in the future. I think several important conclusions can be drawn. First and independently of the researcher’s interest, consistent estimation is a must, and I think that we should not base our conclusions on simple OLS estimates. In the gravity cross-section case, this requires a two-way fixed or random exporter and importer effects panel data model (compare Egger, 2001). If the data vary over time, a two-way model with (fixed) time and (fixed or random) bilateral effects is appropriate. If autocorrelation is present, one should control for it. Whether exporter, importer or bilateral effects should be treated as random or fixed depends on the consistency of the REM and on whether one is interested in the estimation of time-invariant effects (see also Egger, 2000). In general, I would recommend the HTM or the HTM AR(1). If this is not consistent (which is testable by the mentioned over-identification test), the FEM is the only valid alternative. Second, the in-sample approach to the prediction of trade potentials is inappropriate. If the underlying model is consistent, there is no systematic difference between observed and in-sample predicted trade flows. Third, whether out-of-sample predictions make sense depends on the researcher’s suggestion about the stage of the countries’ transformation process. For the CEEC, out-of-sample predictions of EU-CEEC trade potentials probably become less and less appropriate (regarding the development e.g. in Hungary or Slovenia). This approach is most appropriate in the early stage of transformation. Fourth, the calculation of counterfactuals remains a useful tool. Interesting questions are influence of changes in the explanatory variables on bilateral trade flows (e.g. catching up in GDP per capita in the CEEC, the reduction of trade costs via infrastructure investments or tariffs, etc.). For this line of research, the difference between short-term and long-term influences could provide interesting insights.
4. CONCLUSIONS

This paper provides insights into the relevance of the appropriate estimator choice for the analysis of bilateral trade flows. I compare different estimators part of which have been used in previous studies and provide insights that none of the previously used estimators is appropriate in terms of consistency and/or efficiency in my application. I argue that three problems should be kept in mind when estimating gravity models and/or calculating trade potentials. First, traditionally estimated time-averaged cross-section gravity models are very likely to be misspecified since they ignore the presence of exporter and importer effects without testing for their relevance. Second, one should be careful with comparing estimation results between different econometric concepts, which refer to different time horizons with respect to responses of trade flows on changes in the explanatory variables. Third and in contrast to previous research, I do not see any way to derive information about so-called trade potentials of the in-sample prediction approach. Rather, I suggest that any large systematic difference between observed and in-sample predicted trade flows indicates misspecification of the econometric model instead of unused (or overused) trade potentials.

In the present application, the consistent and efficient model is a Hausman and Taylor AR(1) estimator, which has never been used before. According to econometric theory, which demands for white-noise residuals in the case of proper (i.e. consistent and efficient) specification, this estimator fails to identify large systematic differences between residuals among country groups. Large unused in-sample export potentials, which have been identified previously in the context of European integration reveal nothing other than inherent problems of misspecification in terms of consistency and efficiency of the estimators and the econometric models in use. Nevertheless, the gravity model remains a useful tool for counterfactual simulation analysis. Future applications could focus on simulations of changes in the explanatory variables such as convergence in terms of GDP per capita or trade cost reductions.

APPENDIX

A Hausman and Taylor AR(1) Model

Following Baltagi and Wu (1999) in the notation, we have to Prais-Winsten transform the data by:\footnote{Note that in contrast to Baltagi and Li (1991), Baltagi and Wu (1999) allow for unequally spaced panel data and missing observations, which is relevant in my application.}
\( C_i^t(\rho) = (1 - \rho^2)^{1/2} \cdot \begin{bmatrix}
1 & 0 & \cdots & 0 & 0 \\
1 - \left( \frac{\rho^2(t_{i,2} - t_{i,1})}{1 - \rho^2(t_{i,2} - t_{i,1})} \right)^{1/2} & \left( \frac{1}{1 - \rho^2(t_{i,2} - t_{i,1})} \right)^{1/2} & \cdots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \cdots & \left( \frac{1}{1 - \rho^2(t_{i,n_i-1} - t_{i,n_{i-2}})} \right)^{1/2} & 0 \\
0 & 0 & \cdots & \left( \frac{\rho^2(t_{i,n_i} - t_{i,n_{i-1}})}{1 - \rho^2(t_{i,n_i} - t_{i,n_{i-1}})} \right)^{1/2} & \left( \frac{1}{1 - \rho^2(t_{i,n_i} - t_{i,n_{i-1}})} \right)^{1/2}
\end{bmatrix} \)
Accordingly, one can transform the Amemiya Within-type residuals from the initial FEM to obtain the variance component of the remainder disturbance ($\hat{\sigma}_e^2$). Therefore, we have to define:

$$u^* = \text{diag}[C_i^*(\rho)] u = \text{diag}[C_i^*(\rho)] \text{diag}(t_{ni}) \mu + \text{diag}[C_i^*(\rho)] v,$$

(5)

$$g_i = C_i^*(\rho) t_{ni} = (1 - \rho^2)^{1/2} \begin{pmatrix} 1, & 1 - \rho^{(t_{i2}-t_{i1})} & \cdots & 1 - \rho^{(t_{in_i}-t_{i1})} \\ (1 - \rho^2(t_{i2}-t_{i1}))^{1/2}, & \cdots & (1 - \rho^2(t_{in_i}-t_{i1}))^{1/2} \end{pmatrix},$$

(6)

and $P g_i = g_i (g_i' g_i)^{-1} g_i$, $Q g_i = I_{n_i} - P g_i$ in order to obtain:

$$\hat{\sigma}_e^2 = \frac{u^* \text{diag}(Q g_i) u^*}{\sum_{i=1}^{N} (n_i - 1)},$$

(7)

where $N$ refers to the number of cross-sections and $n_i$ is the number of observations in cross-section $i$. This corresponds to $\varepsilon' \varepsilon$, where $\varepsilon$ is the residual vector from the OLS regression on the Within transformed model where each variable corresponds to:

$$y_{i,t_{i,j}}^w = y_{i,t_{i,j}} - \frac{\sum_{s=1}^{n_i} g_{i,s} y_{i,t_{i,s}}}{\sum_{s=1}^{n_i} g_{i,s}}.$$

(8)

In the presence of correlation between (some of) the explanatory variables ($X$) and the unobserved effects ($\mu_{ij}$) we have to average the Within residuals over time (i.e. to construct pseudo-averages) and to run 2SLS of these residuals on the time-invariant, Prais-Winsten transformed variables with the exogenous time-invariant variables as instruments.\(^{(10)}\) This regression not only obtains a parameter estimate for the time-invariant variables, but it also produces residuals, which are used to derive the second required variance component. I call the residuals from this second regression $\eta^*$. We can obtain an estimate of the second required variance component by:

$$\hat{\sigma}_\omega^2 = \eta^* \text{diag}(P g_i) \eta^*.$$

(9)

\(^{(10)}\) In contrast to Hausman and Taylor (1981) we consider all time-invariant variables as correlated with the $\mu_{ij}$. According to Cornwell et al. (1992), we call the correlated variables as singly exogenous and the uncorrelated ones as doubly exogenous.
Accordingly, one can derive an estimate for the cross-sectional variance component via:

$$\hat{\sigma}^2_\mu = \frac{\eta^t \text{diag}(P_{gi}) \eta^* - N \hat{\sigma}^2_\varepsilon}{\sum_{i=1}^{N} g'_i g_i}, \quad (10)$$

which gives:

$$\hat{\omega}^2_i = g'_i g_i \hat{\sigma}^2_\mu + \hat{\sigma}^2_\varepsilon \quad (11)$$

and

$$\hat{\theta}_i = 1 - \left( \frac{\hat{\sigma}^2_\varepsilon}{\hat{\omega}^2_i} \right)^{1/2}. \quad (12)$$

Finally, we can transform our data according to Fuller and Battese (1973 and 1974) by premultiplying the Prais-Winsten transformed data by $\hat{\omega}^{-1/2}$ to get $\hat{y}^{**} = \hat{\omega}^{1/2} y^*$ with the typical elements

$$\hat{y}^{**}_{i,t,j} = y^*_{i,t,j} - \hat{\theta}_i g_{i,j} \frac{\sum_{s=1}^{m_i} g_{i,s} y^*_{i,s,t,j}}{\sum_{s=1}^{m_i} g^2_{i,s}}. \quad (13)$$

Running 2SLS on the transformed model with the proper set of instruments $(A)$ yields the consistent and efficient AR(1) estimator in the spirit of Hausman and Taylor (1981). $A$ consists of the Within transformed time-variant variables (according to (8)) and of pseudo-average over time of the doubly exogenous, time-variant variables (in our case $S_{ijt}, R_{ijt}, V_{it}, V_{j,t}, RL_{it}, RL_{jt}$, and $E_{ijt}$). The latter are derived from the transformation:

$$\bar{y}^{**}_{i,t,j} = g_{i,j} \frac{\sum_{s=1}^{m_i} g_{i,s} y^*_{i,s,t,j}}{\sum_{s=1}^{m_i} g^2_{i,s}}. \quad (14)$$

In our application, the set of time-invariant, singly exogenous variables comprises $D_{ij}, B_{ij}$, and $L_{ij}$. Since we have more time-variant, doubly exogenous variables than time-invariant, singly exogenous variables at hand, the AR(1) Hausman and Taylor-type estimator is efficient and the corresponding AR(1) Within (FEM) estimator is not.
REFERENCES


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