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No. 962

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A GRAVITY MODEL
UNDER MONOPOLISTIC COMPETITION**

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ABSTRACT: The paper presents an alternative derivation of the gravity equation for foreign trade, which is explicitly based on monopolistic competition in the export markets and which is more general than previously in the literature. In contrast to the usual specification, our model allows for the realistic assumption of asymmetry in mutual trade flows. The model is estimated for trade in Europe, producing evidence that trade flows and barriers do, indeed, reveal strong asymmetry. We then carry out a simulation, based on the estimated model, of general equilibrium effects, through trade, of possible UK entrance into EMU and find that the issue of asymmetry also plays a crucial role as to the effects of integration policies.

Key words: Gravity model, trade barriers, asymmetry

JEL classification: F12, F15


Asiasanat: Gravitaatiomalli, kaupan esteet, epäsymmetria
1. INTRODUCTION

The analysis of trade using the classical gravity model has been very intense during the recent years, to analyze, e.g., the trade effects of currency unions. There are, however, two shortcomings in these applications. First, it is commonly assumed that trade barriers are symmetric, i.e., identical in trade from country i to j and in trade from j to i, and no emphasis is paid to differences in exports and imports and the factors underlying them. Secondly, the theoretical basis of the estimated gravity model is insufficient and often lacking totally.

This assumption of symmetry is very dominating in the empirical application of the gravity model, but it is in sharp conflict with the actual situation. Take, for instance, trade flows within Europe. In 1999, the average absolute difference between the logs of the bilateral trade flows of 27 European countries was as high as 0.66, which implies that, on average, the smaller of the bilateral trade flows is only 52 per cent of the bigger. Therefore, it is not surprising that using a gravity model to explicitly test for the symmetry of trade barriers in Europe produces the outcome that they are strongly asymmetric (see Alho, 2003).

James E. Anderson and Eric van Wincoop (2003) presented an important and novel analysis which claims to solve the famous “border puzzle” concerning the effects of a border on trade, originally found by McCallum (1995) to be extremely large with respect to the U.S. and Canada. They build on the early derivation of the gravity model by Anderson (1979). Assuming CES-preferences, symmetric trade barriers, and imposing the general equilibrium constraint for trade, i.e., that total sales equal total production, Anderson and van Wincoop explicitly derive the following gravity equation for bilateral trade,

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1 For instance, the recent analyses of the impact of EMU on trade by Micco et al. (2003) and Barr et al. (2003) both build their trade model on the sum of exports and imports and thereby omit the differences existing between them.
Here $X_{ij}$ is exports from country (region) $i$ to country $j$, $Y_i$ is the income (GDP) of country $i$, $Y_w$ denotes that for the whole world, $t_{ij}$ is the trade barrier factor (inverse of unity minus the ad valorem barrier per unit of exports) between countries (regions) $i$ and $j$, assumed to be the same as $t_{ji}$, and $P_i$ is their key notion of aggregate trade resistance, or simply, the consumer price index of country $i$. The parameter $\sigma$ is the elasticity of substitution between imports from various origins. The authors’ estimation results of (1) produce a much smaller effect of the US-Canada border on trade than what was found out by McCallum.

What is striking about (1) is that it implies total symmetry in trade flows, i.e., $X_{ij} = X_{ji}$, which does not prevail in reality, as mentioned above. Therefore, a more general approach is in place. In this paper we derive a model for bilateral trade flows, expanding on the framework used by Anderson and van Wincoop, by explicitly introducing monopolistic competition in the export market, and by also allowing for asymmetry in trade. We estimate the model for trade flows between European countries to determine the factors behind the trade asymmetries.

The paper proceeds as follows. The gravity model is derived in Section 2 and in Section 3 we present its estimation for trade flows between 27 European countries in 1999. Section 4 illustrates, how to use the estimated model to derive general equilibrium effects of trade policies, which is then applied to evaluate the effect, through trade, of possible UK joining EMU. Here again, the issue of asymmetry turns out to be quite crucial as to the magnitude of the effects of integration policies.
2. A MODEL OF BILATERAL TRADE

The specification of the demand for imports from various countries here follows that of Anderson and van Wincoop, with some minor modifications. The import demand functions in country \( j \), \( j = 1, \ldots, N \), are derived from a CES utility function for aggregate consumption \( D_j \),

\[
D_j = \left[ \sum_{i=1}^{N} a_{ij}^{\frac{1}{\sigma}} Q_{ij}^{(\sigma^{-1})} \right]^{\frac{1}{\sigma}}, \quad \sigma > 0,
\]

where \( Q_{ij} \) is the volume of exports from country \( i \) to \( j \), the \( a_{ij} \)'s are the country-specific positive preference (distribution) parameters summing to unity and \( \sigma \) is, again, the elasticity of substitution between imports from various origins. The import demand functions are then

\[
Q_{ij} = a_{ij} D_j \left( \frac{p_{ij}}{P_j} \right)^{-\sigma},
\]

where \( p_{ij} \) is the price set by the exporters of country \( i \) in the market of country \( j \), inclusive of the cost of trade barriers and, being dual to the quantity index (2), \( P_j \) represents the CES price index of the consumption basket in country \( j \).

\[
P_j = \left[ \sum_{i=1}^{N} a_{ij} p_{ij}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}.
\]

From (3) we can derive the market share of the value of exports \( X_{ij} = p_{ij}Q_{ij} \) in country \( j \), in relation to its GDP, yielding

\[
\frac{X_{ij}}{Y_j} = a_{ij} \left( \frac{p_{ij}}{P_j} \right)^{-\sigma},
\]
where $Y_j$ is the GDP (in nominal terms) of country $j$ and the budget constraint $Y_j = P_j D_j$ is imposed.

We next consider the export supply decision of a monopolistic firm of country $i$ in the market of country $j$. For this we need to specify that aggregate demand $D_j$ is given by the function

$$D_j = b_j P_j^{-\varepsilon}, \varepsilon > 0,$$

where $b_j$ is a scale factor representing the size of the country concerned. Note that typically $\varepsilon < \sigma$. Let there be $K_i$ identical exporting firms in country $i$. The optimal supply decision of an exporter in country $i$ maximizing profit in market $j$ is given by

$$p_y (1 + \varepsilon(p_y, Q_{ikj})) = t_y c_i,$$

where $c_i$ is the marginal cost of production in country $i$ and $Q_{ikj}$ denotes the volume of exports of firm $k$ of country $i$ in the market of country $j$, $t_y$ is, as in Eq. (1), the trade barrier factor (inverse of unity minus the ad valorem barrier per unit of exports) between countries (regions) $i$ and $j$, and $\varepsilon(z_i, z_j)$ denotes the elasticity of the variable $z_i$ with respect to the variable $z_j$. Using (3), (6) and the general result from index number theory that $\varepsilon(D_j, Q_{ikj}) = s_{ikj} = X_{ikj}/Y_j$, i.e., the market share of exporter $k$ in the market of country $j$, and summing over the identical $K_i$ firms, we get the following from (7),

$$p_y [K_j (1 - \sigma^{-1}) + (\sigma^{-1} - \varepsilon^{-1})(s_y + h_j (1 - s_y))] = K_j c_i t_y.$$

Here $h_j$ is the conjectural variation parameter in the proportional output game\(^{2}\) (see e.g., Smith and Venables, 1988 and Alho, 1996 and the appendix for more details) and $s_{ij}$ is the

\(^{2}\) I.e., the parameter $h_j$ is in relative terms the output response by the competitors to a one percent rise in the output of the firm concerned in market $j$. If $h_j$ is, e.g., zero, we have the case of Cournot competition.
aggregate market share of country \( i \) in the market of country \( j \), \( s_{ij} = \sum_{k=1}^{K} s_{ikj} = X_{ij}/Y_j \). The supply equation (8) allows for price discrimination between various export markets. It is therefore more general than the approach of Anderson and van Wincoop, who assume uniform pricing, which takes place when competition is perfect (\( h_j = -s_j (1 - s_j)^{-1} \) and \( \sigma \) approaches infinity). Note that under perfect competition, the export price only depends on the unit cost and the respective trade barrier. But otherwise under imperfect competition, the bigger the country, measured by the number of firms, the lower the export price which its firms charge.

We next need a model for the determination of the cost levels \( c_i \) and introduce therefore the following framework. Assume simply that labour \( L \) is the only factor of production and that there are constant returns to scale, \( Q_i = A_i L_i \), where \( Q \) is the volume of GDP. Let the utility function \( U \) of workers be simply, in a standard manner, \( U_i = \log(D_i) - \frac{1}{\nu} L_i^r \), where \( \nu > 0 \). Now optimizing under the budget constraint \( P_i D_i = W_i L_i + \pi_i \), where \( W \) is the wage rate and \( \pi \) aggregate profits, we get the result for wage formation,

\[
(9) \quad W_i = P_i D_i L_i^{r-1} = Y_i L_i^{r-1} .
\]

In the next step, in deriving the unit cost \( c_i = W_i/A_i \), we could take two approaches. First, we could take the technology, as incorporated in the parameter \( A \), to be identical in all the countries. But, as the countries in our empirical sample of European countries, on which we shall estimate the gravity model, are widely apart from each other as to their income levels and thereby productivities, this assumption of uniformity is not very sensible. There-
fore, we allow for differences in productivities and write $A_i$, being the average labour productivity, as $A_i = Q_i/L_i = Y_i/P_iL_i$. So, we get for the unit cost

$$c_i = \frac{W_i}{A_i} = P_iL_i^\nu.$$  

It depends simply on the price level in the country and positively on the size of the country, if $\nu$ is positive, measured by the labour force, which will be below captured by population.

We further assume that that the average size $\bar{Q}$ of the firms is identical in all the countries, so that $K_i\bar{Q} = Q_i = Y_i/P_i$. Normalise then this average size to unity, and insert this result and (10) into (8). We can, by equating export demand (4) with supply (8), solve then for export price $p_{ij}$ from the equilibrium condition,

$$AY\left[ P_i^{-\nu}(1-\sigma^{-1}) - \frac{t_jP_j}{P_j} \right] - \frac{h_j}{1-h_j} = a_{ij}(\frac{p_{ij}}{P_j})^{1-\sigma},$$

where $A^{-1} = (\varepsilon^{-1} - \sigma^{-1})(1-h_j) > 0$. Insert next this equilibrium solution (11) for the export price in market $j$ into the export demand equation (4). Using the approximation that $\log(x+y) \approx \log(x) + \log(y) + o(x^2) + o(y^2)$, we can solve for the bilateral exports to be as follows, returning back to a power function specification,

$$X_{ij} = \frac{Y_jY_i^{\mu}L_j^{-\mu}a_{ij}^{\mu}}{P_i^\mu P_j^{-\mu}L_j^{\nu}},$$

where $\mu = \sigma^{-1}(\sigma - 1)$.

The parameter $\mu$ is thus positive and smaller than unity, if the elasticity of substitution $\sigma$ is higher than unity. In addition, the function (12) includes higher order terms for $Y_i$, $P_i$, and $P_j$ and the parameter $h$ is assumed to be uniform in all markets. Note that, as mentioned
above, under perfect competition, the $Y_i$ variable is not present in (10), and not in (12), either.

There are several differences between specifications (12) and (1). The coefficients of $Y_i$ and $Y_j$ are normally different from each other in (12), and the coefficients of the price level in the exporting and importing countries are now also equal, but of opposite sign, in contrast to Eq. (1) where they are identical.

3. ESTIMATION AND TESTING FOR ASYMMETRY IN EUROPEAN TRADE

As an illustration, let us estimate the basic trade equation (12) for trade flows between 27 European countries in 1999, the first year of Economic and Monetary Union (EMU), and compare it to the specification (1) of Anderson and van Wincoop. We consider the following regions of countries in our estimations: those countries belonging to EMU, the EU, EU Accession Countries in Central and Eastern Europe, EFTA and Russia. We specify the preference parameters $a_{ij}$ to be simply a function of common language, representing a common culture in the exporting and importing country. The trade barriers are captured by the following specification:

$$t_{ij} = c d_{ij}^2 e^{b_{ij} + \delta n_i + \phi n_j + \sum_{k,m} \beta_{km} r_{ij}(k,m)}$$

Here $d_{ij}$ is the distance between countries $i$ and $j$, $b_{ij}$ is the common-border indicator, equal to unity if countries $i$ and $j$ share a common border and zero otherwise, and $n_i$ is unity if $i$ is an island. The term $r_{ij}(k,m)$ is the regional integration indicator for exports from the region of countries $k$ to region $m$, and equals unity if country $i$ belongs to region $k$ and country $j$
belongs to region \( m \), and zero otherwise. So, we allow for trade barriers to be potentially asymmetric in exports from region \( k \) to \( m \) and from \( m \) to \( k \), i.e. that \( \beta_{km} \) may be different from \( \beta_{mk} \).\(^4\) Trade within the EU Internal Market is the reference point.

The relative price indices, \( P_j \) relative to that in other countries, are here calculated from measured price data as the relation between the current exchange rate of the currency concerned in terms of USD and its corresponding purchasing power parity (PPP) rate. Anderson and van Wincoop (2003) recommend against using measured prices because they are largely based on prices of nontradables. However, normally nontradables and tradables prices are positively related to each other. On the other hand, this information on relative prices between the countries is readily available. Their use also offers a neat way to carry out general equilibrium type of simulations related to changes in trade barriers, see Section 4.

The estimation results, using SUR, are the following. The common culture variable did not turn out to be significant, and is therefore omitted from the results. The inclusion of the labour force in the exporting country, captured here by population, which should have a negative coefficient, see (12), was met as to this property, but otherwise this specification was not successful in the sense that then the coefficient of the income variable \( Y_i \) got a coefficient which is higher than unity and which is against our theoretical model (12). Therefore, we imposed in (12) the constraint that the disutility of labour parameter \( \nu \) goes to zero, which removes the labour force from the unit cost \( c_i \), see (9) above. The estimation results in Table 1 are presented using this specification.

\(^4\) EMU is a subset of the EU, which has to be taken into in the interpretation of the coefficients of the respective dummy variables.
Table 1. Estimation of the bilateral trade model for European countries (the log of the market share of bilateral exports \(X_{ij}/Y_j\) as the dependent variable)

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Model 1 (Eq. (1))</th>
<th>Model 2</th>
<th>Model 3 (Eq. (12))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coeff.</td>
<td>Coeff.</td>
<td>Coeff.</td>
</tr>
<tr>
<td></td>
<td>(St. error)</td>
<td>(St. error)</td>
<td>(St. error)</td>
</tr>
<tr>
<td>Constant</td>
<td>−8.650 (0.143)</td>
<td>−7.560 (0.259)</td>
<td>−7.497 (0.831)</td>
</tr>
<tr>
<td>Log(Y_i)</td>
<td>1.000 (0)</td>
<td>0.949 (0.019)</td>
<td>0.846 (0.037)</td>
</tr>
<tr>
<td>Log(P_j)</td>
<td>−0.360 (0.026)</td>
<td>−0.454 (0.022)</td>
<td>0.846 (0.037)</td>
</tr>
<tr>
<td>Log(P_i)</td>
<td>−0.360 (0.026)</td>
<td>−0.151 (0.052)</td>
<td>−0.846 (0.037)</td>
</tr>
<tr>
<td>(Y_i^2)</td>
<td></td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>(P_j^2)</td>
<td>−0.944 (0.136)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(P_i^2)</td>
<td>1.176</td>
<td>0.132</td>
<td></td>
</tr>
<tr>
<td>Log(distance)</td>
<td>−1.231 (0.020)</td>
<td>−1.313 (0.016)</td>
<td>−1.164 (0.062)</td>
</tr>
<tr>
<td>Common border</td>
<td>0.179 (0.031)</td>
<td>0.150 (0.104)</td>
<td></td>
</tr>
<tr>
<td>i island</td>
<td>0.129 (0.079)</td>
<td>0.251 (0.110)</td>
<td></td>
</tr>
<tr>
<td>j island</td>
<td>−0.216 (0.052)</td>
<td>−0.227 (0.122)</td>
<td></td>
</tr>
<tr>
<td>Regional integration</td>
<td>Yes*</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>dummies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R^2_{c})</td>
<td>0.559</td>
<td>0.801</td>
<td>0.916</td>
</tr>
<tr>
<td>F-test of symmetry of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>regional trade barriers</td>
<td>11.487**</td>
<td>.</td>
<td>13.338**</td>
</tr>
<tr>
<td>F-test of coeff. of (Y_i) being</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>unitary</td>
<td>.</td>
<td>7.590***</td>
<td>.</td>
</tr>
</tbody>
</table>

* The barriers are constrained to be symmetric, \(\beta_{km} = \beta_{mk}\) for all \(k, m\), in Eq. (12), similarly as in Eq. (1)

** \(p < 0.001\)

*** \(p < 0.01\)

+ The t-statistic of this coefficient is 1.8.

We see that Anderson and van Wincoop’s model, presented in Equation (1) above, is not very well supported by the data, see Model 1 in Table 1 and its rather weak explanatory power in comparison to the other models. Models 2 and 3 are, instead, based on our preferred specification in Equation (12) and its versions. Model 3 is based on our gravity equation as specified above in (12) and its constraints imposed.

The hypothesis that trade barriers representing the various stages of regional economic integration are symmetric, i.e., that \(\beta_{km} = \beta_{mk}\) for all pairs of \(k\) and \(m\), is clearly rejected, as shown in the estimation results of Model 3 and also Model 1. Also the coefficient of \(Y_i\) differs significantly from unity, which points to another asymmetry in the specification of the trade equation, in contrast to Equation (1). The effect of a common border on mutual trade is found to be 21 percent, which is similar to the estimate by Anderson and van Wincoop.
concerning the effect of the Canada-US border on trade. The estimate of the elasticity of substitution, \( \sigma \), is 6.5 on the basis of Model 3, as solved from Eq. (12) above.

4. SIMULATION OF A CHANGE IN TRADE BARRIER

Simulating changes in trade barriers \( t_{ij} \), so that their general equilibrium effects through the price variables and income levels are taken into account, is an important issue raised by Anderson and van Wincoop. We suggest a computationally straightforward way to carry this out. Like Anderson and van Wincoop, we first need to make an assumption about the elasticity of substitution \( \sigma \). But what is neat in our model, is that it the estimation of it, at the same time, produces us an estimate of \( \sigma \), see (12). The change in the trade barrier \( t_{ij} \) has both a direct impact on trade, and an indirect one through a change in the price level \( P_j \). To find out the latter, we can solve from (5) the change in the price ratio \( p_{ij}/P_j \) from the change in the market share of exports resulting from a change in \( t_{ij} \). Denote by \( \delta_{ij} \) the elasticity of exports \( X_{ij} \) with respect to \( t_{ij} \) divided by \( 1-\sigma \) in Equation (5). After that we can solve for the elasticity \( \varepsilon(P_j,t_{ij}) \) from the identity

\[
\varepsilon(P_j,t_{ij}) = \varepsilon(P_j,p_{ij})\varepsilon(p_{ij},t_{ij}) = s_{ij}(\delta_{ij} + \varepsilon(P_j,t_{ij})) ,
\]

where we have used, again, the above-mentioned general property in index number theory that \( \varepsilon(P_j,p_{ij}) = s_{ij} \). From (14) we can solve the expression needed in the general equilibrium simulations of changes in trade barriers,

\[
\varepsilon(P_j,t_{ij}) = \frac{s_{ij}\delta_{ij}}{1-s_{ij}} ,
\]

\[5\] In deriving the last step of Eq. (14), we use the identity \( p_{ij} = (p_{ij} / P_j)P_j \).
This allows us to take into account the indirect effect of a change in \( t_{ij} \) on \( P_j \) and further to the trade flow, using the gravity model, in addition to the direct effect estimated above. The changes in the trade barriers have an impact on the income levels, too. These can be captured using the identity,

\[
(16) \quad dY_i = \sum_{i \neq j} dX_{ij} + dX_{ji} = \sum_{i \neq j} dX_{ij} - \sum_{j \neq i} dX_{ji},
\]

as the rise in total imports to country \( j \) offsets the sales by the domestic firms to the domestic market.

Let us now use this framework, and the estimated gravity model, to make an analysis of the general equilibrium effects of possible UK joining EMU. For this simulation, we take the trade equation as estimated in Model 3 in Table 1 and combine it with the price impact as shown in (15) and the income identity in (16). We disaggregate the countries into three groups: the UK, the Euro Area and the rest of Europe. We allow for the trade barrier to be dismantled from UK exports to the Euro Area and respectively in exports from the Euro Area to the UK, if such barriers exist.

The relevant impacts of the trade barriers in the trade between the UK and Euro Area are the estimated coefficients, see the definition in (13) above, \( \beta_{\text{EMU},\text{EU}} \), \( \beta_{\text{EMU},\text{EMU}} \) and \( \beta_{\text{EU},\text{EMU}} \). The total initial impact on UK exports of joining EMU is then \( \beta_{\text{EMU},\text{EMU}} - \beta_{\text{EU},\text{EMU}} \) and that for EMU area exports to the UK being \( \beta_{\text{EMU},\text{EMU}} - \beta_{\text{EMU},\text{EU}} \). The estimates of these coefficients are according to our estimation, \( \beta_{\text{EMU},\text{EU}} = -0.617 \) and \( \beta_{\text{EMU},\text{EMU}} = 0.499 \) and \( \beta_{\text{EMU},\text{EU}} = 0.378 \). Thereby the barrier (measured now by its impact on trade, see Eq. (12) to see the difference between barrier \( t_{ij} \) and its effect on trade, i.e. \( t_{ij}^{-\mu} \)) in UK exports into Euro Area is their difference, i.e. \(-1.116\), and which is zero with probability 0.0245. But the reverse barrier existing in EMU countries’ exports into the UK is 0.12, and does not differ signifi-
cantly from zero. So, the estimation result shows that the impact of joining EMU would boost markedly the exports of UK, but not reverse. In recent studies on trade impact of EMU, like Micco et al. (2004) and Barr et al. (2004), where only the case of symmetric trade barriers is considered, the barrier estimates, reached as to the impact of EMU vs. non-EMU membership, are much smaller than those here. So, let us consider two cases, first, that of abolishing identical barriers in exports and imports of UK with the Euro Area, and, secondly, that of asymmetric barriers, i.e., there being one only in UK exports to EMU but not in reverse trade. Due to the markedly diverging estimates of barriers, reached in the literature, we also allow the estimate of the existing barrier to vary in size.

We depict in Figure 1 the outcome on real GDP when symmetric barriers are assumed to be dismantled between the UK and the Euro Area.

**Figure 1. The impact of UK entrance into EMU on real GDP, percentage deviation from the initial equilibrium, the case of symmetric initial trade barriers existing between the UK and the Euro Area**
Both the UK and Euro Area gain from a liberalisation of trade, as normally, but the UK much more, as is also the basic effect of mutual trade liberalisation for a smaller region, being more open with respect to the bigger region, than the reverse. The gains are, of course, the bigger, the larger the initial barrier existing in trade. There is a also slight negative effect, through trade diversion, on those countries remaining outside. In Figure 2, we have the situation of asymmetric barriers so that they only apply presently to UK exports to the Euro Area, but not to reverse trade.

Figure 2. The impact of UK entrance into EMU on real GDP, percentage deviation from the initial equilibrium, the case of asymmetric trade barriers (only applying in UK exports to EMU)

In this case, in contrast to the symmetric case, the Euro Area loses, but the gain to the UK is now very much bigger than before, as there is only a small offset through a rise in imports from the Euro Area to the UK. The rest of Europe is not affected by this policy. The issue of symmetry vs. symmetry of trade barriers is therefore an important aspect also as to the outcome of integration policies. In our estimated gravity model, the test of equality of
these two barriers, i.e. those in exports from the UK into the Euro Area and in the reverse trade, is strongly rejected.\(^6\)

5. CONCLUSION

We have in this paper derived a gravity model for trade, explicitly based on monopolistic competition, giving up the property that bilateral trade flows are symmetric. We have also found that this more general specification receives strong empirical support and is important as to the outcome of the trade policy simulations with the aid of the model, too.

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\(^6\) I.e. we test equality of estimates of the coefficients \(\beta_{\text{EMU,EU}}\) and \(\beta_{\text{EU,EMU}}\).
APPENDIX. DERIVATION OF THE ELASTICITY IN EQUATION (8)

Taking the standard result (7) as a starting point, we can express the elasticity term \( \varepsilon(p_{ij}, Q_{ik}) \) in it as follows. Let us first write

(A1) \[ p_{ij} = \frac{q_{ij}}{p_j} D_j \]

and then differentiate both sides logarithmically with respect to \( Q_{ikj} \). Defining \( h_j \) as the conjectural variation parameter in the proportional output game, the last term of the differentiation of (A1) gives

(A2) \[ D_j \log(Q_{ikj}) = \frac{\partial \log D_j}{\partial \log Q_{ikj}} + \frac{\partial \log Q^R_j}{\partial \log Q_{ikj}} = s_{ikj} + (1 - h_j)s_{ikj} \]

where \( Q^R_j \) is the supply of other firms to the market \( j \) and where we have used the basic result of index number theory that that \( \varepsilon(D_j, Q_{ikj}) = s_{ikj} = X_{ikj}/Y_j \), i.e., the market share of exporter \( k \) of country \( i \) in the market of country \( j \).

The first term of the logarithmic differentiation of (A1) is, on the basis of (5) and using (A2), equal to \( -\sigma^{-1}(1 - (s_{ikj} + (1 - h_j)s_{ikj})) \). The second term is, using the definition (6), equal to \( -(\varepsilon^{-1} + 1)(s_{ikj} + (1 - h_j)s_{ikj}) \). Combining these three terms gives us the elasticity between the export price and the quantity supplied, included in the export supply optimum, as

(A3) \[ \varepsilon(p_{ij}, Q_{ik}) = -\sigma^{-1} + (-\sigma^{-1} - \varepsilon^{-1})(s_{ikj} + (1 - h_j)s_{ikj}) \]

This is then inserted into (7) and summed over the \( K_i \) firms in country \( i \) to give equation (8).
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