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Estimating Trade Equations from Aggregate Bilateral Data[1]

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Abstract

This paper uses bilateral data on 420 merchandise trade flows between 21 industrial countries are used to estimate standard trade equations. The data set of over 11,000 observations allows the underlying elasticities to be estimated with considerable precision. Remarkably, a single specification appears to explain behavior across these countries in spite of the large number of individual flows analyzed. The results indicate a powerful long-run effect from supply on exports. Also, the real exchange rate elasticity depends upon the behavior of third country exchange rates. There is evidence of pricing to market and of a J-curve.

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I. INTRODUCTION

Trade equations are one of the older, and more rewarding, parts of empirical economics. Numerous standard trade equations relating the volume of exports or imports to relative prices and to levels of activity have been estimated over the last 20 years or so with notable empirical success, so much so that they are now an accepted part of most policy and applied academic work in international economics.[2] Indeed, the lack of controversy about the basic specification may have contributed to a relative lack of academic interest.

The success of the standard trade model does not mean, however, that there remain no controversies. Rather, such disagreements have centered more upon the size and importance of specific parameters and variables than on the underlying empirical approach. For example, differing views about the size of the long-run relative price elasticities has generated extensive discussions on the effectiveness of the exchange rate in altering nominal trade balances in the long run (elasticity optimism versus elasticity pessimism), while similar uncertainties about the profile of relative prices elasticities over time has produced discussion of the short-run impact of the exchange rate on the nominal trade balance (the J-curve).[3] More recently, the 45 degree rule—the observation that estimated foreign activity elasticities for exports are closely related to growth of domestic output—has opened up debate about the role of supply factors in the determination of trade.[4] Finally, third-country competition and pricing to market remain live issues, as does pricing to market.[5]

This paper contributes to these debates by estimating a generalized trade model which encompasses these issues. Its innovation is to use a very large panel data set, comprising data on 420 aggregate bilateral trade-flows between 21 industrial countries, to estimate underlying trade elasticities for real activity and relative prices. The use of such a large data set—which includes over 11,000 observations—provides sufficient detail to allow the critical parameters to be estimated with considerable accuracy, thereby allowing relatively precise answers to questions about the sizes of these underlying elasticities. Remarkably, a single specification appears to explain behavior across these countries in spite of the large number of individual flows analyzed.

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[2]The literature is large. A comprehensive survey is contained in Goldstein and Khan (1985). More recent papers which include both surveys of earlier work and new results include Hooper and Mann (1989), Hooper and Marquez (1995), and Marquez (1995). Clarida (1994) and Gagnon (1989) provide models with stronger theoretical underpinnings.

[3]Krugman (1991) surveys these issues. See also Hooper and Marquez (1995) and Rose and Yellen (1989).

[4]See, in particular Krugman (1989).

[5]Work on pricing to market includes Knetter (1989, 1993) and Gagnon and Knetter (1995).

The remainder of this paper is organized as follows. The next section provides details of the empirical specification used in the estimation. This is followed by a description of the data, and then by the results. Implications and conclusions follow.

II. Empirical Specification

The standard model used in most work on industrial country trade from one country to another assumes that goods are differentiated by country of origin,[6] and that their supply is perfectly elastic. Accordingly, (real) exports from country X to country M (X_{XM}) are defined solely by the demand for such goods in the recipient market. This in turn depends upon the importers' income and the relative price between the goods of the exporter and goods in the recipient country. In the specification below, real GDP is used for the importers income (labeled Y_M)[7] and export deflators are used to measure relative prices (labeled E_X/E_M, with both prices being calculated in a common currency).[8] To test the robustness of the results to alternative price indices, estimates using CPIs and GDP deflators are also reported.

Account also needs to be taken of competition with other countries' export goods. When multilateral data on exports are used, these third-country effects are generally incorporated directly into the weights used in the real effective exchange rate calculation. Using bilateral data on trade flows allows this effect to be estimated separately. For each bilateral equation we assume that consumers in the importing country choose between three types of goods, home goods, goods from the exporter in question, and goods from all other exporters. This implies that the relative price of other export goods should be included in the specification. This is done below by calculating an average price across all other exporters, with individual country export prices being weighted by their share in imports to country M, measured relative to prices in country M (E^M_O/E_M, where E^M_O is the import-weighted average of domestic prices in other countries). Accordingly, the demand function for exports from country X to country M is:

$$X_{XM} = D(Y_M, E_X/E_M, E^M_O/E_M). \quad (1)$$

The focus on demand factors in the "standard" trade model, to the exclusion of supply considerations, has been the subject of significant recent debate, much of it focusing on the 45

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[6]For primary goods, which is generally more relevant for the trade of developing countries, products are generally assumed to be homogeneous across countries.

[7]Real GDP is a relatively standard variable, although considerable variation does exist. For example, world trade or absorption can be substituted for real GDP. Warner (1994) suggests using spending on investment.

[8]This, again, is fairly standard, although large variations exist. Estimates of multilateral trade equations using different exchange rate indexes are presented in Marsh and Tokarich (1994).

degree rule. This is the observation of a positive, approximately one-to-one, relationship between estimated elasticities on foreign activity in export equations and the rate of growth of domestic output. If all economies have the same underlying activity elasticities with respect to foreign activity then, at unchanged real exchange rates, high growth economies should show a tendency for their imports to grow faster than exports, while slow growing economies should exhibit the opposite characteristic. Such a differential would need to be offset by a steady depreciation in the real exchange rate of fast growing economies and appreciation in the real exchange rate of slow growing economies so as to keep nominal trade in balance. In practice, however, countries with high output growth generally see no secular decline in their real exchange rates or trade balances. Rather, the estimated elasticities on foreign activity rise with the level of domestic growth (hence the phrase the 45 degree rule).[9] As a result, rates of expansion of real exports are highly correlated with domestic performance.

The close correspondence between estimated activity elasticities for exports and real domestic growth suggests some form of misspecification. Several authors have hypothesized that this comes from not including a term measuring domestic supply in the export equation. A supply term can be justified in the context of the new trade theories of trade, which focus on the implications for trade of increasing returns to scale in production and the desire of consumers for variety in consumption.[10] Higher output generates an increase in the number of products. As consumers desire variety, this increases the demand for goods from that country. These considerations imply that some measure of productive capacity or diversity of goods in the exporting country should be included in the specification. A number of variables have been used in earlier work.[11] In the interests of simplicity and symmetry, real GDP of the exporter (Y_X) is used as the domestic supply variable in this specification. This implies a real export function of the form:

$$X_{XM} = f(Y_M, Y_X, E_X/E_M, E^M{}_O/E_M). \tag{2}$$

Finally, account needs to be taken of pricing-to-market behavior. The data on bilateral trade is nominal and the relevant bilateral export prices are not available. Accordingly, the nominal values are deflated by the price of aggregate exports. To the extent that exporters

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[9]Houthakker and Magee (1969) and Krugman (1989). Muscatelli, Stevenson and Montagna (1995) and Muscatelli (1995) provide formal models.

[10]The "new" theories of international trade are discussed in Krugman (1980) and Helpman and Krugman (1989). The connection with the "45 degree rule" is made in Krugman (1989).

[11]Earlier work on supply factors include Helkie and Hooper (1988) for the United States, and Muscatelli and Stevenson (1995) for newly industrializing economies. For an alternative view see Reidel and Athukorala (1995).

charge different prices across markets ("price to market"), the prices charged for exports from country X will differ across countries.[12] Hence, rather than considering a single aggregate price index (E_X), one should consider all of the bilateral price indexes separately—for example, for exports from country X to country M the price index would be E_{XM}. The multilateral price index, E_X, is then a weighted average of these individual bilateral price indexes.

Assuming that the export prices charged in different markets correspond to differences in domestic prices of tradeable goods (i.e., that countries in which domestic prices of traded goods are high are the ones in which prices of exported goods from country X are also high), the difference between the bilateral price of exports between X and M (E_{XM}) and the multilateral price of exports from country X to all countries (E_x) can be assumed to depend on the difference between multilateral prices of goods from country M (E_M) and in other export markets (E^X_O). Using lower case letters to represent logarithms:

$$e_{XM} = e_X - \delta\,(e^X_O - e_M) \tag{3}$$

where e^X_O is an export weighted average of export prices in markets other than M.

Equation (3) can be used to derive an estimating equation for bilateral trade in which only multilateral price indexes appear. As the activity terms are not important for this derivation, the underlying export volume equation from equation (2) can be simplified so as to depend only on the bilateral exchange rate and third country competition:

$$xn_{XM} - e_{XM} = -\phi\,(e_{XM} - e_M) + \gamma\,(e^M_{OM} - e_M), \tag{4}$$

where xn_{XM} is the nominal level of exports from X to M, and e^M_{OM} is the import-weighted price charged in market M by other exporters. Substituting equation (3) into equation (4) gives:

$$xn_{XM} - e_X = -\phi\,(e_X - e_M) + \gamma\,(e^M_O - e_M) - \delta(1-\phi)\,(e^X_O - e_M) - \delta\gamma\,(e^{XM}_O - e^M_O)\,, \tag{5}$$

where e^M_O is the import weighted average of domestic prices in other markets, e^X_O is the export-weighted average of domestic prices in other markets and, as discussed above, e^{XM}_O is the exported weighted average of the imported weighted average of prices in other markets.[13]

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[12]See Krugman (1987) for a theoretical discussion and Knetter (1989, 1993) and Gagnon and Knetter (1995) for empirical evidence.

[13]Using equation (3), it follows that $e^M_{OM} = e^{XM}_O - e^M_O$, where e^{XM}_O is the exported weighted average of the imported weighted average of prices in other markets, with all weights being from the point of view of country X.

The last term is close to zero because it is the difference between two averages of export prices across all countries. Excluding this term, and writing $x_{XM}=xn_{XM}-e_X$, where x_{XM} is the level of bilateral real exports calculated using the aggregate export price index, gives:

$$x_{XM} = -\phi\ (e_X - e_M) + \gamma\ (e^M{}_O - e_M) - \delta(1-\phi)\ (e^X{}_O - e_M). \quad (6)$$

Pricing to market effects can therefore be taken into account by adding a term in the export-weighted average of prices in markets other than country M relative to export prices in country M ($e^X{}_O-e_M$) into the specification. Furthermore, the estimated elasticities from this equation are the correct even though "real" bilateral exports are calculated using multilateral export prices.

III. DATA

The estimating equation implied the need to collect data on bilateral trade, relative prices, and real output. Annual data on nominal bilateral exports and imports in dollars from 1960–92 among 21 industrial countries were collected from the machine-readable version of the IMF's *Direction of Trade Statistics.*[14] To minimize data inaccuracies, exports from country X to country M were calculated as the average of the reported bilateral exports from X to M and imports to M from X, and converted into the currency of the exporting country (country X). These were the basic data used to calculate bilateral trade flows and export and import weights for the real exchange rate calculations. As already discussed, there is no comprehensive source for bilateral price deflators. Accordingly, nominal bilateral exports were converted into real values using the multilateral price of exports, while pricing to market effects were captured using the average value of export prices in other countries, with weights defined by the composition of bilateral trade from the exporting country.

Real exchange rates were also calculated from annual data on aggregate merchandize export prices and period average nominal exchange rates, from *International Financial Statistics.*[15] Two other sets of more general national price indices were also collected. GDP deflators (a price level which includes economy-wide movements in domestic prices) and CPIs (another economy-wide price level which includes a significant component of imported goods). Real GDPs were taken from the Penn World Tables. The full data set runs from 1960 to 1992 and

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[14]The countries were the United States, Japan, Germany, France, Italy, the United Kingdom, Canada, Australia, Austria, Belgium/Luxembourg, Denmark, Finland, Greece, Ireland, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, and Switzerland.

[15]The weights used to calculate export- and import-weighted averages of prices in other markets were three year moving averages of the values implied by the underlying data on bilateral trade. To avoid biases caused by changes in these weights from one year to the next, these indices were calculated from data on changes in bilateral real exchange rates rather than their associated levels.

the estimation period was generally 1965–92, providing a sample of 28 years of data for 420 series (210 bilateral links with exports traveling in either direction), for a total of 11,760 observations.

Before reporting regression results it is interesting to look at some of the basic characteristics of the data. Table 1 reports the mean and standard deviation of the growth in bilateral trade, real output, real bilateral exchange rates, export-weighted real exchange rates and import-weighted real exchange rates, all measured in logarithms over 1965–92. Real trade (measured using export prices) grew on average by about 6½ percent per annum over this period (as the data are in logarithms a mean of 0.064 reflects a growth rate of 6.6 percent), about double the rate of real output.[16] When the sample is split in 1973, which coincides with the first oil crisis and the productivity slowdown in developed countries, this basic relationship is still present, although both the growth in bilateral trade and real output is significantly slower in the second period.

The standard deviation of the growth in real bilateral exports is quite large, over 20 percent per annum, and over 7 times that of real output (unlike the means, the standard deviations of both variables are similar before and after 1973). Bilateral trade would be expected to be more variable than real output (and than aggregate trade) as bilateral trading relationships can be affected by specific factors such as changes in specific tariffs, government regulations, and the location of new plants. The data may also, however, contain a significant amount of noise.[17] Note, however, that such random noise will not bias the estimated regression coefficients as it is in the dependent variable.

Bilateral real exchange rates have a standard deviation of about 7½ percent per annum, while the variability of their weighted counterparts are about 40 percent lower, reflecting the effects of combining the individual exchange rates into a single average value.[18] Prior to 1973 the variability of the real bilateral rate is about 5 percent per anum, while after 1973 it is slightly

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[16]When GDP deflators are used to calculate real trade, rather than export prices, the estimated rate of growth is significantly lower, just over 5 percent per annum.

[17]One indication of this is that differences between estimated exports from X to M and imports to M from X are often too large to be explained by the fact that one is measured net of transportation costs and the other includes them, implying that different national authorities produce somewhat different estimates of bilateral trade levels.

[18]The variability of the real exchange rate using GDP deflators is somewhat larger than that using export prices. The results for the means of the change in the exchange rate are of little interest. The mean of the change in the bilateral real exchange rate is zero by construction as each bilateral rate is included both as currency relative to B and the diverse ratio. The two weighted real exchange rates, which can deviate from the mean of zero due to compositional factors, are also very close to zero.

above the full sample value, reflecting the rise in nominal exchange rate volatility after the collapse of the Bretton Woods fixed exchange system.

IV. Results

The basic specification used in the estimation is:

$$x_{XMt} = \alpha_{XM} + \beta(L)\, y_{Xt} + \gamma(L)\, y_{Mt} + \phi(L)\,(e_{Xt} - e_{Mt}) + \mu(L)\,(e^{M}_{Ot} - e_{Mt}) + \zeta(L)\,(e^{X}_{Ot} - e_{Mt}) \qquad (7)$$

where lower case variables indicate the logarithm of the appropriate variable (so x_{XMt} is the logarithm of X_{XM} at time t) and L is the lag operator. The main differences between this specification and that outlined in equation (2) is the addition of relative prices in other export markets compared to those in country M (the pricing-to-market effect discussed above) and the inclusion of lagged values of the independent variables so as to identify their dynamic responses.[19] Note also that the coefficients on pricing to market (the $\zeta(L)$'s) depend upon those on the bilateral exchange rate (the $\phi(L)$'s), being negative if the $\phi(L)$'s are less than one (in absolute value) and near zero if the $\phi(L)$'s are close to one (in absolute value) (see equation 6).

Estimating a panel equation such as equation (7) presents some particular econometric problems. This is particularly true when, as in this paper, the model implies separate constant terms (fixed effects) for each bilateral relationship and the number of individual series (420) is much larger than the number of data points in each series (32). In this situation, the results from estimating equation (7) in levels using fixed effects is consistent only if the independent variables are strictly exogenous, that is, that they are uncorrelated with the error terms at all leads and lags.[20] If not, the coefficient estimates will be biased.

A standard solution to this problem, adopted here, is to first difference the variables in the regression. This eliminates the fixed effects from the estimation, leaving only a single constant term to be estimated across all relationships. Unfortunately, first differencing also induces a first order moving average error. As a result, it is consistent only if the independent variables are not correlated with the first lead or lag of the error term. Results from two standard methods of adjusting the first difference specification for this problem, namely adding a first order autocorrelation term and using instrumental variables, are reported below, as are results from a levels regression incorporating fixed effects.

Table 2 reports the results from estimating equation (7) in first difference form over the period 1965–92 including four lags for each independent variable. For estimation, the equation was

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[19]Unlike most empirical trade specifications, this one does not include a lagged dependent variable.

[20]See Keane and Runkle (1992).

reparamaterized using second differences for all lags except the fourth. The estimating equation was therefore:

$$\begin{aligned}\Delta x_{XMt} &= \alpha + \beta_0\Delta\Delta y_{Xt} + \beta_1\Delta\Delta y_{Xt-1} + \beta_2\Delta\Delta y_{Xt-2} + \beta_3\Delta\Delta y_{Xt-3} + \beta_4\Delta y_{Xt-4} \\ &+ \gamma_0\Delta\Delta y_{Mt} + \gamma_1\Delta\Delta y_{Mt-1} + \gamma_2\Delta\Delta y_{Mt-2} + \gamma_3\Delta\Delta y_{Mt-3} + \gamma_4\Delta y_{Mt-4} \\ &+\phi_0\Delta\Delta(e_{Xt}-e_{Mt})+\phi_1\Delta\Delta(e_{Xt-1}-e_{Mt-1})+\phi_2\Delta\Delta(e_{Xt-2}-e_{Mt-2})+\phi_3\Delta\Delta(e_{Xt-3}-e_{Mt-3})+\phi_4\Delta(e_{Xt-4}-e_{Mt-4}) \\ &+\mu_0\Delta\Delta(e^M_{Ot}-e_{Mt})+\mu_1\Delta\Delta(e^M_{Ot-1}-e_{Mt-1})+\mu_2\Delta\Delta(e^M_{Ot-2}-e_{Mt-2})+\mu_3\Delta\Delta(e^M_{Ot-3}-e_{Mt-3})+\mu_4\Delta(e^M_{Ot-4}-e_{Mt-4}) \\ &+\zeta_0\Delta\Delta(e^X_{Ot}-e_{Mt})+\zeta_1\Delta\Delta(e^X_{Ot-1}-e_{Mt-1})+\zeta_2\Delta\Delta(e^X_{Ot-2}-e_{Mt-2})+\zeta_3\Delta\Delta(e^X_{Ot-3}-e_{Mt-3})+\zeta_4\Delta(e^X_{Ot-4}-e_{Mt-4}). \quad (7')\end{aligned}$$

As the terms in fourth lags are not second differenced, this specification is identical to one in which all of the variables are entered in first difference form. The advantage of the reparameterization is that is makes interpretation of the estimated coefficients somewhat easier. In particular, in this specification the coefficients on each variable represent the elasticity for that year—the coefficient on the contemporaneous real exchange rate term reflects the real exchange rate elasticity on impact, the coefficient on the first lag reflects the elasticity after one year, while the coefficient on the fourth lag reflects the estimated elasticity from the fourth year onwards. To help interpret the results in Table 2, Chart 1 graphs the estimated dynamic path of the elasticities in the restricted model for all of the independent variables, together with 5 percent confidence intervals.

Almost all of the coefficients in Table 2 have the anticipated signs and are highly significant at conventional levels (the t-values generally exceed 10). The results are also consistent with the stylized facts of estimated trade equations discussed, for example, in Goldstein and Khan (1985), the short-run elasticity of trade with respect to foreign activity is large and the impact of the exchange rate increases significantly over time. The estimated contemporary elasticity on the real output of the importer is around 1.8. It stays at this level for 1 year before falling subsequently over time to a long-run value slightly below one after 4 years. Hence, the impact of changes in the importers' activity is larger in the short- than the long-run. The opposite characteristic is true of the exports real output, where the estimated elasticity rises from 0.36 contemporaneously to 0.69 after 4 years. Hence, while the short-term responses are to changes in output in the importing and exporting countries are very different, the long-run responses are similar. Indeed, a t-test indicates that the two long-run values are not significantly different from each other (the t-ratio for the constraint is 1.2), and hence that both coefficients can be made equal to the estimated common elasticity of 0.79.

The elasticities on the bilateral exchange rate are negative and also rise over time (in absolute value), from -0.31 contemporaneously to -0.79 after 4 years. The elasticity on third country competition (the import-weighted price of other countries' goods relative to those in the import market) remains fairly constant at about 0.25 in both the short- and long-run, although the coefficients show significant year-to-year variation. Finally, the coefficient on the pricing to market variable (the export-weighted price of other countries' goods relative to those in the import market) is a highly significant at -0.24 contemporaneously and for the first year, and then becomes smaller and insignificant, as would be expected given the elasticity on the bilateral exchange rate (see equation 6). The estimated value of the constant term is 0.017 and highly significant. As the regression is estimated in first differences, the constant term acts as a time trend. This result, therefore, implies an autonomous increase in trade of the order of 1.7 percent per annum. This autonomous increase appears to reflect the higher rate of growth of productivity of merchandise goods compared to other domestic produced output over the estimation period. When real bilateral exports are calculated using the GDP deflator, rather than its merchandise export equivalent, the constant term becomes insignificant (this regression is discussed further below).[21]

The R^2 of the regression is 0.14, with the low value presumably reflecting the high variance of the dependent variable discussed earlier. Strikingly, an F-test accepts the restriction that the estimated coefficients are equal across all bilateral relationships.[22] A single specification explains behavior across all of the 420 bilateral trading relationships in data set.

A. Specification Tests

Before discussing the implications of these estimates, the results from a number of alternative specifications are reported. As already noted, the first difference specification induces a first order moving average error, which means that the results are only consistent if the errors are uncorrelated with the first lead and first lag of the independent variables. A standard solution to this problem in the case of panel data is to reestimate the first-difference equation including a first order autocorrelation process. The first column of Table 3 reports the results from estimating the basic regression with a first order autocorrelation adjustment. The estimated coefficient on the autoregressive term is -0.18 and highly significant, indicating that first differencing the data did indeed induce negative first order serial correlation. However, the estimated coefficients from this regression are very similar to those found using the unadjusted regression (none of the individual coefficients differ by more than 0.06). Hence, the moving average process does not appear to have significantly biased the estimated coefficients.

This conclusion is supported by the results in column 2 of Table 3, which reports the results from another standard method of adjusting the panel estimation for the first order moving average error, namely using instrumental variable techniques. In this regression the

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[21]This is confirmed by direct calculations of the impact of using different deflators on the rate of growth of real exports. The average rate of increase in real exports is 5.2 percent per annum using GDP deflator, compared with 6.6 percent per annum using the export deflator. The 1.4 percent per annum difference is almost exactly the same as the estimate of the autonomous increase in exports.

[22]The F(10984,840) test statistics is 1.08, implying a p-value of 0.08. Note, however, that there are a relatively large number of estimated coefficients compared to the number of time periods in each equation (26 versus 28).

contemporaneous values and first lags of all of the independent variables were instrumented.[23]

The estimated coefficients from this regression show a similar pattern to those using least squares, particularly for the activity variables, but are considerably less accurately estimated. As the instrumental variable results are consistent whether or not the moving average process significantly affects the estimated coefficients while the least squares results are only consistent in the latter case, a Hausman test can be used to test for biases in the least squares estimates. The results indicate no significant difference between the two sets of coefficients, again indicating that the main case estimates do not contain any significant bias.[24]

The third column in Table 3 reports the results from estimating the regression in levels form (as opposed to first differences) with fixed effects, a regression that will only be consistent if the independent variables are strictly exogenous.[25] In this case, the short-term dynamic responses from this equation are similar to those found in the first difference formulation, but long-run elasticities implied by the levels coefficients are generally somewhat lower; -0.65 for the bilateral exchange rate, -0.16 (and incorrectly signed) for third country competition, 0.07 for prices in alternative export markets and 0.69 for foreign output, although at 1.05 the elasticity on domestic output is somewhat larger in the levels than the first difference formulation. As the first difference formulation is consistent even if the independent variables are not strictly exogenous while the levels equation is not, a Hausman test can be used to test whether the estimated coefficients in the levels are biased. The equality of the two sets of coefficients is rejected, implying that such bias exists.[26]

A final specification issue has to do with the estimated coefficients on the contemporaneous bilateral real exchange rate. While using the same price series to calculate the bilateral exchange rate and to deflate nominal exports has the advantage that the implications for the nominal trade balance are easy to infer, it has the potential disadvantage that the export deflator of the exporting country is included in the construction of both the dependent variable and the real bilateral exchange rate. Errors in this deflator will therefore affect both sides of the equation, implying that the coefficient on the contemporaneous bilateral real exchange rate could be biased towards minus one. To test for this, the basic specification was reestimated

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[23]As extra lags were used as instruments, the regression was run over 1966–92. The instruments were a constant term and the second to sixth lags of the levels of the dependent and independent variables except those representing weighted averages of exchange rates, where the second to fifth lags were used.

[24]The $\chi^2(26)$ test statistic is 30.7, implying a p-value of 0.24.

[25]The original estimates of the levels-models showed considerable correlation in the errors, so the regression was re-estimated with a first order auto regressive term.

[26]The $\chi^2(26)$ statistic is over 178.

using the same instruments as discussed earlier plus the first and second lags of all of the independent variables except the bilateral real exchange rate, for which the change in the real exchange rate using GDP deflators was substituted. The logic behind using the GDP based real bilateral exchange rates is that this series will not have the same pattern of errors as the export deflator. These results, and others using different instruments sets, all showed the estimated coefficients on these contemporaneous variables moving toward minus one, the opposite of what would occur if the original estimates were biased. There appears to be little evidence that these coefficient are significantly biased by errors in variables, plausibly reflecting the fact that most of the variance in the dependent variable comes from the data on bilateral nominal exports, not the chosen deflator.

B. Alternative Price Deflators

The results to date have all focused upon results using export prices to calculate real exports and the real exchange rate. Table 4 reports results from the rerunning the general specification using real exchange rates calculated using GDP deflators and CPIs. The estimated coefficients from using CPIs and GDP deflators to calculate real exchange rates, reported in columns 1 and 2, are very similar. The elasticities with respect to output are near to those estimated using a real exchange rate from export prices, while the elasticities for bilateral and import-weighted real exchange rates are somewhat lower in absolute value.

A possible explanation for these lower estimated elasticities with respect to the real exchange rate is that economy-wide prices, such as the CPI and the GDP deflator, offset changes in the exchange rate less than do export deflators because they include nontraded goods. To investigate this issue further, column 3 of Table 4 reports the results from estimating the basic specification using GDP deflators to calculate both real exports and the real exchange rate. (As the coefficients on the pricing to market variable were insignificant, they were dropped in the reported specification. This has almost no impact on the other elasticities). The estimated bilateral real exchange rate elasticities are larger than those in columns 1 and 2, indicating that the lower estimated elasticities in the earlier regressions probably do reflect differing responses of prices to exchange rate changes.

The estimated bilateral real exchange rate elasticities in column 3 of Table 4 (using GDP deflators) are slightly larger than those in the main case regression in Table 2. When the regression was reestimated using instrumental variables for the contemporaneous value and first lag of the bilateral exchange rate (not reported for the sake of brevity), the estimated coefficients became more similar to those in the main case equation, implying that in this case least squares may well bias the estimated short-run elasticities towards minus one. Two further features of results from this regression are worth noting. The constant term is insignificant, reflecting the lower rate of growth of estimated real exports using the GDP deflator compared to export prices. As discussed earlier, this indicates that the trend in real exports identified in the main case reflects the lower rate of increase in export prices compared to prices in the economy as a whole. Finally, as with the other specifications reported in this paper, the equation passes an F-test for the equality of the parameters over all bilateral relationships.

V. Interpretation

Overall, the results indicate that the specification provides a good description of bilateral trade. The implications for the three topics discussed in the introduction—supply factors, third-country competition, and the J-curve—are now discussed, focusing initially on the main-case regression and then on the results from alternative specifications.

As regards supply factors, the relevant elasticities are those with respect to output in the exporting country (the γ_i coefficients in equation 8). The finding that the long-run elasticity with respect to domestic and foreign output are very similar implies an important role for supply factors in explaining long-term trends in trade, as hypothesized in Krugman (1989), and helps to explain why fast-growing countries experience no secular fall in their terms of trade over time (the 45 degree rule). It implies that the long-run income elasticities are the same for exports and for imports on a pairwise basis, although this does not mean that trade grows equally in all countries. Trade growth will be greater between faster growing countries than slower growing ones. Also, as the sum of the two activity elasticities is over 1, trade grows faster than income. These are results consistently found is empirical work, including that using the gravity model of trade.[27] At the same time, the elasticity on domestic output is significantly less than one, so that a 1 percent increase in domestic supply raises the demand for exports by around 0.8 percent in the long-run. Hence, while increases in domestic supply helps to generate higher foreign demand for exports, this rise is muted. Supply does not fully create its own demand.

The results for third country competition focus on the coefficients on import-weighted average of prices in other markets (the ϕ_i coefficients in equation 8). If third country competition matters and goods are substitutes, then one would expect increases in prices in competitors markets to boost the demand for real exports from country X. The empirical results indicate that such third country competition does matter for bilateral trade. The coefficients on the import-weighted average of prices in other markets are correctly signed and generally significant. As a result, the dynamic response of bilateral real exports to movements in the real bilateral exchange rate depends upon the behavior of other currencies.

Consider, first, a case in which the currency of the exporting country appreciates against all other imported currencies. As the relative price of other goods in the destination country does not change, there is no role for third country competition or pricing to market (in equation 8,

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[27]See Bergstrand (1985, 1989) for a theoretical derivation of the gravity model. Sterne (1986) provides an explanation as to why the coefficients on activity might be expected to sum to more than one. See also Frankel and Wei (1995).

e^M_O-e_M is zero).[28] As a result, the real exchange rate response is given by the estimated elasticities on the bilateral real exchange rate (-0.31 in the short-run and -0.79 in the long-run). As an appreciation in the real multilateral exchange rate for exports is equivalent to an equal increase in prices in the exporting country against all other countries, these are also the implied elasticities for aggregate exports. The dynamic path implied by the main case results for this elasticity, reported in the upper panel of Table 5, is well determined and highly significant.

Now consider a situation in which the exchange rate of the importer depreciates equally against all other currencies, so that the exchange rates of all exporters appreciate equally against the destination country. The increase in the relative price of competitors goods provides some cushion to exports through third country effects. In this case, the real exchange rate elasticity is the sum of the bilateral elasticity and third-country competition (the coefficients μ_i and ϕ_i) in equation 8, as $e_X - e_M = e^M_{Ot} - e_{Mt}$. Hence, the elasticity is -0.08 (-0.31+0.23) in the short-run and -0.50 (-0.79+0.29) in the long-run. This is also the implied elasticity for aggregate imports, as a movement in the multilateral exchange rate for imports is equivalent to an equip.-proportionate movement in the exchange rate against all other countries. The dynamic path for this elasticity is also shown in the top panel of Table 5. The exchange rate elasticities implied by the main case regression are highly significant from lag 1 onwards.

The size of the exchange rate elasticity for any specific bilateral trading arrangements therefore depends upon the behavior of third currencies.[29] Exports are most sensitive to the real exchange rate in cases when the appreciation or depreciation of the real exchange rate in one market is matched by a similar changes in markets, and smallest when this is not the case. This justifies the importance given to third country effects in many multilateral exchange rate calculations. The elasticity on third country effects varies in absolute value between one third and two thirds of the bilateral real exchange rate elasticity, with the ratio falling over time.

The final issue for discussion involves the response of the nominal trade balance to a change in the real exchange rate, and, in particular, to the evidence for a J–curve. When considering the response of the nominal trade balance account, in addition to third country competition account has to be taken of pricing to market term (the coefficients ζ_i on the terms $e^X_O - e_M$ in

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[28]Recall that the e^X_O-e_M term represents a nominal effect (pricing to market) so it is not included in the calculations of the elasticities for real exports.

[29]The real exchange rate elasticity for any given country also depends upon its specific trading patterns, so that it is possible for both countries to experience (say) a significant appreciation of their exchange rate against their other trading partners, even though their bilateral real exchange rate movements must be equal and opposite.

equation 8). To calculate the impact of the real exchange rate on the nominal trade balance it is useful to start from the basic model:

$$xn_{XMt} - e_{Xt} = \alpha_{XM} + \beta(L)\, y_{Xt} + \gamma(L)\, y_{Mt} + \phi(L)\,(e_{Xt} - e_{Mt}) + \mu(L)\,(e^{M}_{Ot} - e_{Mt}) + \zeta(L)\,(e^{X}_{Ot} - e_{Mt}) \quad (9)$$

where xn_{XMt}, is the logarithm of the value of nominal exports from X to M.

As there is a similar expression for trade in the opposite direction (xn_{XMt}), it follows that the ratio of nominal trade in either direction is:

$$xn_{XMt} - xn_{MXt} = (\beta(L)-\gamma(L))(y_{Xt}-y_{Mt}) + (\phi(L)+\mu(L)+\zeta(L)+1)(e_{Xt} - e_{Mt}) + (\mu(L)-\zeta(L))(e^{M}_{Ot}-e^{X}_{Ot}) \quad (10)$$

The first term shows the impact of relative output on the bilateral balance. As the coefficients $\beta(L)$ and $\gamma(L)$ become equal over time, this impact is temporary. The second term in equation (8) indicates the impact of the bilateral exchange rate, while the third part of the expression shows the effect of movements in third currencies due to differences in trading patterns.[30] Assuming that trade is balanced and that trade patterns for the two countries are sufficiently similar that the final term can be ignored, the elasticity of the nominal trade balance with respect to the bilateral real exchange rate (as a proportion to trade in either direction) is equal to twice the bilateral real exchange rate elasticity, plus the impact of third-country competition and pricing to market effects, plus 1. It should be stressed that this is an exact calculation, and does not depend upon assumptions about the behavior of prices of traded goods. This is because the same price series that is used to deflate nominal exports is also used to calculate the real exchange rate.

The elasticity of the nominal trade balance with respect to the real bilateral exchange rate calculated using aggregate export prices is thus +0.37 = (2x-0.31+0.23-0.24+1) on impact and -0.42 = (2x-0.79+0.29-0.13+1) in the long-run. As can be seen in the top panel of Table 5, all of the estimated elasticities over time are highly statistically significant. In response to a real devaluation, the trade balance falls on impact, improves after a year and reaches somewhere around its long-run value after 2 years.[31]

Table 5 also reports the same results for two variants of the basic model, the first being the results when the pricing to market effect is truncated be zero after two years and the second

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[30]To derive equation (8) it is important to realize that the export-weighted average of other currencies from the point of view of country X exporting to country M is equal to the import weighted average for country M exporting to country X.

[31]At -0.42, the long-run response of the nominal trade balance is somewhere between the predictions of the elasticity optimists and pessimists.

from the regression results using GDP deflators to calculate real exports and the real exchange rate reported in the last column of Table 4. As all of the equations give relatively similar results for output, the focus of the subsequent discussion is on the implied exchange rate elasticities. The results from truncating the pricing to market variable gives a similar pattern for the implied exchange rate elasticities as that found for the main case, but the absolute values of the long-run exchange rate responses are generally larger: -0.86 versus -0.79 for multilateral exports; -0.63 versus -0.50 for multilateral imports and -0.49 versus -0.42 for the nominal trade balance. A similar increase in the absolute value of the long-run exchange rate elasticities is found using the regression results using GDP deflators. In this case, however, the estimated short-term responses are also significantly higher, and there is no J-curve effect. To the extent that the use of GDP deflators may cause the estimated short-run real exchange rate elasticities to be too large, the short-term results using export prices would appear to be more reliable.

Overall, these results have several important implications for multilateral export and import equations. First, the estimated real exchange rate elasticities for multilateral export equations are larger than those in multilateral import equations. Second, movements in other exchange rates are important for real bilateral trade through third country competition. Third, pricing to market has a significant impact on the nominal trade balance. Finally, there is a significant J-curve–the nominal trade balance deteriorates in the short-run but improves in the long-run in response to a real depreciation.

VI. Conclusions

This paper has looked at the results from estimating standard trade equations using data on aggregate bilateral trade between 21 industrial countries, involving 420 bilateral flows and over 11,000 data points. This large data set allows the underlying elasticities to be estimated with considerable precision. Remarkably, a single specification appears to explain behavior across these relationships in spite of the large number of individual flows analyzed.

In addition to confirming existing stylized facts about trade models, such as the high short-run elasticity of trade with respect to activity in the importing country and the rise in the size of the exchange rate elasticity over time, the results shed light on a number of areas of unresolved issues. They point to a large long-run impact from domestic output on exports. Indeed, in the long-run this supply effect is as powerful as the increase in the demand for exports coming from higher activity abroad, implying that the underlying elasticity is equal for bilateral exports and imports on a pairwise basis. As a result, differences in economic growth have no impact on the trade balance in the long-run.

Turning to the effects of the real exchange rate on trade, the results indicate significant third country competition effects. As a result, the real exchange rate elasticity for a given bilateral trading relationship depends upon the behavior of third country exchange rates. The elasticity for aggregate exports rises (in absolute value) from -0.31 on impact to -0.79 in the long-run, while that on aggregate imports increases from +0.08 to +0.50. Pricing to market also has a significant impact on nominal trade flows, and there is a significant J-curve in the response of the nominal trade balance. The elasticity of the nominal trade balance with respect to the real bilateral exchange rate is +0.37 on impact, -0.22 after one year, and -0.42 in the long-run.

Finally, some of the limitations of this study should be recognized. As the relevant data on bilateral trade in services does not exist, the study covers only merchandise trade. The results are also limited to industrial countries, and more analysis would be needed to see how applicable this model is for developing countries. They also focus on the behavior of aggregate trade. This is the most relevant level of analysis for macroeconomic issues, such as the response of the overall trade balance to changes in exchange rates, but has little to say about behavior across specific sectors of the economy. However, the fact that a single generic model appears to fit this very large data set well, however, provides some confidence that these results are of general macroeconomic applicability.

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Table 1. Basic Statistics for Variables, 1965–92

	Mean	Standard Deviation	Number of Obs.
Growth in Real Exports	0.064	0.198	11,760
Growth in Real GDP	0.031	0.029	11,760
Bilateral Real Exchange Rate	--	0.074	11,760
Import-Weighted Real Exchange Rate	0.001	0.044	11,760
Export-Weighted Real Exchange Rate	--	0.045	11,760

Notes: All variables are measured in logarithms. For detailed definitions of the data see the text. Real exports and the real exchange rates are all calculated using implicit export prices calculated from aggregate real and nominal merchandise export data.

Table 2. Results from the Basic Specification

Year	Importers GDP	Exporters GDP	Bilateral Real Exchange Rates	Third Country Competition	Pricing to Market
Lag 0	1.84 (.07)**	0.35 (.07)**	-0.31 (.04)**	0.23 (.06)**	-0.24 (.06)**
1	1.84 (.08)**	0.47 (.08)**	-0.65 (.05)**	0.32 (.08)**	-0.24 (.08)**
2	1.27 (.09)**	0.39 (.09)**	-0.82 (.07)**	0.26 (.09)**	-0.08 (.09)
3	1.24 (.10)**	0.63 (.10)**	-0.82 (.08)**	0.10 (.10)	0.03 (.10)
4	0.89 (.10)**	0.69 (.10)**	-0.79 (.09)**	0.29 (.12)*	-0.13 (.12)

R^2: 0.14

Constant: 0.017 (.004)**

F Test of Parameter Equality: $F_{10,894,840}$= 1.08

Notes: Standard errors reported in parentheses. One and two asterisks indicate that the coefficient is significant at the 5 and 1 percent significance level.

Table 3. Specification Tests

		AR1	Instrumental Variables	Levels Regression
Importers GDP Lag	0	1.81 (.07)**	2.02 (.68)**	1.76 (.07)**
	1	1.83 (.07)**	2.75 (.60)**	1.76 (.08)**
	2	1.22 (.08)**	1.71 (.42)**	1.14 (.09)**
	3	1.21 (.09)**	1.78 (.41)**	1.10 (.09)**
	4	0.83 (.09)**	1.37 (.36)**	0.69 (.08) **
Exporters GDP Lag	0	0.40 (.07)**	-0.18 (.69)	0.48 (.07)**
	1	0.49 (.07)**	1.60 (.50)**	0.62 (.08)**
	2	0.43 (.08)**	0.95 (.37)**	0.63 (.09)**
	3	0.66 (.09)**	1.43 (.36)**	0.91 (.09)**
	4	0.75 (.09)**	1.21 (.32)**	1.05 (.08)**
Bilateral Real Lag	1	-0.30 (.04)**	0.15 (0.50)	-0.26 (.04)**
Exchange Rate	2	-0.67 (.05)**	-0.57 (0.50)	-0.61 (.04)**
	3	-0.79 (.06)**	-0.43 (0.57)	-0.73 (.05)**
	4	-0.80 (.07)**	-0.48 (0.60)	-0.71 (.05)**
	5	-0.75 (.08)**	-0.38 (0.69)	-0.65 (.05)**
Third Country Lag	0	0.20 (.06)**	0.65 (.54)	0.10 (.06)
Effects	1	0.28 (.07)**	0.80 (.56)	0.11 (.06)
	2	0.23 (.08)**	0.91 (.60)	0.00 (.06)
	3	0.06 (.09)	0.77 (.59)	-0.20 (.06)**
	4	0.24 (.10)*	1.02 (.62)	-0.16 (.06)**
Pricing to Lag	0	-0.19 (.06)**	0.01 (.70)	-0.18 (.06)**
Market	1	-0.19 (.07)**	-0.15 (.63)	-0.13 (.06)**
	2	-0.04 (.08)	-0.13 (.71)	0.05 (.06)
	3	0.07 (.07)	-0.02 (.69)	0.16 (.06)**
	4	-0.09 (.10)	-0.24 (.73)	0.07 (.04)
Constant		0.016 (.004)**	-0.014 (.011)	.003 (.001)**
R^2		0.16	0.07	0.95
Hausmen Test		-----	30.7	178.2**

Notes: Standard errors reported in parentheses. One and two asterisks indicate that the coefficient is significant at the 5 and 1 percent significance level.

Table 4. Alternative Data

		CPIs	GDP Deflators	GDP Deflators Used to Calculate Real Exports
Importers GDP	Lag 0	2.00 (.07)**	1.94 (.07)**	1.89 (.07)**
	1	1.89 (.08)**	1.87 (.08)**	2.07 (.08)**
	2	1.19 (.09)**	1.20 (.09)**	1.28 (.09)**
	3	1.12 (.10)**	1.16 (.10)**	1.25 (.10)**
	4	0.70 (.10)**	0.76 (.10)**	0.94 (.10)**
Exporters GDP	Lag 0	0.21 (.07)**	0.24 (.07)**	0.39 (.07)**
	1	0.35 (.08)**	0.37 (.08)**	0.57 (.08)**
	2	0.38 (.09)**	0.39 (.09)**	0.37 (.09)**
	3	0.73 (.10)**	0.68 (.10)**	0.63 (.10)**
	4	0.85 (.10)**	0.78 (.10)**	0.82 (.10)**
Bilateral Real	Lag 0	-0.31 (.03)**	-0.24 (.03)**	-0.58 (.03)**
Exchange Rate	1	-0.60 (.04)**	-0.56 (.04)**	-0.85 (.03)**
	2	-0.60 (.05)**	-0.57 (.05)**	-0.94 (.04)**
	3	0.57 (.06)**	-0.49 (.05)**	-0.89 (.05)**
	4	-0.49 (.07)**	-0.47 (.06)**	-0.89 (.06)**
Third Country	Lag 0	0.08 (.05)	0.06 (.05)	0.12 (.04)**
Effects	1	0.07 (.06)	0.01 (.06)	0.09 (.05)*
	2	0.18 (.07)*	0.16 (.07)*	0.28 (.05)**
	3	0.11 (.08)	0.08 (.07)	0.19 (.06)**
	4	0.22 (.08)**	0.16 (.08)*	0.25 (.07)**
Pricing To	Lag 0	-0.24 (.05)**	-0.25 (.05)**	-----
Market	1	-0.14 (.06)*	-0.10 (.06)	-----
	2	-0.13 (.07)	-0.14 (.07)*	-----
	3	-0.14 (.08)	-0.16 (.07)*	-----
	4	-0.27 (.09)**	-0.23 (.08)**	-----
Constant		0.018 (.004)**	0.018 (.004)**	-.004 (.004)
R^2		0.14	0.14	0.17

Notes: Standard errors reported in parentheses. One and two asterisks indicate that the coefficient is significant at the 5 and 1 percent significance level.

Table 5. Implied Elasticities from Changes in Bilateral Real Exchange Rates

	Lag 0	Lag 1	Lag 2	Lag 3	Lag 4
Main Case					
Multilateral Exports	-0.31 (.04)**	-0.65 (.05)**	-0.82 (.07)**	-0.82 (.08)**	-0.79 (.09)**
Multilateral Imports	-0.08 (.07)	-0.33 (.09)**	-0.56 (.11)**	-0.72 (.13)**	-0.50 (.15)**
Pricing to Market	-0.24 (.08)**	-0.24 (.08)**	-0.08 (.09)	0.03 (.10)	-0.13 (.12)
Nominal Trade Balance	0.37 (.06)**	-0.22 (.08)**	-0.46 (.10)**	-0.52 (.12)**	-0.42 (.14)**
Truncated Model					
Multilateral Exports	-0.33 (.04)**	-0.67 (.04)**	-0.87 (.05)**	-0.82 (.06)**	-0.86 (.07)**
Multilateral Import	-0.12 (.06)	-0.37 (.07)**	-0.64 (.07)**	-0.69 (.08)**	-0.63 (.09)**
Pricing to Market	-0.21 (.05)**	-0.20 (.05)**	-----	-----	-----
Nominal Trade Balance	0.35 (.06)**	-0.24 (.07)**	-0.51 (.09)**	-0.51 (.10)**	-0.49 (.12)**
GDP Deflators					
Multilateral Exports	-0.58 (.03)**	-0.85 (.03)**	-0.94 (.04)**	-0.89 (.05)**	-0.89 (.06)**
Multilateral Imports	-0.46 (.03)**	-0.75 (.04)**	-0.66 (.05)**	-0.70 (.05)**	-0.64 (.06)**
Pricing to Market	-----	-----	-----	-----	-----
Nominal Trade Balance	-0.05 (.04)	-0.60 (.06)**	-0.80 (.07)**	-0.59 (.08)**	-0.53 (.10)**

Notes: These elasticities are calculated from the estimated coefficients, as explained in the text. Derived standard error are reported in parentheses. One and two asterisks indicate that the coefficient is significant at the 5 and 1 percent significance level, respectively.

Chart 1. Estimated Elasticities with 95 percent Confidence Bands