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TRADE AND TECHNOLOGY FROM A SCHUMPETERIAN PERSPECTIVE

Contents

ABSTRACT

This paper attempts to implement empirically a Schumpeterian model of international trade. After briefly discussing the literature on trade and technology, we formulate a model in which `real' factors such as R&D expenditures, investment and wage costs have an impact on bilateral trade flows between advanced economies. We also take into account the effect of exchange rate differences. The model is empirically estimated on sectoral data for nine OECD countries. We find that what determines competitiveness differs by sector. In many sectors, either R&D expenditures or wage costs are important. The results for investment indicate a weaker role. Consistent with the Marshall-Lerner logic, we find that the sign of exchange rate changes varies by sector. We conclude the paper by a discussion of the relevance of the results for `technology-based' theories of international trade.

1. Introduction

Whereas the traditional neoclassical approach to trade ruled out the possibility of technology gap motivated trade by assuming common technology across countries, there is a growing literature which considers differences in technology as an important motivating factor for trade. This literature consists of both the formulation of new theories of trade, and the reformulation of traditional theories. In the latter group is the so-called neo-endowment theory of trade, which extends the traditional two-factor model of trade to include a greater number of narrowly defined input factors, including science and technology, while maintaining the assumption of a constant world production function. AS in the analysis of comparative advantage in a two-factor model, countries which have comparatively rich `endowments' of knowledge will produce knowledge intensive goods.(n1) In the former group are a number of theories considering technology as an endogenous factor, including both `new' trade theory(n2) and the so called neo-Schumpeterian, or evolutionary, approach. The last approach provides the background for this paper, in which we estimate the importance of a number of determinants of trade, including differences in technology, in explaining changes in trade performance on a bilateral basis for nine OECD countries in 22 manufacturing sectors. In doing so, we wish to test the relative importance of differences in technology, labour costs and capital intensity in determining long run trade performance, and to examine how the relationship varies at a sectoral level.

The paper is set out as follows. Section 2 introduces the neo-Schumpeterian approach to trade and presents some evidence relating to the role of technology in international trade. Section 3 goes on to describe the data and the empirical model used in this paper. Section 4 presents a summary of the estimation procedure used and an overview of the results. The final section suggests some conclusions. Overall the results show the importance of considering factors of production separately for different industries, and the plurality of possible explanations for trade specialisation patterns. As such it is consistent with the neo-Schumpeterian approach which combines comparative advantage considerations with absolute technology advantages, while stressing the importance of the latter.

2. Trade and Technology

The so-called neo-Schumpeterian tradition focuses on the role of technology in explaining both static trade specialisation and the evolution of trade patterns. This theory is characterised by a detailed treatment of technology as an economic concept (see, for example, Dosi, 1988), and by a disequilibrium approach. In a dynamic context this means that the economy will not automatically move towards an equilibrium, but rather that the international economy is characterised by a continual dynamic adjustment process (Dosi et al., 1990). The absolute advantages of a country, be it in terms of costs (wages) or technology (product quality) are the driving forces behind this adjustment process. This is described in the following quotation:

The hypothesis put forward here (...) is that technology-gap explanations of trade flows are essentially accounts of the impact of different absolute advantages upon competitiveness which can be reconciled within a classical framework of cost-based adjustments. At the core of our explanation are the technological differences between countries (...). Here we will suggest an interpretative model of trade flows based on international and intersectoral technological differences. (Dosi et al., 1990, pp. 142, original emphasis)

The economic ideas underlying the neo-Schumpeterian approach of most relevance to this paper can be separated into four groups. First, absolute, rather than comparative, differences are seen as the motivation for economic dynamics. One way of looking at this proposition is by means of a population perspective,(n3) which originally stems from evolutionary biology. From this point of view, the economy consists of different populations, which in the current context would be firms located in a specific sector and country. These populations are engaged in a competitive process for living space (the biological case), or market space (the economic context), so that absolute differences determinant the competitiveness of the various populations. In the international trade context of this paper, one could think about absolute differences in product-quality or price between different producers as an important determine of competitiveness. Firms which score above average in terms of competitiveness will see their market share increase, and firms with low competitiveness will lose market share.

Second, technology is seen as an endogenous phenomenon (as in `new' trade theory). One characteristic of technology at the microeconomic level is that it has important private as well as public aspects. As a result, the benefits of innovation can be at least partly appropriated. Assuming that diffusion occurs more easily within a country than between countries, technological differences between countries are, to a certain extent, assumed to be persistent, i.e. no country can completely rely on imitation to catch-up to the technological frontier.(n4) This also implies that technology gaps result from an accumulation process, rather than taking the form of different `natural' endowments.

Third, it is assumed there are important linkages between specialisation and growth. These arise due to the higher innovation, and thus growth, potential of some sectors. By specialising in more innovative sectors, a higher national aggregate growth rate can be achieved, indicating that what is produced might be more important than how it is produced. One implication from this is that locking-in to a specific specialisation pattern implies locking-in to a specific growth regime, an outcome which can also arise from other models which introduced endogenous technology and hence endogenous comparative advantage (see for instance Grossman & Helpman, 1990, 1991).

Fourth, the importance of the role of institutions in the development of technological change is emphasised. Institutional differences between countries may lead to, or relate to, technology gaps and therefore have an influence on growth and trade. Such national institutional characteristics include the education system and legal methods to protect innovation rights such as the patent system. More broadly, the history of the country, its past technological achievements and the characteristics of its market, strongly influence its present potential for innovation.

There have been a number of attempts to assess the importance of differences in technology empirically. Soete (1981) presented a static cross-section analysis of trade between OECD countries, and found considerable importance for the role of technology. These estimations are updated in Dosi et al. (1990), including estimations for the change in exports, explained by changes in relative costs and technology gaps. A patent variable was used as the technology proxy, it fumed out to be by far the most important variable in explaining changes in exports and the trade balance. Fagerberg (1988) used pooled data for 15 OECD countries and a technology proxy made up of both patents and R&D expenditure, again he found technological factors to be important influences on international competitiveness.(n5)

Cotsomitis et al. (1991) criticised these type of studies for taking a static point of view, and proposed to use time series data. They found a much more limited role for technology in a technology gap model of OECD trade flows. The technology variable appeared to be significant in only 22 to 33% of the cases considered, and then often with an unexpected sign. Pointing to a number of other recent studies in the field, however, the approach by Cotsomitis et al. (1991) can be criticised for leaving out other, cost-based, explanations for trade, as well as concentrating on a limited number (five) of industries. For example, Magnier & Toujas-Bernate (1994) and Amable & Verspagen (1995), in a model using price and non-price factors to explain trade flows, found that non-price factors such as R&D expenditure were crucial in explaining the change in market shares for five OECD countries.

3. Description of the Model

The aim of the empirical analysis in this paper is to investigate what determines the evolution of (bilateral) trade flows and, in particular, what role technology-related factors play in this evolution. Our functional specification assumes that there are two different effects that influence the bilateral trade balance of countries p and q. First, there is an effect related to absolute differences in competitiveness between the two countries. The functional specification of this part of the model resembles the one in Magnier & Toujas-Bernate (1994) and Amable & Verspagen (1995),and takes the form of an error-correction model, in which the actual trade balance adjusts (slowly) to its long-run equilibrium value. This is in accordance with the `dynamic adjustment' idea proposed by Dosi et al. (1990). The long-run equilibrium value of the (bilateral) trade balance is a function of the country-differences in a number of (real) variables underlying competitiveness, which makes it a moving target, rather than a static objective.

Second, it is assumed that differences in `real competitiveness' between economies can be counteracted by changes in the exchange rate. The general idea here is that a country which is relatively competitive, and thus sees its trade balance increase along the mechanism outlined above, will feel a pressure to revalue its currency. However, because of the many policy aspects related to exchange rates, especially in the European context, we choose to treat exchange rate changes as an exogenous variable, putting it into the right-hand side of our equation. In order to take into account the assumed differences in adjustment speed between the `real' and `monetary' factors of competitiveness, we choose to assume a direct impact of exchange rates, thus keeping it outside the error-correction mechanism chosen for the `real' variables. Of course, we have to keep in mind that the effect of a change in the exchange rate may differ between sectors, depending on the price elasticity for the good in question (the well-known Marshall-Lerner logic). We will come back to this below when we discuss the estimation results. The model is admittedly a very crude `theory' of the trade balance, but one that seems sufficient for our current purposes, i.e. estimating the effects of various `real' factors upon competitiveness of nations.(n6)

The form of the model thus becomes:

(1) [Multiple line equation(s) cannot be represented in ASCII text]

The symbols have the following meaning: X_{pqs} exports in sector s from p to q,

$e_{pq}$the exchange rate between currencies p and q,

w^p the wage rate in country p (in a common currency),

p_p R&D intensity in country p, i.e., R&D as a fraction of value added,

I_p capital intensity in country p, proxied by investment as a fraction of value added,

Alpha equilibrium parameters,

Mu adjustment parameters, the subscript T denotes time.

The adjustment parameter, Mu is assumed to depend on several factors: an independent effect (subscript 0), the countries involved (subscripts p and q), the time period (subscript T), and whether or not the trade flow is intra-EC (subscript ec). The last factor assumes that for intra-EC trade, the two separate country-effects will be enforced by an integration-effect. These country-differences between adjustment speeds are our only way of capturing trade policies and all sorts of institutional and other effects, with the obvious interpretation that the adjustment speed will be low for a protectionist relationship between countries. The terms captured by the summation sign inside the large brackets denote the long-run equilibrium trade balance, which is assumed to be a log-linear function of inter-country (absolute) differences in wage rates, it R&D-intensity (as a proxy for technology gaps), and capital intensity. The initial value of the (log) trade balance is subtracted from this, in order to arrive at the `error' relative to the long-run equilibrium.

The dependent variable in the estimations is the change in bilateral trade over the two periods 1970-78 and 1980-88.(n7) As a result, the estimation does not give an explanation for the level of bilateral trade between two countries, but rather the change in their bilateral relationship over a period of time. Bilateral trade flows have been used, because these lend greater clarity to the issue of inter-country differences in the various explaining factors (compared to total trade). (n8) The dependent variable is measured as the trade balance at period T minus the trade balance at T - 1 (a similar definition is used for the exchange rate variable). The initial trade balance is measured at time T - 1.

All the independent variables in Equation (1) (excluding the exchange rate) are calculated as unweighted means over the years T - 1...T on a country-wise basis, after which the log of the ratio of these means for the two trade partners is taken. The wage rate and relative investment intensity are used to test for cost motivated trade Omega is measured by the wage rate in current US dollars, which is given by the wage sum over employment. I is proxied by gross fixed capital formation relative to production.

Technology is a concept that is hard to measure exactly in economic terms. To a large extent, knowledge is embedded in methods of industrial organisation, in capital equipment, `ideas' from researchers, and the skills of the workforce, none of which are easily quantified. Any proxy for the endowment of technology--either R&D expenditure or the output of patents, which are the most commonly used--will fail to capture the tacit aspects of knowledge. Nevertheless, following the literature in this field, we try to capture the effects of technological differences between countries through relative R&D expenditures. The R&D-data used refer to R&D undertaken (but not necessarily financed by) business enterprises. The technology variable is not lagged, but taken as an average over the period as are the other explanatory variables. Evidence indicates that the pattern of technological specialisation changes only slowly over time (Soete, 1987) and the results are not sensitive to the choice of lag used.

R&D intensity and patent intensity variables are two of the most commonly used proxies for innovation and technological change, although each one has its own limitations.(n9) Briefly, R&D intensity is an input into the innovation process rather than an output, and fails to account for the innovations which occur in small firms which may not have a formal R&D section. Moreover, it is a general finding that

R&D undertaken with government-money (subsidies) or for military purposes has lower pay-offs than pure-business R&D.(n10) This drawback to using R&D expenditure will be discussed in more detail later in the paper.

All the countries in the sample are highly developed, but nevertheless the relationship between trade performance and its determinants can be expected to vary strongly between countries due to the existence of individual national technological profiles. As Archibugi & Pianta (1992) have outlined, the latter may vary greatly even among EC countries, with each country having its own profile based on a combination of factors including historical experience and the pattern of government intervention. This cross-country variation is to be expected as the countries in the sample vary considerably in their expenditure on R&D, their education systems, and their emphasis on military or civilian research.

The industries used in the estimations are all manufacturing industries (ISIC rev. 2, heading 3000). Due to the diversity of these industrial sectors, the importance of each of the variables is likely to differ per sector, as has been assumed above by the sector-specificity of the Alpha-parameters. Soete (1981) finds the significance of technology variables for explaining trade rising with the technological content of the industry, being important for most of the medium and high technology sectors. In his study, the innovation pattern was generally not significant for natural resource industries and, as he terms them, factor proportions industries. For industries in which innovation is an important influence on trade performance, we would expect a positive sign on the coefficient of the technology variable. In some cases limitations to the proxies may cause problems (for instance, high military expenditure in R&D lowers the efficiency of the expenditure).

The a priori expectations on the labour cost variable are not so straight-forward. Low labour costs would, in general, be expected to have a positive effect on trade performance in those industries influenced by the costs of production, thus a negative sign would be expected. In some cases the wage variable could be considered as a proxy for skills (i.e. countries with high wages often have a more skilled workforce) and as a result the relationship could be positive for those industries for which skill considerations are more important than cost benefits. For instance, Kaldor (1978) found that increasing relative labour costs were positively correlated with increased market share from 1963 to 1975 for the UK, US and Japan. This has also been corroborated by Fagerberg (1988) who found capacity constraints and innovation to be more important influences on trade performance than cost competitiveness.

The coefficient on the capital intensity variable should be positive for capital intensive industries, where a high capital intensity will improve performance. A high rate of investment also implies frequent capital renewal and may thus imply that new technologies can be absorbed more quickly by capital intensive industries. This may mean that high technology industries are also characterized by high capital intensities. Finally, we formulate expectations on the sign of the exchange rate variable. A depreciation for the home currency in the bilateral trade relationship will appear as a negative coefficient on the exchange rate variable e. However, no clear expectations can be formulated for the reaction of trade performance to such an exchange rate movement. (n11) If we look at the Marshall-Lerner condition for a successful depreciation (i.e. one which improves the balance of payments) it depends on the price elasticity of demand for imports and exports summing to greater than unity. If the Marshall-Lerner condition is fulfilled a negative movement in e should have a positive influence, hence the sign on the coefficient should be negative. Similarly, a positive sign means no successful depreciation. It has been pointed out (Kravis & Lipsey, 1989) that we may expect high technology goods to experience inelastic demand as they are often high quality goods, which offer significant non-price characteristics. However, Greenhalgh et al. (1992) found little evidence of a relationship between a high rate of innovation and price elasticity of demand. While only a third of the industries in their sample fulfilled the Marshall-Lerner condition of elastic demand, some of these were high technology industries. Other factors such as the degree of oligopolistic competition may limit the impact of depreciation on trade performance.

Before estimating the model, we briefly outline some drawbacks of the approach, which should be kept in mind while interpreting the results. First, the model attempts to explain the international specialisation of production by looking at the relative distribution of factors of production, including technology, across countries. Implicitly, this involves an assumption about causation, i.e. that causation runs from the explanatory factors in Equation (1) to the pattern of trade flows. The issue of causation is not considered explicitly here, for example by taking into account simultaneity between exports and technology.(n12) Second, the use of trade flows to analyse the interrelationships between countries has a number of other limitations. One drawback is that foreign direct investment may take place as a substitute for trade, often by multinational companies (MNCs) whose actions are not captured in trade flows. As far as technology is concerned, the relationship between the location of their research centres and the trade flows between their different subsidiaries is probably not captured in this study. Technology may also be transferred by means other than trade; for instance by licensing the technology to foreign firms. However, despite these limitations, for all the countries considered in this sample, trade constitutes an important part of their domestic economy.

4. Estimating the Model

In this section, some empirical estimates for the model introduced above will be conducted. Since the model is non-linear in the parameters, it is estimated by an iterative least squares method. This method gives estimates which are robust to the presence of heteroscedasticity (White's method).

The final data set includes two periods: 1970-78 and 1980-88. For the first period, the years covered by the R&D variable are slightly shorter (1973-78) due to data availability reasons. It is assumed that relative bilateral R&D intensities for this smaller period are representative for the whole 1970-78 period.

The fact that the theoretical model includes separate effects for sectors, countries and time, makes it possible to pool across these three dimensions. Nine countries(n13) and 22 industries (based on a three-digit ISIC classification outlined in the Appendix) were used. This means there is a maximum of 1584 observations.(n14) The time dummy is set to one for the early period, and zero for the later period. The country-effect for the USA is assumed to go into the constant term Mu_0.

Table 1 shows the results of the estimation.(n15) In general, the results are quite good, with an R_2 (adjusted for degrees of freedom) of 0.59. The signs of the variables are in most cases as expected, and the t-statistics are significant.(n16)

In the case of the wage cost variable, the sign on the coefficient is negative and significant for textiles, chemicals, rubber and plastic, glass etc, basic metals, fabricated metal, machinery, motor vehicles, aerospace and other manufacturing. A positive and significant parameter is found only for food. Eight out of 21 sectors have insignificant t-statistics. Our results thus support the wage cost hypothesis, and do not seem to be distorted to a large extent by effects related to differences in skills between countries.

For the R&D variable, we find 10 cases in which the sign is positive, as expected, and also significant. These cases are wood, paper and publishing, chemicals, pharmaceuticals, rubber and plastic, ferrous metals, fabricated metal, machinery, electrical machinery, and motor vehicles. There are four cases where the R&D parameter is negative and significant: food, textiles, refined oil and aerospace. In general, this provides support for a technology-interpretation of trade, although there are a number of sectors for which the sign of the R&D variable is contrary to expectations, or insignificant. We will discuss these cases in more detail below.

The investment variable has a relatively weak performance in the estimations. There are only seven cases in which the coefficient has the expected sign and is also significant. These are wood, paper and publishing, chemicals, basic metals, fabricated metal and other manufacturing. Four sectors have a negative and significant sign: machinery, computers, electronics and aerospace.

The exchange rate variable, for which we have formulated only weak a priori expectations with regard to the sign, appears significant in 13 sectors. In five of these, there is a negative sign, i.e. depreciation of the domestic currency has a positive impact on the trade balance. This result is consistent with relatively elastic demand in these sectors, suggesting the Marshall-Lerner condition applies. Negative signs are found for food, textiles, wood, chemicals and refined oil. These are all sectors which have relatively homogenous goods, which is consistent with the fulfillment of the Marshall-Lerner requirement.

The sectors for which we find relatively low price elasticities, consistent with no fulfillment of the Marshall-Lerner condition are machinery, computers, electrical machinery, electronics, motor vehicles, aerospace, instruments and other manufacturing. These are indeed all sectors where one would expect quality considerations and technology to play a large role, and hence price elasticities to be low. Thus, our findings with regard to the exchange rate variable are mainly consistent with expectations, as well as the results found in Kravis & Lipsey (1989). With regard to the adjustment parameter, Mu, the EC-dummy does not appear significant. The EC-countries on an individual basis are all characterised by low adjustment speed, i.e. large negative values for their individual part of the Mu. The first period (1970-78) is also characterised by a lower adjustment speed. Norway, Sweden and Canada all display higher adjustment speeds. Thus, the lowest adjustment parameter is found for the case of trade between France and Italy in the first period, and is equal to 0.064 (not taking into account the EC-effect). The maximum value of 11 is found for trade flows between Norway and the USA in the second period, and is equal to 0.814.

There are a number of sectors in the sample which are known as typical high-technology industries. These are pharmaceuticals, computers and office machinery, electronics, instruments and aerospace. These are the sectors where one would expect the innovation variables to perform relatively well. However, the results in Table 1 indicate that for only one of these sectors (pharmaceuticals), has the R&D variable the expected positive sign and is significant. In computers, instruments (negative sign) and electronics (positive sign), the variable is not significant, while in aerospace, the sign on the coefficient is contrary to expectations and the t-test significant.

There are several possible explanations for this. One is that within each of these sectors there is a large degree of diversity between products. For example, although the computers and office machinery sector is considered to be high-tech as a whole, it includes many products ranging from low-tech typewriters to high-tech supercomputers. The influence of R&D intensity on competitiveness is likely to differ between these products, and thus within the sector itself. This also applies, to some extent, to the electronics sector, which includes TVs (which are by now not really a high-tech product any more) and chips such as the Intel 80486.

An additional source of error, already mentioned above, is that in many of the high-tech sectors the influence of government (and especially military) R&D is high. Since this type of R&D may not be aimed at commercial applications it lowers the efficiency of R&D expenditure. As a result, the R&D expenditure statistics used in the estimations, which are R&D undertaken by businesses but funded by any source, may overestimate the commercially significant level of R&D for some sectors in which government and military orientated R&D is important. This is likely to be the case for computers, electronics and aircraft rather than pharmaceuticals, which may explain why the last sector performs relatively well in the estimations.

Internationally comparable data on military R&D expenditure are not available on a sectoral basis, but Table 2 gives government-funded private R&D as a percentage of total private R&D per sector. The data listed are (unweighted) averages over countries, and exclude any missing values. This means that the actual sample used might differ per cell, which implies that the table does not give a completely representative sample in some cases.(n17)

Table 2 shows that electronics and aerospace are indeed two high-tech sectors that have relatively high ratios of government to private funds. The computer industry ranks lower in the table. The other (i.e. non-high-tech) sectors with high government R&D are mostly found in the transport sector (with the exception of motor vehicles). The indicators in the table support the interpretation that military (or government-financed) R&D has an influence on the results in Table 1. In general, these considerations underline our earlier reservations about measuring technology by R&D expenditure, although each proxy for technological change is subject to some reservations.

5. Conclusions

This paper has aimed to develop an empirical model explaining bilateral sectoral trade flows between nine OECD countries, and to identify which factors are the most important in influencing long-run trade performance. This has involved testing a dynamic model of the change in bilateral trade performance explained by cross-country differences in technology, investment, labour costs as well as exchange rate movements. The model is consistent with a neo-Schumpeterian approach to trade, considering absolute differences in competitiveness, and using a long term adjustment mechanism. A considerable amount of flexibility was introduced into the model as the speed of adjustment to the long-run trade balance was allowed to vary with the time period, the country, and whether or not both countries were members of the EC. The estimations were implemented on a sectoral basis and the results showed considerable variations across sectors. As the model is non-linear in the parameters it was estimated using an iterative least squares method.

The estimation results show a generally negative relationship between trade performance and wage costs, a positive relationship for R&D (with some important exceptions) and weak results for the investment variable. The weakness of the R&D variable in some of the sectors may be as a result of the importance of government and, in particular, military R&D expenditure in those sectors. For the exchange rate variable nine industries do not fulfill the Marshall-Lerner condition. These are mostly high technology industries or industries where quality considerations are important. Overall, the evidence indicates that both relative labour costs and differences in technology are important influences on trade. The exchange rate also has an impact, the direction of which depends upon the characteristics of the product.

Our results imply that differences in technology are an important determinant of trade, even in industries not generally known as high or medium technology industries. However, the estimations also show that one cannot abstract from other variables determining the dynamic behaviour of the trade balance (such as wages, investment and the exchange rate), which play an important role in a number of sectors. The industry specific nature of the results gives some justification for an industrial policy that targets certain key industries, seen to be of special significance in terms of their potential for innovation and growth.

Notes

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(n1). See Sveikaukus (1983) and Stem & Maskus (1981) for empirical applications of the neo-endowment approach.

(n2). See for instance Grossman & Helpman (1991).

(n3). See Silverberg (1988) for a detailed overview of population perspectives in economics, or Hofbauer & Sigmund (1988) for a mathematical treatment of the population approach.

(n4). This is consistent with the literature on national systems of innovation (see for instance Lundvall, 1992) which highlights the producer user technological relationship within a country.

(n5). For other recent studies on the relationship between trade and technology see for instance Amendola et al. (1993), Hulst a al. (1991) and Greenhalgh (1990).

(n6). There is a large literature on the sensitivity of trade balances to the exchange rate, see Arestis & Milberg (1994) for an outline of the differences between neoclassical and pOSt Keynesian explanations.

(n7). Sources, definitions and exact sectoral breakdown are explained in the Appendix.

(n8). As Hilton (1981) argues in an endowment based interpretation, in multilateral cases the relative factor intensities of exports may not be clear due to their variation on a bilateral basis, this is avoided of bilateral flows are used.

(n9). For more details on technology indicators, in particular R&D and patents, see Acs & Audretsch (1989), Basberg (1983), Soete & Verspagen (1991) and Griliches (1990).

(n10). See, for example, Hall (1992).

(n11). Causation is assumed to pass from the exchange rate to the trade balance. However, reverse causation could also occur with the trade balance influencing the exchange rate. We will assume here that the use of sectoral bilateral trade flows means that each bilateral pair in each industry can be considered too small to have an influence on the exchange rate.

(n12). Hughes (1986) tests the hypothesis of simultaneous causation between factor endowments and international trade and finds some evidence in support of it.

(n13). Canada, France, Germany (which is always West Germany), Great Britain, Italy, Japan, Norway. Sweden and the US.

(n14). N countries will yield N(N-1)/2, which is equal to 36 here, different and non-trinal pairs. Multiplied by 22 sectors and two periods, this gives the 1584 observations. The actual estimations include less data-pairs, because of missing values in the data set. For example, the number of observations for one of the sectors (other transport) was too small to yield any meaningful estimates. Therefore, this sector was excluded from the estimations.

(n15). We have also carried out estimations including a constant inside the large brackets of Equation (1). This yields roughly the same results. Details are available from the authors.

(n16). We use a significance level of 10% in a 2-tailed test throughout this paper.

(n17). Space considerations prevent the documentation of the exact samples used. These can, however, be obtained from the authors.

Table 1. The results for Equation (1), adj. R2 = 0.59, n = 908, estimates are robust to the presence of heteroscedasticity

Legend for Table:
A - $Alpha_{ws}$
B - $Alpha_{rs}$
C - $Alpha_{is}$
D - $Alpha_{es}$

	Mu	t	Sector	A
Mu_O	0.816	7.13	food	0.211
Mu_T	- 0.188	- 3.67	textiles	-0.131
Mu_{ec}	- 0.087	- 0.91	wood	-0.006
Mu[sum can]	- 0.018	- 0.22	paper & publishing	0.036
Mu_{deu}	- 0.178	- 2.36	chemicals	-0.139
Mu_{fra}	- 0.305	- 3.52	pharmaceuticals	0.031
Mu_{gbr}	- 0.917	- 1.89	refined oil	0.205
Mu_{ita}	- 0.259	- 2.79	rubber and plastic	-0.353
Mu_{jpn}	- 0.175	- 2.36	glass etc.	-0.341
Mu_{nor}	- 0.002	- 0.02	ferrous metals	-0.649
Mu_{swe}	- 0.102	- 1.35	non-ferrous metals	-0.386
			fabricated metal	-0.244
			machinery	-0.166
			computers	-0.008

electricals	-0.116
electronics	-0.076
shipbuilding	-0.255
motor vehicles	-0.377
aerospace	-0.709
instruments	0.048
other manufacturing	-0.275

Sector	t	B	t	C
food	3.07	- 0.444	- 2.22	0.779
textiles	- 1.95	- 0.585	- 3.72	0.517
wood	- 0.05	0.695	2.20	2.653
paper & publishing	0.43	0.381	2.88	2.292
chemicals	- 2.95	1.715	2.47	1.205
pharmaceuticals	0.41	1.546	2.87	0.311
refined oil	1.67	- 1.814	- 4.24	- 0.145
rubber and plastic	- 5.54	1.365	5.40	0.412
glass etc.	- 4.89	0.232	0.96	0.757
ferrous metals	- 10.6	1.318	6.15	1.001
non-ferrous metals	- 3.10	1.556	1.51	3.583
fabricated metal	- 5.05	0.553	2.38	1.064
machinery	- 4.10	2.345	6.52	-1.941
computers	- 0.17	- 0.110	- 0.41	-1.501
electricals	- 1.24	1.579	4.63	-1.371
electronics	- 1.44	- 0.272	- 0.30	-2.567
shipbuilding	- 0.51	0.407	0.50	0.329
motor vehicles	- 4.22	1.539	2.21	-0.096
aerospace	- 3.60	- 1.121	- 3.53	-5.524
instruments	0.89	- 0.067	- 0.36	-0.140
other manufacturing	- 4.47	0.258	1.05	1.159

Sector	t	D	t
food	1.19	- 0.931	- 3.59
textiles	1.05	- 0.501	- 2.35
wood	6.03	- 0.696	- 2.65
paper & publishing	5.00	- 0.273	- 1.29
chemicals	2.04	- 0.923	- 2.68
pharmaceuticals	0.23	- 0.995	- 1.48
refined oil	- 0.38	- 1.253	- 1.89
rubber and plastic	0.92	0.048	0.20
glass etc.	0.74	- 0.330	- 1.31
ferrous metals	2.46	0.501	1.43
non-ferrous metals	6.87	- 0.648	- 1.37
fabricated metal	3.10	0.068	0.37
machinery	- 2.07	0.688	2.85
computers	- 3.93	1.585	4.19
electricals	- 1.30	0.847	2.49
electronics	- 2.18	2.267	3.73
shipbuilding	0.15	0.888	1.03
motor vehicles	- 0.05	1.868	3.65
aerospace	- 3.07	16.088	4.64
instruments	- 0.46	0.458	2.67
other manufacturing	0.78	0.711	2.53

Table 2. Percentage of private R&D financed by government per manufacturing sector, average eight countries, 1973-78 and 1980-88

1973-78	1980-88	Sector
66	48	aerospace
31	25	shipbuilding
25	22	electronics
24	20	other transport
23	11	instruments
16	8	computers and office machinery
174	15	machinery
11	11	electrical
11	7	non-ferrous metals
10	15	wood
10	9	textiles
10	5	paper & publishing
9	8	fabricated metal
8	7	rubber and plastic
7	5	glass etc.
7	9	ferrous metals
7	9	refined oil
5	3	food
5	6	other manufacturing
4	7	motor vehicles
4	5	chemicals
2	2	pharmaceuticals

Source: OECD, Basic Science and Technology Indicators database.

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Appendix: sectoral breakdown, definitions and sources

The sectoral breakdown that is used in the estimations corresponds to ISIC, revision 2. The ISIC-codes used per sector are the following:

3100: food; 3200: textiles; 3300: wood; 3400: paper & publishing; 3510 + 3520-3522: chemicals; 3522: pharmaceuticals; 3530 + 3540: refined oil; 3550 + 3560: rubber and plastic products; 3600: glass etc.; 3710: ferrous metals; 3720: non-ferrous metals; 3810: fabricated metal; 3820-3825: machinery; 3825: computers; 3830-3832: electrical; 3832: electronics; 3841: ships; 3843: motor vehicles; 3845: aerospace; 3840 3841-1843-3845: other transport; 3850: instruments; 3900: other manufacturing.

Data on bilateral exports were used to calculate the trade balance variables. These data were supplied by the OECD in the ISIC classification (taken from the bilateral trade database).

Because these data are originally available in the SITC classification, the OECD secretariat has used a self-developed correspondence table to supply data in ISIC. Data on R&D were also supplied by the OECD. R&D is undertaken by business enterprises, but might be financed by any source. Missing values in this data set were filled by analytical methods by OECD-officials and ourselves (these methods involve interpolation of all sorts). The data on military and government financed R&D are taken from the Basic Science and Technology database of the OECD. Data on the wage rate were calculated by using the total wage costs, the number of employees and the current exchange rate. The source for the exchange rates is International Financial Statistics published by the IMF, other variables came from the STAN database of the OECD. Investment and gross production were also taken from that database

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