

**International Competitiveness and its
Determinants**

Bart Verspagen & Katherine Wakelin 93-008

Bart Verspagen

Maastricht Economic Research Institute on Innovation and Technology (MERIT)
University of Limburg

Katherine Wakelin

European University Institute, Department of Economics
Florence, Italy

I: INTRODUCTION

Trade performance - particularly trade performance in high technology industries - is continually in the news. The current debate in the EC and the USA revolves around the issue of the merits of an industrial policy designed to improve trade performance in a few selected sectors, namely high technology sectors, which are seen to have special significance. Central to this controversy is the important role played by both innovation and exports in promoting domestic economic growth. In this paper we are only interested in looking at one specific area of this issue: that is, the impact of innovation on trade performance. Do technological differences promote trade between developed countries, and if so, in which industries is this impact greatest?

In section two an outline of the main trade theories referring to technology as a factor in trade is presented. Section three goes on to describe in detail the model used in this paper and relates it to trade theory. Section four presents a summary of the estimation procedure used and an overview of the results. Section five shows additional calculations to assess the impact of policies aimed at competitiveness; based on the estimation results in section four. The final section gives some conclusions.

II: TECHNOLOGY THEORIES OF TRADE

Technological differences as a source of trade were ruled out of the neo-classical factor endowments model as the proof of this theory involved the assumption that the techniques for producing goods were the same across countries. The work that has followed in this tradition has thus, in general, ignored the role of differences in technology in influencing which goods are traded and with whom. There have been a number of challenges to this theory, often as the result of disruptive empirical evidence. The first came from the perceived refutation of the theory by empirical tests such as that implemented by Leontief (1956). Another more recent challenge has been the domination of total trade by trade between developed countries with similar factor endowments. Trade between these countries is also often characterised by intra-industry trade i.e., the simultaneous export and import of the same goods by a country. The traditional Heckscher-Ohlin theory fails to give any explanation of these phenomena.

This failure prompted both the formulation of new theories of trade and the reformulation of traditional theories. In the latter group is the neo-endowment theory of trade; and in the former a number of theories stressing motivations for trade with a monopolistic competition setting. These involve the introduction of factors such as product heterogeneity, economies of scale and monopoly power. There have also been a number of attempts to put technology at centre stage. This tradition dates from the 1960s and has recently been incorporated into formal models. An outline of those theories which deal explicitly with technology as a motivation for trade is given below.

i) Neo-technology Theory of Trade

This extends the traditional neo-classical model of trade to include factors other than labour and capital. Originally concentrating on redefining the labour variable into skilled labour (human capital) and unskilled labour, some formulations have also considered knowledge as an endowment to the economy. This implies that knowledge is country specific and becomes a stock which can accumulate over time. Countries which have large endowments of knowledge will produce knowledge intensive goods, and can be said to have a comparative advantage in those goods. A typical empirical test of this model would be to include a technology indicator such as R&D intensity as an explanatory variable into a test of the Heckscher-Ohlin theory. Stern and Maskus (1981) tested a neo-endowment model for the United States over the period 1958 to 1976. They identified three main factors of production (labour, human capital and capital), and additionally included the number of scientists and engineers in each industry and the level of research and development. They found a significant role for the technology variables in influencing trade in manufactured goods in the 1970s¹. Sveikaukus (1983) found science and technology more important factors in explaining US competitiveness than either skill variables or capital intensity.

ii) Theory of the Product Cycle

The theory of the product cycle was first presented by Vernon in 1966. It differs from the neo-technology approach in being a dynamic explanation of the location of the production of a good during the life cycle of that good. The stages of the cycle are determined by the technical requirements of the product (its level of standardisation) and subsequently its price and volume. At the beginning of the life cycle of a good it is assumed that it requires technologically sophisticated production and skilled personnel. It will therefore be produced in a technologically advanced country (assumed to be the United States in the 1960s). As the product becomes more standardised, it will be transferred to countries which have a cost advantage over the country of initial location. As far as technology is concerned, this implies it is only important at the first stage of production (and of course development) of a product, and that some countries will have an advantage in producing goods at the beginning of their life cycle. Bowen (1980) tested this theory. He used price as a monitor for the standardisation of the product and found little justification for the dynamic formulation of the product cycle theory.

iii) The Technology Gap Approach

This theory started with Posner (1961) in an attempt to explain trade between developed countries in manufactured goods. The theory deliberately abstracts from other sources of trade by having no differences in capital, and by countries having

¹ Blomstrom *et al* (1990) in their work on Sweden-US trade found the basis of specialisation as being the variation in R&D intensity of the goods they traded.

the same wage, profit and growth rates. Innovation can confer an advantage via two main routes. The first is by increasing the number of techniques available for production, which leads to cost advantages through the implementation of more efficient methods. The second is with the introduction of new capital and consumer goods, which grant a temporary monopoly to the innovating country. This can increase the variety of goods available, which, in an oligopolistic model of trade such as Lancaster's (1980), provides part of the rationale for intra-industry trade. Technical knowledge and learning may give dynamic economies of scale which compound any initial advantage over time so the technological advantage becomes semi-permanent.

There have also been recent attempts to formalise the technology gap model. For instance Krugman (1979, 1985), and Cimoli and Soete (1992) have developed models, consisting of an innovative North producing new products and a non-innovative South only producing the products after a lag, but then at lower cost. Generally, there is only one factor of production, labour, in these models, which rules out any factor proportions motivated trade. Within this framework, new industries must constantly emerge in the North as the older industries transfer to the South. The North's higher wages reflect the North's rent on the monopoly of the new technology. This fits well with trade between advanced and undeveloped countries, but (unlike the original Posner theory) is not designed to explain trade between developed countries.

Inspired by the technology gap theory of trade, there have been a number of studies looking at the correlations between innovation and trade. For example Soete (1981, 1987), Cotsomitis *et al.* (1991) and Verspagen (1992). Soete's correlations were for OECD countries in a cross-section for 1977. Cotsomitis *et al.* use a time series and a patent stock variable, again using OECD countries. Verspagen uses a panel data set. Most of these studies have used patents as the indicator for innovation. The general outcome of the statistical analysis is that for a sample of OECD countries there appears to be a relationship between technological specialisation and trade patterns. Cotsomitis *et al.* do not find such a relationship. Dosi *et al.* (1990) provide an overview of the subject.

iv) Strategic R&D

Trade theory using the framework of monopolistic competition considers industries (for instance high technology or high investment industries) in which firms are involved in a strategic game with foreign firms and national governments. In Brander and Spencer (1983), there are imperfectly competitive international markets, in which national governments intervene with R&D subsidies, making R&D expenditure a strategy within the game. The objective is to raise domestic welfare by capturing the monopoly rents available in international industries. Such strategic considerations may be another motivation for trade in the context of monopolistic markets.

III: DESCRIPTION OF THE MODEL

The model presented in this section aims to estimate the relative importance of a range of explanatory variables. Essentially it can be seen as a test of the neo-endowment approach, as it includes the traditional Heckscher-Ohlin variables (labour and capital intensity) supplemented by a number of technology variables. These are included to test the significance of technology as a factor explaining trade and can be seen as broadly in accordance with both the neo-technology theory of trade and the technology gap approach².

The wage rate and relative investment intensity are used to test for traditional factor proportions motivated trade and each acts as a proxy for endowments of labour and capital respectively. They will reflect relative cost considerations as motivations for trade. The two technology variables - relative R&D intensity and relative patent intensity - act as proxies for relative innovativeness. The limitations of each proxy prompted the use of both. Finally an exchange rate variable was also included to account for any changes in trade which occurred due to changes in the exchange rate rather than for long term non-monetary reasons.

The use of trade flows to analyse the interrelationships between countries has a number of limitations. One drawback is that foreign direct investment may take place as a substitute for trade. This is often undertaken by multinational companies (MNCs) whose actions are not captured in trade flows³. As far as technology is concerned, the relationship between the location of their research sections and the trade flows between their different subsidiaries is probably not captured in this study. Other problems in capturing technology are the possibilities to transfer technology in ways other than by trade; for instance by licensing the technology to other firms. However, despite these limitations, the importance of trade in the international economy continues and for all the countries considered in this sample trade constitutes an important part of their domestic economy.

The dependent variable in the model of this paper is the change in bilateral trade over the two periods 1970-1978 and 1980-1988. 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. Given that the period under consideration experienced significant growth in intra-industry trade (Greenaway and Milner 1983), net exports have been used following Deardorff (1984) who recommends this variable in order to abstract from the issue of intra-industry trade. Moreover, bilateral trade flows have been used, because these lend greater clarity to the issue of factor intensities (compared to total trade). As Hilton (1981) argues, while in multilateral cases the relative factor intensities of exports may not be clear due to their variation on a bilateral basis, this is avoided if bilateral flows are

² The latter generally implies an abstraction from other sources of trade, but does not have to be seen as mutually exclusive of other explanations for trade, such as the factor proportions approach.

³ Our sample of countries excludes countries where the influence of MNCs dominates, such as the Netherlands.

used.

The theoretical approach used assumes that there are two different effects that influence the bilateral trade balance of countries p and q . First, there is an effect relating to differences in competitiveness between the two countries. The functional specification of this part of the model is taken from Magnier and Toujas-Bernate 1992. This means it is assumed that this effect takes the form of an error-correction model, in which the actual trade balance adjusts (slowly) to its long run equilibrium value. The latter value is a function of a number of (real) variables underlying competitiveness, which makes it a moving target, rather than a static objective. Second, it is assumed that the change in the trade balance is a (linear) function of the movement of the exchange rate. The form of the model to be estimated is

$$\Delta \ln(X_{pqs}/X_{qps})_T = \Delta B_{pqsT} = (\mu_0 + \mu_T + \mu_p + \mu_q + \mu_{ec})(\bar{B}_{pqsT} - B_{pqsT}) + \alpha_{es} \Delta e_{pqT}. \quad (\text{III.1})$$

X_{pqs} stands for exports in sector s from p to q , B is the trade balance, and e is the exchange rate, α and μ are parameters. The adjustment parameter, μ , 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 latter factor assumes that for intra-EC trade, the two separate country-effects will be enforced by an integration-effect.

The essential idea in the theoretical approach is formed by the following equation, which gives the expression for the long run trade balance.

$$\bar{B}_{pqs} = F_s [C_0, \ln(w_{ps}/w_{qs}), \ln(R_{ps}/R_{qs}), \ln(I_{ps}/I_{qs})] \quad (\text{III.2})$$

w stands for the wage rate (in some common currency), R is R&D intensity, and I is capital intensity. Note that the function F is sector-specific, thereby allowing for a different impact of each of the variables in different sectors. In the actual estimations, it will be assumed that the true form of F can be approximated by a linear form, with α_{ws} , α_{rs} and α_{is} denoting the coefficients for the wage rate, R&D intensity and capital intensity, respectively.

The inclusion of sector specific and country specific effects (in the μ parameters) allows the impact of the explanatory factors to vary with sector and country specific effects. This implies that it is not necessary to have one all embracing theory which can explain bilateral trade. There may be some industries for which trade is motivated by relative cost factors (Heckscher-Ohlin) and others which can be explained by technology differences (technology gap theory). As in the paper by Helpman (1981) the different explanations for trade do not need to be mutually exclusive but can explain trade in different circumstances.

All the countries in the sample are highly developed, which is of interest as trade within this group of countries is often cited as being inconsistent with the Heckscher-Ohlin model. Recent formulations of the technology gap theory have also been

considered with respect to trade between an advanced North and an underdeveloped South (Krugman 1979, 1985, Cimoli and Soete 1992). Many observers have assumed that the mutually high level of technological development among the developed countries precludes technology gaps. However, this may not be the case on an industry by industry basis, or even overall. The relationship can be expected to vary strongly between countries due to the existence of individual national technological profiles. As Archibugi and 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 F . The technology variables are included in the estimation to test the hypothesis that technology gaps have an influence on trade performance. The potential importance of innovation in improving trade performance highlights the strategic nature of some industries. However, we would not expect innovation to be the driving force for all trade, and the relative intensity of labour and capital are also included as the traditional Heckscher-Ohlin explanations for trade. Soete (1981) finds the significance of technology variables for explaining trade rising with the technological content of the industry. In his study, the innovation pattern was generally not significant for natural resource industries and, as he terms them, factor proportions industries. That test was a cross-section over 40 industries and for OECD countries. For industries in which innovation is an important influence on trade performance, we would expect positive signs on the coefficients on the technology variables. 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 straightforward. 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 characterised 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 movement⁴. 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 and 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.

IV. ESTIMATING THE MODEL

In this section, some empirical estimates for the model introduced above will be conducted. The equation that will be estimated is equation III.1, into which III.2 is substituted, and to which an error term with the usual characteristics is appended. Since this equation is non-linear in the parameters, the model is estimated by an iterative least squares method. This method gives estimates which are robust to the presence of heteroskedasticity (White's method).

The following proxies were used to measure the variables in the model⁵. Bilateral exports are used to calculate (the change in) the trade balances. The dependent variable is defined 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 III.2 (which excluded 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. w is measured by the wage rate in current US dollars, which is given by the wage sum over employment. R is measured by R&D expenditures undertaken by business enterprise relative to production. I is proxied by gross fixed capital formation relative to production.

⁴ 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.

⁵ Sources, definitions and exact sectoral breakdown are explained in the appendix.

The final dataset includes two periods: 1970-1978 and 1980-1988. For the first period, the years covered by the R&D variable are slightly shorter (1973-1978) due to data availability reasons. It is assumed that relative bilateral R&D intensities for this smaller period are representative for the whole 1970-1978 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 countries⁶ and 22 industries (based on a 3 digit SIC classification outlined in the appendix) were used. This means there is a maximum of 1584 observations⁷. The time dummy is set to one for the early period, and zero for the last period. The country-effect for the USA is assumed to go into the constant term μ_0 .

Table IV.1 shows the results of the first estimation. 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.

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, electronics, 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. As a result we do not find much evidence of the skill-hypothesis, i.e. that a high wage rate implies a high level of skills and therefore may have a positive influence on trade performance. Rather, the results support the wage costs hypothesis.

For the R&D variable, we find 11 cases in which the sign is positive, as expected, and also significant. These cases are wood, paper and publishing, chemicals, pharmaceuticals, rubber and plastic, basic 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 ample support for a neo-technology hypothesis of trade. However, 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:

⁶ Canada, France, Germany (which is always West Germany), Great Britain, Italy, Japan, Norway, Sweden, and the US.

⁷ N countries will yield $N(N-1)/2$, which is equal to 36 here, different and non-trivial pairs. Multiplied by 22 sectors and 2 periods, this gives the 1584 observations. The actual estimations include less datapairs, because of missing values in the dataset. 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.

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. In these sectors elasticities of demand are high enough to fulfil the Marshall-Lerner condition. 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 fulfilment of the Marshall-Lerner requirement.

The sectors for which we find relatively low price elasticities, and consequently no fulfilment of the Marshall-Lerner condition are machinery, computers, electrical machinery, electronics, motor vehicles, aerospace, instruments and other manufacturing. With the exception of the last sector, these are 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 the results found in Kravis and Lipsey (1989).

With regard to the adjustment parameter, μ , 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 μ . The first period (1970-1978) is also characterized 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 0.063. The maximum value of μ is found for trade flows between Canada and the USA in the second period, and is equal to 0.804.

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 IV.1 indicate that for only one of these sectors (pharmaceuticals), the R&D variable has 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 sector computers and office machinery is considered to be high-tech as a whole, it includes many products, ranging from low-tech type writers to high-tech super computers. 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 is the fact that in many of the high-tech sectors the influence of military R&D is high. Since this type of R&D is not aimed at commercial

applications it lowers the efficiency of R&D expenditure, and may as a result distort the relationship that is estimated in Table IV.1. This argument is probably more relevant for computers, electronics and aircraft than it is for pharmaceuticals, which may explain why the latter sector performs relatively well in the estimations.

In order to provide an impression of how important military R&D is, Table IV.2 shows governmental military R&D budgets as a percentage of business R&D for a number of key years. The table shows that the USA, France and the United Kingdom are relatively active in the field of military R&D, with budgets amounting to around 40% of total private R&D spending. Sweden is an intermediate case, and the other countries (including Japan, for which exact data is not available) have relatively low military R&D budgets. This might lead to mis-measurement of the R&D related part of competitiveness for these countries. The table also shows that political issues influence the level of military R&D over time, especially in the USA.

Table IV.2 does not, however, give an impression of how the influence of military R&D varies across sectors. Internationally comparable data on military R&D expenditure are not available on a sectoral basis, but Table IV.3 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 the table does not give a completely representative sample in some cases⁸.

Table IV.2. Government military R&D budgets as a percentage of private R&D, 1972-1990, seven countries*

Country	1972	1975	1980	1985	1990
Canada	11.9	8.8	6.4	5.8	5.6
Germany	9.1	9.7	na	6.9	7.0
France	na	32.3	36.9	36.0	38.6
United Kingdom	42.4	49.9	na	41.2	27.0
Norway	na	na	na	7.6	na
Sweden	na	22.1	na	15.3	na
United States	45.5	40.0	33.6	40.0	38.3

* Source: OECD

The table shows that electronics and aerospace are indeed two high-tech sectors which have relatively high ratios of private to government 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

⁸ Space considerations prevent the documentation of the exact samples used. These can be obtained, however, from the authors.

motor vehicles). Therefore, the indicators in the table support the interpretation that military (or government-financed) R&D has an influence on the results in Table IV.1.

Table IV.3. Percentage of private R&D financed by government per manufacturing sector, average over eight countries, 1973-1978 and 1980-1988*

1973-1978	1980-1988	Sector
66	48	aerospace
31	25	shipbuilding
25	22	electronics
24	20	other transport
23	11	instruments
16	8	computers and office machinery
14	15	machinery
11	11	electrical
11	7	nonferrous metals
10	15	wood
10	9	textiles
10	5	paper and 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

Having pointed to a number of possible sources of distortion affecting the results in Table IV.1, the question arises of how to improve the estimates. The approach undertaken here is to include an alternative innovation indicator, in the form of patenting. The indicator used is Revealed Technology Advantage (RTA), which is defined as $(P_{ps}/P_s)/(P_p/P)$, where P_{ps} denotes the number of patents of country p in sector s (and the absence of a subscript p or s means a summation over this

dimension)⁹. Following III.2 and the procedures adopted above, the indicator in the regression is the log of the ratio of the average for the period of the RTA-indices for each pair of countries. Note, however, that for the first period (1970-1978), the RTA-variable is defined as the average over the 1975-1978 period. Patents used are patents taken out in the USA, which are used to rule out any influences of differences in national patent systems (the 'home advantage' of US-based firms is cancelled out by the relative formulation of the index).

Of course, the use of a patent-indicator does not completely solve the problems mentioned above. In fact, nothing is done about the aggregation problem, since the sectoral breakdown remains the same. If military R&D leads to patenting then this drawback will also affect patent statistics. However, one might expect military R&D to reflect a lower propensity to patent, due to a desire for secrecy (the application for a patent means disclosure of information) and the limited commercial application of this type of R&D.

Thus, the R&D intensity and patent intensity variables will be used here as separate proxies for innovation and technological change as they may capture different aspects of the innovation process. Each one has its own limitations. 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. Patents also have weaknesses as a proxy, while they are an output from the innovation process many innovations may not be patentable and others which are may not be patented. Patents may also not be taken out for strategic reasons. The estimations were repeated with each technology proxy in order to exploit the different information they contain. There is a developed literature¹⁰ discussing the relative merits of the two proxies. In addition to these differences between patents and R&D as proxies for innovation, there is also the fact that we have defined a patent variable (RTA) which is primarily aimed at measuring technological specialization. Thus, while the R&D variable measures absolute differences, the patent variable measures relative differences. This may be an additional source of divergence between the results.

The results for this estimation are shown in Table IV.4¹¹. In general, the results are less convincing than those including R&D. This can be seen by the value of the adjusted R^2 , which is about 10 points lower, and by the lower number of significant t -statistics for the explanatory variables. The results for the wage rate variable, the investment variable and the adjustment parameters are largely consistent with those in Table IV.1.

⁹ The RTA-variable was first introduced by Soete (1987) and is analogous to revealed comparative advantage.

¹⁰ For more details see Acs & Audretsch (1989), Basberg (1985), and Grilliches (1990).

¹¹ Note that patent data is not available for wood, paper and publishing, and other manufacturing.

Table IV.4. The results for equation III.1 with patenting as the innovation indicator, adj. $R^2=0.50$, $n=653$, estimates are robust to the presence of heteroskedasticity

	μ	t	sector	α_{is}	t	α_{ps}	t	α_{is}	t	α_{xs}	t
μ_0	0.735	7.018	food	0.284	3.218	-0.487	-2.728	-0.389	-0.341	-0.820	-2.538
μ_T	-0.071	-1.392	textiles	0.052	0.574	0.314	2.494	3.713	5.551	-0.355	-1.879
μ_{ec}	-0.014	-0.153	chemicals	-0.097	-1.553	-0.287	-1.947	-1.160	-1.881	-0.126	-0.881
μ_{can}	0.021	0.293	pharmaceuticals	-0.033	-0.301	0.421	2.548	1.841	0.624	-0.434	-0.678
μ_{deu}	-0.218	-2.800	refined oil	0.674	2.938	-1.708	-3.982	-2.474	-1.700	-0.611	-0.793
μ_{fra}	-0.264	-2.978	rubber and plastic	-0.476	-5.837	0.512	4.541	3.686	5.084	0.351	1.601
μ_{gbr}	-0.344	-4.784	glass etc.	-0.403	-5.669	0.565	5.233	5.575	6.507	-0.021	-0.104
μ_{ita}	-0.223	-2.760	ferrous metals	-0.521	-4.502	-1.125	-2.526	-2.490	-1.925	0.821	1.910
μ_{jpn}	-0.132	-1.844	nonferrous metals	0.104	0.690	-0.798	-2.463	0.030	0.028	0.110	0.289
μ_{nor}	-0.041	-0.295	fabricated metal	-0.271	-4.588	0.199	2.231	1.688	4.265	0.153	0.946
μ_{swe}	-0.200	-2.752	machinery	-0.333	-5.890	0.239	2.809	-0.094	-0.123	1.071	5.983
C_0	-0.443	-2.972	computers	-0.139	-1.834	0.150	1.033	-1.111	-2.447	1.192	2.549
			electrical	-0.145	-1.256	-0.084	-0.453	-2.218	-1.372	0.885	2.352
			electronics	-0.250	-5.898	0.256	3.008	-0.736	-0.742	1.314	5.129
			ships	-0.649	-2.540	-0.042	-0.143	-2.064	-1.147	-0.301	-0.439
			motor vehicles	-0.427	-2.782	0.223	0.976	0.568	0.259	1.774	2.883
			aerospace	-1.111	-3.598	-1.133	-2.814	-13.260	-3.846	18.258	5.911
			instruments	-0.031	-0.422	0.093	1.288	0.272	0.897	0.301	1.739

The patent variable has a positive and significant sign in seven out of 18 cases. The sectors for which this occurs are textiles, pharmaceuticals, rubber and plastic, glass etc., fabricated metal, machinery, and electronics. There are also six sectors for which the sign is negative and significant: food, chemicals, refined oil, basic metals and aerospace. Thus, although the results for the patent variable are not very strong, there is some indication that for at least one of the 'problem sectors' in the R&D case, a different innovation variable makes the neo-technology hypothesis more plausible. This also implies that the proxy used might indeed be weak in some cases.

V. POLICY EFFECTS IN THE TRIAD JAPAN-UK-USA

The model that has been applied above, can be used to predict the effects of changes in a country's R&D intensity, investment intensity and wage costs on competitiveness. In order to do this competitiveness is defined as the long run equilibrium value of the aggregate export import ratio. The expression of this ratio for country p can be found by starting from an assumed specification for equation III.2, which is as follows.

$$\ln \frac{\bar{X}_{pqs}}{\bar{X}_{qps}} = C_0 + \alpha_{rs} \ln \frac{R_{ps}}{R_{qs}} + \alpha_{is} \ln \frac{I_{ps}}{I_{qs}} + \alpha_{ws} \ln \frac{W_{ps}}{W_{qs}} \quad (V.1)$$

Rewriting and aggregating over sectors and partners, this gives the following expression for the long run equilibrium export import ratio (competitiveness) of country p .

$$\frac{\bar{X}_p}{\bar{M}_p} = e^{C_0} \sum_q \sum_s \frac{\bar{M}_{pqs}}{\bar{M}_p} \left(\frac{R_{ps}}{R_{qs}} \right)^{\alpha_{rs}} \left(\frac{I_{ps}}{I_{qs}} \right)^{\alpha_{is}} \left(\frac{W_{ps}}{W_{qs}} \right)^{\alpha_{ws}} \quad (V.2)$$

This expression can be used to calculate the elasticity of competitiveness with regard to each of the factors R&D, investment and wage costs. This elasticity gives an important quantification of the effects of investment, technology and wage policies upon trade performance. The starting point for the calculation is the derivative of the above expression with respect to each of the factors. For example, in the case of R&D, this gives the following expression (it is assumed that the increase in aggregate R&D intensity is evenly distributed over sectors, i.e., the increase in each sector is equal to the aggregate increase).

$$\frac{\partial(\bar{X}_p/\bar{M}_p)}{\partial R_p} = e^{C_0} \sum_q \sum_s \frac{\alpha_{rs}}{R_{ps}} \frac{\bar{M}_{pqs}}{\bar{M}_p} \left(\frac{R_{ps}}{R_{qs}} \right)^{\alpha_{rs}} \left(\frac{I_{ps}}{I_{qs}} \right)^{\alpha_{is}} \left(\frac{W_{ps}}{W_{qs}} \right)^{\alpha_{ws}} \quad (V.3)$$

An equivalent expression can be calculated for the other two factors, investment and

wage costs. The elasticity of competitiveness can now be obtained easily by dividing this expression by the ratio of the aggregate value of the factor to total competitiveness.

One drawback of this method is that one needs data on each of the factors for each of the countries in each of the sectors, in order to be able to calculate the derivative. Therefore, the calculations must be restricted to a sample for which the underlying data is without missing values. It appears that for the period 1980-1988, elasticities can be calculated if the sample is restricted to Japan, the USA and the United Kingdom, and the transport equipment sectors other than motor vehicles are left out. By way of approximation, the long run equilibrium import shares in equation (V.3) are assumed to be equal to the actual values over the 1980-1988 period. The estimated parameter values from Table IV.1 are used in the calculations. However, where the sign of the estimates is not in accordance with the theoretical expectations, it was set to zero¹².

The results of the calculation for the triad are presented in Table V.1. The bottom line of the table shows the competitiveness of each of the countries vis-a-vis the other two in the sample. It appears that the USA is the only country that has a value larger than one. The UK and Japan both have competitiveness values that indicate they have a negative long run equilibrium trade balance. This is especially surprising for Japan¹³.

Next, the table shows that the technology factor has a relatively high elasticity. In all three countries, the elasticities found are well above 0.5. Labour costs generally have low elasticities, while investment differs between countries; in Japan the elasticity is just above one, while it is below 0.5 in the other two countries.

Table V.1. Competitiveness in the triad Japan-UK-USA, 1980-1988*

Country		United Kingdom	Japan	United States
Elasticities	Labour costs	-0.146	-0.112	-0.208
	R&D	0.717	0.680	0.934
	Investment ratio	0.329	1.090	0.291
Competitiveness		0.78	0.83	1.59

* Based upon the results and data used in Table V.1

These results show that technology policy can be a very effective way of enhancing

¹² I.e., in cases where the sign of the R&D or investment variable was negative, or the wage variable positive.

¹³ Of course, a calculation for a more complete sample could still show a ratio higher than one for Japan. The ordering found here (USA-Japan-UK) seems plausible.

a country's competitiveness. Of course, the results in the previous section seem to indicate that government funded R&D is not necessarily as effective as privately funded R&D. Nevertheless, the results here indicate that a policy aimed at stimulating the innovative climate in general (for example schooling, establishing a research infrastructure) seems to be an effective way of increasing national competitiveness.

VI: CONCLUSIONS

This paper has aimed to assess competitiveness on a bilateral basis between nine OECD countries, and to identify which factors are the most important in influencing competitiveness. This has involved testing a dynamic model of the change in bilateral trade performance explained by technology, investment, labour costs and exchange rate movements. The speed of adjustment to the long run trade balance was allowed to vary with the time period (1970s and 1980s), the country, and whether or not both countries were members of the EC. Estimations of the relationship between trade performance on the one hand and R&D intensity, the wage rate, investment intensity and the exchange rate on the other hand, were implemented on a sectoral basis. As the model is non-linear in the parameters it was estimated with 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 military R&D expenditure in those sectors. For the exchange rate variable nine industries do not fulfil the Marshall-Lerner condition. These are mostly high technology industries or industries where quality considerations are important. The calculations were repeated with patents as the technology variable. The patent variable was positively significant for a number of key industries (computers) which were not positive with the R&D variable. This implies that in different circumstances there are limitations to both the innovation proxies. Overall the evidence indicates that both labour costs and technology are important influences on trade. The exchange rate also has an impact, the direction of which depends upon the nature of the product.

The model applied in this paper is of an eclectic nature and encompasses more than one approach to international trade. The aim was to include additional technology variables without abstracting from other causes of trade, a weakness of some of the technology gap literature. Our results thus indicate that technology is an important determinant of trade, even in industries which are not generally known as high or medium technology industries. This is contrary to the recent findings of Cotsomitis *et al.* (1991), whose approach is much less general than the one adopted here. The results found do support the conclusions drawn by among others Dosi *et al.* (1990) and Magnier and Toujas-Bernate (1992), who stress the relevance of technology variables. At the same time, however, the estimations show that one cannot abstract from other variables determining the dynamic behaviour of the trade balance (wages,

investment and the exchange rate)¹⁴.

Finally the estimation results were used to analyse the elasticity of competitiveness with regard to the three factors (R&D, wages and investment) for the case of trade between the UK, the USA and Japan. Labour had a generally low elasticity, technology a relatively high one while the investment elasticity varied with the country. This indicates the importance of technology as a factor in influencing bilateral trade flows between developed countries, and the potential it has for improving competitiveness. As mentioned earlier this has important implications for government policy. Although government financed R&D may not have as great an impact on competitiveness as private expenditure, encouraging innovation may have a positive impact on a country's trade performance.

¹⁴ This is in accordance with Dosi *et al.*, who include variables other than technology variables to control for such influences on several occasions.

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; 3560+3570: rubber and plastic products; 3600: glass etc.; 3710: ferrous metals; 3720: nonferrous metals; 3810: fabricated metal; 3820-3825: machinery; 3825: computers; 3830-3832: electrical; 3832: electronics; 3841: ships; 3843: motor vehicles; 3845: aerospace; 3840-3841-3843-3845: 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 dataset were filled by analytical methods (the so-called ANBERD database). 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. The patent data (and its classification according to SIC) were supplied by the US Patent and Trademark Office. Reclassification from SIC to ISIC was done by the authors. Patents are dated by year of application, and counted by the so-called fractional count method (this means patents are counted for $1/n$ in each of the n SICs they are classified).

REFERENCES

- Archibugi, D. & Pianta, M. (1992), *The Technological Specialisation of Advanced Countries: a report to the EEC on international science and technology activities*.
- Acs, Z. & Audretsch, D. (1989), Patents as a Measure of Innovative Activity, *Kyklos* 42(2).
- Basberg, B. (1983), Foreign Patenting in the USA as a Technology Indicator: The Case of Norway, *Research Policy* 12 Number 4 pp 227-237.
- Bowen, H. (1980), *Resources, Technology and Dynamic Comparative Advantage: a Cross-country Analysis of the Product Cycle Theory of International Trade*, Ph.D dissertation.
- Blomstrom, M., Lipsey, R. & Ohlsson, L. (1990), What do Rich Countries trade With Each Other? R&D and the composition of US/Swedish trade, *Banco Nazionale del Lavoro Quarterly Review* 173.
- Brander, J. & Spencer, B. (1983), International R&D, Rivalry and Industrial Strategy, *Review of Economic Studies*, 50 (4).
- Cimoli, M. & Soete, L. (1992), A generalized Technology Gap Model, *Economie Appliquée*, XLV, no. 3, pp. 33-54.
- Cotsomitis, J., DeBresson, C., Kwan, A. (1991), A Re-examination of the Technology Gap Theory of Trade: Some Evidence from Time Series Data for OECD countries, *Weltwirtschaftliches Archiv*, volume 127, number 4, pp. 792-799.
- Deardorff, A. (1984), Testing Trade theories and Predicting Trade Flows, in Jones, R & Kenen, P *Handbook of International Economics Volume I*.
- Dosi, G., Pavitt, K. & Soete, L. (1990), *The Economics of Technological Change and International Trade*, Harvester Wheatsheaf Publishers.
- Fagerberg, J. (1988), International Competitiveness, *The Economic Journal*, vol 98, pp. 355-374.
- Greenaway, D. & Milner, C. (1983), On the Measurement of Intra-Industry Trade, *The Economic Journal*, volume 93 pp 900-908.
- Greenhalgh, C., Suer, B., Taylor, P., Wilson, R. (1992), Trade Performance and Innovatory Activity: A Review, in Milner, C. & Snowden, N. (Eds), *External Imbalances and Policy Constraints in the 1990s*.
- Griliches, Z. (1990), Patent Statistics as Economic Indicators: a Survey, *Journal of Economic Literature*, vol 28 (4).
- Helpman, E. (1981), International Trade in the Presence of Product Differentiation,

- Economies of Scale and Monopolistic Competition, *Journal of International Economics*, 11.
- Hilton, R. (1981), *An Estimable Model of the Commodity Version of Trade*, unpublished PhD dissertation.
- Kaldor, N. (1978), The Effect of Devaluations on Trade in Manufactures, in *Further Essays on Applied Economics*, London: Duckworth.
- Kravis, I. & Lipsey, R. (1989), Technological Characteristics of Industries and the Competitiveness of the US and its Multinational Firms, *NBER Working Paper*, number 2933.
- Krugman, P. (1979), A Model of Innovation, Technology Transfer and the World Distribution of Income, *Journal of Political Economy*, volume 87.
- Krugman, P. (1985), A Technology Gap Model of International Trade, in Jungenfelt, K. & Hague, D. (Eds) *Structural Adjustment in Developed Open Economies*.
- Lancaster, K. (1980), Intraindustry Trade Under Perfect Monopolistic Competition, *Journal of International Economics*, vol 10.
- Leontief, W. (1956), Domestic production, Factor Proportions & the Structure of American trade, *Review of Economics and Statistics*.
- Magnier, A. & J. Toujas-Bernate (1992), *Technology and Trade: empirical evidences from the major five industrialized countries*, INSEE Working Paper 9207.
- Posner, M. (1961), International Trade and Technical Change, *Oxford Economic Papers*, Volume XIII, pp. 323.
- Soete, L. (1981), A General Test of Technological Gap Trade Theory, *Weltwirtschaftliches Archiv*, 117.
- Soete, L. (1987), The Impact of Technological Innovation on International Trade Patterns: the evidence reconsidered, *Research Policy*, volume 16.
- Stern, R. & Maskus, K. (1981), Determinants of the Structure of US Foreign Trade 1958-76, *Journal of International Economics*, vol 11.
- Sveikaukus, L. (1983) Science and Technology in US Foreign Trade, *The Economic Journal*, vol 93, pp. 542-554.
- Vernon, R. (1966) International Investment and International Trade in the Product Cycle, *Quarterly Journal of Economics*.
- Verspagen, B. (1993) *Uneven Growth between Interdependent Economies*, Avebury, Aldershot (forthcoming).