The Impact of Technological Opportunity on the Dynamics of Trade Performance

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Abstract

The paper explores firstly the impact of technological change on trade growth at the country level, using trade statistics and statistics on patenting activity in the US, across 20 countries for 17 manufacturing sectors. Secondly, using structural decomposition analysis, the paper examine whether the degree to which countries get access to sectors with above average growth in technological opportunity has any impact on growth in aggregate market shares of exports. The results demonstrate that there is a positive relationship between *change* in trade performance and *change* in technological capabilities across countries for 8 'technology intensive' sectors over the period 1965-1988. It is also shown that there appear to be some (however weak) relationship between the degree to which countries get access to sectors with above average growth in technological opportunity and growth in aggregate market shares. However, there seems to be a much stronger positive relationship between growth rates in trade performance and the individual 'national innovation system's' ability to actively move into technological sectors offering above average technological opportunity.

Keywords

Technological opportunity, trade growth, national systems of innovation, structural decomposition analysis.

JEL Classification

C13, C21, F14, F43, O31

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Contents

1. Introduction

Technology is now well recognised to be one of the major determinants of economic performance such as productivity and trade performance. Fagerberg (1987; 1988) for instance has confirmed the positive effect of technology upon economic growth and as an important determinant of international competitiveness at the macro level, using a combination of R&D data and patent statistics. Likewise - at the sectoral level - Soete (1981), Dosi *et al.*(1990) and Verspagen (1992) found that technological activity (mainly measured by patents granted in the US) had a positive impact on trade performance. However, as argued by Verspagen (1992, p. 175) what is estimated in these models is the relationship between the *structure* of technological capabilities and the *structure* of trade performance. Thus, what is not shown is that changes in technological capabilities affect trade performance from a dynamic point of view. Verspagen (1992) measured aspects of 'competitiveness' as the wage rate, labour productivity and patents and used these variables in a dynamic setting in order to explain trade performance across countries. Nevertheless, the patent variable did not fare well in explaining changes in market shares, since the variable were only significant in a few sectors, and often had a negative sign.

The aim of the paper is firstly to examine the degree to which there is a positive relationship between *change*, in trade (measured as export performance) and technology (measured as US patents) at a sectoral level. Secondly, the paper aims to explore the degree to which countries get access to high (or low) levels of technological opportunity, and whether this has any effect on trade performance across 19 OECD countries.

Section 2 presents some of the literature on technological opportunity, and discusses the possible relation to trade performance. Section 3, starts off by a presentation of the data to be used, as well as a presentation of growth rates, related to the average, in both trade and technology. Subsequently, the 'structural decomposition analysis' methodology to be applied is presented and the results of the analysis will be discussed, both for what concerns technological development and for development of trade performance. Section 4, contains regression analysis, relating firstly trade and technology growth at the sectoral level, taking into account the size of the individual sectors. Secondly, the decomposed effects from section 3 both in terms of technology will be related to trade performance in an attempt to assess the impact of countries getting access to low versus high degrees of growth in technological opportunity on aggregate export performance.

2. Technological opportunity and trade growth

The starting point of this paper is a ‘technology gap’ approach to explaining export performance, emphasising inter-country differences in innovativeness, as the basis for international trade flows. The basic assumption of most of this line of thought is that technology is not a free and universally available good. Instead, and following a Schumpetarian logic there are ample advantages in being first. Thus, according to Posner (1961), it is technical change in one country - and not in others - that will induce exports, as long as it takes other countries to imitate the innovation carried out by the one country. In this context, Mansfield (1981) in a study of 48 product innovations and their corresponding imitations, showed that it took 4 years to ‘get around’ (imitate) 60 % of the patents. In addition, the study showed that imitation is not a costless activity; the cost of conducting the imitation was approximately 65 per cent of the cost of the original innovation. Once imitated, more traditional factors of adjustment might then determine trade flows. However, this needs not take place if a continuous flow of product and process innovation secures a continuous flow of exports.

In their seminal book on evolutionary economics, Nelson and Winter (1982, pp. 258-259) introduced the notion of ‘technological regimes’ as determinants of the patterns of innovative activities across industries. The idea has later on been further developed by Malerba & Orsenigo (1990), such that a technological regime is viewed as a particular combination of some fundamental properties of technologies. These properties are; opportunity and appropriability conditions; degrees of cumulativeness of technological knowledge; and finally characteristics of the relevant knowledge-base.

Since a central focus of this paper is on technological opportunity, opportunity conditions will be discussed a bit further. Basically, opportunity conditions reflect the easiness of innovating, given an amount invested in technological search. In evolutionary economic theory of R&D activity - which analogises R&D to drawing a ball from an urn - technological opportunity describes the distribution of values of the balls in the urn. When technological opportunity is ‘high’ the distribution of draws has a higher mean than when the distribution is low (Klevorick *et al.*, 1995, p. 188).

According to Malerba & Orsenigo four basic dimensions of opportunity can be identified; *level, pervasiveness, sources* and *variety*. A high *level* of opportunities provide strong incentives to the undertaking of innovative activities and denotes the probability of innovating for a given amount of resources devoted to search. Therefore, high opportunities means an environment that is not functionally constrained by scarcity. In the case of high *pervasiveness*, new knowledge may be applied to several products and markets, while in the case of low pervasiveness new knowledge applies to only a few products and markets. The *sources* of technological opportunities differ among technologies and industries, as shown by Klevorick *et al.* (1995). In some industries opportunity conditions are closely related to scientific advance made at universities. In other sectors internal R&D and endogenous learning is the most dominant source of innovation, yet in other sectors users or suppliers seem to the most important source. In some case high levels of technological opportunity are associated with a potentially rich variety of technological solutions, approaches and activities. This might especially be the case in the early stage of an industry life-cycle (Abernathy and Utterback, 1975). At a later stage - when a dominant design has emerged - technical change may proceed along more specific trajectories, where the variety between technical solutions is reduced.

Using industry-specific constants, Geroski (1990) has shown that technological opportunity is an important factor in explaining innovativeness across industrial sectors. Hence, following the ‘technology gap’ approach presented above (i.e. assuming that technology is an important determinant of trade growth), one would expect countries ability to get access to high (low) levels of demand to be affected by whether the countries manage to get into the sectors offering high (low) levels of technological opportunity. It should be stressed that the focus of this paper is not on, what creates differences in technological opportunities, but on how differences in getting access to high levels of technological opportunities might affect trade performance at the country level.

However, as pointed out by Granstrand & Sjölander (1990) the product-technology relationship is not one-to-one, since the development, production and use of a product usually involve more than one technology and each technology can be applied in more than one product. Given the complexity of products, firms are therefore often ‘multi-technology’ i.e. are able to orchestrate several technologies. Therefore, we should not expect a perfect match between growth in trade and technology. A somewhat extreme case in this context is the evidence provided by Patel & Pavitt (1994). They show that among 440 of the world’s largest firms, companies situated in the industry ‘motor vehicles’ only take out 28.8 % of their patents in the technology class ‘transport’. Given that one of the ingredients in gaining competitiveness in automobiles, is the application of electronics it is not surprising that 20.7 per cent of the patents taken out in the US by companies in ‘motor vehicles’, were situated in the patents class ‘electrical equipment’ (including electronics).

However, while this line of argument should be taken into account, the problem is less dramatic at higher levels of aggregation (e.g. at the level of 17 sectors, as used in this study) since e.g. the evidence provided by Patel and Pavitt also displays a broad concordance between the firm’s principal product group and the share of patents in the corresponding technology group.

3. Empirical analysis

3.1. The data

In order to avoid too much influence of cyclical variations in export market shares (expressed in current prices), four ‘peak’ years, were selected from the IKE trade database; namely 1965, 1973, 1979 and 1988. These years broadly correspond to peaks in business and trade cycles. Concerning the country patenting in the US, these were chosen to correspond to the trade data. However, because of small number problems the patents[1] were aggregated three years back, so e.g. that the first observation in terms of patents consists of the years 1963-1964-1965; and the last observation consists of the years 1986-1987-1988. Another reason for such a procedure is

1 The use of patents as a proxy for technological capabilities, will not be discussed at length here. For a good survey of the pros and cons of the use of patent data in this context, see Pavitt (1988).

that technological development is expected to influence trade performance with some lag. The patent data used is taken from the U.S. patent office, and concerns patent grants, dated by the year of grant. The attribution of patents to countries and industrial sectors is done by the patent office. Whenever a patent is attributed to more than one, say *m* sectors, the patent is counted as 1/*m* in each of these. It was chosen to work with U.S. patents because, rather than patent statistics from each of the national patent offices, US patents are subject to a common institutional system (novelty requirements, etc.), and moreover, the U.S., for most of the period under consideration, constituted the largest 'technology market' in the world.

[Table 1, just about here]

Before starting to explore the relationship between technological opportunity and development in export market shares, it can be a good idea to take a closer look on, how fast the 17 sectors grow, both in terms of trade and technology. Table 1 shows that annual growth rates in terms of trade and technology, related to the averages, are related to each other.[2] When sectors grow faster than average of the world total in technology, this also seems to be the case for the sector's growth in exports. There are exceptions however; the sectors textiles, footwear and leather; stone, clay and glass; basic metals; and electrical machinery do all have different signs. Nevertheless, for the first 3 sectors this is not so surprising since e.g. Soete (1981, p. 651) found that the performance of these sectors were not closely related to technology.

The Table also displays that the growth rates in relation to the mean are much more dispersed (measured by the standard deviation) across sectors in technological activity, than are the growth rates in export growth across sectors.

3.2. SD-analysis

One way of looking at the dynamics of technological activity can be by way of applying a 'structural decomposition analysis' (SD) methodology, often used in an empirical trade context

2 $\rho = 0.58$, significant at the 1% level.

(cf. Fagerberg and Sollie, 1987), here known as constant market share (CMS) analysis. This paper is going to apply SD analysis to technology, as well as to exports.

In the case of technology, the starting point is whether or not a country manages to get more US patents granted as a percentage of total world US patenting over time, between two periods. As an example, Canada's share of the worlds US patenting activity made up 1.28 per cent in 1965, rising to 1.76 per cent in 1988, this being equivalent to a growth rate of 37.9 per cent. The basic idea of the method is then to decompose the growth rate, in such a way that structural change gets isolated. It is then possible to say something about whether a rise (or fall) of a country's share of world US patenting is due to (i) the 'right' ('or wrong') specialisation pattern; (ii) a movement into sectors with fast-growing (or stagnating) technological activity (iii) a movement out of sectors with generally stagnating technological activity (or fast-growing), and finally (iv) whether the rise (or fall) is due to the fact that the country has gained shares of patenting, assuming that the structure is the same in the two periods in question.

Below is a presentation of the methodology to be applied. Superscript *t*-1 denotes the starting year, while *t* denotes the end year. Δ denotes a change from year *t*-1 to year *t*.

$$p_j = \sum_i P_{ij} / \sum_i \sum_j P_{ij} \qquad \text{(a country's aggregate share of total world patents);}$$

$$p_{ij} = P_{ij} / \sum_j P_{ij} \qquad \text{(a country's share of a given sector in terms of patents);}$$

$$o_{ij} = \sum_j P_{ij} / \sum_i \sum_j P_{ij} \qquad \text{(a sector's share of total world patents),}$$

where P_{ij} denotes patents granted to firms in country *j* in sector *i*. The rate of change of a given country's aggregate share of total world patents (Δp_j) can be decomposed into:

$$\Delta p_j = \underbrace{\sum_i (\Delta p_{ij} o_{ij}^{t-1})}_{\text{Technology share effect}} + \underbrace{\sum_i (p_{ij}^{t-1} \Delta o_{ij})}_{\text{Structural technology effect}} + \underbrace{\sum_i (\Delta p_{ij} \Delta o_{ij})}_{\text{Technology adaptation effect}}. \qquad (1)$$

Thus, the technology share effect measures whether a country is gaining or losing shares of world patents, assuming a fixed structure in the two periods. The structural technology effect measures whether a country is gaining or losing patent shares because of a 'right' or a 'wrong' specialisation pattern. Finally, the technology adaptation effect measures whether a country is gaining or losing shares because of an active movement into (or out of) the 'right' sectors or a movement out of (or into) the ‘wrong’ sectors. However, since for instance, a positive value of the latter effect can be caused by either a movement into to ‘right’, or a movement out of the ‘wrong’ sectors, it can be useful to further decompose the ‘technology adaptation effect’ and distinguish between a ‘technology growth adaptation effect’ (positive, if a country move into the fast-growing sectors) and a ‘technology stagnation adaptation effect’ (positive, if a country move out of the stagnating sectors):

$$\underbrace{\sum_i (\Delta p_{ij} \Delta o_{ij})}_{\text{Technology adaptation effect}} = \underbrace{\sum_i (\Delta p_{ij} \, (\Delta o_{ij} + |\Delta o_{ij}|)/2)}_{\text{Technology growth adaptation effect}} + \underbrace{\sum_i (\Delta p_{ij} \, (\Delta o_{ij} - |\Delta o_{ij}|)/2)}_{\text{Technology stagnation adaptation effect}}. \qquad (2)$$

Thus, in other words, if (2) is inserted into (1) we get that the four components, namely ‘the technology share effect’, ‘the structural technology effect’, ‘the technology growth adaptation effect’, and the ‘technology stagnation adaptation effect’ add up to the total rate of change (Δp_j) of a given country’s share of the worlds total patents granted in the US.

Since the relative growth of a sector in terms of patents, probably reflects, whether growth in technological opportunity is relatively high or low in that sector, a possible interpretation of the three latter effects is that these effects measure a given national innovation system’s (Lundvall, 1992; Nelson, 1993) ability to get into sectors with relatively high levels of technological opportunity. The parts of a national innovation system include the efficiency of the education system; the technological support system; the financial system; the quality of intra- and inter-firm co-operation; the relationship between the public sector and business firms etc. (see Lundvall, 1992)

If the structural effect for a country is positive and high, this means - following the interpretation suggested above - that the national innovation system has been ‘fortunately’ specialised in the initial year; being specialised in sectors which has generally experienced high growth in technological opportunity (indicated by high levels of patenting growth). Following the same logic, if the two latter effects are high and positive, it indicates that a NSI has *actively* moved into sectors with higher levels of technological opportunity (the growth adaptation effect), or actively moved out of a sector with lower technological opportunity (the stagnation adaptation effect). Likewise, such a decomposition can be conducted for growth in export market shares:

$$\Delta x_j = \sum_i (\Delta x_{ij} y_{ij}^{t-1}) + \sum_i (x_{ij}^{t-1} \Delta y_{ij}) + \sum_i (\Delta x_{ij} \frac{\Delta y_{ij} + |\Delta y_{ij}|}{2}) + \sum_i (\Delta x_{ij} \frac{\Delta y_{ij} - |\Delta y_{ij}|}{2}), \quad (3)$$

Market share effect	Structural market effect	Market growth adaptation effect	Market stagnation adaptation effect

where:

$x_j = \sum_i X_{ij} / \sum_i \sum_j X_{ij}$ (a country's aggregate share of OECD exports to the world);

$x_{ij} = X_{ij} / \sum_j X_{ij}$ (a country's share of a given sector in terms of exports);

$y_{ij} = \sum_j X_{ij} / \sum_i \sum_j X_{ij}$ (a sector's share of total OECD exports to the world).

where X_{ij} denotes exports by firms situated in country j in sector i.

[Table 2, just about here]

Table 2 displays the results of the 'constant market share' calculations. Generally speaking, 'catching up' countries (such as Japan, Austria, Finland, Greece, Ireland, Italy, Portugal, Spain & Turkey)[3] have had high levels of growth rates in terms of aggregate exports. The initial (1965) sectoral specialisation of these countries have however, had a significant negative impact on the overall export performance, since the structural market effect is negative for all these 'catch up' countries. Likewise most of these countries (all, except Japan) have further moved into sectors offering low levels of market opportunity, as displayed by the negative impact of the 'market stagnation effect' on overall performance. The reason for these countries moving increasingly into sectors offering low levels of market opportunity might be path-dependence (Arthur, 1989; David, 1985) in trade specialisation, as countries might deepen their specialisation in sectors where already strong (Krugman, 1987), disregarding that these sectors might be offering low market opportunities. The table also shows that only a small group of countries have been initially specialised in sectors offering high levels of market opportunity, namely initially rich countries such as the US, Germany, Switzerland and Great Britain. Thus, these countries appear to have benefited from the observed strong stability in export specialisation (Dalum *et al.*, 1996).

3 $\Delta x_j > 10\%$

[Table 3, just about here]

Table 3 shows the results of the 'constant technology share' analysis. It can be seen that most 'catching up' countries (Japan, Finland, Ireland, Spain, Austria, Italy & Turkey) have experienced very high levels of growth in terms of technology, measured as shares of US patents. At the same time these countries generally appear to have been specialised in the 'wrong' (i.e. sectors offering lows levels of technological opportunity) sectors in 1965, since the structural technology effect is negative for these countries. An interesting feature is that Japan already in 1965 tended to be specialised sectors offering higher levels of technological opportunity than the average in the period 1965-1988. This is to be compared with the Japanese specialisation in exports in 1965, which offered relatively low levels of market opportunities in the period 1965-1988. Thus, already early on Japan were specialised in the technologies, which grew above the average in the period 1965-1988. Both with regard to adjustment into sectors offering high levels of technological opportunity and especially with regard to the active movement into sectors offering high levels of market opportunity, Japan has done extra ordinary well, since e.g. the 'market growth adaptation effect' made up 40% of the increase in export market shares of 97% (from a relatively high level). Thus, it would seem that the national innovation system of Japan have had a strong ability to adjust to changes in opportunities in both trade and technology. This finding is in line with the observations of Freeman (1988), who furthermore argues that social and institutional changes played a major role in this context.

4. Regression analysis

4.1. The role of growth of technological capabilities in market share growth

The first part of this section will apply the calculations from above to examine whether trade growth is affected by changes in technological capabilities in the long run, using simple regression analysis. The design of the analysis is set up in such a way that the dependent variable expresses whether a sector makes a positive contribution to the overall export performance of the country. The design is analogous for the independent variable (i.e. technology, measured as patents). As argued by Soete (1981, p. 645) the core of a 'technology gap' approach has to do with the variation of innovativeness in a sector, across countries. Thus, the regressions are specified for each of the 17 sectors, across the 20 countries:

$$\Delta E_{ij} = \alpha + \beta \Delta T_{ij} + \epsilon, \tag{4}$$

where

$$\Delta E_{ij} = \Delta x_{ij} y_{ij}^{t} + \Delta y_{ij} x_{ij}^{t-1},$$

$$\Delta T_{ij} = \Delta p_{ij} o_{ij}^{t} + \Delta o_{ij} p_{ij}^{t-1}.$$

Thus, at the level of the individual sector the sum of the 'market share effect', 'the structural market effect', 'the market growth adaptation effect', and the 'the market stagnation adaptation effect' add up to ΔE_{ij}.[4]

Accordingly, whether the sector makes a positive or negative contribution to the overall gain or loss in market shares (ΔE_{ij})[5] is determined by the joint contribution of the growth of the country's share of total OECD exports in a sector (weighted by the sectors's share in the year *t*) and of the growth of the sectors share of OECD exports in that sector (weighted by the country's share of the sector in year *t*-1). So even though a country loses market shares the contribution from an individual sector might well be positive. However, it should be pointed out that no attempt to distinguish between the effects of sectoral versus country dynamics in the regression analysis, as is done in the analysis conducted by Amable and Verspagen (1995), will be made.

[Table 4, just about here]

The results of regressions, set up in equation 4 are reported in Table 4. Because of data availability it was impossible to estimate a fuller (long-term) model. Even though one have to

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4 Since:

$$\Delta x_{ij} y_{ij}^{t-1} + x_{ij}^{t-1} \Delta y_{ij} + \Delta x_{ij} \Delta y_{ij} = \Delta x_{ij} y_{ij}^{t} + \Delta y_{ij} x_{ij}^{t-1}$$

5 The design is the same for ΔT_{ij}.

be cautious, given the fact the estimations rely on simple regressions only, it is quite remarkable that the estimations are in general either highly significant on the one hand, or highly insignificant on the other. The table shows that for 8 out of the 17 sectors, technology dynamics have a significant impact on increase in market shares at the sectoral level, weighted by the size of the sector as a proportion of the total market share of a given country in the initial year. The results are broadly consistent with the static findings of Soete (1981; 1987) showing a significant impact in the 'technology intensive' sectors, while there seems to be no relationship in what might be termed 'low technology' sectors. One exception (another might be rubber and plastics) is the chemical sector in which the relationship is non-significant. However, the sign is as expected, even though estimate escapes the 10% level of significance. But also in the machinery sectors a strong relationship is recorded. It has also been tried to split the change over the long run into 3 sub periods, broadly corresponding to peaks in business and trade cycles and then run a pooled regression. The results of this regression turned out not to be significant for nearly all sectors. Thus, it would seem that the lag structure between the two variables is a complex one in the shorter run.

It can be noted the sum of the ΔE_{ij}'s sum up to the total gain in market shares for a country:

$$\Delta x_j = \sum_i \Delta E_{ij} = \sum_i (\Delta x_{ij} y_{ij}^t + \Delta y_{ij} x_{ij}^{t-1}). \tag{5}$$

If one follow the arguments of post-Keynesian export-led growth theory (Thirlwall, 1979), the prediction is that given a balance-of-payment constrained growth rate, growth in exports is a main determinant of the growth rate of the country, because income elasticities with respect to the export goods of the country are bigger than the income elasticity with respect to the demand for imports. However, and as argued by Fagerberg (1988) the main problem is that the meaning of income elasticities for demand is unclear. Instead Fagerberg (following Kaldor and Thirlwall) argued that 'income elasticities' reflects 'the innovative ability and adaptive capacity' of producers in different countries. In his empirical balance-of-payments restricted (macro) growth model Fagerberg found that the main determinants of growth and international competitiveness are technological competitiveness and the ability to compete on delivery. Thus, with respect to international competitiveness the results of this paper confirm the macro level findings of Fagerberg, at a sectoral level showing that (where growth at the sectoral level add up to the overall change in competitiveness; see equation 5) technological competitiveness is an important determinant in many sectors.

4.2. The role of technological opportunity in competitiveness

The purpose of this sub section is to examine whether there is an impact on trade performance, from a country's gain (or loss) in terms of getting access to sectors that offer above average growth in technological opportunity. In this context it is worth noting that the 'multi-technology' problem discussed in section 2, is not relevant for the analysis conducted in this section, as no sectoral match between trade and technological variables is attempted.

In order to reach conclusions, a model of the determinants of growth of aggregate market shares will be tested, including variables reflecting technological opportunity. The model to be tested in this section is:

$$\hat{x}_j = k_j + a_j U\hat{L}C_j + b_j INV_j + c_j TL_j + d_j DUS_j + e_j S\hat{M}E_j + f_j S\hat{T}E_j + g_j TG\hat{A}E_j + \epsilon_j. \tag{6}$$

The dependent variable is the growth of aggregate market shares across countries. The independent variables are growth in unit labour costs (*ULC*); the investment-output ratio (*INV*, a proxy for the capital stock); a proxy of the technological level of a country, relative to the world leader (*TL*); a dummy for the US (*DUS*); a proxy for the effect of structural change in world demand (*SME*, i.e. the structural market effect from Table 2); a proxy for the effect of change in technological opportunity (*STE*, i.e. the structural technology effect from Table 3); and finally a proxy for the ability of countries to actively move into sectors with above average growth in technological opportunities (*TGAE*, i.e. the technology growth adaptation effect from Table 3). The observations from the three sub-periods (1965-1973, 1973-1979 and 1979-1988) are pooled. Since some of the additional variables are not available for Turkey and Portugal these countries are excluded in the present part of the analysis. Since data (export data) are only missing for Australia in 1965 only, Australia was included.

The unit labour costs, investment, GDP and population data have been taken from OECD Economic Outlook and Reference Supplement (No. 59). The growth in unit labour costs is expressed as annual growth rates. Both the growth of unit labour cost variable and the investment variable are expressed in relation to the average values of the 19 countries for each period. This procedure has been followed, since the export variable is expressed in relation to the total (as shares).

The investment variable is used as a proxy of the growth of ‘physical production equipment, transport equipment and infrastructure’, in the same manner as Fagerberg (1988). The *TL* variable is constructed in order to pick up effects, related to catching-up (see Verspagen, 1992, for a discussion of theories of catch-up). The variable is analogous to that of Fagerberg (1988). Following Fagerberg, the variable is calculated as per capita patenting activity in the US, divided by the highest value found in the sample in each period, adjusted for the degree of openness of the economy.[6] Thus, the variable varies between 1 (the country at the world’s technological frontier in the initial year) and 0 (a hypothetical country with no technological activity in the initial year). However, Fagerberg used a synthetic mix of the R&D measure and U.S. patent data. But since the weight of the measures is somewhat arbitrary, the patent measure was chosen on its own. Since only the catching-up variable contains a *level* of patenting, it is not necessary to adjust the other patent-based variables for the degree of openness. This is so because Basberg (1983) provide evidence, indicating that patents granted in the US to foreigners, is a measure of technological activity, rather than being a reflection of the pattern of exports by foreign countries to the US.

Also included in the model is the measure of the impact of change in world demand on the market share of the individual country (*SME*). The measures of technological opportunity are the structural technology effects (*STE*) and the technology adaptation effects (*TGAE*). Because it is expected that U.S. firms have relatively much patents due to a ‘home-market’ effect, a dummy for the U.S. is included in the regressions (*DUS*).

Concerning the signs of the variables, the sign of the dummy for the US; the sign of the catch-up variable; as well as the sign of the unit labour cost measure are expected to be negative. Nevertheless, the labour cost measure deserves a brief discussion. From a production cost perspective, one would expect high wage costs to lead to low competitiveness. Regardless, high growth in wage costs might also reflect highly growing skill levels, so that low growth of wages

6 Whether one adjust for the degree of openness of the economies, did not make any significant difference in the estimations.

imply low growth in levels of skills. Thus, in some sectors with high-skill requirements, the sign might be positive. However, as the estimated model is a macro model, a negative sign is expected. The other variables are expected to have positive signs.

[Table 5, just about here]

The results of the regressions are displayed in Table 5. Specification tests are reported at the bottom of the table. Using the Chow test, the null hypothesis of no structural change (across the three time periods included) cannot be rejected at the 1% level. For what concerns normality of the error terms, the null hypothesis of normality cannot be rejected at any reasonable level, using the Jarque-Bera test. However, the ARCH test proposed by Engle (1982) strongly indicates heteroscedasticity in the error terms. With a panel data set like the present one - containing countries at very different levels of development - it is hard to avoid heteroscedasticity. This was one of the reasons for including the catch-up variable (*TL*). By including this variable, homoscedasticity is still rejected for both equations, but not as strongly as before.

The estimate of the growth of unit labour costs has got the expected sign, but is not significant. This observation might be due to the fact that the model estimated in this paper is of a long-term nature, while price factors such as *ULC*, might be more important in the shorter run. The catching-up variable has got the expected sign, but was also insignificant as is the dummy for the US. The non-price factors all have the expected positive signs. The demand variable, i.e. the measure of being specialised (initially) in the fastest growing sectors in terms of exports is significant. Also significant , at the 1% level, is the proxy for the growth of 'physical production equipment, transport equipment and infrastructure' (*INV*).

Out of the 'technological opportunity variables' only the technology adaptation growth effect is significant at the 1% level, whereas the variable reflecting the effect of being initially specialised in sectors offering above average technological opportunity (*STE*) is insignificant. Thus, it can be concluded that it appears to be more important for national systems of innovation to actively move into to sectors offering above average technological opportunity, rather than being 'fortunately' specialised initially.

It would have been desirable to have included a proxy for the total growth of technological activity in country in the model, as well as the variables capturing technological opportunity.

However, due to problems of multicollinearity, the total growth of technological activity (*TTG*) could not be included in the same model as the technology growth adaptation effect (*TGAE*). Hence, an additional model have been estimated (model (ii)), including the *TTG* variable instead of the *TGAE* variable. However, the two models faire equally well, and the *TGAE* and the *TTG* variables are both significant at the 1% level.

5. Some conclusions

The aim of the paper was firstly to assess the impact of technological change upon trade growth at the country level. The second aim was to examine whether the degree to which countries get access to sectors with above average growth in technological opportunity has any impact on growth in aggregate market shares of exports at the country level.

Concerning the dynamics of trade performance *per se*, ‘catching up’ countries (Japan, Austria, Finland, Greece, Ireland, Italy, Portugal, Spain & Turkey) have experienced high levels of growth rates in terms of aggregate exports. The initial (1965) sectoral specialisation of these countries have however, had a significant negative impact on the overall export performance, since the structural market effect is negative for all these ‘catch up’ countries in the period 1965-1988. Likewise most of these countries (all, except Japan) have further moved into sectors offering low levels of market opportunity. In addition it was shown that only a small group of countries have been initially specialised in sectors offering high levels of market opportunity, namely initially rich countries such as the US, Germany, Switzerland and Great Britain.

With regard to the dynamics of ‘technological capabilities’ *per se* it can likewise be seen that most ‘catching up’ countries (Japan, Finland, Ireland, Spain, Austria, Italy & Turkey) have experienced very high levels of growth in terms of technology, measured as shares of US patents. At the same time these countries generally appear to have been specialised in the ‘wrong’ (i.e. sectors offering lows levels of technological opportunity) sectors in 1965.

The results of the regression analysis demonstrated that there is a positive relationship between change in trade performance and change in technological capabilities across countries for 8 ‘technology intensive’ sectors over the period 1965-1988. In this context it was argued that the setup provide an endogenous explanation for the ‘income elasticities’ with respect to the export goods of the countries for the 8 ‘technology intensive’ sectors. Nevertheless, if changes in performance in the ‘non-technology’ sectors is going be explained, additional variables are needed. Therefore, in order to arrive at a fuller model, further research is needed in this direction.

Concerning the regression analysis of the determinants of growth of country export market shares, the results do not support a hypothesis stating the importance of being specialised in the fastest growing technological sectors initially. However, there seems to be a significant relationship between growth rates in trade performance and the individual ‘national innovation system’s’ ability to *actively* move into technological sectors offering above average technological opportunity.

With regard to policy the findings seem to suggest that there is some room for an active technology policy, even though it is a ‘stylised fact’ that specialisation patterns both in trade and technology are known to be very stable over time (Cantwell, 1991; Dalum *et al.*, 1996). However, as it is a ‘stylised fact’ that technological innovation involves fundamental uncertainty (Dosi, 1988), it might be difficult (if not impossible) to predict precisely which sectors are going to grow fastest *ex ante*. In addition it might be too late to catch up in a fast growing sector, when the sector has started to grow rapidly, if no technological competence is present at all. Hence, from the perspective of a policy-maker, it is probably wise to attempt to increase ‘option values’ (Mitchell and Hamilton, 1988) in terms of keeping doors open to the future, by means of non-committal support for emerging technologies.

(1988)

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Table 1: Annual growth rates expressed in percent of total world patenting in the US and of total OECD exports to the world 1965-1988. Relative to the average.

	1965-1988	
	Patents	Exports
Food, drink and tobacco	-30.69	-12.21
Textiles, footwear and leather	23.28	-15.51
Industrial chemicals	-22.32	6.60
Pharmaceuticals	246.90	6.10
Rubber and plastics	39.78	12.84
Stone, clay and glass	16.18	-3.91
Basic metals	2.20	-20.41
Fabricated metal products	-50.52	-9.48
Non-electrical machinery	-80.51	-6.76
Office machines and computers	128.23	47.49
Electrical machinery	-16.44	11.01
Communication eq. and semiconductors	89.11	29.32
Shipbuilding	-106.28	-29.68
Other transport	-77.44	-17.32
Motor vehicles	12.84	16.83
Aircraft	-55.99	-1.43
Instruments	91.62	11.44
Standard deviation	88.34	19.36

Source: IKE trade database & patent data delivered to MERIT by the US Department of Commerce, Patent and Trademark Office.

Table 2: Changes in market shares of total OECD exports to the world 1965-1988

Country	Share 1965	Share 1988	Total Change (%)	MS-effect	Structural m. effect	M. growth adap.ef.	M. stagnation adap.ef.
Canada	3.90	4.25	8.84	1.10	-8.34	10.57	5.51
USA	21.20	14.64	-30.92	-37.49	8.43	-6.90	5.03
Japan	8.24	16.21	96.76	70.19	-13.40	39.81	0.16
Austria	1.22	1.60	31.20	47.00	-15.51	8.04	-8.35
Belgium	5.66	4.51	-20.32	-11.79	-13.46	-0.15	5.08
Denmark	2.01	1.38	-31.32	-17.88	-16.15	-1.34	4.05
Finland	0.42	0.72	72.66	116.27	-23.19	12.56	-32.97
France	8.72	8.77	0.50	4.77	-1.64	-2.35	-0.29
Germany	16.89	18.19	7.68	7.40	7.40	-3.93	-3.20
Greece	0.15	0.25	70.18	140.92	-23.62	1.18	-48.30
Ireland	0.37	1.05	187.28	165.66	-23.88	65.07	-19.57
Italy	6.31	7.05	11.65	26.79	-0.94	-5.60	-8.60
Netherlands	5.21	5.05	-3.07	4.57	-2.52	-3.97	-1.16
Norway	1.17	0.78	-33.68	-10.61	-24.45	-0.23	1.62
Portugal	0.43	0.56	29.14	62.71	-20.90	5.72	-18.40
Spain	0.65	2.05	214.69	239.51	-17.04	39.50	-47.28
Sweden	2.63	2.27	-13.57	-13.86	-0.38	-5.44	6.11
Switzerland	2.78	2.73	-1.54	1.85	5.62	-5.89	-3.11
Turkey	0.13	0.58	359.38	535.21	-29.60	15.95	-162.18
United Kingdom	11.93	7.37	-38.23	-36.85	5.01	-9.64	3.25

Source: Calculations based on the IKE trade database

Table 3: Change in shares of world patenting in the US by country 1965-1988

Country	Share 1965	Share 1988	Total Change (%)	TS-effect	Structural t. effect	T. growth adap.ef.	T. stagnation adap.ef.
Canada	1.28	1.76	37.95	46.65	-5.75	4.85	-7.80
USA	79.87	51.32	-35.74	-35.70	0.06	-4.83	4.72
Japan	1.28	20.78	1523.27	1412.04	8.00	252.01	-148.77
Austria	0.20	0.44	114.17	138.11	0.89	2.66	-27.49
Belgium	0.27	0.37	34.72	37.37	6.32	-1.18	-7.80
Denmark	0.14	0.24	70.24	80.38	-2.11	6.10	-14.12
Finland	0.03	0.30	857.71	983.23	-10.76	69.21	-183.97
France	2.18	3.47	59.41	61.23	-0.84	7.15	-8.12
Germany	5.52	9.96	80.42	92.91	1.07	3.35	-16.90
Greece	0.01	0.01	66.45	64.03	8.19	3.04	-8.81
Ireland	0.00	0.05	1221.44	1204.65	-16.44	171.77	-138.54
Italy	0.71	1.41	96.83	108.49	-2.26	10.17	-19.58
Netherlands	0.82	1.11	36.03	31.04	7.72	2.39	-5.12
Norway	0.08	0.14	75.29	92.20	-12.51	11.16	-15.57
Portugal	0.01	0.01	-8.91	7.50	-6.73	-10.41	0.74
Spain	0.06	0.15	158.26	188.36	-5.30	12.30	-37.11
Sweden	0.86	1.11	29.04	42.05	-5.42	0.74	-8.33
Switzerland	1.51	1.70	12.52	19.63	-2.53	0.37	-4.95
Turkey	0.00	0.01	361.74	263.99	-10.36	106.72	1.38
United Kingdom	4.24	3.45	-18.64	-19.16	-1.04	-1.41	2.97

Source: Calculations based on data delivered to MERIT by the US Department of Commerce, Patent and Trademark Office.

Table 4: Estimates of simple regressions, explaining the increase in (weighted) micro market shares across countries for 17 sectors. N=20.

Dependent variable ΔE_{ij} #	Estimate ΔT_{ij} #	R^2	R^2 (adj.)
Food, drink and tobacco	-0.30 (0.21)	0.10	0.05
Textiles, footwear and leather	-1.69 (2.24)	0.03	-0.02
Industrial chemicals	0.09 (0.05)	0.13	0.09
Pharmaceuticals	0.10 (0.02)*	0.51	0.48
Rubber and plastics	0.01 (0.03)	0.01	-0.05
Stone, clay and glass	-0.72 (0.08)	0.04	-0.01
Basic metals	-0.09 (0.72)	0.00	-0.05
Fabricated metal products	0.03 (0.02)	0.11	0.06
Non-electrical machinery	0.06 (0.02)*	0.47	0.44
Office machines and computers	0.22 (0.11)*	0.21	0.16
Electrical machinery	0.13 (0.02)*	0.77	0.76
Commu. eq. and semiconductors	0.04 (0.01)*	0.57	0.55
Shipbuilding	-0.04 (0.23)	0.00	-0.05
Other transport	0.10 (0.02)*	0.40	0.36
Motor vehicles	0.72 (0.24)*	0.33	0.29
Aircraft	0.04 (0.07)	0.01	-0.04
Instruments	0.04 (0.01)*	0.46	0.43

Standard error in brackets. */**/*** denotes significance at the 1%, 5% & 10% levels respectively.
Variables expressed in percentages

Table 5: Regression results for the impact technological opportunity on aggregate trade performance.

	Model (i)		Model (ii)	
		R^2 = 0.38 (0.29)		R^2 = 0.38 (0.29)
Variable	Estimate	*p*-value	Estimate	*p*-value
k	-1.49	0.8943	-2.09	0.8518
ULC	-0.12	0.2264	-0.10	0.3018
INV	0.24	0.0006	0.06	0.0010
TL	-39.63	0.5549	-36.96	0.5816
DUS	21.17	0.7359	62.36	0.7744
SME	1.56	0.0405	1.62	0.0317
STE	1.44	0.1529	1.00	0.1125
TGAE	1.30	0.0059		
TTG			0.08	0.0053
Chow test		0.0299		0.0276
Jarque-Bare test		0.3210		0.8089
ARCH test		0.0002		0.0002

Note: Adjusted R^2 in brackets.

ULC = Growth in unit labour costs; relative to the average
INV = Investment-output ratio; relative to the average
TL = Technological level of a country, relative to the world leader
DUS = Dummy for the US
SME = Structural market effect
STE = Structural technology effect
TGAE = Technology growth adaptation effect
TTG = Total technology growth

Danish Research Unit for Industrial Dynamics

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The DRUID-research programme is organised in 3 different research themes :

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- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

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The theoretical perspective confronts and combines the ressource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human ressources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

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The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO--matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

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