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The impact of technological opportunity on the dynamics of trade performance

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Abstract

The paper examines statistically whether the degree to which countries are specialised in and/or increasingly move into sectors with above average levels of technological opportunity has any impact on growth in aggregate market shares of exports. A novelty of the paper is that it applies structural decomposition (SD) analysis not only on trade statistics, but also on US patent statistics. Nineteen countries and 17 manufacturing sectors for the period 1965–1988 are considered. A number of variables, in addition to the effects from the SD analysis, are included as explanatory variables. In this context, it is shown that there is a positive relationship between trade performance and the individual country's ability to move into technological sectors offering above average technological opportunity. © 1999 Elsevier Science B.V. All rights reserved.

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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

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at the macro level, using a combination of R&D data and patent statistics. Likewise, at the sectoral level, Soete (1981) and Dosi et al. (1990) found that technological activity (measured by patents granted in the US) had a positive impact on trade performance, in a cross-section setting. From a more dynamic point of view, Magnier and Toujas-Bernate (1994), Amable and Verspagen (1995) and Verspagen and Wakelin (1997) also found convincing support for the hypothesis of technology being an important factor in explaining trade performance.

However, this paper is more similar to the papers of Fagerberg (1988) and Amendola et al. (1993) in exploring the determinants of market share dynamics (or 'competitiveness') at the aggregate level of the country. Still, those papers aim at examining the effect of general technological activity on trade performance. The question that this paper aims at answering concerns whether countries' specialisation in, or movement into sectors offering high levels of technological opportunity[1] has any effect on the growth of export market shares of countries.

Section 2 briefly presents some of the literature on trade and technology. Section 3, starts off by a presentation of the data to be used, as well as with 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 is discussed, both for what concerns technological development and for development of trade performance. Section 3 then moves on to a regression analysis, applying the decomposed effects (as well as other variables) from the first part of Section 3, in an attempt to assess the impact on aggregate export performance of countries being specialised in, or increasingly moving into, sectors offering low versus high levels of technological opportunity.

2. Technological opportunity and trade growth

The traditional explanation for trade flows assumed that technology was equally available to all countries and had instead of technology, its focus on factor endowments, and hence concentrated on factor prices. However, empirical studies show that price effects are rather weak, if at all significant (see e.g. Bairam, 1988). However, alternative theoretical explanations can been found in different strands of literature. Within the neoclassical New Trade Theories, authors like Krugman (1985) have stressed the importance of technology as an explanation, in terms of product differentiation and increasing returns to scale on the supply side, as well as in terms of differences in consumer preferences on the demand side. Within the framework of evolutionary economics, e.g. Dosi et al. (1994) have underlined the

[1] 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). For a thorough discussion of technological opportunities, see Malerba and Orsenigo (1990).

importance of sector and country specific learning processes resulting in (stochastic or 'uncertain') technological innovations, in determining trade flows. Because it is assumed in evolutionary approaches that agents have limited computational capabilities, the so-called mechanism of transmission secures a certain degree of stability in trade specialisation patterns.

Common to all of the approaches mentioned so far in this section is, that they have considered various *resources* as determinants of trade flows. We shall term these contributions under the heading 'resource-based trade growth'. Hence, the hypothesis is that endowments or various aspects of technology determine trade flows, irrespective of the type of activities (e.g. agricultural products vs. electronics) the individual countries are specialised in. In contrast, a number of authors—within various schools of thought—have made theoretical contributions, which implies that the type of sectors countries are specialised in matters for determining the level of trade flows. In particular, the implication of these (different) approaches is that countries specialised in sectors offering high levels of technological opportunity should experience higher growth in terms of export market shares when compared to other countries. We shall term these contributions under the heading 'specialisation-based trade growth'.

A number of formal models have considered various aspects of 'specialisation-based trade growth'.[2] From a neoclassical point of view, Grossman and Helpman (1991) (chapters 7 and 8 in particular) construct a two-country, two-sector growth model. The model encompasses a manufacturing sector that offers no prospect for technological change (the 'traditional sector'), while in another manufacturing sector new goods are continuously being introduced (the 'high technology sector'). Given the assumption of spill-overs being (only) national in scope, the model implies that for a country specialised in the high-technology sector, real output growth is faster in that country compared to the other country, as the overall growth rate is a weighted average of the growth rate of the two sectors. However, it should be pointed out that the fast growing country does not, in long run equilibrium, experience a higher growth rate of real consumption. The reason for this is that consumers enjoy benefits from innovation through the purchase of traded goods. Hence, the deteriorating terms of trade offsets the faster growth of output by the country specialised in 'high-tech', in the long run.

Also, the post-Keynesian approaches of demand-induced ('export-led') growth by Kaldor (1966, 1970), or the Thirlwall (1979) version in terms of 'balance-of-payments constrained' growth, look at trade and growth in an open economy setting. The emphasis in this literature lies on non-price factors of competitiveness, as price factors cannot in the long run explain increasing exports, since relative prices cannot decrease continuously in the long term. Often the post-Keynesian literature on economic growth relies on the ratio between the income elasticities of exports and imports. However, and as argued by Fagerberg (1988), the main problem is that the meaning of income elasticities for demand is unclear, as the elasticities can have a number of interpretations.

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[2] 'Patterns of specialisation-based growth' would have been a more precise heading, but we leave out 'pattern' for reasons of exposition.

From an evolutionary perspective Verspagen (1993) (chapter 8) constructs a model inspired by the post-Keynesian tradition. In the model, economic growth is basically driven by growth of exports (determined by competitiveness, mainly determined by technological factors), under a balance-of-payments constraint. In the model, a ‘domestic’ country competes with a ‘foreign’ country (the rest of the world) in a number of sectors. If the competitiveness of a country in a given sector is higher than average, the country expands its market share in that sector. An important aspect of the model, in the context of this paper, is that non-symmetric technological opportunities across sectors (as well as demand side factors; non-symmetric consumption structures) cause differences in growth rates among countries. Hence, given that the sum of the individual sectors add up to the country aggregate (there are no spill-overs in the model), aggregate market share of a country should rise, if specialised in, or is becoming increasingly specialised in, sectors offering the highest levels of technological opportunity.

The two competing hypotheses of this paper concern whether (i) growth in export market shares is due to the expansion of countries’ resources only, or whether (ii) some part of the trade growth can be attributed to countries’ specialisation in sectors offering high levels of technological opportunity. That is, whether there can be found any support for the ‘specialisation-based trade growth’ hypothesis.

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, this data was chosen to correspond to the trade data. However, because of small number problems the patents[3] 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 that technological development is expected to influence trade performance with some lag. The patent data used is taken from the US patent office, and concerns patent grants, dated by the year of grant. For more information on the trade and patent data, see the Appendix A to this paper.

Before exploring the relationship between technological opportunity and development in export market shares, it can be a good idea to take a closer look at how fast the 17 sectors have grown from 1965 to 1988, both in terms of trade and technology. Table 1 displays annual growth rates, related to the averages. In order to illustrate the figures given in Table 1, it can e.g. be seen that the aggregate

[3] 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).

growth rate in terms of numbers of patents in the sector 'office machines and computers' is 128% higher than the average growth rate of all patents. It can also be seen from the table that growth rates in terms of trade and technology are related to each other.[4] In other words, when sectors grow faster than the average of the world total in technology, sectors also seem to grow faster in terms of 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.

Table 1 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' (SD) analysis methodology, often used in an empirical trade context (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.

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 (percentage difference from the average)[a]

	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

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

[4] $P = 0.58$, significant at the 1% level.

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 world's US patenting activity made up 1.28% in 1965, rising to 1.76% in 1988, this being equivalent to a growth rate of 37.9%. 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.

$$p_{\mathrm{j}} = \sum_{\mathrm{i}} P_{\mathrm{ij}} \Big/ \sum_{\mathrm{i}}\sum_{\mathrm{j}} P_{\mathrm{ij}} \quad \text{(a country's aggregate share of total world patents);}$$

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

$$o_{\mathrm{i}} = \sum_{\mathrm{i}} P_{\mathrm{ij}} \Big/ \sum_{\mathrm{i}}\sum_{\mathrm{j}} P_{\mathrm{ij}} \quad \text{(a sector's share of total world patents),}$$

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:

$$\Delta p_{\mathrm{j}} = \underbrace{\sum_{\mathrm{i}} (\Delta p_{\mathrm{ij}} o_{\mathrm{i}}^{t-1})}_{\text{Technology share effect}} + \underbrace{\sum_{\mathrm{i}} (p_{\mathrm{ij}}^{t-1} \Delta o_{\mathrm{i}})}_{\text{Structural technology effect}} + \underbrace{\sum_{\mathrm{i}} (\Delta p_{\mathrm{ij}} \Delta o_{\mathrm{i}})}_{\text{Technology adaptation effect}}. \quad (1)$$

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 moves into the fast-growing sectors) and a 'technology stagnation adaptation effect' (positive, if a country moves out of the stagnating sectors):

$$\underbrace{\sum_i \Delta p_{ij} \Delta o_i}_{\text{Technology adaptation effect}} = \underbrace{\sum_i (\Delta p_{ij} (\Delta o_i + |\Delta o_i|)/2)}_{\text{Technology growth adaption effect}} + \underbrace{\sum_i (\Delta p_{ij} (\Delta o_i - |\Delta o_i|)/2)}_{\text{Technology stagnation adaption effect}} \quad . \tag{2}$$

Thus, in other words, if Eq. (2) is inserted into Eq. (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 world's total patents granted in the US.

The relative growth of a sector in terms of patents is argued to reflect whether growth in technological opportunity is relatively high or low in that sector. In this way, e.g. Cantwell and Andersen (1996) and Meliciani and Simonetti (1998) have applied growth rates of patents as measures of technological opportunities. Applying the results of Yale Survey as a more direct indicator of technological opportunity, Nelson and Wolff (1997) showed that technological opportunity and R&D intensity are indeed closely related. If growth rates in patents are used as a proxy for technological opportunities, a possible interpretation of the three latter effects is that these effects measure a given country's access to sectors with relatively high levels of technological opportunity.

If the structural effect for a country is positive and high, this means that the country has been 'fortunately' specialised in the initial year; being specialised in sectors which has generally experienced high levels of 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 country has *actively* (that is, faster than average) 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).

A drawback using the SD methodology on patents is that it is well known that the propensity to patent differ across sectors (Levin et al., 1987; Pavitt, 1988). As the methodology applies first differences, large sectors will tend to grow faster than small sectors. However, this problem is common to all studies looking at aggregate patenting (e.g. Fagerberg, 1988; Amendola et al., 1993).[5] An alternative procedure could, in the present setting, be to use a specialisation figure for the fastest growing sectors (say the top 20%) as e.g. done by Cantwell and Andersen (1996) and by Meliciani and Simonetti (1998). However, such a procedure suffers from the exclusion of a large part of the variation in the data material. The SD analysis looks at all the data.

The decomposition can also be conducted for growth in export market shares:

[5] If a country is specialised in sectors with a high propensity to patent, aggregate patent growth will be higher compared to a situation in which the country is specialised in a sector with an average propensity to patent.

$$\Delta x_j = \underbrace{\sum_i (\Delta x_{ij} y_i^{t-1})}_{\text{Market share effect}} + \underbrace{\sum_i (x_{ij}^{t-1} \Delta y_i)}_{\text{Structural market effect}} + \underbrace{\sum_i \left(\Delta x_{ij} \frac{\Delta y_i + |\Delta y_i|}{2} \right)}_{\text{Market growth adaptation effect}}$$

$$+ \underbrace{\sum_i \left(\Delta x_{ij} \frac{\Delta y_i - |\Delta y_i|}{2} \right)}_{\text{Market stagnation adaptation effect}} \quad (3)$$

where:

$$x_j = \sum_i X_{ij} \Big/ \sum_i \sum_j X_{ij}$$

(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);

$y_i = \sum_i X_{ij} \Big/ \sum_i \sum_j X_{ij}$ (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 displays the results of the 'constant market share' calculations. Generally speaking, 'catching up' countries (such as Japan, Austria, Finland, Greece, Ireland, Italy, Portugal, Spain and Turkey)[6] 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 (David, 1985; Arthur, 1989) 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., 1998).

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 and 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 in sectors offering higher levels of technological opportunity than the average in the period 1965–1988. This is to be compared with

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[6] $\mathrm{D}x_j > 10\%$.

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

Country	Share 1965	Share 1988	Total change (%)	MS-effect	Structural market effect	Market growth adaptation effect	Market stagnation adaptation effect
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

[a] Source: calculations based on the IKE trade database.

the Japanese specialisation in terms of exports in 1965, which offered relatively low levels of market opportunities in the period 1965–1988. Thus, already early on Japan was 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 extraordinarily 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 Japan has 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.

To sum up this sub-section, it can be said that some support was found for the ‘specialisation-based trade growth’ hypothesis at the descriptive level, as the OECD catching up countries have adapted their specialisation patterns towards sectors offering both higher market opportunities, as well as towards higher technological opportunities. However, in order to obtain more firm conclusions, a more general test of the hypothesis is performed in the next sub-section.

3.3. The role of technological opportunity in competitiveness

This sub-section is going to apply some of the SD effects from the previous sub-section as explanatory variables (as well as other variables) in regression analysis, in attempting to explain market share dynamics. In order to reach conclusions, an empirical model of the determinants of growth of aggregate market shares will be tested. The model to be tested is:

$$\hat{x}_j = k_j + c_j\mathrm{TL}_j + d_j\mathrm{DUS}_j + a_j\mathrm{U\hat{L}C}_j + b_j\mathrm{T\hat{T}G}_j + e_j\mathrm{S\hat{M}E}_j + f_j\mathrm{S\hat{T}E}_j + g_j\mathrm{T\hat{G}AE}_j + \varepsilon_j \quad (4)$$

The dependent variable is the growth of aggregate market shares across countries. The independent variables are: a proxy of the technological level of a country, relative to the world leader (TL); a dummy for the US (DUS); growth in unit labour costs (ULC); the investment–output ratio (INV, a proxy for changes in the capital stock); a proxy for the growth of general technological activity (TTG); 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 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

Table 3
Change in shares of world patenting in the US by country 1965-1988[a]

Country	Share 1965	Share 1988	Total Change (%)	TS-effect	Structural technology effect	Techonology growth adaptation effect	Technology stagnation adaptation effect
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

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

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 TL variable is constructed in order to pick up effects related to catching-up (see Verspagen, 1993, for a discussion of theories of catch-up). The variable is analogous to a variable used by 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.[7] 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 US patent data. But since the weight of the measures is somewhat arbitrary, the patent measure was chosen on its own. Because it is expected that US firms have relatively many patents due to a 'home-market' effect, a dummy for the US is included in the regressions (DUS). The investment variable is used as a proxy of the growth of 'physical production equipment, transport equipment and infrastructure', in the same manner as done by Fagerberg (1988).

If the empirical model is related to the theoretical discussion found in Section 2, the variables ULC, INV and TTG can be said to represent the 'resource-based explanations', while SME, STE and TGAE represent aspects of the 'specialisation-based' hypothesis.

Concerning the signs of the variables, the sign of the catch-up variable, the sign of the dummy for the US, 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 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.

The results of the regressions are displayed in Table 4. 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. The estimations are heteroscedasticity consistent (using the White estimator).

The catching-up variable has got the expected sign, but is also insignificant, as is the dummy for the US. 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

[7] Whether one adjusts for the degree of openness of the economies did not make any significant difference in the estimations.

Table 4
Regression results for the impact technological opportunity on aggregate trade performance (n = 57)[a]

	Model (i) $R^2 = 0.38$ (0.29)		Model (ii) $R^2 = 0.38$ (0.29)	
Variable[b]	Estimate	*P*-value	Estimate	*P*-value
k	−1.49	0.8724	−2.09	0.8192
ULC	−0.12	0.2390	−0.10	0.2876
INV	0.24	0.0031	0.06	0.0018
TL	−39.63	0.3852	36.96	0.4423
DUS	21.17	0.6007	62.36	0.6759
SME	1.56	0.0239	1.62	0.0187
STE	1.44	0.1085	1.00	0.0778
TGAE	1.30	0.0000		
TTG			0.08	0.0000
Chow test		0.0299		0.0276
Jarque–Bera test		0.3210		0.8089

[a] Adjusted R^2 in brackets.

[b] 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.

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. Significant at the 1% level, is the proxy for the growth of 'physical production equipment, transport equipment and infrastructure' (INV).

The demand variable, i.e. the measure of being specialised (initially) in the fastest growing sectors in terms of exports, is significant. 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 countries to actively move into 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 a 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 has been estimated (model (ii)), including the TTG variable instead of the TGAE variable. However, the two models fair equally well, and the TGAE and the TTG variables are both significant at the 1% level.

Given these findings, some support has been found for the 'specialisation-based trade growth' hypothesis, since the market opportunity variable was significant, as was the technology growth adaptation effect. But while the finding of this paper is that the level of exports is not only determined by the resources of countries, the single minded specialisation-based trade growth approach only found limited support, given the insignificant parameter of the variable reflecting initial specialisation in fast growing technologies (STE). Hence, the finding is call developments in theory, dealing in a more satisfactory way with the *dynamics* of technological opportunity, and its effect on trade growth.

4. Some conclusions

The aim of the paper was to assess the impact of differences in technological opportunity among sectors upon trade growth at the country level. A number of theoretical approaches were combined into a framework, stressing the importance of technological specialisation for trade growth, under the label 'specialisation-based trade growth'. This framework was contrasted with the more conventional resource-based trade growth view, in which only countries' resources (endowments or technology) matter for trade growth.

Concerning the dynamics of trade performance per se, 'catching up' countries (Japan, Austria, Finland, Greece, Ireland, Italy, Portugal, Spain and 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 and 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.

Based on a regression analysis of the determinants of growth of country export market shares, some support was found for the specialisation-based growth hypothesis, as there is a significant relationship between growth rates in trade performance and the individual country's ability to move into (faster than average) technological sectors, offering above average technological opportunity. However, the results did not support a hypothesis stating the importance of trade growth being specialised in the fastest growing technological sectors initially.

Finally, it should be pointed out that the present paper (as most other papers in this field) probably underestimates the effects of technology as a determinant of market share dynamics, as technological spill-overs from other sectors are not included in the model. The task of including such spill-overs in the analysis of market share dynamics is an important task for future research.

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Appendix A. The trade and patent data applied

The trade data are based on the taped version OECD's *Trade by Commodities, Series C*, which has been published annually since 1961. The OECD tapes consist of exports from and imports to 23 OECD countries. The data are delivered at their most detailed level according to the Standard International Trade Classification (SITC).

The IKE trade database at the Department of Business Studies, Aalborg University, was initiated in the early 1980s for studies of long term structural features of OECD trade. Construction of comparable time series data has been the major analytical aim from the beginning. The database contains a selection of years 1961–1992. As far as possible, the selection criterion has been 'peak years' in world trade/'average' OECD business cycles. The following years have been used in the present paper 1965, 1969, 1973, 1979, 1984 and 1988. Given the long term focus mentioned, all data have been converted from the two more recent versions of the SITC to SITC, Revision 1. In 1961–1977, the OECD reported the data in Revision 1. But in 1978–1987 the data have published according to SITC, Revision 2. The latter has been converted to the previous classification in order to construct comparable time series. From 1988 the data are published according to SITC, Revision 3.

The first step in handling the data consists of aggregating the 'raw' tapes to country matrices with 625 rows (the number of commodity groups at the 4-digit SITC, Revision 1 level) and 33 columns (23 OECD countries, the World, OECD, the Nordic countries and seven groups of non-OECD countries, including e.g. the former Soviet Union, the OPEC countries, a group of Newly Industrialised Countries). Then, several steps of checking for confidentiality clauses in the tapes, whether at the commodity or the country level. The tapes, thus, contain a large amount of so-called alphanumeric codes (instead of the usual numeric SITC codes) for which the trade information is omitted *at the given level of disaggregation*. This information is, however, included in the SITC codes at a more aggregate level.

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 US 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 US, for most of the period under consideration, constituted the largest 'technology market' in the world.

The patent data and the trade data was matched by using the STAN Database's classification into 22 International Standard Industrial Classification sectors (ISIC, revision 2). For what concerns the patent data, no data are available for 'wood cork and furniture', 'paper and publishing', as well as for 'other manufacturing'. The trade data mentioned above has been re-classified according to the ISIC nomenclature by Bent Dalum, Bart Verspagen and the present author (see http://www.business.auc.dk/ike/ike-attach/trade.pdf, Appendix 4, for the concordance table) into 15 sectors. Among these 15 sectors, 'chemicals' was split into 'industrial chemicals' and 'pharmaceuticals'. 'Transport' was split into 'motor vehicles', 'aerospace', and 'other transport'. In the trade data, 'refined oil' could not be detected. Hence, this sector had to be dropped. When the patent sectors and the trade sectors are matched, one ends up with the 17 industrial sectors, applied in the paper (see Table 1).

References

Amable, B., Verspagen, B., 1995. The role of technology in market shares dynamics. Appl. Econ. 27, 197–204.

Amendola, G., Dosi, G., Papagni, E., 1993. The dynamics of international competitiveness. Weltwirt. Arch. 129, 451–471.

Arthur, W.B., 1989. Competing technologies increasing returns and lock-in by historical events. Econ. J. 99, 116–131.

Bairam, E., 1988. Balance-of-payments, the Harrod foreign trade multiplier and economic growth: the European and North American experience. Appl. Econ. 20, 1635–1642.

Cantwell, J., Andersen, B., 1996. A statistical analysis of corporate technological leadership historically. Econ. Innov. New Technol. 4, 211–234.

Dalum, B., Laursen, K., Villumsen, G., 1998. Structural change in OECD export specialisation patterns: de-specialisation and 'stickiness'. Int. Rev. Appl. Econ. 12, 447–467.

David, P.A., 1985. Clio and the Economics of QWERTY. Am. Econ. Rev. Pap. Proc. 75, 332–337.

Dosi, G., Fabiani, S., Aversi, R., Meacci, M., 1994. The dynamics of international differentiation: a multi-country evolutionary model. Industrial Corp. Chang. 3, 225–241.

Dosi, G., Pavitt, K.L.R., Soete, L.L.G., 1990. The Economics of Technical Change and International Trade. Harvester Wheatsheaf, Hemel, Hempstead.

Fagerberg, J., 1987. A technology gap approach to why growth rates differ. Res. Policy 16, 87–99.

Fagerberg, J., 1988. International competitiveness. Econ. J. 98, 355–374.

Fagerberg, J., Sollie, G., 1987. The method of constant-market-shares analysis reconsidered. Appl. Econ. 19, 1571–1585.

Freeman, C., 1988. Japan: a new national system of innovation? In: Dosi, G., et al. (Eds.), Technical Change and Economic Theory. Pinter Publishers, London.

Grossman, G.M., Helpman, E., 1991. Innovation and Growth in the Global Economy. MIT Press, Cambridge, Massachusetts.

Kaldor, N., 1966. Causes of the Slow Rate of Economic Growth of the United Kingdom. Cambridge University Press, Cambridge.

Kaldor, N., 1970. The case for regional policies. Scott. J. Politic. Econ. 17, 337–348.

Klevorick, A.K., Levin, R.C., Nelson, R.R., Winter, S.G., 1995. On the sources and significance of interindustry differences in technological opportunities. Res. Policy 24, 185–205.

Krugman, P., 1985. A 'technology gab' model of international trade. In: Jungenfelt, K., Hague, D. (Eds.), Structural adjustment in Advanced Economies. Macmillan, London.

Krugman, P., 1987. The narrow moving band, the Dutch disease, and the competitive consequences of Mrs. Thatcher: notes on trade in the presence of dynamic scale economics. J. Dev. Econ. 27, 41–55.

Levin, R., Klevorick, A., Nelson, R.R., Winter, S., 1987. Appropriating the returns from industrial research and development. Brook. Pap. Econ. Act. 3, 783–820.

Magnier, A., Toujas-Bernate, J., 1994. Technology and trade: empirical evidence for the major five industrialized countries. Weltwirt. Arch. 131, 494–520.

Malerba, F., Orsenigo, L., 1990. Technological regimes and patterns of innovation: a theoretical and empirical investigation of the Italian case. In: Heertje, A., Perlman, M. (Eds.), Evolving technologies and market structure. Cambridge University Press, Cambridge.

Meliciani, V., Simonetti, R., 1998. Specialisation in areas of strong technological opportunity and economic growth. In: Eliasson, G., Green, C., McCann, C. (Eds.), Microfoundations of Economic Growth. University of Michigan Press, Ann Arbor.

Nelson, R.R., Wolff, E.N., 1997. Factors behind cross-industry differences in technical progress. Struct. Change Econ. Dyn. 8, 205–220.

Pavitt, K.L.R., 1988. Uses and abuses of patent statistics. In: van Raan, A.J.F. (Ed.), Handbook in Quantitative Studies of Science and Technology. Elsevier Science Publishers, Amsterdam.

Soete, L.L.G., 1981. A general test of the technological gap trade theory. Weltwirt. Arch. 117, 638–666.

Thirlwall, A.P., 1979. The balance of payments constraint as an explanation of international growth rate differences. Banc. Naz. Lav. Q. Rev. 32, 45–53.

Verspagen, B., 1993. Uneven Growth Between Interdependent Economies. Edward Elgar, Aldershot.

Verspagen, B., Wakelin, K., 1997. Trade and technology from a Schumpeterian perspective. Int. Rev. Appl. Econ. 11, 181–194.