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TECHNOLOGY AND NON TECHNOLOGY DETERMINANTS OF EXPORT SHARE GROWTH

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TABLE OF CONTENTS

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INTRODUCTION

Technology in the competitiveness debate

Over the past years, the notion of "competitiveness" has played a prominent role in discussions about firms' and countries' capacities to compete successfully in an increasingly integrated world market. In this debate, the role of technology has loomed large although the relation between technology and competitiveness had already been approached in the 1960s in the context of the literature on product cycles and technology gaps between countries (for an overview, see Dosi and Soete, 1988). Many of these attempts were, explicitly or implicitly, based on Schumpeter's analysis of innovation and diffusion as the driving forces behind competitiveness and economic growth.

Empirically, some of the impetus behind the studies on technology and competitiveness can be traced to the "Kaldor paradox", the observation that countries with high increases in relative unit labour costs (*i.e.* low price competitiveness) often had fast rises in their export shares. Hence, cost and price factors could not by themselves explain failure or success on international markets.

As a way out of the Kaldor paradox, empirical studies of determinants of market shares took into account so-called "non-price factors", in particular technological or innovation efforts. Some of the earlier contributions focused on growth of shares in total exports, for example, Thirlwall (1979) who related cross-country differences in growth to the ratio of the income elasticities of demand of their exports and imports. More recent work complemented the non-price variables with technology and other factors (*e.g.* capacity, size of home market).[1] Fagerberg (1988) tested an empirical model for 15 OECD countries over the period 1961-83. Results indicated a strong impact of technology (patents and R&D) and capacity-related variables, while the price factor (approximated by unit labour cost) was less important, although significant. Amendola, Dosi, and Papagni (1993) studied the impact of technology on competitiveness dynamics at the macro-level for 16 OECD countries for the period 1967-87. To explain current export market shares, they considered export market shares in previous years, patent and investment shares and unit labour costs. They showed a significant impact of the lagged patent and investment variables.[2]

Such analyses at the aggregate level were a step forward in that they started to integrate technology factors in models examining the determinants of international competitiveness. At the same time, they suffer from several well-known disadvantages: aggregate analysis may hide significant variations across industries and the picture of technology links at the industry level could be quite different from macro-economic averages. Also, macro-level analysis cannot normally disentangle the "pure" effects of technology on export performance from the effects of structural shifts in the economy.

To address these points, several studies focused on the industry-level. Among them Soete (1981) who regressed, for each of about 40 industries, the level of export market shares against patent shares and other variables. He found that the patent variables had an important and significant impact for many industries, especially for technology-intensive ones. Magnier and Toujas-Bernate (1994) studied the sectoral export market shares of the five biggest OECD countries in the period 1971-87 using an error correction model and allowing country and sector specific additive coefficients for the regressors. They find an important, significant impact of R&D and investment, along with prices, for many industrial sectors – and not only for high-technology ones. Amable and Verspagen (1995) use a modified error-correction model[3] and patent instead of R&D data as technology variable and interpret their results in terms of an industry typology, proposed by Dosi, *et al.* (1990), that distinguishes between "Supplier dominated", "Production intensive" and "Science based" sectors. They also find an important impact of technology along with price variables and confirm that the impact of the variables differs across countries and sectors. Landesmann and Pfaffermayr (1995) discuss the role of technology in the framework of a demand system and model its effects either as cost reducing or quality improving, incorporating R&D in different ways.

In a simplified way, the main conclusion of these studies is that technology matters as a determinant of export shares, but not in all industries. While this is an important result in itself, it tells us little about the reasons behind inter-industry differences which may be rooted in the nature of products (one would expect technology to matter more in high-tech than in low-tech industries) or in the form of competition that is prevalent in a particular industry. For example, in a situation of sharp competition between suppliers (because markets are open and/or products are close substitutes), process innovation may be vital to improve productivity and to be able to compete under small profit margins.

The present study: a step towards explaining industry differences

The objective of the present contribution is to examine the factors that determine export competitiveness in different industries. A theoretical framework provides the basis for empirical specification and a simple typology of industries is used to better explain inter-industry differences.

One of the side-effects is to clarify the frequently-used distinction between "price" and "non-price" factors in competition. The latter are typically associated with product attributes such as quality or functionality which are in turn linked to technology. What a more rigorous framework shows is that technology or knowledge will always affect prices. Hence, there is no obvious way to disentangle "price" and "non-price" competition. The present approach distinguishes therefore between "technology-related" and "non-technology related" variables which will both have an impact on prices. R&D-induced productivity-increases or product quality improvements are examples for the first category, wages or exchange rates for the second.

Another objective of this study is to be more explicit about which aspects of technology are taken into account. Typically, in similar work, technology factors have been limited to R&D expenditures or patents taken out by industries as proxies of their innovative effort or success. Firms carry out R&D or develop patents and, as a consequence of accumulating knowledge, improve their production processes or their products. The technology diffusion aspect has usually been absent. Yet firms also improve their products by acquiring technology developed elsewhere through the purchase of technologically sophisticated machinery, equipment and components. The inclusion of the notion of acquired R&D into measures of total R&D can in fact considerably change the picture of industries ranked by their R&D intensities. Thus this study also examines whether measures of indirect R&D can help to explain the change in competitors' export shares.

The paper examines export shares of 10 OECD countries (United States, Japan, Germany, France, Italy, the United Kingdom, Canada, Australia, Denmark and the Netherlands) for three distinct periods (1977-80, 1980-85, 1985-90)[4] and 22 manufacturing industries.

The approach is exclusively directed at individual industries across countries. Industries are not grouped together for estimation, so that parameters for one industry are independent from results for other industries. Although this reduces the degrees of freedom (only about 30 observations per regression), it has important advantages. First, results are truly cross-country and the relative importance of various determinants in different industries can be distinguished without introducing a bias by assuming identical coefficients across industries.[5] Second, by allowing the variance of the error terms to vary across industries, the model may explain export performance in some industries better than in others. This is not possible when industry and country observations are pooled to increase the degrees of freedom.[6] Finally, approaching questions of competitiveness at the level of individual industries avoids the more general debate whether competitiveness is a notion that can usefully be applied to entire economies as opposed to individual firms or industries.

Despite the absence of a theoretical consensus about the notion of "competitiveness", empirical studies have come up with several, mainly trade-related variables to measure international performance. One of these measures is export shares, an indicator to capture the performance of a country's industry in the world market. Other indicators include import penetration rates, coverage and export/import price ratios, or measures of firm or industry profitability. Each of them has its advantages and drawbacks but to keep things simple, and for reasons of data availability, this paper adopts the rate of change of a country's export share as the performance measure in a given industry.

The paper proceeds as follows: first, it offers some theoretical considerations to substantiate the econometric set-up described thereafter; the following parts of the paper present results and are by means of conclusions.

THEORETICAL CONSIDERATIONS

Model of competition

What is a possible model of competition consistent with an empirical specification to determine export shares by industry? First, the very notion of explaining variations in export *shares* excludes reference to a model with perfect competition where each participant holds a very small market share. An appropriate model would allow for some market power of individual suppliers and it would feature asymmetry between suppliers (*i.e.* allowing for prices and quantities to vary between suppliers), because a symmetric model implies equal market shares for all competitors in equilibrium. Asymmetry arises if consumer tastes are heterogeneous and if producers differentiate their products vertically and/or horizontally. Vertical differentiation refers to a situation where consumers agree on the valuation of a product characteristic (*e.g.* speed of calculation for a computer; everybody agrees that, at a given price, higher speed is preferable to lower speed); horizontal differentiation refers to a situation where consumers' tastes do not provide an unanimous ranking of goods (*e.g.* preference for a good that can be acquired in the geographical proximity).

However, explicit modelling of asymmetric competition with product differentiation comes at the cost of significant complexity of models. In particular, it is difficult to obtain explicit results for equilibrium prices and market shares of individual producers as they depend on consumer preferences and technology as well as on the strategic interaction between producers (for a general treatment, see Shaked and Sutton, 1987). To avoid such complexity and yet provide a theoretical background for empirical estimates, this paper limits itself to discussing the short-term behaviour of suppliers without attempting to model long-run equilibrium outcomes of industry competition.

Analytically, this can be achieved by introducing a time dimension for investment decisions. This feature builds on Sutton (1992) who describes an industry where investment decisions have to be taken before suppliers decide on prices. In the present case, it is assumed that technology choices have to be taken in advance. Once the R&D stock is in place, exporters compete via prices or quantities. For a given level of technological knowledge, producers maximise current profits, given a demand function and a cost function. Empirically, this implies that the technology variables can be treated as exogenous, along with other explanatory variables that are not determined by the producer, in particular wages, exchange rates and the overall market growth.

Innovation and demand

In the present model, exporters in a given industry offer a differentiated good on export markets. Differentiation can be vertical as well as horizontal. The degree of horizontal differentiation corresponds to the number of varieties offered, the degree of vertical differentiation to the quality of a particular variety. The degrees of differentiation are determined in the first stage of investment decisions – producers decide whether to enter a market (this influences the degree of horizontal differentiation) and they decide on the quality characteristics of their product (this determines the degree of vertical differentiation). Two types of technology are distinguished, one based on process innovation, the other on product innovation. Process innovation, or the capacity to produce a given product more efficiently, reduces unit costs of production and is an important element in a producer's decision to enter a market or to remain there. Product innovation, on the other hand, permits to change product quality, characteristics and vertical differentiation.[7] As technology decisions are taken in the first stage of the competitive process modelled here, they are predetermined in the second stage where producers set their prices and quantities, given a certain stock of knowledge and cumulated process and product innovations (denoted as *Aproc* and *Aprod* in what follows).

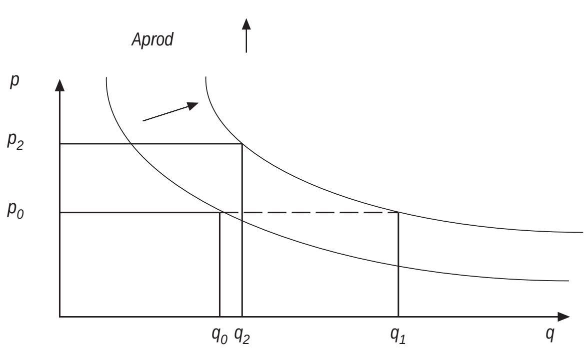
More formally, a model is considered where, for each industry, producers from different countries compete on M geographical export markets.[8] On each market, consumers spend a total amount E_m on imports of a certain type of goods corresponding to an industry's activity[9] (for example motor vehicles or chemicals). Demand for producer i's variety on this market m, q_{im}, depends on producer i's own price, p_{im}, the prices charged by other exporters, p_{jm} ($j = 1,2, .., N; j \neq i$); producer i's product quality (captured by the innovation term $Aprod_{im}$), and other producers' quality $Aprod_{jm}$. Denoting average prices and qualities on the market as p_m and $Aprod_m$, the export demand for producer i's product on geographical market m is expressed as:

$$q_{i,m} = f(p_{im}, p_m, Aprod_{im}, Aprod_m, E_m) \quad [1]$$

where $p_m = \sum_j^N s_{jm}\, p_{jm}$ is the average price on market m, a weighted average of each exporter's price. Current-price market shares of each producer provide the relevant weights s_{jm}. Similar, $Aprod_m = \sum_j^N s_{jm}\, Aprod_{jm}$ is the average quality prevailing on market m.

Only product innovation enters the demand function as process innovation acts on costs and prices but not directly on demand. The effects of a product innovation on the demand function are shown in Figure 1: a rise of $Aprod_i$ implies an outward shift of the demand curve, leading to a situation where the consumer obtains a greater quantity (q_1 instead of q_0) at the same price p_0. If product innovation involves a modification of the physical properties of a product (easier to operate, faster, etc.), quantities have to be defined over product characteristics (for example, storage capacity and CPU speed of a computer) so that they are comparable over time or space.

◆ Figure 1. ***Demand function***



Source: Author.

Innovation and supply

Without much loss of generality, it is assumed that producer *i*'s cost function is made up of a variable cost term g_i and a fixed cost term F_i. Variable costs depend positively on the level of output q_i (equivalent to export volumes in the present case), on wages w_i and negatively on process innovation $Aproc_i$. Both product and process innovation enter the cost function via the fixed cost term F_i with the assumption that product innovation will generally raise fixed costs whereas process innovation will reduce the cost term. Total costs are given by:

$$C_i = g_i(q_i, w_i, Aproc_i) + F_i(Aprod_i, Aproc_i) \qquad [2]$$

In a situation of monopolistic competition, producers set export prices as mark-ups to marginal costs, taking into account the demand functions prevailing in the different export markets *m*. The mark-up factor depends on the producer's own price elasticity of demand on market *m*, ε_{im}:

$$P_{im} = \frac{1}{1 + 1/\varepsilon_{im}} \frac{\partial C_i}{\partial q_i} \qquad [3]$$

Unless ε_{im} is a constant, it will depend on producer *i*'s own price, on those of his competitors and on product quality and [3] can be written as:[10]

$$P_{im} = h_i\left(P_m, Aprod_i, Aprod_m, \frac{\delta C_i}{\delta q_i}\right) \qquad [4a]$$

$$P_{im} = h_i(P_m, Aprod_i, Aprod_m, ULC_i, Aproc_i) \qquad [4b]$$

For empirical purposes, marginal costs are replaced by unit labour costs $ULC_{i,m}$ in equation [4*b*]. Marginal and unit labour costs are linked by several terms, in particular the elasticity of variable costs with respect to output and with respect to wages. In general, neither of these terms is constant and both depend on *Aproc*, the process innovation variable. As a consequence, *Aproc* is present in the price equation [4*b*] with an expected negative sign. However, process innovation *Aproc* operates also via unit labour costs where it enhances labour productivity. Producer *i*'s own product innovation $Aprod_i$ enters the price equation with a positive sign, those of his competitors, $Aprod_m$, with a negative one.

Equations [1] and [4*b*] form the basis for the empirical specification: as a first step, both equations are linearised and expressed in logarithmic differences. This yields expressions for $\Delta\ln(q_{im})$ and $\Delta(p_{im})$ which can be used to construct weighted averages $\Delta(q_m)$ and $\Delta(p_m)$, the changes in total volume exports to market *m* and the changes in the average market price. Then, changes in exporter *i*'s shares on market *m* are given by:

$$\Delta ln(Market\ share_{im}) = \Delta \ln(q_{im}) - \Delta \ln(q_m) = \alpha \Delta ln(Aprod_{im}/Aprod_m) - \beta \Delta ln(p_{im}/p_m) \qquad [5]$$

and

$$\Delta ln(p_{im}/p_m) = \gamma\ \Delta ln(Aprod_{im}/Aprod_m) - \delta\ \Delta ln(Aproc_{im}/Aproc_m) + \zeta\ \Delta ln(ULC_{im}/ULC_m) \qquad [6]$$

Within a given market, the expenditure variable E_m drops out as it only affects total demand but not its distribution among exporters. To consider the movements of the export shares of a country's industry in *all* geographical markets, aggregation is carried out across markets. It can be shown that this aggregation has two components: one that is due to changes in export share *within* a particular market (market share effect) and one that is due to diverging growth rates *between* markets (market composition effect), as given by expression [7], where the change in producer *i*'s export shares is the sum of a market share effect (weights s_{im} reflect the share of each geographical market in producer *i*'s total exports) and a market composition effect. (For a full derivation, see Annex 1.)

$$\Delta \ln(Export\ share_i) = \Delta \ln(q_i\ /\ q) = \sum_m s_{im} \Delta \ln(Market\ share_{im}) + Market\ composition\ effect_i \qquad [7]$$

The estimation of this expression comprises two equations, one that relates total export shares to relative prices, product innovation and the market composition effect and the second that explains movements in relative prices by changes in technology and unit labour costs. More detailed specifications are given in Box 1.

Mapping of industries

The above discussion showed that any non-trivial analysis of market shares implies that markets can be characterised by some variant of asymmetric monopolistic competition or oligopoly. *A priori*, little can be said about the degree of competition although it has been demonstrated (Shaked and Sutton, 1987) that the interplay of consumer preferences, and cost structures are important elements in shaping the degree of competition and the evolution of market structures. Furthermore, it is plausible that the importance of different determinants of market shares varies with these conditions. For example, it can be argued that

Box 1. **Set-up of equations**

The following equations were estimated industry-by-industry, pooling ten exporting countries and three time periods. Further discussion of the estimation method can be found in Annex 3.

Demand

$$\Delta\ln(XMS_{it}) = a_1 * R\Delta\ln(RDS_{it}) + a_2 * R\Delta\ln(TINTI_{it}) + a_3 * R\Delta\ln(P_{it}) + a_4 * RCHD_{it} + e_{it}$$

Prices

$$R\Delta\ln(P_{it}) = b_1 * R\Delta\ln(RDS_{it}) + b_2 * R\Delta\ln(TINVI_{it}) + b_3 * R\Delta\ln(TINTI_{it}) + b_4 * R\Delta\ln(ULC_{it}) + h_{it}$$

where:

$R\Delta\ln(XMS_{it})$:	Relative changes of export shares (volumes)
$R\Delta\ln(RDS_{it})$:	Relative changes of R&D-stock
$R\Delta\ln(TINVI_{it})$:	Relative changes of technology intensity of investment goods
$R\Delta\ln(TINTI_{it})$:	Relative changes of technology intensity of intermediate goods
$R\Delta\ln(P_{it})$:	Relative changes of export prices
$R\Delta\ln(ULC_{it})$:	Relative changes of unit labour costs
$RCHD_{it}$:	Relative changes of demand structure
e_{it}, h_{it}:	Error terms

For:

$i = 1, ..., 10$ Exporting countries

$t = t_1, t_2, t_3$; t_1 = 1977-80; t_2 = 1980-85; t_3 = 1985-90.

The notation $R\Delta\ln(X)$ stands for changes of variable X in country i relative to the trade-weighted average of competitors' value for X:

$$R\Delta\ln X = \sum_m \frac{p_{im} q_{im}}{p_i q_i} \left\{ \Delta\ln X_{im} - \sum_j \frac{p_{jm} q_{jm}}{p_m q_m} \Delta\ln X_{jm} \right\}$$

Definition of variables

All variables relate to a particular industry (Table 2). In the following definitions, no specific industry subscript has been set to improve readability.

Geographical markets

Ten exporting countries plus: Norway; Portugal; Spain; Sweden; Finland; New Zealand; Rest of OECD, Brazil; Hong Kong, China; Indonesia; India; Malaysia; Mexico; Philippines; Singapore; South Korea; Thailand; China; Chinese Taipei; Rest of world.

(continued on next page)

(continued)

XMS$_i$ Competitor *i*'s volume-share in total exports of ten countries. See Annex 1 for a full derivation.

RDS$_i$ Competitor *i*'s R&D-stock at time *t*. See Annex 2 for derivation.

TINVI$_i$ Competitor *i*'s indirect R&D intensity, based on investment goods: $TINVI_i = TINV/GFCF_i$; where:
TINV$_i$: indirect R&D expenditure, acquired via investment goods, at current prices;
GFCF$_i$: gross fixed capital expenditure at current prices;

TINTI$_i$ Competitor *i*'s indirect R&D intensity, based on intermediate goods: $TINTI_i = TINT/IG_i$, where:
TINT$_i$: indirect R&D expenditure, acquired via intermediate goods, at current prices;
IG$_i$: intermediate inputs at current prices;

ULC$_i$ Competitor *i*'s unit labour costs: $ULC_i = WAGE/KVAL_i$: where:
WAGE$_i$: Labour compensation in current US$

KVAL$_i$ Competitor *i*'s value added at constant 1985 prices, converted to 1985-US$ with 1985 PPPs. The deflator underlying KVAL is the sectoral gross output deflator;

RCHD$_{it}$ Relative demand structure (market composition effect):

$$RCHD_i = \sum_m^M \left\{ \frac{p_{im} q_{im}}{p_i q_i} - \frac{p_m q_m}{p\ q} \right\} \Delta \ln(q_m)$$

in an industry with a fragmented market structure (*i.e.* low concentration) factor costs or exchange rates play a more important role in explaining market share gains or losses than in segmented industries with high mark-ups and a tendency towards concentration. Hence, we shall distinguish between fragmented and segmented industries under the plausible assumption that industries in these groups share common characteristics.

A second feature, in line with the above discussion, is the importance of technology. If we investigate market shares under the assumption that technology is a factor to be considered, it is only consistent to expect that determinants of market shares differ between industries with high technology intensity and those with low technology intensity. The combination of these criteria (high/low technology intensity and segmented/fragmented market structure) form an industry typology, very similar to the approach adopted by Oliveira Martins *et al.* (1996).

Table 1 sets out the four different combinations and associates them with characteristics of the competitive process:[11] competition via process innovation and prices (in technology-intensive industries with fragmented market structure); competition via factor costs (in industries with low technology intensity and with fragmented market structure); competition via product innovation and quality (in segmented, technology-intensive industries); and competition mainly via scale economies (in segmented industries with low technology intensity). Empirically, R&D intensities are employed to allocate industries to the high- and low-tech segment while concentration ratios serve to distinguish between segmented and fragmented industries.[12]

Table 1. **Industry typology: technology and market structures**

	Fragmented (low mark-ups, low concentration)	Segmented (high mark-ups, tendency towards concentration)
High technology intensity	Competition mainly via process innovation	Competition mainly via product innovation and quality
Low technology intensity	Competition mainly via factor costs	Competition mainly via scale economies

EMPIRICAL SET-UP

Following equation [7], the dependent variable under consideration is the growth rate of a country's share in overall exports in a given industry, where shares are measured as volume shares. For empirical purposes, operational expressions have to be found for the technology variables *Aproc* and *Aprod,* for the market composition effect and for unit labour costs. While the latter is straightforward, the former merit some discussion.

Technology variable

First, a necessary deviation from the theoretical model is the approximation of innovation and the stock of knowledge by input-related measures, in particular R&D expenditure or the stock of R&D efforts. Also, data availability does not, in general, permit to differentiate between R&D efforts directed at product innovation and those directed at process innovation. However, in some instances the theoretical discussion above helps to distinguish product from process innovation:

- In the estimate of the demand equation [1], the effects of a technology variable with a significant and correct (positive) coefficient should be attributed to product innovation;

- Partly, this reasoning also holds for the price equation [4]: process and product innovation enter with opposite signs and permit with some caution – the association with product innovation in the case of a significant positive coefficient (the price elasticity of demand falls in absolute terms and so raises the mark-up over costs and thereby prices) and the association with process innovation in the case of a negative sign.

- A third element of distinction between product and process innovation can be drawn from the empirical measurement of acquired technology: recent work by OECD[13] produced measures of R&D incorporated in capital and intermediate goods – a technology dimension that is neglected if only an industry's own R&D is considered. Indirect R&D intensities are constructed by relating acquired R&D to investment expenditures or expenditures on intermediate inputs, depending on how indirect R&D has been acquired. A case can be made that acquired R&D embodied in intermediate inputs is more likely to show up as a product improvement and hence can be used to approximate the theoretical variable *Aprod* whereas R&D embodied in capital goods is more readily associated with process innovation. Thus, to the extent that these acquired R&D variables produce empirically significant effects, they permit a distinction between efforts to enhance product and process innovation.

A second point is the specification of the R&D variable: a natural first choice is R&D intensities, the ratio between an industry's own R&D expenditure and the value of its production. There are several studies (especially cross-industry ones) that show a positive impact of R&D intensities on performance variables, typically productivity growth. However, in an industry-based study, R&D intensities may be inappropriate to explain market share gains or losses. Essentially, this is because production (the denominator of R&D intensities) is not independent of R&D expenditures (the numerator); rather, theory suggests a positive link. Hence, if production rises in line with R&D efforts, rising output (and possibly market shares) can be accompanied by a constant R&D intensity. Take the hypothetical case where, initially, all competitors in one industry have the same market share. If one competitor doubles his R&D efforts and production follows suit or rises even faster, rising market shares would be accompanied by constant or declining R&D intensities.

In the present study, efforts to use R&D intensity variables produced insignificant or even negative results. Similar phenomena have been observed by other researchers. Landesmann and Pfaffermayr (1995) who use a time-series approach which also allows for different coefficients by country find that direct R&D-intensities show negative coefficients for almost as many countries as they register positive coefficients.

If R&D intensities are inappropriate measures, what are the alternatives? From a theoretical viewpoint, a measure of growth rates of R&D stocks is preferable, very much in line with measures of physical capital stocks. To construct a capital stock series with the usual perpetual inventory method requires three ingredients: *a)* a measure for an initial stock, *b)* a deflator for current R&D expenditures, *c)* a depreciation rate for the R&D stock. None of these elements are readily available for the construction of an R&D stock. However, issue *a)* is of limited importance here, since we focus on relative changes of the stock, and the effect of the initial stock on these changes decreases exponentially over time. Concerning *b)*, the GDP deflator is applied to R&D expenditures. With respect to *c)*, the choice of the depreciation rate, neither theory nor empirical studies provide clear guidance. Therefore, rather than assuming a fixed depreciation rate for all sectors, R&D stocks for alternative depreciation rates were constructed and the one that explained relative increases in export shares best was chosen. In this sense, an "optimal" R&D-stock was constructed (see Annex 3).

Market composition variable

The market composition effect (for a derivation, see Annex 1) is defined as a weighted average of the overall growth rates of a country's export markets. Weights represent the difference between the importance of each market for a given country and for the importance of the same markets for all competitors. Note that the term will equal zero if market *m* has the same importance for country *i* as it has, on average, for all competitors. Put differently, the market composition effect *RCHD* will be large and positive (negative) in sign if country i's exports are concentrated in markets that grow fast (slowly):[14]

$$RCHD_i = \sum_m \left\{ \frac{p_{im} q_{im}}{p_i q_i} - \frac{p_m q_m}{p \; q} \right\} \Delta \ln(q_m)$$

where:

$p_{im}\, q_{im}$ competitor *i*'s exports to market *m;*

$p_m\, q_m = \sum_j p_{jm}\, q_{jm}$ all competitors' exports to market *m;*

$p_i\, q_i = \sum_m p_{im}\, q_{im}$ competitor *i*'s exports to all markets;

$p\,q = \sum_j p_j\,q_j$ all competitors' exports to all markets.

Final empirical specifications are set out in Box 1. All variables that take the form $R\Delta\ln X$ represent changes of competitor i's variable X_i relative to his competitors. This formulation of the variable entails a double-weighting procedure that takes into account both the relative importance of a particular competitor j on a given market m and the importance of this market for the country i under consideration.

Table 2. **List of industries**

	ISIC Rev. 2	Description	Short name
1	31	Food, beverages and tobacco	Food
2	32	Textiles, apparel and leather	Textiles
3	33	Wood products and furniture	Wood
4	34	Paper, products and printing	Paper
5	351 + 352 – 3522	Chemicals excl. drugs	Chemicals
6	3522	Drugs and medicines	Drugs
7	353 + 354	Petroleum refineries and products	Petroleum
8	355 + 356	Rubber and plastic products	Rub. and plast.
9	36	Non-metallic mineral products	Non-met. miner.
10	371	Iron and steel	Ferrous metals
11	372	Non-ferrous metals	Non-fer. metals
12	381	Metal products	Metal products
13	382 – 3825	Non-electrical machinery	Non-elec. mach.
14	3825	Office and computing equipment	Computers
15	383 – 3832	Electrical machines excl. communication equipment	Electr. machin.
16	3832	Radio, TV and communication equipment	Electron. equip.
17	3841	Shipbuilding and repairing	Shipbuilding
18	3842 + 3844 + 3849	Other transport	Other transport
19	3843	Motor vehicles	Motor vehicles
20	3845	Aircraft	Aircraft
21	385	Professional goods	Instruments
22	39	Other manufacturing	Other manuf.

RESULTS

General

A first, general result is in line with basically all earlier studies in the field. There is considerable variety of results across industries concerning the significance and importance of export share determinants. There are several industries (petroleum, shipbuilding, chemicals, non-ferrous metals) where the overall explanatory power of the factors presented is weak, implying that other determinants, not captured by the model, prevail in these industries. There are other industries, where a large proportion of the variation in export shares is captured by the proposed determinants, for example the wood industry, ferrous metals or motor vehicles. On average, technology and non-technology factors can explain some 30 to 40 per cent of variations in export volume shares, but only 10 to 30 per cent of relative price variations.

The following part of the paper discusses in greater detail the role of technology, demand and non-technology cost factors in explaining countries' export share gains and losses. The basis for discussion are the results from regression analysis presented in Table 3.

Technology

Not surprisingly technology variables play a more important role in explaining export share developments in high-technology than in low-technology industries. This is apparent from Table 4 where industries with significant R&D coefficients have been shaded to show their occurrence in both the demand and price equation. Figure 2 provides a more systematic look at the role of R&D in demand and plots the estimated elasticities of demand with respect to R&D against industries' technology intensity. A clear positive correlation[15] emerges.

Other, and more specific conclusions are:

- In nearly all segmented industries of the high technology sector, the R&D variable shows up with a significant and positive sign in the demand (export volume) equation. This confirms the notion that product innovation and vertical differentiation mark the competitive process in these industries. At the same time, the R&D variable plays no explicit role as a determinant of relative prices. While consistent with the type of competition expected for segmented, high-technology industries, this does not necessarily imply that process innovation is unimportant: as pointed out earlier, the unit labour cost variable should be expected to capture a good deal of the effects of process innovation and improved productivity and indeed, unit labour cost variables are significant determinants of price changes in this industry segment.
- Within the high-tech segment, the effects of R&D stock on prices are more pronounced in fragmented industries. The sign of the technology variable is negative, indicating that process innovation is important and has effects that go beyond those picked up by the (widely significant) unit labour cost variable. Only in two industries does the technology variable show up as a significant determinant in the demand function. Again, both results are consistent with the earlier characterisation of competition in this industry segment as one that is largely driven by process innovation.

Table 3. **Regression results**[1, 2, 3, 4]

Export volume shares

Fragmented

	RDln RDS	RDln TINTI	RDln PR	RCHD	R2&n
Technology intensity high					
Non electrical machinery	**0.13** **t(1.62)**	–0.05 t(–0.17)	0.04 t(0.17)	**1.35** **t(5.12)**	41.0% 30 obs.
Instruments[6]	0.03 t(0.32)	0.16 t(0.84)	**–0.30** **t(–2.01)**	**1.04** **t(3.63)**	61.3% 27 obs.
Other manufacturing	**0.22** **t(2.32)**	0.13 t(0.33)	–0.38 t(–1.05)	**2.30** **t(4.29)**	68.7% 25 obs.
Other transport	0.10 t(0.70)	**–0.58** **t(–1.57)**	**–0.52** **t(–1.53)**	**0.44** **t(2.51)**	24.8% 24 obs.
Chemicals	1.04 t(1.40)	–0.19 t(–0.77)	**–1.52** **t(–2.60)**	0.14 t(0.26)	25.1% 30 obs.
Technology intensity low					
Wood	0.13 t(0.73)	0.24 t(0.52)	**–1.32** **t(–2.34)**	**0.80** **t(2.83)**	38.9% 24 obs.
Textiles	–0.07 t(–0.36)	–0.56 t(–1.36)	**–1.23** **t(–2.28)**	0.17 t(0.33)	22.7% 29 obs.
Metal products	–0.06 t(–0.71)	–0.01 t(–0.02)	**–0.78** **t(–1.85)**	**1.13** **t(3.75)**	36.7% 30 obs.
Paper	–0.02 t(–0.15)	0.17 t(0.70)	**–1.65** **t(–4.28)**	**1.08** **t(3.00)**	46.0% 30 obs.
Food	**0.28** **t(2.49)**	**–0.51** **t(–2.78)**	–0.36 t(–1.43)	**0.72** **t(1.89)**	38.7% 30 obs.
Rub. and plast.	0.01 t(0.04)	0.15 t(0.73)	–0.28 t(–0.77)	**1.00** **t(5.47)**	47.8% 30 obs.
Non-metallic minerals	0.04 t(0.49)	–0.25 t(–1.26)	–0.34 t(–0.91)	**0.93** **t(3.66)**	26.5% 30 obs.

Segmented

	RDln RDS	RDln TINTI	RDln PR	RCHD	R2&n
Technology intensity high					
Drugs	**0.40** **t(1.55)**	0.41 t(1.25)	**–0.77** **t(–2.79)**	0.15 t(0.16)	26.2% 30 obs.
Computers	**0.34** **t(2.65)**	0.09 t(0.43)	**–1.08** **t(–5.03)**	**1.03** **t(2.70)**	69.0% 30 obs.
Electrical machinery[5]	**0.23** **t(2.18)**	0.27 t(0.83)	**–1.23** **t(–3.12)**	**1.68** **t(4.72)**	62.1% 18 obs.
Electronic equipment[6]	**0.36** **t(1.60)**	0.08 t(0.31)	**–1.02** **t(–4.63)**	**1.03** **t(4.08)**	62.7% 27 obs.
Motor vehicles	**0.82** **t(2.26)**	–0.51 t(–1.08)	–0.40 t(–1.02)	**1.14** **t(6.09)**	66.7% 27 obs.
Aircraft[5]	**0.73** **t(2.30)**	**0.83** **t(1.76)**	0.15 t(0.32)	0.54 t(1.03)	28.4% 16 obs.
Technology intensity low					
Ferrous metals	0.06 t(0.69)	0.33 t(1.12)	**–1.83** **t(–4.98)**	**1.15** **t(5.84)**	76.5% 30 obs.
Petroleum	0.20 t(0.43)	–0.04 t(–0.10)	–0.82 t(–1.37)	0.33 t(1.01)	–0.2% 27 obs.
Shipbuilding	0.07 t(0.24)	–0.53 t(–0.98)	**–1.33** **t(–4.58)**	**1.90** **t(3.43)**	56.6% 27 obs.
Non-ferrous metal	0.09 t(0.22)	–0.52 t(–0.74)	–0.16 t(–0.15)	**1.01** **t(2.28)**	12.0% 30 obs.

Table 3. **Regression results**[1, 2, 3, 4] *(cont.)*

Export prices

Fragmented						Segmented					
	RDln RDS	RDln TINTI	RDln TINVI	RDln ULC	R2&n		RDln RDS	RDln TINTI	RDln TINVI	RDln ULC	R2&n
Technology intensity high						**Technology intensity high**					
Non electrical machinery	–0.10	0.05	0.07	0.09	–5.8%	Drugs	0.19	0.12	–0.12	0.20	2.1%
	t(–1.06)	t(0.12)	t(0.35)	t(0.51)	28 obs.		t(0.79)	t(0.38)	t(–0.44)	t(1.19)	28 obs.
Instruments[6]	**0.29**	0.12	–0.14	**0.24**	12.8%	Computers	**0.21**	–0.05	–0.24	**0.37**	54.3%
	t(2.06)	t(0.23)	t(–0.46)	**t(1.56)**	22 obs.		**t(1.65)**	t(–0.29)	t(–1.21)	**t(4.25)**	28 obs.
Other manufacturing	**–0.18**	**0.62**	–0.05	**0.47**	26.1%	Electrical machinery[5]	0.06	**0.27**	–0.04	**0.20**	34.3%
	t(–2.58)	**t(2.16)**	t(–0.27)	**t(2.23)**	24 obs.		t(1.30)	**t(1.68)**	t(–0.42)	**t(2.85)**	17 obs.
Other transport	–0.06	–0.04	0.19	0.24	–20.6%	Electronic equipment[6]	0.06	0.09	–0.08	0.15	–3.2%
	t(–1.25)	t(–0.14)	t(0.39)	t(1.30)	9 obs.		t(0.37)	t(0.45)	t(–0.46)	t(1.21)	25 obs.
Chemicals	0.28	0.02	–0.05	**0.16**	16.2%	Motor vehicles	–0.06	**–0.90**	0.09	**0.17**	58.0%
	t(1.08)	t(0.19)	t(–0.40)	**t(1.95)**	28 obs.		t(–0.34)	**t(–4.50)**	t(0.52)	**t(1.68)**	25 obs.
						Aircraft[5]	0.13	–0.18	**0.35**	–0.07	24.7%
							t(0.98)	t(–0.83)	**t(2.27)**	t(–0.48)	15 obs.
Technology intensity low						**Technology intensity low**					
Wood	–0.03	–0.08	0.23	**0.30**	0.8%	Ferrous metals	–0.03	0.17	–0.07	–0.08	–7.9%
	t(–0.38)	t(–0.37)	t(0.92)	**t(1.76)**	22 obs.		t(–0.43)	t(0.64)	t(–0.44)	t(–0.81)	28 obs.
Textiles	**–0.16**	0.11	**0.30**	**0.27**	38.9%	Petroleum	–0.20	–0.10	0.03	0.02	–4.5%
	t(–2.69)	t(0.81)	**t(1.89)**	**t(2.82)**	27 obs.		t(–1.10)	t(–0.54)	t(0.11)	t(0.22)	22 obs.
Metal products	–0.03	0.10	**0.16**	**0.35**	45.6%	Shipbuilding	–0.24	–0.34	–0.94	–0.37	–3.4%
	t(–1.21)	t(1.09)	**t(1.98)**	**t(4.57)**	28 obs.		t(–0.95)	t(–0.85)	t(–1.16)	t(–1.07)	25 obs.
Paper	–0.05	–0.06	0.05	**0.28**	60.0%	Non-ferrous metals	0.05	0.09	0.05	0.08	0.9%
	t(–1.29)	t(–0.54)	t(0.97)	**t(5.40)**	28 obs.		t(0.54)	t(0.56)	t(0.34)	t(1.40)	28 obs.
Food	–0.04	–0.03	–0.15	**0.32**	34.8%						
	t(–0.43)	t(–0.23)	t(–0.88)	**t(3.71)**	28 obs.						
Rub. and plast.	**–0.12**	–0.02	–0.02	0.05	5.1%						
	t(–1.62)	t(–0.11)	t(–0.21)	t(0.59)	28 obs.						
Non-metallic minerals	0.04	–0.01	–0.18	**0.32**	37.9%						
	t(1.15)	t(–0.08)	t(–1.45)	**t(3.29)**	28 obs.						

1. See text for methodological aspects (weighting of observations, assumed covariance structure of residuals).
2. Variable abbreviations: RDln: average annual growth rate relative to competitors; RDS: R&D-stock; TINTI: acquired technology (intermediate goods); TINVI: acquired technology (investment goods); PR: export unit values; RCHD: relative change of the demand structure; ULC: Unit labour costs.
3. Below the coefficient in parenthesis the value of the t-statistic (t).
4. Bold indicates that the t-value of coefficient absolutely greater than 1.5.
5. Modified sample in order to exclude outliers: the Netherlands were excluded totally; the period 1977/80 was also excluded for all countries.
6. Modified sample in order to exclude outliers: the United Kingdom was excluded totally.

Source: OECD: ANBERD, STAN, Input-Output and BILAT databases; INSEE: FLUBIL database.

Table 4. **Significance of R&D stock changes on shifts in export shares and prices**

By type of industry

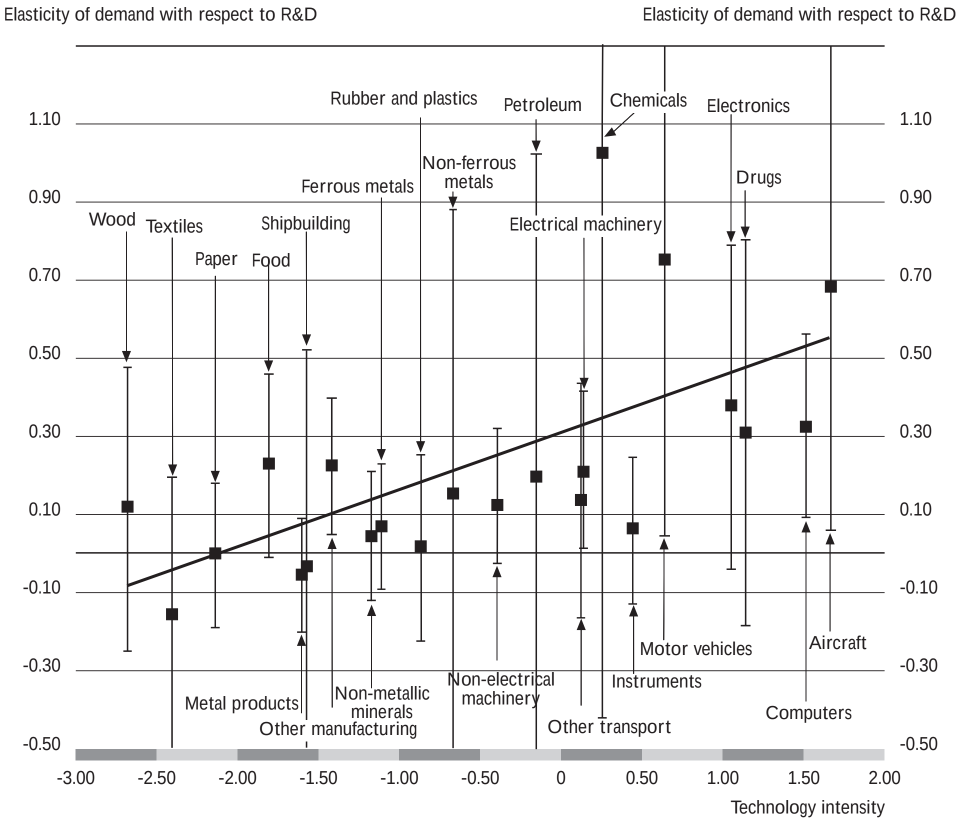
	Shifts in export volumes		Shifts in export prices	
	Fragmented	Segmented	Fragmented	Segmented
High Technology intensity	**Non-elec. mach.**	**Drugs**	Non-elec. mach.	Drugs
	Instruments	**Computers**	Instruments	Computers
	Other manuf.	**Electr. machin.**	**Other manuf.**	Electr. machin.
	Other transport	**Electron. equip.**	**Other transport**	Electron. equip.
	Chemicals	**Motor vehicles**	Chemicals	Motor vehicles
		Aircraft		Aircraft
Low Technology intensity	Wood	Ferrous metals	Wood	Ferrous metals
	Textiles	Petroleum	**Textiles**	Petroleum
	Metal products	Shipbuilding	Metal products	Shipbuilding
	Paper	Non-fer. metals	Paper	Non-fer. metals
	Food		Food	
	Rub. and plast.		**Rub. and plast.**	
	Non-met. miner.		Non-met. miner.	

There is only one high-technology sector (drugs) where the R&D variable is only weakly significant as a determinant of demand. As the pharmaceutical industry is one where product innovation clearly plays a key role, a possible explanation for this is the presence of time lags between the R&D effort and results on export markets which may exceed the five-year time spans underlying the present study.

Indirect R&D variables did not add much to explaining technology-related developments of industry export shares. R&D embodied in intermediate goods – the variable more closely associated with product innovation, only produces a theoretically correct and significant sign in the aircraft industry where it has a positive impact on volume export shares. In all other industries, it is either insignificant or has a negative sign. R&D embodied in investment goods – the variable associated with process innovation, shows a positive impact on volume export shares of four industries. Again, this is at odds with theory which suggests no impact of process innovation on export volumes.

There is no ready explanation for the absence of significance of the effects of indirect R&D, even more so as Fagerberg (1995) reports a strong and significant impact of the same variable, albeit in a different econometric specification. However, any interpretation of the weak explanatory power of indirect R&D intensities has to take into account the measurement problems of this variable which cannot be disentangled from the real influence of acquired R&D on industry competitiveness.

◆ Figure 2. ***Estimated elasticities of demand with respect to R&D*[1] *and average technology intensities*[2] *in different industries***



1. Estimated coefficients of R&D stock in the demand equation (see Box 1), under exclusion of indirect technology intensities. The error-bars indicate 95% confidencce intervals.
2. Defined as the logarithm of the average OECD R&D expenditures/value added.

Source: OECD: ANBERD, STAN, Input-Output and BILAT databases; INSEE: FLUBIL database.

Demand structure

Among the different determinants of export share growth, the one with the single largest explanatory power is the variable capturing demand structures and demand growth. It shows up with significant and positive signs in a large number of industries.[16] The magnitude of its impact is better understood if one compares the (adjusted) R^2 for the full model with those of a model which includes only the demand variable. For example, in the case of the motor vehicle industry, the full model explains 70 per cent of the variation in volume export shares but the demand structure effect alone accounts for 50 per cent of the total variance. Similar figures are obtained for many other sectors. In general, sectors with a comparatively high R^2 value owe more than half to the demand.

This means that variations of imports of a certain country will tend to be passed proportionately to its suppliers. Countries with high market shares in fast growing regions will tend to increase their overall market-shares faster than other exporting countries. Similarly, countries with high market shares in regions which are contracting, will tend to loose their overall export shares faster than other exporting countries. The implication is twofold: first, the geographical composition of export markets is of key importance in the overall export performance and, secondly, there is sluggishness in market shares. This is quite plausible, given that export efforts to a given market require a certain amount of investment, physically, and in terms of building up a network. These factors will benefit incumbent and experienced exporters in growing markets and disadvantage newcomers or exporters with small market shares. At the same time, it renders competitors with large market shares more vulnerable to demand shocks in individual markets.

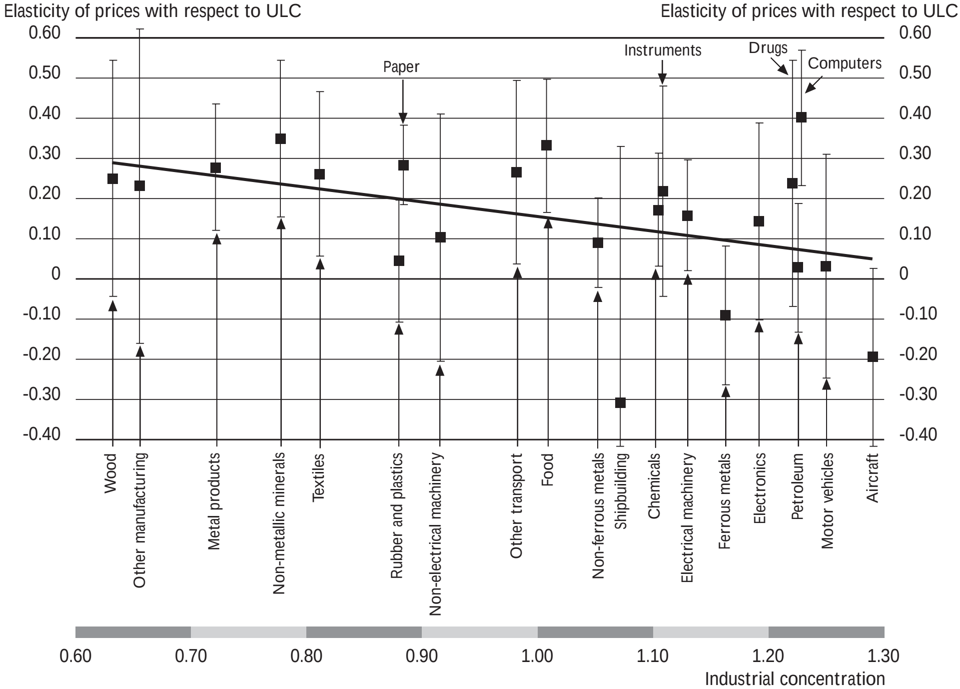
Unit labour costs

Changes in unit labour costs – which reflect movements in wages, exchange rates and labour productivity – play a significant role as price determinants in most types of industries. The absence of any effect of unit labour costs on relative prices in the segmented, low technology part of the industry fits this picture. However, closer inspection shows that the link between prices and factor costs weakens with rising industrial concentration: wage- and exchange-rate shifts are more important in fragmented than in segmented industries, in line with the proposed industry typology where fragmented sectors are marked by competition via factor costs (in the low technology segment) and by competition via process innovation (in the high-technology segment). Both factor costs (in particular wages) and process innovation have a direct bearing on unit labour costs.[17]

A more systematic way of considering the evidence is to plot the estimated coefficients of the unit labour cost variable together with their 95 per cent confidence intervals against an indicator of industries' average concentration ratios) (Figure 3). The picture shows a negative relationship between coefficients and concentration.[18]

In the demand function, price changes have the expected negative sign. Their coefficients, the price elasticities of demand, are largest in industries with the lowest technology intensity, especially in the fragmented industry segment.

◆ Figure 3. ***Estimated elasticities of export prices with respect to unit labour costs***[1] ***and industrial concentration***[2] ***in different industries***



1. Estimated coefficients of ULC in the price equation (see Box 1), under exclusion of indirect technology intensities. The error-bars indicate 95% confidence intervals.
2. Average OECD share of value added in establishments with more than 100 employees relative to total manufacturing.

Source: OECD: ANBERD, STAN, Intput-Output and BILAT databases; INSEE: FLUBIL database.

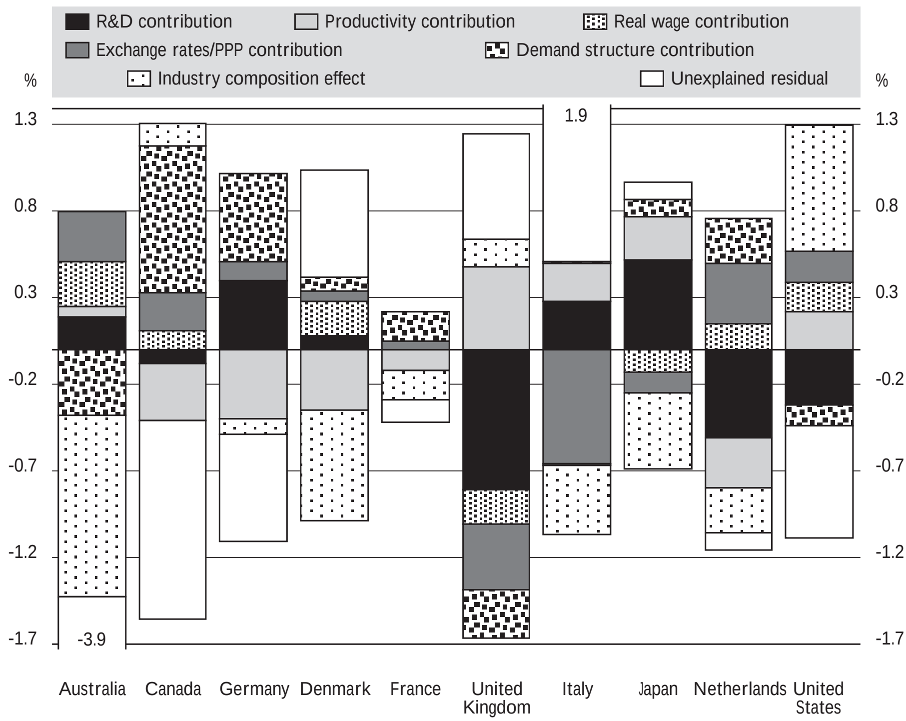
This looks plausible because a high degree of horizontal differentiation which often marks fragmented industries (such as the food, paper and textile industries) is synonymous with a high degree of product substitutability and therefore a price elasticity that is large in absolute terms.

A country-by-country overview

Along with industry-by-industry results, it is of interest to present a country-specific view of the determinants of overall export performance between 1977 and 1990) (Figure 4). Moving from the industry to the country level introduces an additional factor with positive or negative contributions to a country's total export

◆ Figure 4. ***Contribution of different factors to changes in total manufacturing export value shares***[1]

Average annual growth rates of export shares in 1977-90



1. Contributions of the different factors to a country's overall changes in export shares were calculated as follows: indirect R&D variables were excluded; the coefficient of the market composition effect was set to unity. For each industry, the estimation results of both equations (demand and prices) were combined to obtain the impact of each factor on shifts of value shares. The contribution of ULC was broken down into contributions of wages, exchange rates and productivity, based on the definition of ULC: Δln(ULC) = Δln(wages in PPPs) – Δln(exchange rates/PPPs) – Δln(productivity). Then, the estimated coefficient of ULC was applied to each component. Aggregation of the contribution of individual factors across industries to the country level was carried out with the following methodology: denoting with $p_{ik} q_{ik}$ the exports of country *i*'s industry *k*, with $p_{i+} q_{i+}$ country *i*'s total exports, with $p_{+k}\ q_{+k}$ the aggregate exports of all countries' industry *k*, and with pq total exports of all countries, then $\Delta \ln(p_{ik} q_{ik} / p_{+k}\ q_{+k})$ is the change in country *i*'s export share in industry *k*, and $\Delta\ln(p_{i+} q_{i+} / pq)$ the change in country *i*'s share in exports of all industries. The following relation holds: $\Delta \ln(p_{i+} q_{i+} / pq) = \sum_k \frac{p_{ik} q_{ik}}{p_{i+} q_{i+}} \Delta \ln(\frac{p_{ik} q_{ik}}{p_{+k} q_{+k}}) + \sum_k \frac{p_{ik} q_{ik}}{p_{i+} q_{i+}} \Delta \ln(\frac{p_{+k} q_{+k}}{pq})$.

   The second term on the right-hand side is an industry composition effect. It will be zero if, on average, the importance of industries does not change. It will be high for country *i* if its initial shares are high in an industry that grows comparatively faster than others.

Source: OECD: ANBERD, STAN, Intput-Output and BILAT databases; INSEE: FLUBIL database.

performance: the industry composition effect. This effect will be positive if a country's industry structure is biased towards industries with above-average export growth and negative if a country's exports are specialised in industries with below-average global export growth.[19]

Concerning the overall contribution of different factors on manufacturing export share growth, Figure 4 suggests that the increase in the United States' export share was due primarily to an industry composition effect: from the beginning, the United States held high market shares in industries which gained in weight in total exports, for example computers. This effect was combined with an advantageous evolution of unit labour costs and its components, exchange rates, wages and labour productivity: exchange rate developments influenced performance positively, although the net effect was small because the dollar both appreciated and depreciated strongly during the period of observation. Labour productivity increases were higher than those of its competitors and wage increases lower and thus had a positive impact on export share evolution. Relatively weak growth rates in R&D expenditures resulted in a negative contribution to the evolution of export shares. Overall, and with the appropriate caveats, it may be concluded that technology-related factors were not the main impetus behind US export performance – cost-related factors were. It should however be noted that this conclusion concerns *changes* in export shares, not the *levels* of shares; of all OECD countries, the United States started the observation period with the highest share (with Germany) and innovative efforts undoubtedly played a role in gaining that position. However, R&D efforts contributed little to further increase overall export shares while other countries benefited from a catch-up effect.

In contrast, Japan drew much of its success in export share gains from a comparatively high growth rate of R&D efforts. The second positive contribution came from productivity increases. Exchange-rate and wage impacts were negative – but relatively small in size. This stems from the fact that, in value terms, estimated price elasticities are low, in particular for technology-intensive products. The industry composition effect, on the other hand, showed up with a negative sign: in 1980, Japan had high market shares in industries which lost in weight in total OECD exports (*e.g.* shipbuilding and ferrous metals). On the whole, therefore, Japan's export performance tended to be dominated by technology-related factors.

The determinants of export performance of the four large European economies have been quite mixed. Relatively weak growth of the R&D stock in the United Kingdom was responsible for most of its export share losses. Germany and Italy gained from the increase of their R&D efforts, whereas in France they had little visible impact. Germany's R&D-related gains in export shares originate in the high-technology/segmented industry group (where France and Italy had negative contributions) and especially in the car industry, while in the high-technology/fragmented group it had marginal ones (while France and Italy had positive ones). Productivity effects were positive for Italy and the United Kingdom, slightly negative for France and more significantly negative for Germany. Relative wage developments played only a marginal role in the for major European countries. Exchange rate developments brought losses to Italy and the United Kingdom, while their impact on France and Germany was negligible. Germany and France export share changes benefited from a demand structure effect which played no role for Italy and was negative for the United Kingdom.

Canada's export shares decreased slightly during the 1977-90 period and the determinants of export shares are quite similar to those of the United States. The main positive contribution came from the demand structure effect, in the sense that the geographic orientation of its exports was favourable, mainly for high-tech industries. Another positive contribution came from a favourable (relative to competitors) evolution of wage rates which can be observed in all types of industries except in the high-technology/segmented group. Of the negative contributions, that of labour productivity was the most important one. Generally, R&D contributions to relative export growth were modest in all industry groups although one can find individual industries where it had an important positive contribution (computers).

CONCLUSION

This paper provided empirical estimates of countries' determinants of industry-level export shares. In broad terms, it distinguished between technology-related and non-technology related determinants. Among the technology-related factors, a distinction was made between technology in conjunction with product innovation and technology linked to process innovation. Specifications were based on an explicit theoretical model that also provided the background for a simple industry typology used to present empirical results. The following main conclusions arose:

– The determinants of export performance vary significantly between industries. However, commonalties emerge when industries are clustered in a typology that combines elements of technology intensity and market structures. The relative importance of determinants of export shares varies, in a consistent manner, between industry segments.

– One exception to the broad variance of explanatory factors is the pervasiveness of a demand structure effect: the initial presence of countries' exporters in high growth markets is an important determinant for the overall export performance. This underlines the importance of managerial decisions in the choice of geographical markets, and of medium-term investments in export networks.

– Technology-related factors, proxied by different R&D measures, play an important role as determinants of export competitiveness; most visibly as product innovation in high-technology industries but also as process innovation that reduces unit labour costs relative to competitors in other, low-technology industries. Non-technology variables (wage rates, exchange rates) tend to be important in fragmented industries where substitutability between products is high and/or technology intensity is low. Despite its plausibility, no systematic influence of technology embodied in investment or intermediate products on competitiveness could be detected. However, the absence of a clear result for this variable may as much be caused by measurement and econometric problems as by real phenomena. Hence, care should be taken before discounting embodied technology as a determinant of competitiveness.

NOTES

1. Developments in trade theory in the 1980s also helped to shed further light on the determinants of export shares: "new trade theory" introduced notions of imperfect competition into trade models (Krugman, 1990, Helpman and Krugman, 1991) and, in its version as "strategic trade theory" explained how government policies could raise market shares by helping domestic industries to capture oligopoly rents (see Helpman, 1984, for an overview). Technology variables, in particular R&D, enter as investment expenditure with an element of fixed cost that gives rise to economies of scale, market imperfections and/or strategic behaviour. However, R&D expenditure and technology do not typically enter as factors that explicitly modify product quality or production processes and, by that avenue, market shares.
2. These results are more generally consistent with the "Technology Gap" approach which puts technology at the centre of its considerations (*e.g.* Dosi, Pavitt and Soete, 1990) and sector-specific differences in technological and innovative capabilities across countries become the main driving forces in the competitive process. They operate either via the positive effects of technology on productivity or via product differentiation that may generate limited monopoly power for firms.
3. In the estimation procedure, the parameter driving autocorrelation of residuals is allowed to differ by country.
4. Annual time series of indirect R&D expenditure were not available as observations are based on input-output tables which, in most countries, are compiled only about every five years.
5. Thus, by construction, estimated coefficients are not country-specific. However, the possible bias introduced by this assumption should be smaller than the alternative bias arising from estimates for each country across industries.
6. One advantage of a pooled approach would be that it permits to introduce some industry specificity while preserving degrees of freedom. Also, the validity of those coefficients that are set to be equal across industries could be tested. However, in a strict sense, such tests can only *reject* the hypothesis of equal coefficients, not *affirm* the contrary.
7. These types of innovation and their effects have to be distinguished from the way they are developed. Both types of innovation can either be the product of research and development carried out directly by an industry or they can be acquired indirectly through investment or intermediate goods employed in the production process (see section 3).

8. To keep things simple, we assume that all output is exported.

9. This implies that consumers maximise a utility function of the Cobb-Douglas type with constant elasticities (and therefore expenditure shares), for various types of differentiated goods.

10. If the own price elasticity of demand is not constant, equation [3] which solves for P_{im}, is generally non-linear.

11. Hereby it is meant that certain factors are *a priori* expected to play a more important role than others as determinants of export success in a type of industry.

12. Oliveira Martins *et al.* (1996) use the same industries and the same criteria (R&D intensity and concentration rates) to map industries on two axes but their interpretation of these axes is different. In particular, they associate the degree of R&D intensity with the degree of product differentiation – a link that does not fit the present context where R&D has the double function of differentiating products and enhancing productive efficiency. As a consequence, the current typology simply labels the *y*-axis as the degree of R&D intensity.

13. See Papaconstantinou, Sakurai and Wyckoff, (1996). The construction of acquired R&D indicators is based on the assumption that: *a*) direct R&D expenditures of an industry spread uniformly on its product and are embodied in it, and *b*) if sector A buys the product of sector B as an intermediate good, it automatically acquires the technology which is embodied in it. This acquired technology spreads, on its turn, uniformly over the product of sector A. Similarly, a sector acquires the technology embodied in the investment goods it buys. Technology diffusion flows were traced with Input-Output, GFCF-flows and Bilateral trade matrices.

14. The demand structure effect, captured by the variable *RCHD*) is similar to the "market composition" effect derived under *constant market share analysis* (Fagerberg and Sollie, 1988*a*).

15. A regression of these elasticities against the technology intensity indicator (using the inverse of their estimated standard deviations as weights) yields a significant slope (t-value = 3.27).

16. It is significant for 16 out of 21 industrial sectors and for most of them the t-statistic is bigger than 3. As would be expected from the mechanics of decomposition (see Annex 1), the estimated coefficients are not significantly different from unity.

17. Fixed costs provide one explanation for this observation: where fixed costs are relatively high (which amounts to higher returns to scale), the link between total average costs and unit labour cost becomes weaker. In return, fragmented industries are probably characterised by comparatively low fixed costs (and lower returns to scale), implying a closer link between total average and unit labour costs. In an industry equilibrium with free entry, total average costs are equal to prices which in turn correspond to marginal costs times an industry mark-up. Hence, the link between prices and unit labour costs weakens as fixed costs play an increasing role in technology.

18. Regressing these elasticities against a concentration indicator (using the inverse of their estimated standard deviations as weight) yields a significant slope (*t*-value = 2.3). Without *computers* and *shipbuilding* the *t*-value rises to 3.6.

19. See Figure 4 for the methodology to derive country aggregates.

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Annex 1

DERIVATION OF MARKET SHARES AND MARKET COMPOSITION EFFECTS

For the decomposition of the change in competitor *i*'s export shares, the following notation is used:

$p_{im}\ q_{im}$ competitor *i*'s exports to market *m* at current prices;

q_{im} competitor *i*'s export volumes to market *m*

p_{im} competitor *i*'s export prices on market *m*

$p_m\ q_m = \sum_j p_{jm}\ q_{jm}$ all competitors' exports to market *m*;

$p_i\ q_i = \sum_m p_{im}\ q_{im}$ competitor *i*'s exports to all markets;

$p\ q = \sum_j p_j\ q_j$ all competitors' exports to all markets.

$$RCHD_i = \sum_m \left\{ \frac{p_{im}q_{im}}{p_i q_i} - \frac{p_m q_m}{p\ q} \right\} \Delta \ln(q_m)$$

where the change in competitor *i*'s volume share on market *m* is:

$$\Delta \ln(q_{im}) - \Delta \ln(q_m) = \Delta \ln(q_{im}) - \sum_j^N \frac{p_{jm} q_{jm}}{p_m q_m} \Delta \ln(q_{jm})$$

and the change in competitor *i*'s volume share on all markets is given by:

$$\Delta \ln(q_i) - \Delta \ln(q\ ) = \sum_m^M \frac{p_{im} q_{im}}{p_i q_i} \Delta \ln(q_{im}) - \sum_m^M \frac{p_m q_m}{p\ q} \Delta \ln(q_m)$$

This expression can be expanded to:

$$\Delta \ln(q_i) - \Delta \ln(q\ \ ) = \sum_{m}^{M} \frac{p_{im} q_{im}}{p_i q_i} \{\Delta \ln(q_{im}) - \Delta \ln(q_m)\}$$

$$+ \sum_{m}^{M} \frac{p_{im} q_{im}}{p_i q_i} \Delta \ln(q_m) - \sum_{m}^{M} \frac{p_m q_m}{p\ \ q} \Delta \ln(q_m)$$

After rearranging the last two terms, one gets:

$$\Delta \ln(q_i) - \Delta \ln(q\ \ ) = \sum_{m}^{M} \frac{p_{im} q_{im}}{p_i q_i} \{\Delta \ln(q_{im}) - \Delta \ln(q_m)\}$$

$$+ \sum_{m}^{M} \left\{ \frac{p_{im} q_{im}}{p_i q_i} - \frac{p_m q_m}{p\ \ q} \right\} \Delta \ln(q_m)$$

or:

$$\Delta \ln(q_i) - \Delta \ln(q\ \ ) = \sum_{m}^{M} s_{im} \{\Delta \ln(\mathit{Market\ share}_{im})\} + \mathit{Market\ composition\ effect}_i$$

Annex 2

DATA SOURCES

The data used in the study originate from the following databases:

Database	Variables
OECD STAN Database for Industrial Analysis 1975-94, OECD, Paris, 1995	Current price exports Exchange rates Value added Persons engaged Compensation of Employees
OECD Bilateral Trade Database (BTD) for Industrial Analysis, OECD, Paris, 1996	*Current price bilateral trade flows*
FLUBIL (Flux Bilateraux), INSEE, Division des Échanges extérieurs, 1995	Volume changes of trade flows
Analytical Business Enterprise Research and Development Database (ANBERD), OECD, Paris, 1996	Current price R&D expenditures by industry
OECD Input-Output Database, OECD, Paris, 1995	Gross output deflators Inter-industry flows of investment and intermediate goods for the construction of indirect R&D intensities

Annex 3

DEFINITION OF THE OPTIMAL R&D STOCK

The R&D stock in country *i*'s industry *j* and year y,[1] $RDS_{i,j,y}$, was defined as $RDS_{i,j,y} = (1 - d_j) \cdot RDS_{i,j,y-1} + RD_{i,j,y}$ where d_j is the depreciation rate, $RD_{i,j,y}$ are R&D expenditures, deflated with the GDP deflator and converted to 1985-US$, using 1985 PPPs. *A priori*, no information was available for the depreciation rate. Rather than assuming a particular rate of depreciation, its choice was governed by a simple statistical technique: among several alternative depreciation rates (10 per cent, 20 per cent, 30 per cent, 40 per cent, 100 per year), we chose the one that maximised the R^2 measure in the regression below.[2]

$$\begin{aligned} \Delta\ln(\text{export value shares}) = & \text{ coef1} * \text{R}\Delta\ln\text{ [R\&D-Stock (depreciation)]} \\ & + \text{coef2} * \text{R}\Delta\ln\text{ (Unit Labour Costs)} \\ & + \text{coef3} * \text{Demand Structure changes} \end{aligned}$$

(As before, $R\Delta\ln_x$ stands for the rate of change of *x* relative to the trade-weighted average of competitors' rate of change of *x*).

Since the "optimal" depreciation rate depends on the concrete sample, it is a random variable. The conjecture is that its variance will be bigger for sectors for which the own R&D efforts are weakly correlated to export performance (no significant coefficient). Thus, for such sectors the obtained "optimal" depreciation rate will be very unstable.

The growth rates of R&D stocks based on different depreciation parameters are highly correlated. Naturally, this is strongest for depreciation rates of similar size, although it is still true for the correlation between the change in the R&D stock based on the lowest and the highest depreciation rate (10 per cent and 100 per cent, respectively). Thus, the quality of regression results should be insensitive to changes in the depreciation pattern, *i.e.* *t*-statistics of coefficients are unlikely to change, although the value of coefficients, and hence the importance of the R&D effects on export shares may vary with the underlying depreciation rate.

Another observation is that, empirically,[3] the size of the "optimal" depreciation rate tends to be correlated with the technology intensity of industries (for example, high depreciation in computers and drugs, but low depreciation in the food or paper industries). This observation holds also when volume shares replace value export shares and when acquired technology variables are substituted for direct R&D expenditure. A possible interpretation is that in high-tech industries knowledge diffuses quickly so that only the most recent R&D efforts yield a competitive advantage. Or, technical change takes place faster than in other sectors, implying a faster obsolescence of the R&D stock.

NOTES

1. *y* relates to yearly observations between 1973 and 1990. The time variable *t* used throughout the paper stands for the three periods 1977-80, 1980-85, 1985-90 that underlie the estimation of the equations in Box 1.

2. This is easier to handle than the problems faced by classical model selection-criteria where the main difficulty is to adjust for a number of parameters across different possible models. In the present case the number of parameters does not vary across the possible models and thus R^2 is a sufficient criterion.

3. Results are available from the authors upon request.

Annex 4

NOTES ON THE ECONOMETRIC PROCEDURE

WEIGHTED OBSERVATIONS IN THE REGRESSIONS

Weighting observations in regressions is often proposed as a tool to face heteroscedasticity. In the present context, however, it is used as the analogue of building the weighted mean instead of the simple mean when estimating a location parameter. This has the advantage of making the analysis more invariant to problems due to mixing observations from countries of vastly different size. Consider the example of six exporting countries, one of which occupies 50 per cent of a market while the others hold a 10 per cent share each. Now assume that the big country is split into five smaller countries each of which behaves in exactly the same way as the former aggregate country. If only growth rates of variables enter the analysis and the weights are proportional to the size of the countries, then weighted regressions would lead to exactly the same results for both samples, while non-weighted regressions could lead to completely different results for the two samples.

In the regressions, each observation was weighted with its export share (in an industry) at the beginning of the period. The weighted *LS* estimator is defined as:

$$\tilde{\beta} = \arg\min_{\beta}\left[\sum_{i=1}^{n} w_i\left(y_i - \beta^T x_i\right)^2\right]$$

where y_i is the independent variable, x_i the vector of dependent variables for the i-th observation and w_i its weight. It is obvious that parameter values vary with the weights attached to them.

COVARIANCE MATRIX

As the model is set up to explain the change in export shares, there are implicit restrictions across observations, in particular, the sum of all (weighted) changes in export shares (and also in regressors) has to equal zero. It follows that the random fluctuations around the model are subject to linear restrictions of the type:

$$\sum_{i=1}^{n} \nu_i \varepsilon_i = 0,$$

where n is the number of countries, ε_i is a random shock and v_i the initial share of country i. In such a situation, it is plausible to assume that another random variable in the n-1 dimensional space has independent components and is orthogonal to $\{v_i\}_{i=1,\ldots,n}$. Under this assumption it can be shown that the vector $\{\varepsilon_i\}_{i=1,\ldots,n}$ has a covariance matrix of the form $\sigma^2(I_n - \| v \|^{-2} v v^T)$, where I_n is the identity matrix, v is the vector $\{v_i\}_{i=1,\ldots,n}$, $\| v \| = (\Sigma v_i^2)^{1/2}$ its Euclidean norm and v^T its transpose. The variance σ^2 is assumed to be constant over time and independent between periods. Although these assumptions imply that the weighted least squares estimator loses its unbiased minimum variance (Gauss-Markov) property, its covariance can still be correctly estimated and the derived tests remain valid.