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Abstract

This paper basically adopts a 'technology gap' approach for explaining international export specialisation. Within this broad label there has been one tradition which has applied cumulativeness in technological change as an explanation, while another tradition has emphasised the role of inter-sectoral linkages (the so-called home market effect) in this context. However, given that the sources of innovation (inducements mechanisms) differ between firms according to principal sector of activity, different variables should not be expected to be of equal importance across industrial sectors. Thus, using the Pavitt taxonomy as a starting point, the paper statistically investigates the importance of variables reflecting different inducement mechanisms, across 9 OECD countries.

The paper concludes that the two types of technological activities, namely technological activities in the 'own' sector, and inter-sectoral linkages are both important in the determination of national export specialisation patterns. However, the importance differ according to the mode of innovation in each type of sector.

JEL classification

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Keywords

international export specialisation, patent data, input-output analysis, inter-sectoral linkages

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Contents

1. Introduction

The explanation for international trade specialisation has been a central research topic in economics, at least since Ricardo's *Principles of Political Economy and Taxation* (1817/1951). But whereas Ricardo applied differences in labour productivity across nations as the explanation, the standard explanation for international export specialisation has in contemporary economics, relied on particular endowments of countries (Ohlin, 1933; Heckscher, 1949). However, the factor proportions theory was first challenged by what became known as the 'Leontief-paradox' (1953), stating that the exports of the US ('endowed' with an internationally high K-L ratio), were slightly less capital-intensive than its imports. The finding spurred a hot debate on the empirical validity of the theory, ranging (at least) into the 1980s. However, Leamer (1980) shows that Leontiefs findings do not reveal relative abundance of capital and labour in a multi-factor world, among a set of criticisms. Probably the most comprehensive test of the *n-factor case* of the Heckscher-Ohlin model, also known as the Heckscher-Ohlin-Vanek theorem (Vanek, 1968), was conducted by Bowen *et al.* (1987). The study calculated the factor content of each of 12 factors embodied in net export of 27 countries in 1967, using a US matrix of total input requirements for that year. These data were contrasted with national endowment data on the same 12 factors. Rank correlations were made both 'factor-wise' and 'country-wise'. For what concerns the factor-wise (across countries) results, only in four out of the twelve cases, the variables were positively and significantly related. The country-wise (across factors) results displayed only eight out of 27 positive and significant rank correlations. In the words of Paul Krugman:

> While nobody would deny that there must be some relationship between a country's resources and the resource content of its trade pattern, the effort to explain trade solely on the basis of such resources **-** in other words without making allowances for differences in national production functions **-** is generally seen as having, at long last, failed (1996, p. 345).

Bearing the lacking explanation power of the traditional factor endowment theory in mind - but without totally discarding it, this paper adopts a 'technology gap' approach for explaining international trade (export) specialisation, by testing the effect of a range of different sources of technology on export specialisation in 9 OECD countries. The theoretical perspectives against which the empirical findings of this paper are going to be interpreted are outlined in section 2. Section 3 describes the data to be applied, as well as the empirical set-up and findings of the paper. Finally, section 4 sums up, concludes, and presents a few - albeit important - policy implications of the paper.

2. Theories of international trade specialisation

A general starting point of this paper is the Ricardian explanation of trade specialisation resting on differences in labour productivity. Ricardo originally ascribed the differences in labour productivity to climate and other factors related to agricultural production, as well as to a relative immobility of capital. This paper explores a range of other possible reasons for differences in labour productivity all sharing a common relation to the technological levels of the countries. In this context section 2.1 discusses the importance of cumulativeness in technological change; while section 2.2 focusses on the role of inter-sectoral linkages (the so-called home market effect) in explaining trade specialisation.

2.1. The importance of technology for specialisation

The idea that temporary monopoly profits could be appropriated, based on a technological lead dates back to Schumpeter (1912/34). This idea was applied by Posner (1961) in an international trade context under the label of 'technology gap theory'. Given the assumption that technology is not a free and universally available good, Posner argued that while technology might be important for trade in some sectors, and not in others, innovations made in one country (in technology intensive sectors) would benefit that country as long as the lead could be kept. That is, a country will have ample first-mover advantages, until other countries have imitated the innovation. In the original formulation, once imitation has taken place, more traditional factors of adjustment and specialisation would take over and determine trade flows. However, as argued by Dosi and Soete (1988), there is not necessarily anything impermanent about the importance of technology in determining trade flows, since static and dynamic scale economies flowing from the initial break-through acts to prolong the lead. Coupled with new product innovations, these scale economies might well secure a continuous trade flow.

A formalised neoclassical treatment of the idea is found in Krugman (1985). In the model technology differs between (two) countries in terms of level, but also goods can be ranked by technology-intensity. The trade pattern reflects an interaction between countries and goods; technologically advanced countries have a comparative advantage in technology-intensive goods (but an absolute advantage in all sectors). One of the outcomes of the model is that technical progress in an advanced country, which widens the technological gap, opens up greater opportunity to trade, which in turn raises real income levels in both countries, whereas 'catch up' by a follower tends to hurt the leader by elimination of gains from trade. An interesting (but implicit) feature of these experiments is that the technological level is not treated as a given resource (an 'endowment'). Rather, it can be constructed by means of human action, even though it might not (necessarily) be the result of deliberate actions at the level of the country.

In 'evolutionary' ('technology gap') literature on international trade (Dosi *et al.*, 1990; Verspagen, 1993; Dosi *et al.*, 1994) international trade specialisation is the outcome of country- and sector-specific (technological) learning processes. In evolutionary theory the mechanism of transmission secures a certain level of stability of trade specialisation, because of limited computational capabilities of the agents in question. Firms (and hence countries) will try to diversify their technology by searching in zones that enable them to build on the firms existing technology base. In other words trade patterns are firstly likely to be stable and secondly, changes in the patterns are likely to be rooted in previous activities of the firms of a particular country.

From an empirical point of view, the technology gap theory has gained support from Soete (1981) and Dosi *et al.* (1990). Based on cross-country regression analysis, for a single year, these two studies showed that among 40 sectors about half of these were found to be influenced in their direction by technological specialisation (measured as US patents) in the same sector. From a panel data perspective - in an aggregate country perspective - Amendola *et al.* (1993) found convincing support for the hypothesis as well. Also applying panel data - and from a sectoral as well as a country-wise perspective - Amable and Verspagen (1995) showed that competitiveness in trade was significantly influenced by technological capabilities (US patenting) in eleven out of the eighteen sectors in question.

2.2. The ‘home market effect’

The idea that inter-sectoral linkages in the domestic economy have an impact on competitiveness has its most important roots in development economics. In this context Hirschman (1958) distinguishes between backward and forward linkages. Backward linkage effects are related to derived demand, i.e. the provision of input for a given activity. Forward linkage effects are related to output-utilisation, i.e. the outputs from a given activity will induce attempts to use this output as inputs in some new activities (Hirschman, 1958, p. 100). Hirschman generalises the linkage concept to the observation that:

> ...ongoing activities because of their characteristics, push or, more modestly, invite some operators to take up new activities. Whenever that is the case, a linkage exists between the ongoing and the new activity.(Hirschman, 1958, p. 80).

These ‘new activities’ emerging as a consequence of the supply and demand effects of ongoing activities could be perceived as induced innovations. But the upstream and downstream linkages are not automatic: variables such as technological ‘strangeness’ or ‘alienness’ of the new economic activities in relation to the ongoing ones, as well as obstacles in form of the need of large amounts of capital due to scale requirements and the lack of marketing access and knowledge play an important role for the effectiveness of linkages (Hirschman, 1977, pp. 77-78). These factors are somewhat parallel to the concepts of ‘absorptive capacity’ (Cohen and Levinthal, 1989) or ‘technological relevance’ (Fikkert, forthcoming) in the spillover literature; a certain degree of technological closeness is presumable necessary for the linkage to have an actual effect. In other words, if a relatively strong domestic upstream producer is present, it might in turn improve the comparative advantage of (or the competitiveness of) domestic users.

The importance of domestic linkages (the ‘home-market effect’) in a trade theory context, was suggested by the Swedish economist Linder (1961). The basic idea is that a country’s domestic market may act as a ‘kindergarten’ for new products, before exports to foreign markets are initiated. One possible interpretation of Linder has been formalised by Krugman (1980). The model is based on imperfect competition, and allows for economies of scale and transportation costs. In a two country, two industry setting the model demonstrates that when the two countries trade, each will be specialising (although not necessarily perfect specialisation, depending on the relative importance of transportation costs vis á vis economies of scale) in the industry for whose products it has the *relatively* larger demand. The reason for this is that there will be an incentive to concentrate the production of a good near its largest market, in order to reap economies of scale, while minimising transportation costs.

However, it should be pointed out that Linder was primarily concerned with the quality of demand, rather than the mere size of demand. In other worlds, the original formulation made by Linder concerned the conditions for learning on the (national) home-market:

> If, for some odd reason, an entrepreneur decided to cater for a demand which did not exist at home, he would probably be unsuccessful as he would not have easy access to crucial information which must be funnelled back and forth between producers and consumers. The trial-and-error period which a new product almost inevitably go through on the market will be more embarrassing costwise, the less intimate knowledge the producer has of the conditions under which his product will have to be used. And, if there is no home demand, the producer will be completely unfamiliar with such conditions (Linder, 1961).

Lundvall (1988) has further developed this idea by means of the *organised market*, which involves close, and sometimes face-to-face interaction between sellers and buyers as a fertile environment for innovation. The interaction may take the form of mutual exchange of information, but may also involve direct co-operation between user and producers of technology. Two properties of the user-producer relationship are important in a ‘home market’ context. Firstly, because it is time-consuming and costly to develop efficient channels of communication and codes of conduct (often tacit) between users and producers, the relationships are likely to be durable and selective. Secondly, when technology is sophisticated and changing rapidly, proximity in terms of space and culture is seen to be conducive to innovation and thereby to competitiveness (1988, p.355). Thus, such localised and durable linkages give rise to dynamic increasing returns at the level of the country (or region). In the context of increasing returns, it should be pointed out that we are dealing with interaction between firms[1], situated in different industries (Young, 1928), rather than activities internal to the firm.

As pointed out by Fagerberg (1995), given the tacit nature of the user-producer interaction, such relationships are not only ways of increasing localised learning and innovation, but also act as a means of appropriating returns from learning and innovation, at least in the shorter run.

Thus, localised vertical linkages might create/reinforce competitiveness or specialisation of both users (an upstream linkage) and producers (a downstream linkages), making sectors co-evolve at the national level (Andersen *et al.*, 1981). Linkages might be interpreted as localised 'spillovers'(cf. Verspagen, 1997). In this context it can be useful to distinguish between rent-spillovers, as opposed to pure knowledge spillovers as done in a seminal paper by Griliches (1979). *Rent-spillovers* consist of the R&D embodied in purchased inputs. One example of this type of spillover is the contribution to aggregate productivity from the computer industry. Because of competitive pressure within the industry, the full effect could not be appropriated by the industry itself, but instead improved the productivity of purchasing firms in other industries.[2] However, Griliches argues that real *knowledge spillovers* are the ideas borrowed by the research teams of industry *i* from the research results of industry *j*. In this context Griliches states that it is not clear that this kind of borrowing is particularly related to input purchase flows. Nevertheless, as pointed out by Los (1996), among a number of channels of knowledge spillovers are supplier-buyer relationships regarding innovative behaviour. Thus, in that case knowledge spillovers are related to input purchase flows (or output sales).

Empirically, the hypothesis has gained some support at the descriptive level by Andersen *et al.* (1981) and econometrically by Fagerberg (1992; 1995). However the tests conducted by Fagerberg only applies one variable reflecting a 'backward spillover', and is not based on data on economic transactions. Instead the independent variable is the trade specialisation (Balassa figure) of a country in an 'upstream sector' with respect to the dependent variable (also measured

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1 The sectors in the input-output tables, which are used for measuring linkages are constructed on the basis of goods and not firms, and a firm can thus belong to several sectors. At the level of aggregation used in the present analysis it is assumed that the problem with single firms belonging to more than one sector is negligible though.

2 In should be pointed out that rent spillovers are mainly related to the market structure in the technology producing industry, rather than being true externalities in the strict sense of the word (Griliches, 1979; Verspagen, 1997).

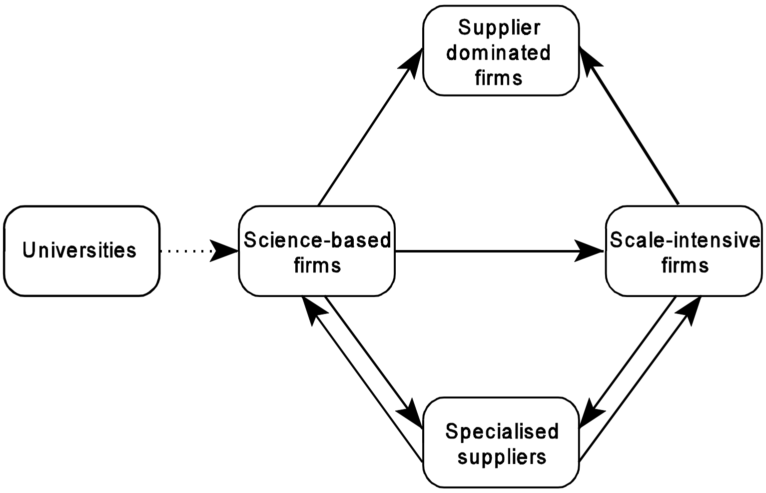

Figure 1: The main technological linkages amongst different categories of firms and universities (cf. Pavitt, 1984, p. 364)

as Balassa). This paper will apply data on actual economic transactions (I-O data) used as weights (see section 3.1, below) on the technological output from upstream or downstream sectors with respect to the sector to be explained.

2.3. The Pavitt-taxonomy in a trade context

Given that the principal sources of technological change (inducements mechanisms) differ between firms according to principal sector of activity, different explanations should not be expected to be of equal importance across industrial sectors. Thus, if trade specialisation is determined to a large extent by technology, we should not expect the importance of 'technology' to appear along the same dimensions.

Pavitt (1984), identifies differences in the importance of different sources of innovation according to which broad sector the individual firm belongs. The taxonomy of firms, according to principal activity, emerged out of a statistical analysis of more than 2000 postwar innovations in Britain and was explained by the sources of technology; the nature of users needs; and means of appropriation.

Four types of firms were identified accordingly, namely supplier dominated firms, scale-intensive firms, specialised suppliers and science-based firms. *Supplier dominated* firms are typically small and found in manufacturing and non-manufacturing sectors. Most technology comes from suppliers of equipment and material (see Figure 1, for a description of the main external technological sources of different types of firms). *Scale intensive* firms are found in bulk materials and assembly. Their internal sources of technology are production engineering and R&D departments. External sources of technology include mainly interactive learning with specialised suppliers, but also inputs from science-based firms are of some importance. *Specialised suppliers* are small firms, which are producers of production equipment and control instrumentation. Their main internal sources are primarily design and development. External sources are users (science-based and scale-intensive firms). *Science-based firms* are found in the chemical and electronic sectors. Their main internal sources of technology are internal R&D and production engineering. Important external sources of technology include universities, but also specialised suppliers.

Even though the taxonomy was devised at the level of the firm, it has implications at the level of the industry, as we would expect the broad sectoral regularities of firms to be reflected in the aggregate behaviour of the sector. Thus, given the above description of the taxonomy, one would expect internal R&D to be most important for specialisation in science-based sectors, while upstream and downstream linkages should be expected to be more important in the case of specialised suppliers. For scale intensive sectors, investment and inter-sectoral linkages - but also to some extent R&D - should be of importance, while supplier dominated sectors should to some extent be expected to be determined by upstream linkages. But as we are dealing with sectors of traditional manufacturing in this case, more traditional factors (resource endowments) might be particularly important for these sectors.

Thus, using Pavitt taxonomy as a starting point, the paper statistically investigates the importance of variables reflecting different inducement mechanisms for trade specialisation, in 19 manufacturing sectors (see Appendix Table A1 for a description of the sectors), across 9 OECD countries.

3. Empirical analysis

3.1. The data

Patent data are taken from the U.S. patent office. Bibliometric figures are taken from Archibugi & Pianta (1992). All other data applied are taken from the OECD STAN database (1995 edition). The main limiting factor is the use of the STAN input-output tables, which are only available for nine OECD countries (Australia, Canada, Denmark, France, Germany, Great Britain, Japan, the Netherlands, and the United States). Also the input-output data is only available for five points in time (early 1970s, mid 1970s, early 1980s, mid 1980s and 1990). It should be noted that the I-O tables are not exactly from the same year. For instance, the 'mid 1970s' observation is 1974 for Australia, while this observation for Canada was obtained in 1976. Even though the inclusion of I-O data severely reduces the amount of observations, the inclusion allows for the calculation of up- and down-stream 'technology flows', based on 'real' economic transactions. Often, in this kind of study, the intensity of economic transactions between sectors, are calculated on the basis of one country. Accordingly, the *intensity* of transactions between sectors of that country is then assumed to be the same in other countries in the analysis, while e.g. the structure of production differ. So this advantage has to be judged against the smaller number of observations, and a number of missing values. Concerning the selection of years, the other variables were picked so that they match the I-O data more or less (i.e 1973, 1977, 1981, 1985 and 1990).

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

The dependent variable is the Revealed Comparative Advantage (Balassa, 1965):

$$RCA_{ij} = \frac{X_{ij} / \sum_i X_{ij}}{\sum_j X_{ij} / \sum_i \sum_j X_{ij}}.$$

The numerator represents the percentage share of a given sector in national exports - X_{ij} are exports of sector *i* from country *j*. The denominator represents the percentage share of a given sector in OECD exports. The RCA index, thus, contains a comparison of national export structure (the numerator) with the OECD export structure (the denominator). When RCA equals 1 for a given sector in a given country, the percentage share of that sector is identical with the OECD average. Where RCA is above 1 the country is said to be specialised in that sector and vice versa where RCA is below 1. However, since the RCA turns out to produce data that does not conform to a normal distribution, the index is made symmetric, obtained as *(RCA-1)/(RCA+1)*; this measure ranges from -1 to +1. The measure is labelled ‘Revealed Symmetric Comparative Advantage’ (*RSCA*).

The downstream linkage-variable[3] can be defined as:

$$DL = (\boldsymbol{y}_{ab} / \boldsymbol{Y}_a)\boldsymbol{P}_a, \quad for\ a \neq b,$$

where $\boldsymbol{y}_{ab}$ is a matrix of the deliveries of intermediates from the sector in question and $\boldsymbol{Y}_a$ is a vector of total output. $\boldsymbol{P}_a$ is a vector of US patents taken out by the receiving sectors (normalised for country-size), as a proxy of the technological competence of these sectors. In other words the variable measures sector b’s importance as a user of sector a’s output. Likewise for the upstream linkage variable:

$$UL = (\boldsymbol{y}_{ab} / \boldsymbol{Y}_b)\boldsymbol{P}_b, \quad for\ a \neq b,$$

where $\boldsymbol{Y}_b$ is a vector of total input, while $\boldsymbol{P}_b$ is a vector of US patents taken out by the delivering sectors (normalised for country-size), yet again as a proxy of the technological competence of these sectors. Thus, the variable measures sector a’s importance as a supplier to sector b.

3 In the vocabulary of the linkage literature, the variable can be described as a forward linkage.

3.2. Applying the Pavitt-taxonomy in a international trade context

Each of the 19 sectors have been assigned to the four Pavitt sectors. The classification is shown in Appendix Table A1. However, since any such assignment is somewhat arbitrary on the boundaries, the chosen classification deserves some comments. First of all, the classification, according to the Pavitt taxonomy, used in this paper follows to a large extent OECD (1992), and differ only from this in the case of 'industrial chemicals'; 'instruments'; and 'fabricated metal products'. In the two first cases, the sectors are on the boundaries of the 'Pavitt sectors'. Firms in the 'industrial chemicals' sector posses both science based characteristics, but also some scale intensive characteristics, and firms in the instruments sector both carry specialised supplier characteristics, but also some science based characteristics. In both cases we opted for the original Pavitt classification, as science based and specialised suppliers respectively. If one look at the ISIC nomenclature, under 'fabricated metal products', it can be seen that this sector produces mainly standard products (nails, screws, steelwire etc.). In contrast to the OECD, we argue that this type of production is not mainly carried out by specialised supplier firms.

The *a priori* reasons for including 'food, drink and tobacco' and 'petroleum refineries' as supplier dominated sectors, even though the firms in these sectors are probably to some extent scale-intensive, is that we are dealing with national specialisation. Thus the specialisation in these sectors is to some extent determined by what goes on in the (related) primary sectors, which in turn are supplier dominated, in addition to being influenced by natural resource availability. As other sectors on the boundary should be mentioned non-ferrous metals (classified as supplier dominated, but could be classified as scale intensive) and electrical machinery (classified as supplier dominated, but have some science based properties). Because of the arbitrary assignments of some of the sectors, we have made some test for sensibility to the aggregation chosen. The results of these experiments will be briefly presented at the end of this section.

For now, the empirical model can be set up as follows:

$$RSCA_{ij} = \alpha + \beta_1 INV_{ij} + \beta_2 ULC_{ij} + \beta_3 RSTA_{ij} + \beta_4 UL_{ij} + \beta_5 DL_{ij} + \beta_6 CIT_j + \epsilon_{ij}$$

where *RSCA* is the 'revealed symmetric comparative advantage'; *INV* is the equivalent measure for investment; *ULC*[4] is unit labour cost (relative to the average); while *RSTA* is 'revealed technological advantage'. *UL* is a proxy for upstream linkages with producers, and are measured as technological output (US patents) performed in upstream sectors (normalised for country-size), weighted by the input-output-coefficients. *DL* is proxy of downstream linkages with users (technological activity, performed in downstream sectors, normalised for country-size, weighted by the output-coefficients). *CIT* is finally a country-specific variable, measuring the strength of the science-base, using citations of academic papers in science per capita as a proxy (relative to the average).

Our expectations on behalf of the specific 'Pavitt-sectors' were described above. However, we do also have more general expectations, which will be described subsequently. The investment variable is expected to turn out with a positive sign, as we would expect physical capital to be a necessary condition for being specialised in a given sector. We have no specific expectation for the wage variable as it might reflect low labour costs (negative sign), as well as a high skill requirement (positive sign). The technology variable is expected to have a positive impact, as well as are the both of the 'linkage' variables. This is also the case for the measurement of the quality of the science-base, even though this variable is only expected to be of importance for science-based sectors.

We pool all countries, all sectors, and all years, and estimate a model for the whole sample, using ordinal least squares. We shall allow for the slopes of the different variables to vary according to which Pavitt-sector the individual sectors belong. The results are reported in Table 1.

Given the presence of multicollinarity[5] between *DL* and *UL*, three separate models have

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4 One should note that the variable is not a precise unit wage cost measure. It would be so if we had a 'physical' productivity measure as the denominator. As we are forced to use current prices and exchange rates, the ratio of wages to value added is a mixture of unit wage costs and income distribution (see Dosi *et al.*, 1990, p. 196).

5 The variance inflation factor (VIF) display high values for *UL* & *DL*, which indicates that these variables might be involved in multicollinarity. For the *i*th independent variable, the variance inflation factor is determined as $1/(1-R^2_i)$, where R^2_i is the coefficient of determination for the regression of the *i*th independent variable on all other independent variables. The VIF statistic show how multicollinarity has increased the instability of the coefficient estimates.

Table 1: Regression results for explaining international trade specialisation (n=622).

		Model (i)		Model (ii)		Model (iii)	
		R^2 =0.38		R^2 =0.38		R^2 =0.38	
Sector Type	Variable	Estimate	*p*-value	Estimate	*p*-value	Estimate	*p*-value
Supplier dominated	*INV*	0.612	0.0001	0.602	0.0001	0.609	0.0001
	ULC	-0.151	0.0086	-0.161	0.0050	-0.159	0.0055
	RSTA	0.259	0.0025	0.303	0.0004	0.282	0.0010
	DL	0.753	0.0897				
	UL			-0.189	0.7031		
	P1					0.014	0.5063
	CIT	0.110	0.0210	0.126	0.0094	0.116	0.0159
Science based	*INV*	0.401	0.0001	0.418	0.0001	0.410	0.0001
	ULC	0.019	0.6236	0.022	0.5691	0.021	0.5928
	RSTA	0.622	0.0001	0.623	0.0001	0.621	0.0001
	DL	0.090	0.7887				
	UL			-0.168	0.6629		
	P1					-0.002	0.9221
	CIT	0.163	0.0007	0.167	0.0005	0.166	0.0006
Scale intensive	*INV*	0.480	0.0001	0.479	0.0001	0.481	0.0001
	ULC	0.069	0.0001	0.068	0.0001	0.068	0.0001
	RSTA	-0.002	0.9826	-0.010	0.8985	-0.005	0.9464
	DL	0.442	0.0524				
	UL			0.567	0.0443		
	P1					0.025	0.0351
	CIT	-0.091	0.0101	-0.101	0.0042	-0.096	0.0069
Specialised suppliers	*INV*	0.484	0.0001	0.548	0.0001	0.514	0.0001
	ULC	-0.060	0.0022	-0.065	0.0009	-0.063	0.0013
	RSTA	-0.062	0.8276	0.091	0.7411	0.013	0.9612
	DL	1.005	0.0187				
	UL			1.027	0.0284		
	P1					0.048	0.0178
	CIT	-0.002	0.9720	0.006	0.9094	0.001	0.9829

ULC = Level of unit labour costs; relative to the average
INV = Investment specialisation
RSTA = Revealed symmetric technological advantage
DL = Downstream linkages. Technological activity, performed in downstream sectors (normalised for country-size), weighted by the output-coefficients.
UL = Upstream linkages. Technological output (patents) performed in upstream sectors (normalised for country-size), weighted by the input-output-coefficients.
CIT = Citations in academic papers per capita per country; relative to the average.

been estimated. In other words, if sectors have many linkages downstream, they have many linkages upstream as well. Hence, first we estimated two separate models (models (i) and (ii)), each including *UL* and *DL*, respectively. In addition to that, principal component regression has been applied, which is one way of tackling multicollinarity. Principal component analysis is a type of factor analysis, and the analysis computes linear combinations of the original variables. Given a data set with *p* numerical variables, *p* principal components can be computed. The first principal component has the largest variance of any linear combination of the observed variables, and the last principal component has the smallest variance of any linear combination of the observed variables. In other words, each principal component maximises 'the explained residual variance' in *p* rounds. As the synthetic variables (i.e. the principal components) are jointly uncorrelated, by definition, the methodology can sometimes be useful in addressing multicollinarity. Thus, in Table 1 synthetic variables have been computed for *UL* and *DL* (model iii). Only the first principal component is used in the regressions, as the explained variance exceeds 0.86. In other words, we only leave out 14% of the variance of the two variables. The parameters of the so-called factor loadings (i.e. the parameters relating the original variables to the principal components) display identical signs (positive); i.e. the contribution of each of the two original variables to the first of the principal components goes in the same direction.

Specification tests are reported in Table 2. Using the Chow test, the null hypothesis of no structural change (across the five time periods included) cannot be rejected at any reasonable level. For what concerns normality of the error terms, the null hypothesis of normality can be rejected at a very low level, using the Jarque-Bera test. It should also be pointed out that the ARCH test proposed by Engle (1982) strongly indicates heteroscedasticity in the error terms. Therefore, it should be kept in mind that the reported *t*-values might not be as significant as they look.

The results of the estimations for the *supplier dominated sectors* are found in the top of Table 1. It can be seen that the first principal component (i.e. the synthetic combination of *UL* and *DL*) is not significant[6], indicating that national linkages do not appear to be of importance for specialisation in these sectors. However, we would have expected upstream linkages to be of importance for specialisation in this type of sector. One possible explanation for this is that it

6 More generally, the results based on the application of principal components did not differ in any dramatic way from the results of the estimation based on separate estimations of *UL* and *DL*.

Table 2: Specification tests for the regressions

	Model (i)	Model (ii)	Model (iii)
	p-value	*p*-value	*p*-value
Chow test (poolability over time)	1.0000	1.0000	1.0000
Jarque-Bera test	0.0002	0.0001	0.0001
ARCH test	0.0001	0.0001	0.0001

might be that strongholds of countries in these sectors are to some extent determined by the ability to absorb technology developed elsewhere. If that is the case, upstream linkages need not be national. *ULC* and *INV* come up with the expected signs, but surprisingly enough do also technological specialisation appear to be positively related to export specialisation. While this finding is not untenable, the positive correlation in the case of *CIT* is hard to explain from a theoretical point of view. In this context it should be pointed out that these sectors might be particularly influenced by natural resource availability, such as arable land, forest, oil and so on. Since such factors are not included in the present paper, the regressions, presented in Table 1, might be exposed to mis-specification in relation to the supplier dominated types of sectors.

As expected, with regard to the *science-based sectors*, coefficients for citations and technological specialisation are found to be the highly significant. In the latter case the coefficient is relatively high, both when compared to the other variables in the regression, but even more so, when compared to the other types of sectors. The highly significant coefficient for *CIT* confirms the idea that a strong national science-based is a necessary condition for being specialised in these sectors. In contrast, the insignificant linkages confirms the findings of Klevorick, (1995) and Laursen (1996), concluding that inter-sectoral linkages do no not seem to be of critical importance for science-based sectors more generally, and for pharmaceuticals in particular.

For what concerns *scale intensive sectors* a number of points should be made. First of all, the (direct) technology variable does not seem to be of importance for these sectors, which was not expected for this type of sectors. Secondly, investment is (also) highly significant in this case. Thirdly, it is worth noting that the wage variable is significant, but that it has a positive sign, thus probably implying the importance of high-skill requirements for human capital in these sectors. Finally, the linkage variables are significant in this case, as we would expect for one of the two 'production intensive' type of sectors.

The results with regard to the *specialised supplier* type of sectors, display a negative correlation between trade specialisation and relative unit labour costs of the sectors, like in the case of supplier dominated sectors. In other words, those countries which are specialised in these sectors, also appear to have the relatively lowest unit labour costs. Both of the linkage variables are significant, and have a high parameter. This finding corresponds neatly to the idea that specialised suppliers have the most technological linkages to the surrounding system (cf. Figure 1).

Finally, we reclassified 'food, drink and tobacco'; 'petroleum refineries'; and 'non-ferrous metals' to scale intensive sectors from supplier dominated sectors, and 'electrical machinery' to science based from specialised supplier sectors, in order to test for the sensitivity to the chosen 'sectoral affiliation'. The results of this experiment display (not explicitly documented for reasons of space), that for supplier dominated sectors only investment is significant. In this context it should be pointed out that only 'textiles, footwear and leather' is left in this Pavitt sector. For science based sectors, investment, US patent specialisation and citations are all robust to the change made. For scale intensive sectors investment and the linkages variables are robust, while unit labour costs is not robust to the change made. For specialised suppliers, investment and the linkage variables retain their sign and significance.

4. Conclusions

This paper has outlined two approaches, within the broad label 'technology gap' theory. One of them has emphasised the importance of own technological activity of the sectors or firms in question, while another approach has emphasised the importance of up- and downstream technological linkages.

Thus we estimated a model including all time periods, all countries and all sectors, but allowing for different slopes, according to which Pavitt-sector the individual sectors belong. The results displayed that investment in physical capital appear to be important for all types of sectors. Unit labour costs have a negative impact in the case of supplier dominated sectors and for specialised supplier types of sectors, whereas the positive relationship for scale intensive sectors might well imply the importance of high skilled labour in these sectors. Revealed technological advantage has the expected positive impact for science-based sectors, but surprisingly also a positive impact for supplier dominated sectors. The linkage variables appeared to be important for scale intensive sectors, but even more so for specialised supplier sectors. Much in accordance with what was expected.

Hence, it seems fair to conclude that the two types of technological activities, discussed in the theoretical section, namely technological activities in the ‘own’ sector, and inter-sectoral linkages are both important in the determination of national export specialisation patterns. However the importance differ according the mode of innovation in each type of sector.

Of course such a conclusion has important policy implications. The prime policy implication is that generic technology policies might not lead to the desired results. If a policy maker wants to influence trade specialisation towards a higher technology level through innovation by means of a policy that gives support to specific sectors (e.g. in the form of support for corporate R&D), it is not likely to have any effect on firms situated in specialised supplier sectors. In that case support for upstream and downstream interaction, might be much more appropriate. On the other hand, such policies might not have the desired effect for firms situated in science-based sectors. Given these observations policy makers should take into account the given export specialisation profile of the country, when determining which portfolio of policies should be held.

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Appendix Table 1: Sectors used in the analysis; classified according to Pavitt sector; and compared to other studies applying the Pavitt taxonomy

		Pavitt (1984)	Versp/Amable (1995)	OECD	This paper
1	Food, drink and tobacco	SCAI	SDOM	SDOM	SDOM
2	Textiles, footwear and leather	SDOM	SDOM	SDOM	SDOM
3	Wood, cork and furniture	-	-	SDOM	-
4	Paper and printing	-	-	SCAI	-
5	Industrial chemicals	SCIB	SCIB	SCAI	SCIB
6	Pharmaceuticals	SCIB	SCIB	SCIB	SCIB
7	Petroleum refineries (oil)	-	-	SDOM	SDOM
8	Rubber and plastics	-	PROD	SCAI	SCAI
9	Stone, clay and glass	SCAI	PROD	SCAI	SCAI
10	Ferrous metals	SCAI	PROD	SCAI	SCAI
11	Non-ferrous metals	SCAI	PROD	SDOM	SDOM
12	Fabricated metal products	SCAI?	PROD	SDOM	SCAI
13	Non-electrical machinery	SPEC	PROD	SPEC	SPEC
14	Office machines and computers	SCIB	SCIB	SCIB	SCIB
15	Electrical machinery	SPEC	SCIB	SPEC	SPEC
16	Communic. eq. and semiconduct.	SCIB	SCIB	SCIB	SCIB
17	Shipbuilding	SCAI	PROD	SCAI	SCAI
18	Other transport	-	PROD	SCAI	SCAI
19	Motor vehicles	SCAI	PROD	SCAI	SCAI
20	Aerospace	-	SCIB	-	SCAI
21	Instruments	SPEC	PROD	SCIB	SPEC

SDOM = Supplier dominated
SCAI = Scale intensive
SPEC = Specialised suppliers
SCIB = Science-based
PROD = Production intensive (SPEC+SCAI)
– = Not included in the analysis

Danish **R**esearch **U**nit for **I**ndustrial **D**ynamics

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

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

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

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

Theme B: Competence building and inter-firm dynamics

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

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

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

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

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

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