The Importance of Technology-Based Intersectoral Linkages for Market Share Dynamics

By

Keld Laursen and **Valentina Meliciani**

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I. Introduction

This paper introduces technology-based intersectoral linkages (or put in a different vocabulary: technological spillovers)[1] in an empirical model of international market share dynamics. While the explanation of market share dynamics has been an important aspiration of a large part of the recent empirical literature on international trade (e.g. Amendola et al. 1993; Magnier and Toujas-Bernate 1994; Amable and Verspagen 1995; Verspagen and Wakelin 1997), technological linkages have, to the mind of the present authors, not been incorporated in such a model. In the words of Magnier and Toujas-Bernate: "Of course, some important features [of market share dynamics] remain largely unexplained. With respect to future empirical work, along with the introduction of other technological accurate variables (granted patents, labor skills, number of researchers, ...), we suggest some potential improvements ... But above all, other country specificities related to the diffusion of technology between industrial sectors in each country should be underscored" (Magnier and Toujas-Bernate 1994: 516; our insert in square brackets).

That linkages or spillovers should matter in this context can be derived from various strands of the theoretical literature, including neo-

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[1] The differences and similarities between technological linkages and spillovers are discussed later in the paper.

classical approaches (e.g. Grossman and Helpman 1991), but also from evolutionary approaches such as Verspagen (1993). In addition it is clear that since the idea of (national) intersectoral linkages underlies theories of national systems of innovation as a generic foundation (Lundvall 1992), the findings of the paper have important implications for how theories of national systems of innovation should be confined, as such linkages might not be equally important across industrial sectors.

The set-up of the model, used in this paper, is similar to the dynamic model developed by Amendola et al. (1993), although we estimate a model at the sectoral level, as opposed to the (country) aggregate model estimated by Amendola et al. As in the case of Magnier and Toujas-Bernate (1994), we allow the slopes to differ in the sectoral dimension. Accordingly, the estimations carried out in this paper aim at explaining market share dynamics by means of unit labour costs (as an indicator of production costs), patent statistics (an indicator of the technological development), and additionally a variable similar to the linkage variable constructed by Laursen and Drejer (1999), in order to see whether such linkages (or national spillovers) matter for gaining or losing market shares over time.

Moreover, the paper attempts to reconcile the different views on which dimension of technological development is the most important one in determining trade flows between countries. In this context some theorists have argued that because of 'knowledge stickiness', knowledge developed in a particular sector and country would induce trade flows from that country. In contrast, the proponents of the so-called home market hypothesis have emphasized another aspect of technology in arguing that particularly strong intersectoral linkages within a particular country determine trade flows from that country. By adopting a sectoral approach to this issue it is the aim of the paper to draw conclusions concerning the extent to which the two types of explanations are in fact complementary rather than substitutes.

II. Technology-Based Theories of International Trade

A general starting point of this paper is a 'technology gap' approach to explaining trade flows, stressing the importance of differences in technological levels of countries. In this context we first discuss the importance of the direct influence of technology; while we subsequently focus on the role of technology-based intersectoral linkages (the so-called home market effect) and spillovers in explaining trade flows.

The Direct Importance of Technology for Trade

Under the label of 'technology gap theory' Posner (1961) introduced the idea that temporary monopoly profits based on a technological lead can be achieved in an international trade context. 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 in a given sector until other countries have imitated the innovation. In the words of Posner (1961: 323–324): "... the development of new products does not occur simultaneously in all countries – in most cases the only reason they are introduced is because the entrepreneur concerned is hoping to achieve a quasi-monopoly for a period of time. During this period of time a cause of trade exists which is independent of any previously existing comparative cost differences".

Hence, in the original formulation of Posner, once imitation has taken place, more traditional factors of adjustment and specialization would take over and determine trade flows. However, as argued by Dosi and Soete (1988), there is not necessarily anything transitory about the importance of technology in determining trade flows, since static and dynamic scale economies flowing from the initial breakthrough act to prolong the lead. Coupled with new product innovations, these scale economies might well secure a continuous trade flow. A formalized neoclassical treatment of aspects of this idea is found in Krugman (1985). Metcalfe and Soete (1984) also observe that trade can be due to the difference between national rates of demand diffusion and capacity growth and due to time lags in technology transfer with respect both to demand and production. While this type of trade should be transitory, it is possible that different diffusion patterns may result in different patterns of development within one technology, thus affecting countries' long-run comparative advantages. Overall, studies using the technology-gap approach to trade emphasize intercountry differences in technical change as the basis of international trade flows. In this framework, it is variation across countries in innovation capabilities within each sector, rather than interindustry differences in endowments, which matters in explaining the direction of trade.

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 in about half of them international competitiveness was influenced by technological advantages (measured as US patents) in the same sector. From a panel data perspective, in a dynamic setting – and 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 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, when using a dynamic specification of the model.

The Home Market Effect

The importance of domestic linkages (the home market effect) in a trade theory context was suggested by the Swedish economist Staffan Burenstam Linder (1961). The basic idea is that a country's domestic market may act as a protected environment for new products, before exports to foreign markets are initiated. In this context, Hirschman's (1958) distinction between backward and forward linkages can be useful. Backward linkage effects are related to derived demand, i.e. the provision of inputs for a given activity. Forward linkage effects[2] are related to the use of output, i.e. the outputs from a given activity will induce attempts to use this output as inputs in some new activities (Hirschman 1958: 100).

Extending the model due to Linder, Vernon (1966) introduced the product-life cycle model in which (labour-saving) innovation is first created in the most advanced countries, and then subsequently diffuses to lesser and lesser advanced countries. According to Vernon, geographical proximity is conducive to innovation because of the ease of communication over short distances: "There is good reason to believe, however, that the entrepreneur's consciousness of and responsiveness to opportunity are a function of ease of communication; and further, that ease of communication is a function of geographical proximity. Accordingly, we abandon the powerful simplifying notion that knowledge is a universal good, and introduce it as an independent variable in the decision to trade and invest. The fact that the search for knowledge is an inseparable part of the decision making process and that the relative ease of access to knowledge can profoundly affect the outcome are now

2 In the empirical part of the paper we are going to apply the term 'downstream linkage' as the label for what is known as a 'forward linkage' in the linkage literature.

reasonably well established through empirical research. One implication of that fact is that producers in any market are more likely to be aware of the opportunity to introduce new products in *that* market than producers located elsewhere would be". (Vernon 1966: 192, our italics).

In a model based on imperfect competition and allowing for economies of scale and transportation costs, Krugman (1980) formalized a possible interpretation of the Linder-Vernon hypothesis. However, it should be noted that both Linder and Vernon were primarily concerned with the quality of demand, rather than the mere size of demand, as modelled in the paper by Krugman. In other words, the original formulation made by Linder (and Vernon) concerned the conditions for learning on the (national) home market.

Upstream linkages might also be interpreted as localized 'spillovers'. The public good aspect of technology has recently been recognized in economics, in particular in the field of new growth theory (see e.g. Barro and Sala-i-Martin 1995). Technology developed by one firm can be used by others at a cost typically lower than the original cost of development. In addition, knowledge developed by one firm can be seen to enhance the productivity of producing knowledge by other firms, as the knowledge can be 'built on' by the other firms, when they produce new knowledge themselves.

Before discussing the differences and similarities between technological linkages and technological spillovers and between the home market hypothesis and the spillover literature, it can be useful to distinguish between rent spillovers, as opposed to pure knowledge spillovers as done in the 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.[3] In contrast to rent spillovers, Griliches argues that real *knowledge spillovers* are the ideas borrowed by the research teams of industry i from the research results of industry j, and that it is not clear that this kind of borrowing is particularly related to the purchase flows of inputs.

[3] It 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).

While rent spillovers are difficult to distinguish empirically from technological linkages (as they both involve interindustry transactions), in our view there are at least two conceptual differences. First, technological linkages do necessarily involve the existence of externalities; second, they are consistent with a two-way interaction between sectors rather than involving the one-way transfer of technology from one sector to another.

The argument concerning rent spillovers is that, when commodities flow freely across sectors, the firms of the sector in question have access to the R&D stock of all sectors (in an extreme case – where all sectors' outputs are equally 'relevant' to each other). This occurs because independent of the fact in which sector an input has been developed or improved, the firms of any sector can purchase the input and employ it in manufacturing (Coe and Helpman 1995). In comparison with the idea of rent spillovers, the home market hypothesis is a more dynamic argument, in the sense that the focus is on how *new* technologies and products are created, in terms of exchange of information between suppliers and users of a product, rather than on diffusion issues, as is dealt with in the case of rent spillovers. Nevertheless, as real knowledge spillovers are the ideas borrowed by the research teams of industry i from the research results of industry j, one can argue that home market linkages are a particular kind of knowledge spillovers, related to input purchase flows (Los 1996).

Another difference between the literature on spillovers and the home market hypothesis concerns the following: in the home market hypothesis particular importance is given to domestic demand and to the role of customers, while demand does not play a substantial role in the literature on technological spillovers. It should also be pointed out that spillovers can be both national or international in scope, whereas home market linkages are localized (national) per definition. In this paper we are going to apply an input-output measure of linkages. In the spillover literature, the input-output measure would be equivalent to rent spillovers. Nevertheless, our empirical analysis aims at assessing the importance of the technological capabilities of upstream and downstream sectors in affecting export shares of a particular sector irrespective of whether these linkages might be interpreted as evidence of spillovers.

Empirically, the home market hypothesis has gained some support at the descriptive level by Andersen et al. (1981) and econometrically by Fagerberg (1992, 1995). However, the test 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 specialization (Balassa figure) of a country in an 'upstream sector' relevant to each observation in the dependent variable (also measured as Balassa figure). This paper will apply data on actual economic transactions (I-O data) used as weights (see below) on the technological output from upstream or downstream sectors with respect to the sector to be explained.

The Pavitt Taxonomy in a Trade Context

Given that the principal sources of technological change (inducement mechanisms) differ between firms according to the principal sector of activity, different explanations for trade should not be expected to be of equal importance across industrial sectors. Thus, if trade specialization 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 2,000 post-war 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, specialized 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. *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 specialized suppliers, but also inputs from science-based firms are of some importance. *Specialized suppliers* are small firms which are producers of production equipment and control instruments. Their main internal sources are 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 specialized suppliers.

Even though the taxonomy was devised at the firm level, it has implications for the industry level, 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 'own' sector technology to be most important for gaining market shares in science-based sectors, while downstream linkages should be expected to be more important in the case of specialized suppliers. For scale-intensive sectors intersectoral 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 and by low unit labour costs.

The Pavitt taxonomy has been criticized on a number of points, including a set of criticisms relating to the fact that the sectoral boundaries are not always straightforward. That is, firms (and sectors) cannot always readily be defined in an unambiguous way as one of the four Pavitt-type firms. Some firms (and sectors) may have such attributes, so that they can be said to be affiliated to more than one of the Pavitt-type sectors. It should be stressed, however, that while the Pavitt taxonomy has held up reasonably well in subsequent empirical tests (Cesaratto and Mangano 1993; Arundel et al. 1995), it inevitably simplifies.

Using the Pavitt taxonomy as a starting point, this paper statistically investigates the importance of variables reflecting different inducement mechanisms for trade flows over 19 years, in 19 manufacturing sectors (see Appendix Table A 1 for a description of the sectors), across 9 OECD countries.

III. Empirical Analysis

The Variables

In most empirical analyses on the determinants of export shares, cost and technological competitiveness have been identified as the major explanatory variables (Soete 1981; Greenhalgh et al. 1994; Magnier and Toujas-Bernate 1994; Amable and Verspagen 1995; Meliciani and Piermartini 1997; Carlin et al. 1998; Laursen 1999).

Cost competitiveness is generally measured by either wages per employee or unit labour costs. Here we use unit labour costs, since the level of wages *per se* can be related to labour productivity and therefore its effects on export shares might be ambiguous. Our measure is defined as follows:

$$ULC_{ijt} = \ln(W_{ijt}/VA_{ijt}) - \ln\left(\sum_i (W_{ijt}/VA_{ijt})(1/n)\right), \quad (1)$$

where W_{ijt} is the wage sum of country j, in sector i, at time t, expressed in current prices and VA_{ijt} is value added in fixed prices; n is the number of countries.[4]

Different contributions have used different proxies in order to measure technological competitiveness. The most-used measures of disembodied technology are R&D and patent statistics: the former is better suited to capture the inputs to the innovation process, while the second is a measure of the innovation output. In this context it is important to note that appropriability of R&D expenditures is likely to be lower than that of patents, since it is an input measure from which a larger part of the benefit presumably spills over to other firms/sectors. Following this line of argument, we apply R&D expenditures for measuring what regards technological linkages between sectors, while we use US patent statistics for measuring the 'own sector' technological activity, since it is a more accurate proxy for proprietary knowledge. Accordingly, our measure of 'own sector' technological activity can be defined as

$$PAT_{ijt} = \ln(PAT_{ijt}/(\sum_j PAT_{ijt}/n)), \tag{2}$$

where PAT_{ijt} is the number of patents of country j, in sector i, at time t. It should be noted that we apply a three-year moving average for the patenting variable in order to avoid problems of small numbers, in particular with respect to the smaller countries in our sample. The downstream linkage variable can be defined as

$$DL_{ijt} = (\mathbf{y}_{iz}^{tj}/\mathbf{Y}_i^{tj})\mathbf{RD}_z^{tj} \quad \text{for} \quad i \neq z, \tag{3}$$

where $\mathbf{y}_{iz}^{tj}$ is a vector of deliveries of intermediates from the sector in question (sector i) to the other sectors (sector z) and $\mathbf{Y}_i^{tj}$ is a vector of total output at time t in country j. $\mathbf{RD}_z^{tj}$ is a vector of R&D expressed in fixed prices (deflated using the manufacturing price deflator)[5], a proxy for the technological competence of these sectors. In other words, the variable measures sector z's importance as a user of sector i's output.

[4] Note that our sample includes four-digit ISIC sectors for which no constant-price value added are available (pharmaceuticals, computers and office machines, electronics). For these sectors, we use the corresponding three-digit (implicit) price indices for calculating constant-price value added.

[5] Unfortunately the deflator for R&D expenditures is not available. Therefore, we have followed Braconier and Sjöholm (1998) in using the manufacturing price deflator.

Likewise for the upstream linkage variable:

$$UL_{ijt} = (\mathbf{y}_{zi}^{tj}/\mathbf{Y}_i^{tj})\mathbf{RD}_z^{tj} \quad \text{for} \quad i \neq z, \tag{4}$$

where $\mathbf{y}_{zi}^{tj}$ is a vector of the deliveries of intermediates to the sector in question.[6] Thus, the variable measures sector z's importance as a supplier to sector i. As with the other variables, the linkage variables are expressed in logarithmic differences from the country mean at any given time and sector (not shown for reasons of simplicity). All technology variables are in levels (they are not standardized by value added or employment). Our choice is motivated by the fact that the level reflects in a better way the technological content (or the quality) of the goods produced in the case of vertical product differentiation. In the case of horizontal product differentiation, the number of patents (or the level of R&D expenditures) can be a proxy for the number of varieties (Magnier and Toujas-Bernate 1994). In addition, most other contributions in the field, such as Amendola et al. (1993) and Amable and Verspagen (1995), also use the relative number of patents for explaining export market shares. The dependent variable is export market shares (*MS*) in fixed prices (deflated using sectoral value added deflators).

The patent data are taken from the United States Patent and Trademark Office (USPTO). 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 are 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 I-O data are not available on a yearly basis, the inclusion allows for the calculation of up- and downstream 'technology flows', based on 'real' economic transactions. Often, in this kind of study, the intensity of economic transactions between sectors is 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

[6] Rent spillovers have been calculated in a similar way by Braconier and Sjöholm (1998), using the same input-output tables. They found no effect of such national (nor international) spillovers on productivity.

structure of production differs. So this advantage has to be judged against the smaller number of observations and a number of missing values.

It can be argued that capital goods embody R&D to a larger extent than other types of goods. However, input-output matrices on capital formation suffer from a series of problems, including the lack of compatibility between countries and a (very) large number of missing values. Given those serious limitations, we use the matrices available on flows of intermediate products. As pointed out above, the I-O data are only available for five points in time. However, as we would like to estimate our model on a panel data basis, we make linear point-to-point interpolations of the I-O component of the variable. In this way we apply the I-O observations for the early 1970s and for the mid-1970s – as starting point and end point, respectively – over the four years in the period 1973–1976 (the I-O observations for the mid-1970s and the early 1980s to the years 1977–1980; the early 1980s and the mid-1980s to 1981–1984; the mid-1980s and 1990 to 1985–1988; and the I-O observation from 1990 applies to the years 1989–1991).[7] The model used in this paper is estimated for 19 years over the period 1973–1991.

Econometric Method

We adopt a dynamic specification of export market shares with an autoreggressive structure in the dependent variable. The autoregressive model should capture several cumulative mechanisms that reinforce the competitiveness of firms on international markets. Since there is consensus in trade literature on the persistence of countries' export market shares (Dixit 1989; Papagni 1992; Amendola et al. 1993; Giovannetti and Samiei 1996), this approach is preferred to other dynamic specifications that estimate adjustment equations (Magnier and Toujas-Bernate 1994; Amable and Verspagen 1995). Moreover, our dynamic specification allows comparing short- and long-run effects of the independent variables on market shares. This approach can be applied to stationary variables and has already been applied in a similar context by Amendola et al. (1993).

Inferences about the existence of a unit root in the series are drawn from the unit root test for dynamic panel data, suggested by Im et al.

[7] Out of the 45 possible input-output tables, five tables are missing in the OECD data. In those cases we made interpolations of the I-O relations for longer time periods than the 'normal' 3–4 years.

(1997).[8] Their test is based on the average of Augmented Dickey-Fuller (ADF) t-statistics computed for each time series in the panel. They show, in the presence of autocorrelation, that if a large enough order is chosen for the underlying ADF regressions, the finite sample performance of their *t*-bar test is reasonably satisfactory. We base our inferences about the existence of a unit root on ADF(3) tests. All the variables included in the estimation are expressed as ratios and it happens that they display stationary characteristics along the years considered. In particular, at the 5 per cent significance level the relevant critical values for the *t*-bar statistic are –1.502 for relative patents, –1.504 for relative exports, –1.513 for relative unit labour costs and –1.508 for relative upstream and downstream linkages.[9] The values of the ADF(3) statistic are –1.714 for relative exports, –1.564 for relative patents, –1.755 for relative unit labour costs, –1.650 for relative upstream linkages and –1.544 for relative downstream linkages. On the basis of this analysis, we can assume the series to be I(0).[10]

Adopting the autoreggresive representation on the variables described above, we obtain:

$$MS_{ijt} = \alpha_1 MS_{ijt-1} + \alpha_2 PAT_{ijt} + \alpha_3 ULC_{ijt} + \alpha_4 UL_{ijt} + \alpha_5 DL_{ijt} + \alpha_{6i} + \alpha_{7j} + e_{ijt}\,, \qquad (5)$$

where α_{6i} is a sector-specific effect, α_{7j} is a country-specific effect, e_{ijt} is the error term. This specification allows obtaining only indirect estimates of long-run multipliers; in order to obtain direct estimates we can reformulate (5) as follows:

$$MS_{ijt} = \beta_1 (MS_{ijt} - MS_{ijt-1}) + \beta_2 PAT_{ijt} + \beta_3 ULC_{ijt} + \beta_4 UL_{ijt} + \beta_5 DL_{ijt} + \beta_{6i} + \beta_{7j} + u_{ijt}\,, \qquad (6)$$

[8] The reason for choosing this test statistic is that Im et al. (1997) show that when errors are serially correlated and heterogeneous across groups, the condition required for the asymptotic validity of the t-bar test, $\sqrt{N/T}$, is weaker than that required by the panel unit root test proposed by Levin and Lin (1992; 1993). Moreover, the panel unit root test proposed by Quah (1994) does not allow for individual specific effects and different patterns of residual serial correlation.

[9] These values are calculated from Im et al. (1997: Table 2), with N = the number of non-missing cross-sections for each variable (171, 168, 148 and 159 for relative patents, exports, unit labour costs, and upstream and downstream linkages, respectively).

[10] In the case of R&D expenditures the value of the ADF(3) statistic is –1.413, while the critical value at 95 per cent with N = 170 is –1.503. On the basis of this test we cannot reject the hypothesis that R&D is I(1). This is another reason for including patents rather than R&D as a measure of 'own sector' technology.

where $\beta_1 = -\alpha_1/(1-\alpha_1)$, $u = e/(1-\alpha_1)$ and $\beta_i = \alpha_i/(1-\alpha_1)$ with $i = 2, 3, 4, 5, 6, 7$. In this equation, which can be obtained by deducting $\alpha_1 MS_{ijt}$ from each side of (5), the coefficients on the independent variables are the long-run multipliers. (5) is estimated by pooled least-squares with dummy variables for country and sector fixed-effects. (6) requires instrumental variables to be estimated. Applying an instrumental variable estimator to a reformulated equation such as (6), with the set of instruments given by all explanatory variables in the original equation, allows obtaining the same long-run estimates which can be computed indirectly from the OLS estimation of (5) (Wickens and Breusch 1987).

Sectoral Affiliation and Expectations

Each of the 19 sectors has 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 differs from it only in the case of 'industrial chemicals' and 'fabricated metal products'. Firms in the industrial chemicals sector both carry scale-intensive characteristics, but also some science-based characteristics. Firms in the fabricated metal products sector carry both supplier-dominated characteristics, but also some scale-intensive characteristics. In these cases we opted for the original Pavitt classification, as science-based and scale-intensive, respectively.

The a priori reasons for including 'food, drink and tobacco', 'petroleum refineries', and 'non-ferrous metals' 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 market shares. Thus high market shares in these sectors are 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. Two final sectors on the boundary, which should be mentioned, are 'electrical machinery' (classified as specialized suppliers, but has some science-based properties) and 'instruments' (classified as science-based, but has some specialized-suppliers properties).

To recapitulate from the above description of the Pavitt taxonomy, we expect internal technology to be most important for competitiveness in science-based sectors, while downstream linkages are expected to be more important in the case of specialized suppliers. For scale-intensive sectors, upstream intersectoral linkages should be of importance, while exports in supplier-dominated sectors are expected to depend on low unit labour costs and upstream linkages. In general we expect all parameters to have a positive sign, except for the parameter for unit labour costs.

Estimation

Table 1 reports the results of the estimation for each of the four Pavitt sectors. The dynamic specification allows estimating both the long-run and the short-run impact of each variable; the first is referred to as β and the second as α in Table 1. Autocorrelated error diagnostic is implemented via the Ljung and Box (LB) test for three-year lags. Estimated values of the LB are far below 7.82, the critical value of χ^2 with three degrees of freedom, at the 5 per cent level of significance.

Overall the results appear to be consistent with our expectations on the relative importance of the different factors of competitiveness in the different sectors. In particular the 'own' sector technology proxied by patents appears to play the largest role in science-based industries, unit labour costs in supplier-dominated industries, upstream linkages in scale-intensive and downstream linkages in specialized-supplier industries.[11]

It is worth observing that patents affect export shares not only in science-based industries but also in supplier-dominated and specialized-supplier industries. While the importance of patents in specialized-supplier industries is not surprising considering that some 'medium-tech' sectors are included in the category, its role in supplier-dominated sectors shows the growing importance of technology also in more traditional industries.

The cost variable plays the major role in supplier-dominated sectors. However, it is also significant in science-based industries. Nevertheless, in supplier-dominated sectors the numerical size of the parameter is relatively high, as compared to the other estimated parameters in the model. This finding is in accordance with what we expect. The negative impact of unit labour costs on export shares in science-based industries may be due to the fact that many firms in these industries are multinational enterprises, which make localization decisions in terms

[11] If we use R&D rather than patents as a measure of 'own' sector technology, we find this variable to be significant in specialized supplier- and scale-intensive type of industries. The largest coefficient is still found in science-based industries but the variable is not significant at conventional levels (Student's t = 1.330). The other findings are robust to the measure of technology used (the results are available upon request).

Table 1 – *Regression Results for Explaining Market Share Dynamics, Using a Pavitt Taxonomy Classification (No. obs. = 2,882)*

	Supplier-dominated		Science-based		Scale-intensive		Specialized suppliers	
	β	α	β	α	β	α	β	α
Unit labour costs								
Coefficient	−1.871	−0.103	−0.783	−0.035	−0.020	−0.001	0.248	0.044
t-value	−2.698	−3.587	−2.234	−2.884	−0.037	−0.037	1.643	1.454
Patents								
Coefficient	0.472	0.026	1.258	0.056	0.026	0.001	0.452	0.081
t-value	1.870	1.617	3.329	2.712	0.080	0.080	2.155	1.774
Upstream linkages								
Coefficient	−0.286	−0.016	0.246	0.011	0.615	0.034	0.023	0.004
t-value	−0.912	−0.984	1.139	1.264	2.110	2.145	0.117	0.118
Downstream linkages								
Coefficient	0.176	0.010	0.075	0.003	0.017	0.001	0.273	0.049
t-value	0.780	0.787	1.524	1.930	0.494	0.489	2.025	1.939
Lagged exports								
Coefficient		0.945		0.955		0.945		0.820
t-value		70.369		52.569		80.808		21.645
Adjusted R^2 (short run)	0.983							
Root MSE (short run)	0.188							
Root MSE (long run)	3.476							
Durbin-Watson	1.806							
Ljung and Box	4.844							

Note: Critical values are 2.58, 1.96, 1.64 at 1%, 5% and 10% levels of significance, respectively; α is the short-run estimate and β is the long-run estimate. MSE denotes the mean square error. The *t*-values are based on heteroscedasticity-consistent standard errors (using White's method). Country and sectoral fixed effects not printed for reasons of space.

of production partly based on cost considerations. The result for unit labour costs differs from that of Amendola et al. (1993), who only found such a relationship in the short run, while the effect appeared to be reabsorbed in the longer run. Apart from the fact that the analysis made by Amendola et al. (1993) is a (national level) macro model, we have also to consider that their dependent variable is export shares in current prices and we expect unit labour costs to affect negatively export quantities but positively export prices.

The upstream linkage variable appears to play an important role in affecting export shares in scale-intensive sectors. In can be noted that we expect upstream linkages (spillovers from other sectors) to be positive and significant also for supplier-dominated industries. This expectation is not supported by our results. However, it should be pointed out that the important vertical linkages for these sectors might in fact be international, rather than national as assumed in this paper. We leave the issue of the effect of international linkages on market share dynamics for future research. Downstream linkages have a positive impact on market shares in specialized-supplier industries. Hence this result supports the hypothesis that the existence of advanced (proxied by R&D content) home market users is conducive to export success for specialized suppliers in particular.

In order to investigate whether the Pavitt taxonomy performs better than the taxonomy based on the technological intensity of the sectors, we have also tested the model while distinguishing between high-, medium- and low-technology sectors.[12] The results of this analysis are reported in the Appendix Table A2. We find that unit labour costs have the largest impact in low-technology sectors (but they are significant in high-technology sectors as well) and patents the largest impact in high-technology sectors. Among the linkage variables only upstream linkages are significant in high-technology sectors. Overall it appears that the adoption of the Pavitt taxonomy is crucial for highlighting the impact of downstream linkages on export market shares; moreover the positive role of upstream linkages on export market shares is larger in the Pavitt taxonomy (in scale-intensive industries) than in high-technology sectors.

[12] The classification is taken from the OECD (1996). High-tech: aerospace, office machines and computers, communication equipment and semiconductors, electrical machinery, pharmaceuticals, instruments; medium-tech: industrial chemicals, rubber and plastics, non-ferrous metals, non-electrical machinery, motor vehicles, other transport; low-tech: food, drink and tobacco, textiles, footwear and leather, petroleum, stone, clay and glass, iron and steel, fabricated metal products, shipbuilding.

IV. Conclusions

This paper has explored the role of intersectoral linkages (or spillovers) in generating innovation and thus affecting export shares. We have found that R&D imported from other sectors through upstream and downstream linkages has a significant positive effect on international competitiveness in scale-intensive and specialized-supplier types of industries, respectively.

Overall, the results appear to be broadly consistent with our expectations on the relative importance of the different factors of competitiveness in the different sectors. In particular, unit labour costs appear to play the largest role in supplier-dominated industries, while 'own sector' technology (proxied by patents) plays the largest role in science-based industries. Upstream and downstream linkages are particularly important in determining market shares in those industries which have important linkages with the other industries (scale-intensive for upstream linkages and specialized suppliers for downstream linkages, respectively).

The importance of upstream-downstream interaction as a fertile environment for innovation and performance is central to the home market hypothesis and to the concept of national systems of innovation (Lundvall 1992). However, it should also be pointed out that while downstream linkages were found to matter for competitiveness in specialized-supplier types of industries, and upstream linkages for scale-intensive industries, such linkages do not matter equally for all sectors. It can be noted that the insignificant parameter for downstream and upstream linkages in science-based industries confirms the findings of Klevorick et al. (1995) and Laursen (1996), concluding that intersectoral linkages do no not seem to be of critical importance for science-based sectors more generally, and for pharmaceuticals in particular. In relation to theories of national systems of innovation we believe that research will gain from moving away from generic determinants of performance towards looking at several aspects of technological development (as done in a stylized way in this paper). Moreover, we believe that research should aim at increasingly producing empirically testable hypotheses focussing on the level and the character of the relevant knowledge flows in the system in question.

The results of this paper reconcile the different views on which dimension of technological development is the most important one in determining trade flows between countries. By showing that both direct technological effort and technological linkages are important in determining export shares and that their importance varies across sectors, our results are consistent with both the tradition that stresses the importance of knowledge developed in a particular sector for trade flows, and with the so-called home market hypothesis that points out how intersectoral linkages within a particular country determine trade flows from that country. In terms of policy implications the results also suggest the importance of sector-specific technology policies that take into account the relative importance of the different sources of innovation across sectors.

Appendix

Table A1 – *Sectors Used in the Analysis and Compared to Other Studies Applying the Pavitt Taxonomy*

		This paper	Pavitt (1984)	Amable and Verspagen (1995)	OECD (1992)	Laursen and Drejer (1999)
1	Food, drink and tobacco	SDOM	SCAI	SDOM	SDOM	SDOM
2	Textiles, footwear and leather	SDOM	SDOM	SDOM	SDOM	SDOM
3	Industrial chemicals	SCIB	SCIB	SCIB	SCAI	SCIB
4	Pharmaceuticals	SCIB	SCIB	SCIB	SCIB	SCIB
5	Petroleum refineries	SDOM	–	–	SDOM	SDOM
6	Rubber and plastics	SCAI	–	PROD	SCAI	SCAI
7	Stone, clay and glass	SCAI	SCAI	PROD	SCAI	SCAI
8	Ferrous metals	SCAI	SCAI	PROD	SCAI	SCAI
9	Non-ferrous metals	SDOM	SCAI	PROD	SDOM	SDOM
10	Fabricated metal products	SCAI	SCAI	PROD	SDOM	SCAI
11	Non-electrical machinery	SPEC	SPEC	PROD	SPEC	SPEC
12	Office machines and computers	SCIB	SCIB	SCIB	SCIB	SCIB
13	Electrical machinery	SPEC	SPEC	SCIB	SPEC	SPEC
14	Communic. eq. and semiconductors	SCIB	SCIB	SCIB	SCIB	SCIB
15	Shipbuilding	SCAI	SCAI	PROD	SCAI	SCAI
16	Other transport	SCAI	–	PROD	SCAI	SCAI
17	Motor vehicles	SCAI	SCAI	PROD	SCAI	SCAI
18	Aerospace	SCAI	–	SCIB	–	SCAI
19	Instruments	SCIB	SPEC	PROD	SCIB	SPEC

Note: SDOM = supplier-dominated; SCIB = science-based; SCAI = scale-intensive; SPEC = specialized suppliers; PROD = SCAI + SPEC.

Table A2 – *Regression Results for Explaining Market Share Dynamics, Using a Low/medium/high-Tech Classification (No. obs. = 2,882)*

	High technology		Medium technology		Low technology	
	β	α	β	α	β	α
Unit labour costs						
Coefficient	–0.666	–0.033	–0.467	–0.018	–1.913	–0.084
t-value	–2.069	–2.409	–0.598	–0.651	–2.591	–3.229
Patents						
Coefficient	0.741	0.037	0.548	0.021	0.024	0.001
t-value	2.093	1.843	1.103	0.980	0.071	0.071
Upstream linkages						
Coefficient	0.537	0.027	0.207	0.008	0.061	0.003
t-value	1.891	1.769	0.681	0.757	0.214	0.214
Downstream linkages						
Coefficient	0.063	0.003	0.003	0.000	–0.080	–0.003
t-value	1.345	1.209	0.031	0.031	–1.401	–1.396
Lagged exports						
Coefficient		0.950		0.961		0.956
t-value		75.591		68.614		95.006
Adjusted R^2 (short run)	0.983					
Root MSE (short run)	0.188					
Root MSE (long run)	4.356					
Durbin-Watson	1.814					
Ljung and Box	4.307					

Note: Critical values are 2.58, 1.96, 1.64 at 1%, 5% and 10% levels of significance, respectively; α is the short-run estimate and β is the long-run estimate. MSE denotes the mean square error. The *t*-values are based on heteroscedasticity-consistent standard errors (using White's method). Country and sectoral fixed effects not printed for reasons of space.

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Abstract: The Importance of Technology-Based Intersectoral Linkages for Market Share Dynamics. – The paper introduces technology-based intersectoral linkages (or technological spillovers) in an empirical model of international market share dynamics. The Pavitt taxonomy is applied as a yardstick for interpreting the empirical results. Overall, the results appear to be broadly consistent with the criteria behind the taxonomy, on the relative importance of the different factors of competitiveness in the different sectors. In particular, unit labour costs appear to play the largest role in supplier-dominated industries, 'own sector' technological activity plays the largest role in science-based industries, upstream linkages in scale-intensive and downstream linkages in specialized-supplier types of industries. JEL No. C33, F14, O31.

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Zusammenfassung: Die Bedeutung der technologiebestimmten intersektoralen Verflechtungen für die Dynamik internationaler Marktanteile. – Der Artikel führt technologiebestimmte intersektorale Verflechtungen in ein empirisches Modell zur Erklärung der Dynamik von Anteilsverschiebungen auf internationalen Märkten ein. Bei der Interpretation von empirischen Ergebnissen wird auf eine von Pavitt aufgestellte Klassifikation der Industriesektoren zurückgegriffen. Größtenteils entsprechen die Ergebnisse den Kriterien der Taxonomie, bei denen es um die relative Bedeutung verschiedener Faktoren für die Wettbewerbsfähigkeit der einzelnen Sektoren geht. Lohnstückkosten sind sehr bedeutsam für Sektoren, in denen meist kleine Firmen von der Lieferung von Anlagen und Zwischenfabrikaten stark abhängen; die eigenen technologischen Aktivitäten spielen die größte Rolle in Sektoren, die vom wissenschaftlichen Fortschritt abhängen; die vorgelagerten Industrien sind bedeutsam für Sektoren mit Massenfertigung; die nachgelagerten Industrien sind wichtig für Sektoren mit kleinen Firmen, die sich auf die Fertigung von Anlagen und Kontrollinstrumenten spezialisiert haben.