Research Policy 39 (2010) 687–697

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

The role of ICT knowledge flows for international market share dynamics

Keld Laursen[a], Valentina Meliciani[b,*]

[a] DRUID, Department of Innovation and Organizational Economics, Copenhagen Business School, Kilevej 14A, 2000 Frederiksberg, Denmark
[b] University of Teramo, Faculty of Political Sciences, viale F. Crucioli, 122, 64100 Teramo, Italy

ARTICLE INFO

Article history:
Received 27 February 2007
Received in revised form 1 February 2010
Accepted 2 February 2010
Available online 6 March 2010

JEL classification:
C23
F14
O31

Keywords:
ICT
Export shares
National knowledge flows
International knowledge flows
Bibliometric data

ABSTRACT

This paper investigates the role of Information and Communication Technologies (ICTs) related knowledge flows for international market shares. Using bibliometric data on scientific publications, we analyse the relationship between the strength of 14 OECD countries in four ICT-related scientific fields and the ability of those countries to maintain and acquire export market shares in the OECD market, across 16 manufacturing industries over the period 1981–2003. We find that domestic and foreign ICT-related scientific knowledge flows have a positive and significant impact on export market shares in ICT industries, while only domestic flows positively affect export shares in non-ICT industries. We also find that small open economies benefit more than other countries from foreign knowledge flows both in ICT and in non-ICT industries.

1. Introduction

International competitiveness is generally understood to refer to "the ability of a country to expand its [market] shares in domestic and world markets" (Magnier and Toujas-Bernate, 1994: 495, our insert in brackets). Such competitiveness of nations continues to be a concern for people working in academia (e.g., Leon-Ledesma, 2005) and for policy-makers (e.g., Obama and Biden, 2008). Even though many academic papers have been written about the drivers of international competitiveness, we still need to know much more about what determines it. Although few would deny the importance of standard price factors in affecting competitiveness or export market shares, there is an emerging consensus in the literature that non-price factors – particularly those related to technology – are a major determinant (e.g., Fagerberg, 1988; Amendola et al., 1993; Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Carlin et al., 2001; Montobbio, 2003). In general, studies that look at the technology factor have relied on "own-industry" technological activities, typically measured as research and development (R&D) spending or patenting activity.

Recently, attempts have been made to incorporate technological flows (or "spillovers")[1] in models of international market share dynamics either by looking at embodied R&D flows between industries (Fagerberg, 1997; Laursen and Meliciani, 2000; Laursen and Meliciani, 2002) or by estimating the effect of national and international knowledge stocks for trade performance (Gustavsson et al., 1999; Leon-Ledesma, 2005). Although there are not many papers looking at such flows, the ones that exist have generally found support for the idea that intra-industry and inter-industry domestic knowledge flows matter for international export market shares, while the support for the importance of international knowledge flows, in this context, is much more limited. However – to our knowledge – no paper exists which looks at the role of national and international ICT knowledge flows in determining competitiveness while attempting to trace actual interactions between countries. Information and Communication Technologies (ICTs) have become centrally important in many industries of the economy and have

* Corresponding author. Tel.: +39 065884069; fax: +39 065884069.
E-mail addresses: kl.ino@cbs.dk (K. Laursen), vmeliciani@unite.it (V. Meliciani).

[1] While spillovers – in this and other contexts – are difficult to distinguish empirically from knowledge flows (as they both involve science–industry transactions), in our view there are at least two conceptual differences. First, knowledge flows, as opposed to spillovers, do not necessarily involve externalities; and second, they are consistent with a two-way interaction between actors rather than involving the one-way transfer of technology from one actor to another. In this paper, we adopt the notion of knowledge flows.

0048-7333/$ – see front matter
doi:10.1016/j.respol.2010.02.007

a growing impact on the organisation of economic activity, due to the ample range of applications of the technologies. Moreover, in terms of types of technology diffused within and across nations, the ICT industries are the main sources of technology acquired in most developed countries (Papaconstantinou et al., 1998). However, capturing the importance and impacts of ICTs is always not straightforward (OECD, 2005). We combine research on the impact of technology on international economic performance with the bibliometric approach pertaining to the localized geographical reach of the benefits of scientific research (e.g., Jaffe et al., 1993; Hicks et al., 1994; Audretsch and Feldman, 1996; Agrawal and Cockburn, 2003).[2] More specifically, this paper is concerned with the importance of national and international science-based ICT knowledge flows for the ability of OECD countries to maintain or acquire export market shares at the industry level.

The basic idea is to use the science-production relevance matrix, constructed by Laursen and Salter (2005). Based on publications by private business firms, the relevance of four ICT-related scientific fields for 16 manufacturing industries is conjectured. The procedure hinges on the assumption that when firms in particular industries publish papers in particular fields of science then they do it – at least partly – because they have, and wish to maintain, an “absorptive capacity” in the relevant scientific fields. In other words, we assume that firms from an industry that publishes in some fields will make use of knowledge developed within the same fields. Using this relevance scheme, we analyse the relationship between the strength of 14 OECD countries in four ICT-related scientific fields and the ability of those countries to maintain and acquire export market shares in the OECD market, across 16 manufacturing industries over the period 1981–2003. Among other variables, unit labour costs, the exchange rate and “own industry” technological activity are controlled for, while using a dynamic panel data model. The data used for the study are drawn from the ISI National Indicators, SPRU BESST, US Patent Office and from the OECD STAN databases.

The idea of the present paper is not only to look at domestic sources of ICT-related knowledge, but also to try to assess the importance of international scientific knowledge flows in ICTs for the ability of OECD countries to maintain or acquire market shares at the 16 industry level. However, for calculating such flows of international scientific knowledge, country-level weights are needed in order to determine the importance of each country as a knowledge source to any of the other countries in the analysis. In this context we are using data on international co-publications in ICT fields of science across 23 partner countries. The key assumption here is that the more the scientists of a given country collaborate with scientists of another country, the more is drawn from the science-base of the foreign country.

The main findings of the paper support the important role played by both domestic and foreign ICT-knowledge flows for international market share dynamics. However, we also find that the importance of such flows varies across industries (ICT and non-ICT industries) and across countries. In particular, small open economies benefit significantly more than other countries from foreign knowledge flows.

The paper is structured as follows. Section 2 contains a discussion of the existing theoretical and empirical literature on the role of technology and ICT-related knowledge flows for competitiveness. Section 3 describes the data and the construction of the knowledge flow variables, while Section 4 depicts the empirical specification and econometric methodology. In Section 5 our estimations are presented and discussed. Finally, Section 6 concludes.

2. The role of ICT-related knowledge flows for international market shares

2.1. Theory

In the standard specification, the quantity of export demand is modelled as a function of three factors: the level of income in the importing region; the price of the imported good; and the price of domestic substitutes (Goldstein and Khan, 1978; Magnier and Toujas-Bernate, 1994; Leon-Ledesma, 2005). Accordingly, one would expect relative prices to be a central determinant. However, the well-known “Kaldor paradox” is based on the finding (Kaldor, 1978) that the fastest growing countries in terms of exports shares also experienced the highest rise in unit labour costs. Although later research (e.g., Magnier and Toujas-Bernate, 1994; Laursen and Meliciani, 2000; Carlin et al., 2001) has shown that unit labour costs can help explain export shares with the expected negative sign, relative prices – as proxied by unit labour costs – are far from being able to explain a lion share of countries export shares in most industries. In the standard literature, other non-price influences are lumped together in the income elasticises of imports and exports. Here, a higher than average income elasticity of exports implies that a country will benefit more than others from growth of world income.

The determinants of this elasticity may, however, be many (McCombie and Thirlwall, 1995), but common to most of them is that they are based on technological advantages as a result of investments in R&D. It may reflect the commodity composition of the vector of exports, as some industries experience higher than average demand growth, as income increases. In particular, high-tech products typically have a higher than average demand growth (Amable and Verspagen, 1995). In this paper, however, we focus on drivers of international export competitiveness at the industry-level, so we can discount this effect. More pertinent to this paper, the elasticity may also reflect the quality of the exported goods; either/or in terms of a higher reliability of the goods or in terms of the new and better features resulting from product innovations, so that countries with superior products gain market share over other countries. A supply-side explanation (Krugman, 1989, p. 1039) pertains to the possibility that fast growing countries expand their export market shares, not by reducing their relative prices, but by expanding the range of goods they produce as their economies grow. Although Krugman does not seriously endogenise product variety (it is assumed to be proportional to the labour force), it is likely to be a function of investments in innovation (Leon-Ledesma, 2005). All of these mechanisms suggest that a given country’s level of technology should affect the country’s market share in terms of gains or losses. As mentioned in the introduction to this paper, there is plenty of empirical support to back up this claim.

Recently, theoretical and empirical models have begun to incorporate international knowledge flows as determinants of export performance. Since technology can be nationally produced or available through international knowledge flows, the export demand function will also depend on the national and international stock of knowledge. Provided the arguments concerning the expected positive effect of national knowledge leading to increased exports, the impact of foreign knowledge is ambiguous (Leon-Ledesma, 2005). There is a negative effect: an increase in foreign knowledge increases the market share of foreign firms reducing national exports. However, there is also a positive effect: an increase in foreign knowledge may increase knowledge flows and may hence

[2] Note that although we look at science-based knowledge flows, based on scientific journal publication, this does not imply that all of this research is produced at universities. To be sure, employees of private firms often publish in scientific journals, also in the field of ICT (see, Rosenberg, 1990).

enhance exports through a higher reliability of the goods, new features or through an increased product variety of products produced at home. In other words, domestic firms may use knowledge initially produced abroad to enhance their own knowledge production, which should in turn, lead to higher exports.

In this paper, our aim is to analyse the specific effect of national and international science-based ICT knowledge flows on export competitiveness. As mentioned above ICT can be considered pervasive technologies (or General Purpose Technologies; GPTs), which may affect the organisation of production in all industries of the economy. For that reasons we will briefly discuss the properties of GPTs. One of the fundamental insights provided by Schumpeter (1939) is that technological innovations are not evenly distributed over countries, industries and time. Extending on this insight, neo-Schumpeterian authors, using a historical approach, introduced the concept of a *techno-economic paradigm* in the 1980s. The concept has been used to refer to a set of guiding principles, which become managerial and engineering common sense for each major phase of development (Freeman and Perez, 1988). A change in paradigm carries with it many clusters of radical and incremental innovations and has pervasive effects throughout the economy, spreading from the initial industries where it takes place to the whole economy. Such characteristics may be found in different waves of development in coal, steel, oil, and nowadays in microelectronics and telecommunications.

More recently, economists have made attempts to formalise the introduction and effects of pervasive technologies, under the label General Purpose Technologies (GPTs) (Bresnahan and Trajtenberg, 1995; Helpman, 1998; Aghion et al., 2002). GPTs are radical new ideas or techniques that have the potential for important impacts on many industries in an economy. Bresnahan and Trajtenberg identified three key characteristics of GPTs: pervasiveness (they are used as inputs by many downstream industries), technological dynamism (inherent potential for technical improvements), and “innovational complementarities” with other forms of advancement (meaning that the productivity of R&D in downstream industries increases as a consequence of innovation in the GPT).

The recent ICT “revolution” can be seen to be one such GPT, since today, computers and related equipment are used in most industries of the economy—if not directly incorporated into the products of ICT or non-ICT-industries. ICTs have also displayed a substantial level of technological dynamism spurring not only radical improvement in computational capacity (following Moore’s Law), but also a successive wave of new technologies (ranging from the semiconductor to the Internet). Moreover, ICTs have seriously facilitated new ways of organising firms, including the decentralisation of decision making, team production, etc. (Milgrom and Roberts, 1990; Brynjolfsson and Hitt, 2000; Bresnahan et al., 2002). Thereby ICTs have clearly exhibited innovational complementarities with other forms of advancement.

One of the main issues analysed within the GPT literature has to do with the attempt to understand why GPTs are most often – if not always – slow in fulfilling their potential for increasing economic performance. While the GPT literature arguably is focussed on general mismatches (such as the “Solow-paradox”) with respect to GPTs, the arguments can be extended to assist in explaining why some countries have more problems in adopting a GPT as compared to others, since the potential mismatches may be weaker or stronger from country to country. As a consequence, countries’ ability to achieve better than average economic performance, including growth in export market shares is likely to be linked to the extent to which they are able to produce and use ICTs. In particular – and despite the possibility of a countervailing negative effect of knowledge flows – we expect that domestic firms may use not only ICT knowledge produced at home, but also ICT knowledge produced abroad, to enhance their own knowledge production, which should in turn, lead to higher export market shares.[3]

2.2. Previous empirical findings

Within the “technology-gap” literature on international trade, Soete (1981) initiated the research tradition looking at the role of own-industry technology for market shares (“international competitiveness”). Subsequently, a substantial amount of contributions have provided more sophisticated econometric analyses on this issue, also in a dynamic context (e.g., Fagerberg, 1988; Amendola et al., 1993; Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Verspagen and Wakelin, 1997; Anderton, 1999; Carlin et al., 2001; Montobbio, 2003). As mentioned in the introduction, recent attempts have been made to also incorporate technological flows in models of market share dynamics either by looking at embodied R&D flows between industries or by estimating the effect of national and international knowledge stocks for trade performance.

Fagerberg (1997) examines the effect of domestic and foreign R&D on export market shares, in a pure cross-section (for the year 1985), using a combination of OECD input–output tables and R&D statistics. He finds that indirect R&D from domestic sources appears to be more conducive to competitiveness than indirect R&D from abroad. Gustavsson et al. (1999) examine the effect of within-industry national knowledge stocks and also include a variable reflecting the openness of the economy as a crude proxy for the countries’ ability to absorb foreign knowledge. They find a positive effect of both variables. Using input–output tables weighted by R&D intensity of the delivering industries, Laursen and Meliciani (2000) show that national inter-industry technological linkages are important for maintaining and acquiring market shares on the OECD market. Laursen and Meliciani (2002) use a similar approach to their earlier paper, but augment the input–output approach analysis with bilateral trade data, so they are able to measure “actual” international technological linkages based on observed (technology weighted) transactions. The main result is that while national linkages have a positive impact on the trade balance in several industries this is not the case for international linkages. Based on a country-level analysis using a panel of aggregate export data for 21 OECD countries Leon-Ledesma (2005) finds that the home stock of R&D always affect competitiveness positively. However, the foreign stock of knowledge affects exports positively for the less advanced countries in the sample and negatively for the G7 economies.

While these studies including knowledge flow variables in determining export market shares have been very helpful in increasing our knowledge of the determinants of competitiveness, they either do no include international knowledge flows (Laursen and Meliciani, 2000); depend on a single cross-section (Fagerberg, 1997); rely on a very rough proxy (Gustavsson et al., 1999); or use aggregate country-level data, ignoring important industry heterogeneity, while assuming that the knowledge produced in one country is equally relevant to the other countries, irrespective of how much the countries interact (Leon-Ledesma, 2005); or are based on trade flows and do not find any impact of foreign knowledge flows on international competitiveness (Laursen and Meliciani, 2002). Our strategy to overcome some of these problems in the literature is to focus on a much more specific set of knowledge flows—that is, those related to science-based ICT knowledge. Therefore our paper differs with the previous ones in at least two important dimensions: first it focuses on the

[3] As strongly emphasized in the literature, ICTs will also contribute to enhance firms’ productivity. In our setting this effect will at least partly be caught by our cost variable.

exchange of ideas (as captured by co-publications) rather than goods (as captured by trade flows) as a vehicle for the international transmission of knowledge and secondly it considers ICT-related international flows since these are expected to have a pervasive effect.

While there is a large literature of empirical analyses assessing the impact of ICTs on the level (or rate of growth) of total factor productivity (TFP), labour productivity and GDP (see for instance, Jorgenson and Stiroh, 2000; Bassanini and Scarpetta, 2002; van Ark and Timmer, 2005), for what concerns ICT and international trade, only a few studies are available. However, at the firm level – for the German service sector – Ebling and Janz (1999) show that (firm-level) investments in ICT is a determinant of the magnitude of innovative activities, which in turn is a central determinant of firms' export performance. At the country level, Guerrieri and Meliciani (2005) find that investment in ICT has a positive impact on export market shares in producer services. Also at the aggregate level, Meliciani (2002) shows that national specialisation in fast-growing technological fields (where ICTs – measured by patent statistics – are *the* fastest growing technologies) is positively associated with the rate of growth of export shares and negatively associated with the rate of growth of import shares. This may be taken as indirect evidence of the existence of national ICT-related knowledge flows. In this paper, we aim at estimating not only such knowledge flows more directly, but also at assessing how the contribution of ICT-related knowledge flows to international competitiveness may vary across ICT and non-ICT industries and across groups of countries.

3. The data and the knowledge flows variables

The bibliometric data used for the analysis are drawn from the ISI National Indicators ("Deluxe Version") and from the SPRU BESST database on UK publications (for more information on the BESST database, see Hicks and Katz, 1997). Based on the SPRU BESST database's data on the publishing activity by UK firms over the period 1981–1994, we conjecture the relevance of 4 ICT-related scientific fields (Robotics & Auto Control; Computer Science & Engineering; Electrical & Electronic Engineering; Information Technology & Communication Systems) for 16 manufacturing industries. As mentioned in the introduction, this procedure hinges on the assumption that if firms in particular industries publish papers in particular fields of science, then they – at least partly – do it because they have, and wish to maintain, an "absorptive capacity" in the relevant scientific fields. The ISI database contains publication data for 250 fields of science for 193 countries over the period 1981–2007. The economic data are taken from the OECD STAN database (the on-line version, 2008), while patent data are obtained from the US Patent Office. We use the data over the period 1981–2003 – the maximum number of years with relatively complete data for all datasets – and we use the information for 14 countries.[4]

As argued above, by exploring patterns of publications by firms in an individual industry, it is possible to understand how firms draw and exploit different pools of scientific knowledge. In this context, we use a science-production relevance matrix (or concordance table between scientific fields and manufacturing industries) constructed by Laursen and Salter (2005). They separated out the scientific publications of industrial firms in the UK research system over the period 1981–1994 (in one pool). For the analysis, they used 292 firms, each of which had at least 10 scientific publications. These firms were then divided into 17 industries (following the STAN classification),[5] drawing from an existing classification developed by Hicks and Katz (1997) and based on the Financial Times list of companies. For each firm, their main line of business was explored, using annual reports and business publications, and the firm was subsequently placed in the industry that best corresponded to its profile of production. 172 firms were classified according to this method. Those firms where information about their main line of business was unavailable were removed from the analysis. Since the BESST database does not exactly use the ISI classification of scientific disciplines, some disciplines had to be collapsed (aggregated) and we focussed on science and engineering (excluding social sciences and humanities). As a result, 77 scientific disciplines were considered. Out of these 77 disciplines, we focus in this paper on the 4 ICT-related scientific fields, and disregard the 73 other rows in the matrix. Each row in the matrix is a simple count of the number of publications (by firms) within each field of science for each of the different industries. The columns represent each of the 16 industries.

It is of course a critical assumption that UK firms share similarities with at least the other advanced countries in our sample. In renowned empirical studies of international trade (such as Bowen et al., 1987) it has been custom to assume the input–output tables obtained for a single country (the US) for all other countries as well, when calculating the factor content of the export vector of countries. We have followed a similar research strategy. Nevertheless, ideally, we would have liked to have based the science relevance matrix on all the advanced countries in the sample. However, the BESST – on which the matrix is based – data base covers the UK only. On the other hand, we have no reason to suspect that the scientific publication pattern of UK firms should be dramatically different from firms of other advanced countries. What we are postulating is that, if UK firms in office and computing machinery publish in the scientific fields "Computer Science, Software Engineering" and "Computer Science, Theory & Methods" then it is also likely that, say, German or US firms, within the same industry, will do the same. A piece of evidence somehow supporting this idea is provided by Patel and Pavitt (1997), and pertain to the fact that firms within the same industry display remarkably similar patent portfolios, irrespective of their nationality. The science-relevance matrix used in this paper (first used in a working paper, later published as Laursen and Salter, 2005) has been compared to another relevance matrix based on "expert opinion of relevance" in a paper by Arundel and Geuna (2004). The results obtained when using these two different matrixes are very similar in their set-up. Moreover, in our empirical analysis, the obtained results are not sensitive to the inclusion of the UK in the sample (in fact, in the results we report explicitly in this paper, the UK is not included, due to the lack of investment data—however, if we drop the investment variable and include the UK, the results are robust to this change in specification).[6]

In order to obtain the national relevant scientific strength, we calculate the share of publications by a given country (for a given year), in each of the 4 scientific fields from the ISI database and normalise the obtained vector by the total population of the given country. Subsequently, the resulting vector is multiplied (element-wise) by the relevance matrix (4 ICT-related fields of science $\times$ 16 industries). The variable is then calculated by adding up the 4 fields for each of the 16 industries. In this way we get a single figure for each country, industry and time, measuring the relevant national scientific strength in ICT-related fields for each industry, country

[4] The 14 countries are: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Netherlands, Italy, Japan, Spain, Sweden, Great Britain, United States.

[5] Due to data availability, we use only 16 of those industries in this paper.

[6] Results are available on request.

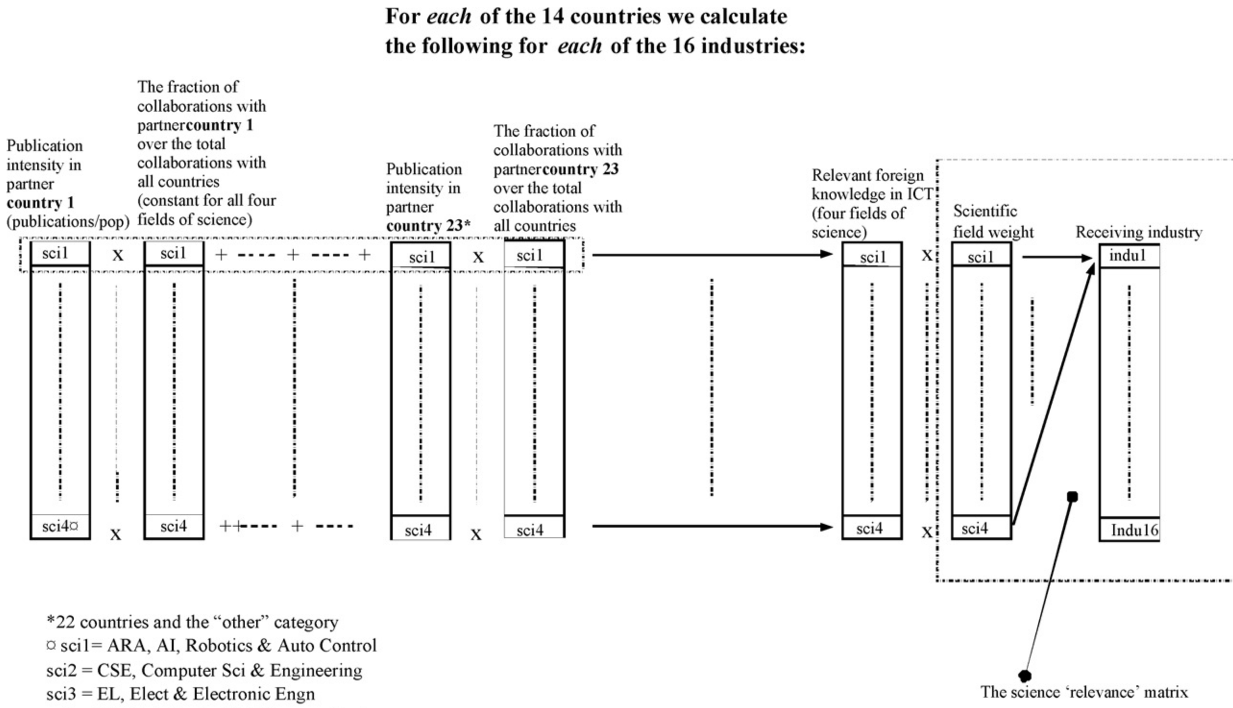

Fig. 1. Calculation of international flows of ICT knowledge.

and year ("Domestic ICT knowledge flows"; DICT):

$$DICT_{ijt} = \sum_{f=1}^{4} W_{fi}^{R} \frac{P_{jtf}}{POP_{jt}} \quad (1)$$

where W^R is the 4×16 science-production relevance matrix, P = publications, POP = population, i = industry, j = country, t = time and f = ICT field. In sum, the variable is constructed so that it will take higher values for each industry within a country in a certain year, the higher is the country's number of publications in ICT-related fields in that year and the more relevant is ICT knowledge to that industry (given by the science-production relevance matrix).

The calculation of the international ICT knowledge variable is illustrated in Fig. 1. For a given country, industry and year we perform the following operation: first, the publication intensity of each of the 23 partner countries in each of the 4 scientific fields is considered. This component is calculated as the number of publications by the partner country, in the given scientific fields, divided by the population size of the partner country. The obtained component is then weighted by the collaborations with the given partner country over the population size of the receiving country. In this context we are using data given by Tijssen and van Wijk (1998) on international co-publications in "computers and data processing" and in "telecommunications" for 1993–1996 across the 23 countries. We use Tijssen and van Wijk's category "computers and data processing" as a weight for "Robotics & Auto Control" and "Computer Science & Engineering", while we use Tijssen and van Wijk's category "telecommunications" to give weight to "Electrical & Electronic Engineering" and "Information Technology & Communication Systems". As stated earlier in this paper, the key assumption here is that the more the scientists of a given country collaborate with scientists of another country, the more is drawn from the science base of the foreign country.[7] The obtained figure is then subsequently added up for each of the four scientific fields, across the 23 partner countries. This vector, containing four elements is then in continuation hereof, weighted by the science-production relevance table described above. The international ICT knowledge flow variable is then finally – and analogues to the national ICT knowledge flow variable – calculated by adding up the 4 fields for each country, industry and time period. In this way, we get a single figure measuring the relevant international scientific strength in ICT-related fields for each industry, country and year ("Foreign ICT knowledge flows"; FICT):

$$FICT_{ijt} = \sum_{f=1}^{4} \sum_{k=1}^{23} W_{fi}^{R} W_{fkj}^{C} \frac{P_{ktf}}{POP_{kt}} \quad (2)$$

where W^R is the 4×16 science-production relevance matrix, W^C is the 23×23 international co-publications matrix (where each element is standardised by the population of the receiving country and where we consider all the 23 partner countries but only 14 receiving countries)[8] P = publications, POP = population, i = industry, j = receiving country, k = partner country, t = time and f = ICT field. In sum, the variable is constructed so that it will take higher values for each industry within a country in a certain year when the most important international collaborators are citizens of countries with a high number of scientific publications per capita in the relevant ICT scientific fields (to the particular industry, given by the relevance matrix), and when the receiving country is more

[7] In Tijssen and van Wijk (1998), the ICT co-publications data are only broken down on all the 23 countries in one dimension. We have obtained the 23×23 matrix on co-publications directly from Robert Tijssen of the University of Leiden, The Netherlands. For more details of the ICT co-publications data see Tijssen and van Wijk (1999).

[8] As already stated above the international co-publication matrix of Tijssen and van Wijk has only two ICT fields ("Computers and data processing" and "Telecommunications"); in our setting each of these two fields is repeated twice since the category "Computers and data processing" is used to give weight to "Robotics & Auto Control" and to "Computer Science & Engineering", and the category "Telecommunications" to give weight to "Electrical & Electronic Engineering" and to "Information Technology & Communication Systems".

Table 1
Science-based ICT knowledge flows. Averages across time, 1981–2003.

Country—av. across industries	DICT	FICT	Industry—av. across countries	DICT	FICT
Austria	0.90	0.21	Food, beverage and tobacco	0.01	0.00
Belgium	1.75	0.39	Industrial chemicals	0.08	0.02
Canada	2.84	0.52	Pharmaceuticals	0.02	0.00
Denmark	1.27	0.57	Petroleum refineries	0.24	0.05
Finland	1.82	0.51	Rubber and plastic products	0.86	0.18
France	1.28	0.27	Non-metallic mineral products	0.21	0.04
Germany	1.13	0.20	Basic metals	0.32	0.07
Italy	0.99	0.26	Fabricated metal products	0.64	0.13
Japan	1.63	0.10	Non-electrical machinery	2.75	0.57
Netherlands	1.74	0.48	Office and computing machinery	3.54	0.71
Spain	0.49	0.07	Electrical machinery	3.79	0.79
Sweden	1.96	0.70	Communication eq. and semiconductors	7.28	1.51
Great Britain	2.49	0.27	Other transport equipment	1.60	0.33
USA	2.73	0.17	Motor vehicles	2.26	0.45
			Aerospace	2.39	0.49
			Instruments	0.32	0.07

Note: The figures can be compared across countries only; the relative size of DICT vis-à-vis FICT is not comparable.

"open" to international collaboration (it has a higher number of co-publications in that field).

Table 1 displays the average values of the domestic scientific ICT knowledge flows (DICT) and the foreign scientific ICT knowledge flows (FICT) in the country (average over time and industries) and in the industry (average across time and countries) dimensions. Not surprisingly, we find that in the country dimension the US, Canada and Great Britain are by far the strongest "producers" of domestic scientific ICT knowledge flows, while Spain is by far the weakest producer. Also Austria and Italy perform relatively poorly in creating domestic ICT knowledge flows—a result that is in agreement with "conventional wisdom". The Nordic countries (Sweden, Denmark and Finland) and Canada receive the highest level of foreign scientific ICT knowledge, followed by the Netherlands, while some of the largest producers of domestic knowledge flows such as Japan and the US receive little in terms of foreign knowledge flows. Italy, Austria and Spain are not only poor in producing domestic knowledge flows, but also in receiving foreign knowledge, indicating that some domestic effort is a prerequisite also for being able to capture international knowledge flows.

With respect to the industry dimension we find, predictably, that industries that typically produce ICT goods (office and computing machinery; electrical machinery; communication equipment and semiconductors) receive very high levels of scientific domestic and foreign knowledge flows. This is also the case for industries that are typically users of ICTs (but with somewhat lower values as compared to the values for the ICT producing industries), including Non-electrical machinery; other transport equipment; motor vehicles; and aerospace.

In order to trace the country of origin of the foreign scientific knowledge flow variable (FICT), displayed in Table 1, we present a matrix in Table 2, where we disentangle the country sources (23 countries of origin) of the "industry relevant" scientific ICT knowledge flows for each of our 14 countries in the sample (average across time and industries). From the table (the figures have been normalised so that the values in the table range from 0 to 100) it can be seen – again not surprisingly – that the US is the single most important source of international scientific ICT knowledge flows for the 14 countries in the sample, followed by Great Britain. Other larger countries, including Germany, France and Canada are important sources as well. Switzerland is also a relatively important source—in particular to Germany. The largest recipients of foreign knowledge flows tend to be, as expected, mostly small open economies and, in particular the Nordic countries (Sweden, Denmark and Finland) and the Netherlands, but also Canada does well in this regard. The table is also evidence of the importance of geography, since countries with close geographical proximity, typically transmit and receive a disproportionate amount of knowledge from each other: for instance, Germany transmits a high level of scientific ICT knowledge to Austria and the Netherlands, while two of the most important receivers of Swedish scientific ICT knowledge are Denmark and Finland.

4. Hypotheses and econometric methodology

In order to capture several cumulative mechanisms that reinforce the competitiveness of firms in international markets, we estimate a dynamic model with an autoregressive structure in the dependent variable (as in, Amendola et al., 1993; Greenaway et al., 1998; Laursen and Meliciani, 2000; Laursen and Meliciani, 2002; Santos-Paulino and Thirlwall, 2004).

Together with national and international ICT knowledge flows, as it is standard in technology-based theories of trade, we explain export market shares with price and technology variables. In addition to being common in the literature (see the literature review in Section 2.2 above), the preference for using this dependent variable (rather than, for instance, the value of exports) depends on both econometric and conceptual considerations. From an econometric point of view, exports normally grow over time (as world income does) and a variable measuring exports in absolute terms is very likely to be a non-stationary variable. By definition, an export market share variable is very unlikely to be non-stationary. Secondly, an equation with relative exports has a straightforward evolutionary interpretation as a selection equation: when a country is better in terms of cost and technology competitiveness relatively to its counterparts, it will increase its exports more than the counterparts (for a formal representation, see Amendola et al., 1993). As proxies of technological differences across countries, we use patents and investment, while as proxies of price factors we use unit labour costs and the exchange rate. Finally, we introduce population in order to control for differences in countries' size. Adopting the autoregressive representation on the variables we obtain:

$$EXP_{ijt} = \alpha_0+\alpha_1 EXP_{ij,t-1}+\alpha_2 ULC_{ijt}+\alpha_3 DICT_{ijt} + \alpha_4 FICT_{ijt} + \alpha_5 PAT_{ijt} + \alpha_6 POP_{jt} + \alpha_7 INV_{ijt} + \alpha_8 EXCH_{jt} + \mu_j + \mu_t + v_{ijt} \quad (3)$$

where EXP_{ijt} is export market shares in current prices and exchange rates of country j in industry i, at time t; ULC is unit labour costs (wages per worker in current prices, divided by labour productivity)[9]; $DICT$ is domestic ICT knowledge flows; $FICT$ is for-

[9] Labour productivity is value added at constant prices per worker. Value added at constant prices was obtained by calculating price deflators at the industry level

Table 2
Inter-country science-based ICT knowledge flows. Averages across time and industries.

Generator	Recipient														Row sum
	AUT	BEL	CAN	DEN	FIN	FRA	DEU	ITA	JPN	NLD	ESP	SWE	GBR	USA	
Australia	0.7	1.7	3.1	3.7	0.0	0.4	0.7	0.4	0.5	0.7	0.1	2.6	2.7	1.3	18.5
Austria (AUT)	0.0	0.0	0.1	0.2	0.2	0.3	0.8	0.1	0.0	0.5	0.0	0.1	0.2	0.3	3.1
Belgium (BEL)	0.0	0.0	0.8	5.0	5.9	2.2	0.9	0.9	0.1	9.3	1.0	4.0	2.2	0.8	33.3
Canada (CAN)	1.8	3.9	0.0	5.3	15.5	5.8	2.1	2.8	3.4	2.9	0.5	6.5	6.0	11.4	67.8
Denmark (DEN)	0.2	1.9	0.4	0.0	3.5	0.9	0.4	0.6	0.1	3.0	0.1	4.8	1.4	0.4	17.8
Finland (FIN)	0.3	3.1	1.6	4.8	0.0	0.6	0.6	0.5	0.5	2.4	0.1	6.0	1.2	0.5	22.3
France (FRA	3.6	9.9	5.1	11.5	5.1	0.0	4.1	4.9	0.7	5.9	1.9	19.0	5.7	2.9	80.2
Germany (DEU)	10.7	4.6	2.2	5.8	6.3	4.7	0.0	4.5	1.0	8.9	0.8	9.5	4.9	2.8	66.7
Greece	0.2	1.3	1.5	2.7	2.7	1.1	0.7	0.8	0.0	2.0	0.3	1.1	1.0	0.6	16.1
Italy (ITA)	0.9	2.9	1.8	4.9	3.0	3.5	2.8	0.0	0.3	5.2	1.2	16.5	2.1	2.4	47.7
Japan (JPN	1.3	1.5	8.0	3.7	10.2	1.7	2.4	1.3	0.0	3.0	0.4	4.5	2.1	4.7	44.6
Korea	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.2	1.1	2.1
Netherlands (NLD)	2.0	14.1	0.9	12.3	7.1	2.1	2.7	2.6	0.4	0.0	0.4	7.4	4.3	1.9	58.1
Portugal	0.1	0.3	0.1	1.0	0.2	0.2	0.1	0.1	0.0	0.3	0.0	0.1	0.3	0.0	2.9
Spain (ESP)	0.1	1.1	0.1	0.2	0.1	0.5	0.2	0.4	0.0	0.3	0.0	0.3	0.4	0.3	4.0
Sweden (SWE)	0.3	3.9	1.3	12.8	11.2	4.2	1.8	5.0	0.4	4.5	0.3	0.0	3.7	1.4	50.7
Great Britain (GBR)	4.5	18.2	9.9	30.3	19.6	10.6	7.9	5.4	1.5	22.7	2.8	31.0	0.0	5.7	170.3
USA (USA)	34.2	37.3	100.0	48.3	42.0	28.6	23.6	33.5	18.0	52.5	11.7	63.6	30.2	0.0	523.7
Ireland	0.2	2.1	0.1	7.3	5.7	0.4	0.1	0.1	0.0	0.7	0.0	3.8	1.7	0.1	22.3
Luxembourg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Switzerland	2.2	3.9	3.0	4.5	4.9	7.8	8.0	11.0	1.4	11.2	0.4	22.4	6.1	3.2	90.2
Singapore	0.0	3.6	3.3	0.0	5.8	0.5	0.0	0.1	1.2	0.4	0.0	2.4	2.8	2.3	22.5
Taiwan	0.0	0.4	0.9	0.0	0.9	0.4	0.7	1.6	0.1	0.9	0.0	0.5	0.5	3.9	10.8
Column sum	63.3	115.9	144.6	164.5	150.1	76.7	60.8	76.8	30.1	137.3	22.1	206.1	79.4	48.0	

Note: Figures have been normalised, so that the highest possible value is 100.

eign ICT knowledge flows; PAT_{ijt} is patents (registered at the US patent office) over population[10]; POP_{jt} is population of a given country; INV_{ijt} is investment per employee; $EXCH_{jt}$ is the dollar exchange rate and $\mu_j + \mu_t + \nu_{ijt}$ is the error term where μ_j and μ_t are the country and time specific residuals respectively. All variables are divided by the average value for all countries in the sample (for each industry and time period) and are expressed in logarithms.[11]

When an estimated coefficient in our model obtains a positive sign (as we expect in the majority of cases) this implies that when the country increases (decreases) its relative technology (knowledge flows, investment, etc.) in a given industry, the country increases (decreases) its market share in that industry. Obviously, the logic is reversed in the case of a negative sign. As it is standard in the literature, we expect unit labour costs to have a negative impact on export share dynamics (although this effect could be null considering that the dependent variable is expressed in current prices), the exchange rate can have a positive or negative effect on export shares depending on whether the impact on prices prevails over the impact on quantities or vice-versa; technology variables (both patents and investment) should positively affect export shares; while we have no a priori expectations for the impact of the size of the country on the dynamics of export shares.

The novelty of the paper lies in introducing the domestic and foreign ICT knowledge flows in the export share equation. As explained in Section 2, we expect these variables to positively affect international competitiveness by increasing ICT knowledge from domestic scientific effort and from international scientific collaborations (despite the possibility of a countervailing negative effect). Moreover, ICT flows may affect export shares also via a decrease in prices and this effect should be captured by our unit labour cost variable. It can also be noted that what we capture with the ICT knowledge flow variables are "additionality effects" as we control for own-industry innovative activities using a variable based on patent data (including ICT-related patents).

Instead of assuming constant impacts for all industries and all countries it may also be useful to distinguish groups of countries and industries (Castellacci, 2009). First, it may be important to distinguish groups of industries, as the impact of ICT knowledge flows on the higher reliability of the country's goods, new features or through an increased product variety of products produced within the country should be expected to be much higher for firms in industries that produce ICTs, rather than primarily using them. In other words, science-based ICT knowledge flows are expected to affect competitiveness much more strongly in ICT industries than in other industries. In order to define ICT industries we have adopted the OECD classification (in 1998, OECD member countries agreed on a common definition of the ICT sector, see, OECD, 2002), but since the OECD classification is based on a more detailed level of disaggregation (four digit ISIC Rev. 3) than the one used in this paper, we define an industry as being ICT, when it includes a sub-industry that is classified by the OECD as being ICT. Thus, we give the following definition of ICT industries: "office and computing machinery"; "electrical machinery"; "communication equipment and semiconductors" and "instruments".

Second, since we aim at distinguishing between the importance of national vis-à-vis international knowledge flows as well, the size and openness of the country may play a role. In particular, the ability to exploit foreign knowledge flows to gain market shares may depend on the degree of openness of the country (that is generally higher for small economies), while no such effect should be found for domestic flows. To test this hypothesis we will allow the coefficients on domestic and foreign knowledge flows to vary for small open economies. Based on both the size of the country (a population below 20 millions inhabitants) and the degree of scientific open-

from information on the volume of value added taken from the STAN database. For some industries where we did not have the information on volumes we calculated price deflators at a higher level of aggregation.

[10] We apply a three years moving average for the patenting variable in order to avoid problems of small numbers.

[11] The purpose of the empirical analysis is to explain export market shares (absolute advantages) for each industry and time period. These are defined as: $EXP_{ijt}/\sum_{j=1}^{n} EXP_{ijt}$, but we standardize exports by all countries' average $EXP_{ijt}/\sum_{j=1}^{n}(EXP_{ijt})/n$, rather than all the countries' sum to obtain symmetry with the cost variable (where the sum would make no sense). For the same reason, we standardize the other variables as well in a similar fashion. This is common in the literature (Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Laursen and Meliciani, 2000).

ness (as measured by the relevance of foreign knowledge flows, see Table 2) the group of small open economies includes Sweden, Denmark, Finland and the Netherlands (we also perform robustness checks by excluding the Netherlands from the group).

In equation (3), since EXP_{ijt} is a function of μ_j, so is $EXP_{ij,t-1}$ and this renders the Ordinary Least Squares (OLS) estimator biased and inconsistent. The fixed effects (FE) estimator eliminates μ_j but will be biased for short time-series since $EXP_{ij,t-1}$ will be correlated with the FE-transformed residual by construction. Due to the short time-series of our sample (23 years) we therefore adopt the Blundell–Bond (BB) Generalised Method of Moments (GMM) estimator, that gives consistent estimates provided that there is no second order serial correlation among the errors, and we report tests for first and second order autocorrelation. This GMM specification is preferred to the original Arellano–Bond estimator due to the high persistence in the series (see, Blundell and Bond, 1998). We estimate a robust version of BB with heteroscedastic errors and we assume, as it is standard in this literature, exogeneity of all explanatory variables. The exogeneity of relative prices is a common hypothesis in estimating export equations and is based on the idea that the export supply price elasticities facing any individual country are infinite. Technology variables are assumed to be exogenous since they should capture structural characteristics that may respond only very slowly to changes in export shares.

5. Estimation results

Table 3 reports the results of the estimation of Eq. (3). As stated above, we distinguish between "ICT industries" and "non-ICT industries" and we report both short and long run coefficients. Moreover, we report results for a specification with lags of the knowledge flow variables and for a specification where we allow the coefficients on domestic and foreign knowledge flows to vary for small open economies (SOE). The reason why we think that the results make sense, also without a lag, is that the ICT publications and co-publications reflect technological activity that is on-going (often long) before the publication in the field of ICT is published in scientific journals.

From the table we can see that both cost and technology variables play an important role in affecting countries' export shares. There are, however, differences across ICT and non-ICT industries in the performance of these variables. In particular, the unit labour cost variable is significant in ICT industries only. This is somewhat surprising since these tend to be industries with higher technology intensities, and costs have generally proved to be important in low technology industries as well (see for example, Amable and Verspagen, 1995; Laursen and Meliciani, 2000). However, non-ICT fields are very heterogeneous in terms of technological intensity and this may explain why unit labour costs, although showing a negative coefficient as expected, are non-significant.[12] Among technology variables, patents perform well only in ICT industries, while fixed investment has a significant positive impact on export shares in non-ICT industries only. In ICT sectors fixed investment has a negative impact on the dynamics of export shares. This may depend on the fact that in this group of industries (where patents are a better proxy of technology) less capital intensive industries (countries) perform better in terms of international competitiveness. The size of the country has a positive impact on the dynamics of export shares only in ICT industries, while the exchange rate shows up being consistently significant with a positive coefficient, indicating that the price effect prevails over the impact on quantities (this is not surprising since we are capturing the contemporaneous effect).

The main contribution of this paper has to do with the introduction of the ICT knowledge flow variables in the market share dynamics literature. In this context, the results mostly confirm our expectations. First – and as expected – knowledge flows from a domestic ICT science base appear to be important for ICT industries. In other words, it seems that having a strong national science-base in ICT is a precondition for achieving international competitiveness in these industries. This result is consistent with the view that through ICT knowledge flows new goods are generated and traded and the quality of existing goods is increased. Moreover, knowledge flows from international collaborations in ICT have a positive and significant impact on export market shares in ICT industries as well. Since there are some countries that are at the frontier in the development of ICT (e.g. the USA and, in Europe, the UK), co-operation in ICT-related fields with scientists of these countries can be an important source of international diffusion of ICT competencies—indeed, this channel of diffusion seems to be at work in ICT industries. Allowing for time lags the results for ICT-related industries continue to show the importance of domestic and international ICT knowledge flows for market share dynamics with the best results being obtained when allowing for a 3-year time lag.

Turning to non-ICT industries, only domestic ICT knowledge flows are significant. This result also holds when we allow for time lags—with the best results being obtained when allowing for a 4-year time lag. The positive impact of domestic ICT knowledge flows on export market shares also in non-ICT industries supports the view that ICTs are pervasive technologies, and therefore, they do not affect only the industries that are producing ICT goods, but also other industries; probably through increases in product quality and/or increases in goods' tradability. The result that foreign knowledge flows do not affect export market shares in non-ICT industries may depend on the fact that international scientific co-operation is more important for "radical" innovations leading to the generation of new goods (and this channel mainly works in generating exports in ICT producing industries). It is also possible that, since we are analysing a very heterogeneous group of countries with very different levels of ICT co-operations, the results hide different behaviours across economies.

The last set of estimations (reported in Table 3) allows for the coefficient of domestic and foreign knowledge flows to vary for small open economies (Finland, Sweden, Denmark, and the Netherlands), for both ICT and non-ICT industries. We find that, while the coefficient of domestic ICT knowledge flows is not significantly different in small open economies, the coefficient on foreign ICT knowledge flows is significantly higher for SOE both in ICT and in non-ICT industries. Moreover, while for the entire sample foreign ICT knowledge flows are not significant in non-ICT industries they are significant for SOE (the coefficient is 2.314 significant at 5%). It can be noted that the results are robust to removing the Netherlands (the largest of these economies in terms of population) from the group of SOE.

These findings are largely in line with the results found on the impact of ICT on productivity and growth, emphasising how the importance of ICT varies substantially across countries. In particular, small countries with high levels of international scientific co-operations in ICT fields seem to have been able to benefit from international ICT-related knowledge flows, thereby maintaining or gaining export market shares also in non-ICT industries—in addition to the "usual" positive effect for ICT industries.

[12] If we split non-ICT sectors into low (food, beverages and tobacco; petroleum; non-metallic mineral products; basic metals; other transport equipment), medium (rubber and plastic products; metal products; machinery and equipment; motor vehicles) and high (chemicals; drugs and medicines; aircraft) technology we find that unit labour costs have a significant negative coefficient (−0.121) in low technology sectors only. These results are available on request.

Table 3
Regression results using the Blundell–Bond estimator: explaining international market share dynamics for ICT and non-ICT industries.

	All industries		ICT Industries		Non-ICT Industries		ICT	Non-ICT	ICT	Non-ICT
	Short-run	Long-run	Short-run	Long-run	Short-run	Long-run	Lags	Lags	Interaction	Interaction
Lagged exports										
Coefficient	0.641***		0.408***		0.720***		0.378***	0.697***	0.419***	0.636***
z-Value	9.81		9.76		11.60		88.61	11.82	9.82	9.32
Unit labour costs										
Coefficient	−0.161***	−0.448***	−0.252***	−0.426***	−0.029	−0.104	−0.267***	−0.050	−0.260***	−0.022
z-Value	−3.61	−3.68	−2.59	−2.45	−0.60	−0.59	−2.80	−1.27	−2.62	−0.42
Domestic ICT knowledge flows										
Coefficient	0.067**	0.187**	0.115*	0.194	0.054*	0.192*	0.088*	0.088***	0.166**	−0.004
z-Value	1.97	1.99	1.61	1.51	1.72	1.61	1.71	2.74	2.24	−0.08
Domestic ICT know. flows SOE										
Coefficient									−0.164	0.060
z-Value									−1.32	0.73
Foreign ICT knowledge flows										
Coefficient	0.146	0.407	0.531**	0.898**	0.117	0.420	0.598**	0.011	0.467***	0.144
z-Value	0.90	1.00	2.28	2.16	0.88	0.98	2.32	0.06	3.01	0.83
Foreign ICT know. flows SOE										
Coefficient									2.875***	2.171*
z-Value									4.06	1.81
Patents over population										
Coefficient	0.053*	0.149*	0.119*	0.201*	0.001	0.002	0.140**	0.024	0.105***	−0.055**
z-Value	1.60	1.60	1.74	1.79	0.02	0.02	1.96	0.58	2.44	−1.99
Population										
Coefficient	0.280	0.782*	0.674***	1.139***	0.123	0.440	0.736***	0.091	0.618***	0.042
z-Value	1.48	1.91	5.18	4.77	0.68	0.78	5.48	0.42	5.28	0.20
Investment per employee										
Coefficient	−0.015	−0.042	−0.093**	−0.157**	0.050***	0.179***	−0.087*	0.047***	−0.059	0.035
z-Value	−0.72	−0.68	−2.10	−2.15	2.81	3.04	−1.80	2.88	−1.97	1.51
Exchange rate										
Coefficient	0.293***	0.817***	0.590***	0.997***	0.216***	0.774**	0.580***	0.140**	0.635***	0.267***
z-Value	3.04	2.52	9.59	6.89	2.71	2.19	9.40	2.11	12.14	2.70
Number of observations	1851		386		1465		364	1332	386	1465
Wald X^2	3881***		172,276***		5176***		53,920***	5143***	7,920,000***	3565***
AR (1)	−4.29***		−2.88***		−4.10***		−3.24***	−3.78***	−2.76***	−3.78***
AR (2)	1.57		1.42		1.19		1.37	−0.01	1.49	1.22

Notes: Lagged estimates are based respectively on 3 (4) years lags of domestic and foreign knowledge flows in ICT (non-ICT) sectors. Interaction estimates allow the coefficient on domestic and foreign knowledge flows to vary for small open economies (SOE) (the estimated coefficient is the difference between the coefficient for other countries and that for SOE). Time dummies included but coefficients not reported. The *t*-values are based on heteroscedasticity consistent standard errors (using White's method). AR (1) and AR (2) are Arellano–Bond tests that average autocovariance in residuals of respectively order 1 and 2 are zero. Tests for multicollinearity suggest that independent variables are not collinear (all variance inflation factors (VIF) below 10, mean VIF = 2.21). Tests for intercept and slope homogeneity between ICT and non-ICT sectors indicate significant differences (the Wald X^2-tests of homogeneity are respectively 80.94 for intercepts and 41.40 for slopes and reject homogeneity at 1%).

* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.

6. Conclusion

This paper has focussed on the impact of ICT-related knowledge flows on international competitiveness. The main result of the paper is that such flows – both domestic and international – have a positive and significant impact on export shares in ICT-producing manufacturing industries. In other words, the positive effect of international knowledge flows seems to dominate in this case. When considering non-ICT industries domestic flows continue to have a significant impact on export shares, while international flows affect export shares only in a sub-set of countries (small open economies).

Overall, our results are consistent with those of previous empirical analyses on the determinants of export shares that highlight the crucial role of both cost and technology advantages (Fagerberg, 1988; Greenhalgh, 1990; Magnier and Toujas-Bernate, 1994; Amable and Verspagen, 1995; Anderton, 1999; Carlin et al., 2001). In this tradition, however, only few papers exist, examining knowledge flows at an industry level. At this level, Laursen and Meliciani (2000) found that (trade-related) embodied technological domestic upstream and downstream knowledge flows play a positive and significant role on export shares in some industries (scale intensive and specialised supplier industries), while Laursen and Meliciani (2002) found that (also trade-related) embodied foreign knowledge flows do not play a significant role on bilateral trade in most industries. The results of this paper complement the previous results.

In fact, it seems that when we focus the attention on scientific disembodied knowledge flows and, in particular on ICT based knowledge flows, domestic knowledge flows appear to play an important role for export success in both ICT and non-ICT industries. Moreover, in contrast to the previous research (Laursen and Meliciani, 2002), we find that international science-based knowledge flows also play a role in determining market share dynamics—in particular in ICT industries. This may depend on the fact that we are considering scientific rather than trade related knowledge flows (knowledge flows directly based on the exchange of ideas rather than on trading goods) and that this might be a better vehicle for the international diffusion of knowledge, particularly for small open countries that have invested in establishing international networks in ICT-related fields. Related, while previous studies have looked at knowledge flows broadly, in this paper, we have focussed on a specific set of knowledge flows—a set of flows that from a theoretical point of view should have pervasive effects across industries and countries.

Our findings concerning the importance of national and international knowledge flows as a result of the presence of a strong and ICT relevant national science-base, or the capability to develop international research networks in ICT-related fields, has important implications. First, in the context of trade performance, it appears that ICT is a pervasive technology, as domestic ICT flows have a positive impact on export market shares, not only in ICT producing industries, but also when considering all industries together. Second, the potential pervasive benefits linked to these technologies vary substantially across countries, consistent with the view of the crucial role played by the match between pervasive technologies and specific institutions that facilitate or hinder their diffusion (Freeman and Perez, 1988; Bresnahan and Trajtenberg, 1995). It is true – as previous studies on the impact of GPTs on productivity have shown – that the potential of the impact of the new technologies on international competitiveness may not have been fully realised yet. However, this study has shown that most larger European countries (with UK as the exception) have displayed a limited effort in performing scientific research in ICT-related fields as compared to the efforts made in the US, Canada and in Japan (see also, Dosi et al., 2006). The results of the paper suggest that it will be difficult for these European countries to exploit the benefits of these new technologies in international markets if they do not invert this negative trend. Finally, this study has demonstrated that small open economies may benefit from international knowledge flows in ICT-related fields. It is, however, important to note that the benefit of international research in ICT is not a free lunch: Since participation in international networks is a precondition for gaining such benefits, it is simply not possible to take part in international collaboration with scientists of the leading countries, within the field of ICT, if local (national) investments in ICT-related science are not made.

This paper has come some way in analysing the role of national and international ICT knowledge flows as a determinant of international market share dynamics. Important aspects remain, nevertheless, unexplored. Despite the fact that analyses is difficult because of poor data availability, improvements involving the application of exports from services industries, and the use of FDI-related knowledge flows as an independent variable, should be underscored as centrally important components for future research in this area.

Acknowledgements

We wish to thank Robert Tijssen of the University of Leiden, The Netherlands, for providing us with the 23 × 23 country breakdown of international co-publications. We wish to thank Bart Los, Bart Verspagen, Nick von Tunzelmann (the editor of this journal) and two anonymous referees for very valuable comments given on earlier versions of this paper. The usual caveats apply.

References

Aghion, P., Howitt, P., Violante, G.L., 2002. General purpose technology and wage inequality. Journal of Economic Growth 7, 315–345.
Agrawal, A., Cockburn, I., 2003. The anchor tenant hypothesis: exploring the role of large, local, R&D-intensive firms in regional innovation systems. International Journal of Industrial Organization 21, 1227–1253.
Amable, B., Verspagen, B., 1995. The role of technology in market shares dynamics. Applied Economics 27, 197–204.
Amendola, G., Dosi, G., Papagni, E., 1993. The dynamics of international competitiveness. Weltwirtschaftliches Archiv 129, 451–471.
Anderton, B., 1999. Innovation, product quality, variety, and trade performance: an empirical analysis of Germany and the UK. Oxford Economic Papers 51, 152–167.
Arundel, A., Geuna, A., 2004. Proximity and the use of public science by innovative European firms. Economics of Innovation and New Technology 13, 559–580.
Audretsch, D.B., Feldman, M.P., 1996. R&D spillovers and the geography of innovation and production. American Economic Review 86, 630–640.
Bassanini, A., Scarpetta, S., 2002. Growth, technological change, and ICT diffusion: recent evidence from OECD countries. Oxford Review of Economic Policy 18, 324–344.
Blundell, R., Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. Journal of Econometrics 87, 115–143.
Bowen, H.P., Leamer, E.E., Sveikauskas, L., 1987. Multicountry, multifactor tests of the factor abundance theory. The American Economic Review 77, 791–809.
Bresnahan, T.F., Brynjolfsson, E., Hitt, L.M., 2002. Information technology, workplace organization, and the demand for skilled labor: firm-level evidence. Quarterly Journal of Economics 117, 339–376.
Bresnahan, T.F., Trajtenberg, M., 1995. General purpose technologies: engines of growth. Journal of Econometrics 65, 83–108.
Brynjolfsson, E., Hitt, L.M., 2000. Beyond computation: information technology, organizational transformation and business performance. Journal of Economic Perspectives 14, 23–48.
Carlin, W., Glyn, A., Van Reenen, J., 2001. Export market performance of OECD countries: an empirical examination of the role of cost competitiveness. Economic Journal 111, 128–162.
Castellacci, F., 2009. The interactions between national systems and sectoral patterns of innovation: a cross-country analysis of Pavitt's taxonomy. Journal of Evolutionary Economics 19, 321–347.
Dosi, G., Llerena, P., Labini, M.S., 2006. The relationships between science, technologies and their industrial exploitation: an illustration through the myths and realities of the so-called 'European Paradox'. Research Policy 35, 1450–1464.
Ebling, G., Janz, N., 1999. Export and Innovation Activities in the German Service Sector: Empirical Evidence at the Firm Level, No. 99-53. Center for European Economic Research (ZEW), Mannheim, http://ssrn.com/abstract=376220.
Fagerberg, J., 1988. International competitiveness. Economic Journal 98, 355–374.

Fagerberg, J., 1997. Competitiveness, scale and R&D. In: Fagerberg, J., Lundberg, L., Hansson, P., Melchior, A. (Eds.), Technology and International Trade. Edward Elgar, Cheltenham, UK and Lyme, US.
Freeman, C., Perez, C., 1988. Structural crises of adjustment, business cycles and investment behaviour. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), Technical Change and Economic Theory. Pinter Publishers, London.
Goldstein, M., Khan, M.S., 1978. The supply and demand for exports: a simultaneous approach. The Review of Economics and Statistics 60, 275–286.
Greenaway, D., Morgan, W., Wright, P., 1998. Trade reform, adjustment and growth: what does the evidence tell us? Economic Journal 108, 1547–1561.
Greenhalgh, C., 1990. Innovation and trade performance in the United Kingdom. Economic Journal 100, 105–118.
Guerrieri, P., Meliciani, V., 2005. Technology and international competitiveness: the interdependence between manufacturing and producer service. Structural Change and Economic Dynamics 16, 489–502.
Gustavsson, P., Hansson, P., Lundberg, L., 1999. Technology, resource endowments and international competitiveness. European Economic Review 43, 1501–1530.
Helpman, E. (Ed.), 1998. General Purpose Technologies and Economic Growth. MIT Press, Cambridge.
Hicks, D., Ishizuka, T., Keen, P., Sweet, S., 1994. Japanese corporations, scientific research and globalization. Research Policy 23, 375–384.
Hicks, D., Katz, J.S., 1997. The British Industrial Research System, SPRU Working Paper. University of Sussex, Brighton.
Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics 108, 577–598.
Jorgenson, D.W., Stiroh, K.J., 2000. Raising the speed limit: U.S. economic growth in the information age. Brookings Papers on Economic Activity, 125–211.
Kaldor, N. (Ed.), 1978. The Effects on Devaluation on Trade in Manufactures.
Krugman, P., 1989. Differences in income elasticities and trends in real exchange rates. European Economic Review 33, 1031–1054.
Laursen, K., Meliciani, V., 2000. The importance of technology-based intersectoral linkages for market share dynamics. Weltwirtschaftliches Archiv 136, 702–723.
Laursen, K., Meliciani, V., 2002. The relative importance of international vis-a-vis national technological spillovers for market share dynamics. Industrial and Corporate Change 11, 875–894.
Laursen, K., Salter, A., 2005. The fruits of intellectual production: economic and scientific specialisation among OECD countries. Cambridge Journal of Economics 29, 289–308.
Leon-Ledesma, M.A., 2005. Exports, product differentiation and knowledge spillovers. Open Economies Review 16, 363–379.
Magnier, A., Toujas-Bernate, J., 1994. Technology and trade: empirical evidence for the major five industrialized countries. Weltwirtshaftliches Archiv 130, 494–520.
McCombie, J.S.L., Thirlwall, A.P., 1995. Economic Growth and the Balance-of-Payments Constraint. St. Martin's Press, New York.
Meliciani, V., 2002. The impact of technological specialisation on national performance in a balance-of-payments-constrained growth model. Structural Change and Economic Dynamics 13, 101–118.
Milgrom, P., Roberts, J., 1990. The Economics of Modern Manufacturing Technology, Strategy and Organization. American Economic Review 80, 511–528.
Montobbio, F., 2003. Sectoral patterns of technological activity and export market share dynamics. Cambridge Journal of Economics 27, 523–545.
Obama, B., Biden, J., 2008. The Obama–Biden Plan, Washington DC, http://change.gov/agenda/economy_agenda/.
OECD, 2002. Measuring the Information Economy. OECD, Paris.
OECD, 2005. New Perspectives on ICT Skills and Employment. OECD, Paris.
Papaconstantinou, G., Sakurai, N., Wyckoff, A., 1998. Domestic and international product-embodied R&D diffusion. Research Policy 27, 301–314.
Patel, P., Pavitt, K.L.R., 1997. The technological competencies of the world's largest firms: complex and path dependent, but not much variety. Research Policy 26, 141–156.
Rosenberg, N., 1990. Why do firms do basic research (with their own money)? Research Policy 19, 165–174.
Santos-Paulino, A., Thirlwall, A.P., 2004. The impact of trade liberalisation on exports, imports and the balance of payments of developing countries. Economic Journal 114, 50–72.
Schumpeter, J.A., 1939. Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process. McGraw-Hill, New York and London.
Soete, L.L.G., 1981. A general test of the technological gap trade theory. Weltwirtschaftliches Archiv 117, 638–666.
Tijssen, R.J.W., van Wijk, E., 1998. The global science base of information and communication technologies: bibliometric analysis of ICT research papers. Scientometrics 42, 41–60.
Tijssen, R.J.W., van Wijk, E., 1999. In search of the European paradox: an international comparison of Europe's scientific performance and knowledge flows in ICT research. Research Policy 28, 519–543.
van Ark, B., Timmer, M.P., 2005. Does information and communication technology drive EU-US productivity growth differentials? Oxford Economic Papers 57, 693–716.
Verspagen, B., Wakelin, K., 1997. Trade and technology from a Schumpeterian perspective. International Review of Applied Economics 11, 181–194.