Sectoral Specificity in the Relation between Technology and Market Share Dynamics.

European Meeting on Applied Evolutionary Economics
CNRS- Institute for Energy Policy and Economics (IEPE)
INRA-Unit of Sociology and Economics of Research & Development (SERD)
7 - 9 June 1999, Grenoble, France

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May, 1999

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JEL Code: O3, F10

Communication to

European Meeting on Applied Evolutionary Economics

7 - 9 June 1999, Grenoble, France

Organised by the Institute for Energy Politics and Economics
Organisé par lInstitut dEconomie et de Politique de lEnergie /
IEPE, BP 47, 38040 Grenoble Cedex 9, France

And the INRA-Unit of Sociology and Economics of Research and Development
Et lùnité Sociologie et Economie de la Recherche Développement de lINRA
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Abstract:

This paper focuses on a selected number of OECD countries and manufacturing sectors and shows the importance of sectoral diversity in the innovative process and in the relation between technology and world market share dynamics. The main hypothesis that underpins the analysis is that there are important sectoral differences in the way firms innovate and develop and that these differences originate mainly in the technological domain. This hypothesis is accounted for by R&D intensities and cannot be rejected. These differences are persistent through time and emerge consistently in all countries. The econometric exercise confirms the importance of technological variables in the relation with world market shares in two ways. First they are, in general, statistically significant, second the taxonomy of technological classes in terms of R&D intensity seems to be meaningful in disentangling the role played by sectoral diversity in the relation between embodied and disembodied investment and competitiveness. Sectoral diversity emerges in the statistical significance of the coefficients and in the time lag structure. Moreover the values of estimated R&D parameters are correlated with the sectoral R&D intensity. This result suggests that R&D intensity is an important cornerstone not only to understand the technological content of the sectoral activity but also to evaluate the dynamic relation between relative R&D effort and market share dynamics. Country-specific effects also emerge. This reveals that important national institutional and organisational forces are at work as pointed out by the literature on innovation systems.

1. Introduction

This paper is an attempt to explore empirically the links between three groups of studies. The first group of studies emphasises the role of technological diversity and tries to map industrial specificity (in terms of technological knowledge bases, technological opportunities, and incentives to innovation) into regular patterns of innovative activity and firm behaviour (Pavitt, 1984; Dosi, 1988; Levin, 1988; Patel, Pavitt, 1994, 1996; Malerba, Orsenigo, 1996, Breschi et al., 1999). The second group draws on the technological gap tradition and shows the mechanisms by which technology and firms' innovative activity explain the variance in countries' export performance (Soete, 1981; Fagerberg, 1988; Dosi et al. 1990; Amendola et al., 1993; Amable and Verspagen, 1995). The third group stresses the institutional and organisational specificity of the environment, which supports firms' innovative activity (Freeman, 1987, Lundvall, 1992, Nelson, 1993, Edquist, 1997).

This paper focuses on the nature of sectoral diversity in the innovative activity and is aimed at analysing the impact of sectoral diversity on the dynamic relation between technology and the export performance of countries. The work is composed of three sections. In the first section the theoretical issues underpinning sectoral diversity are analysed. Then the empirical work is composed of two parts. In the first part the importance of sectoral diversity is analysed through a descriptive analysis of the data. In the second part an econometric (panel dynamic) DL specification is used in order to test the link in different sectors between technology and export performance dynamics.

2. The Sources of Sectoral Specificity

The main hypothesis that underpins this work is that there are important sectoral differences in the way firms innovate and develop and that these differences originate mainly in the technological domain. Technology is a multi-dimensional concept. On the one side technology is a specific set of industrial methods and systems of production. Methods and systems of production include both physical equipment and related organisational rules. On the other side technology is knowledge, which is applied systematically in order to combine inputs and transform them into output.

Technology is not only information, because it is not always freely available in blueprints, manuals and operating instructions, neither is exogenous science (Laudan, 1984; Dosi, 1988; De Liso, Metcalfe, 1996). The information input, related to each technology, which is used in the innovation process, is often called technological knowledge base (Dosi, 1988; p.1126). The technological knowledge base is built on previous experience, on formal and freely available knowledge and on learning processes about uncodified and tacit understanding and competence. It affects communication, knowledge spillovers among firms and, importantly, innovative activities (Nelson, Winter, 1982; Dosi 1988, Malerba, 1992).

As indicated by Dosi (1982, 1988, p.1125), innovation is a technological problem-solving activity. Problems turn out to be ‘ill defined’ because freely available information does not suffice in order to produce automatically a solution. Since technology is knowledge, partly codifiable, partly not, and is a method of production, which is embedded both in technical equipment and in practical and specific skills, the solving-activity follows a specific ‘pattern of solution’ guided and constrained by the technological knowledge bases[1].

It follows that technical changes are not simply the result of choices on a known set of substitutable and reversible technical options and production possibilities. The technological opportunity frontier is limited and guided by the specific competencies and procedures that agents build within a specific set of institutional interactions. Agents learn continuously and therefore the available knowledge about product and production process changes as well. Since learning is not simply about codified blueprints, rather it is a highly specific experience about searching and solving procedures, which are partly tacit and routinised, the set of technological options develops endogenously.

Given this stylised characterisation of technology and of the innovation process, it is asked which technological variables can account for sectoral diversity and affect firm innovative activity. Consider that profit driven agents must perceive some technological opportunities in order to undertake an innovative activity (Breschi et al., 1999). It follows from our discussion that technological opportunities are not only, to a great extent, endogenous, but also determined by the heuristics, procedures and competencies that are specific to the product or process that is invented, adopted or improved. The probability to actually achieve an innovative outcome, the conditional likelihood to continue on innovating (cumulativeness) and the variety of possible solutions emerge within a specific set of technological characteristics[2]. Accordingly Breschi et. al. (1999) show thoroughly that intra-industry and external technological opportunity conditions affect importantly the sectoral patterns of innovative activity.

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[1] These definitions of the set of characteristics of technology have been named technological paradigm (Dosi, 1982, 1988). Technological paradigms, then, guide and constrain problem-solutions and innovation from two points of view. Firstly because a paradigm is an artefact, a specific object to be improved and developed. Secondly because a paradigm is a set of heuristics, procedures and competencies. Technological paradigms provide "shared cognitive frameworks" (Metcalfe, 1995a, p.35) for innovative firms and organisations. According to the famous definition of Dosi (1988, p. 1127) a technological paradigm can be defined as. “...a techno-economic problems, based on highly selected principles derived from the natural sciences, jointly with specific rules aimed to acquire new knowledge and safeguard it, whenever possible, against rapid diffusion to the competitors.” See also Gutting (1984) for the relation between the concept of paradigm in technology and science and Håd (1994) for an interesting case study. Moreover the sociological literature on socially constructed technological systems provides many interesting examples of historical developments of technological paradigms (even if this concept is not used) and related institutional and organisational changes (see Bijker et al., 1989).

[2] Technological paradigms are expected to have a life cycle, which determines the level of technological opportunities and the reliance upon external scientific research. The literature on technological and product life cycle is huge. Utterback, Abernathy (1975) and Klepper (1996,1998) are two important references. Miozzo and Montobbio (1997) surveyed parts of this literature.

Economic agents are also influenced in their innovative choices by the structure of incentives which, in turn, are affected by the appropriability conditions (Levin et al. 1987; Levin, 1988; Dosi, 1988; Malerba, Orsenigo 1997; Breschi et al., 1999). Firms may rely upon patents, secrecy, continuous and cumulative R&D, learning curve effects, service efforts to protect their product and process innovations. The choices of the appropriabilty means are again, to a great extent sector specific, because it is the technological content of the economic activity which determines the appropriate mean of reaping economic benefit from innovation.

Finally our characterisation of the innovative process suggests that sectors differs on the organisational rules and institutional arrangements according to which technical change processes take place (Dosi, 1997). Different knowledge bases require different sources of information and different solving procedures. This means for example that sectors vary on firms' reliance upon formal scientific research performed in external agencies or universities or on the intensity and stability of firms' interactions with other firms in vertically linked sectors. If knowledge bases integrate different scientific and engineering disciplines, innovation is about assembled products and is the result of the interaction of designers, material and component producers (aircraft, computer mainframe and motor vehicles). Conversely when knowledge bases refer specifically to a specific scientific field, innovation relies less on suppliers of intermediate goods and more on direct scientific inputs (chemicals, pharmaceutical, synthetic fibres).

Moreover a noteworthy amount of recent literature has focused on the concept of system of innovation in order to analyse the mechanisms by which institutions and non-firm organisations support firm innovative activity (e.g. Freeman, 1987, 1995; Lundvall, 1992; Nelson, 1993; Edquist, 1997). The innovation system concept has been used to study the degree to which a specific regional/national institutional environment is conducive to innovative activity. At the same time the importance of sectoral diversity in defining the typology of the interfaces between firms and institutions has also been recognised (Nelson, 1993, ch.1; Carlsson, 1995; Breschi, Malerba, 1997).

Finally some recent developments in international economics tend to emphasise the role played by technological variables in determining the dynamics of competitive advantages of advanced countries. It is shown that the dynamic of technological variables (world patent shares, relative R&D expenses, fixed investment) and, the quality and novelty of products and productive processes affect importantly the dynamic of world market shares in the advanced countries (Fagerberg, 1988; Dosi et al., 1990; Greenhalg, 1990; Amendola et al., 1990; Magnier-Toujas-Bernate, 1993, 1994; Amable Verspagen, 1995). Moreover the relation technology-competitiveness shows substantial sectoral specificity. Competitiveness depends also on technological sophistication, which, in turn, is affected by industry-specific imperatives.

In particular Amable and Verspagen (1995) try to map the results of their regressions into the Pavitt's taxonomy. They distinguish price and non- price factors in determining competitiveness and find mixed evidence. Expectations, based on the taxonomy, on price factors coefficients values are corresponded. Conversely non-price factors coefficients, whilst showing important sectoral differences, cannot be interpreted through the same taxonomic lens. They conclude that: "there is still a need for a theory that can be applied in a broader field than just the one inspired by 'institutional economics' " (Amable, Verspagen, 1995; p. 204). Magnier and Toujas-Bernate find as well substantial sectoral diversity. In particular, although competitiveness in Aerospace and Office-machinery shows high sensitivity to R&D expenses, their estimations do not display a clear correlation between the technological contents of the sectors and their sensitivity to R&D expenses.

3. The Empirical Analysis: Sectoral and National Specificity

In the previous section the idea of sectoral specificity has been discussed. Section 3 and 4 aim at using a merge of two standard databases (STAN, Structural Analysis Industrial Database and ANBERD, Analytical Business Enterprise R&D, OECD, 1996, 1997) to explore the extent to which the hypothesis of sectoral diversity is accounted for in standard economic indicators and in the relation between technology and export performance. In particular it is asked whether sectoral and technological specificity are extended across countries and for which sectors this is more significant.

The analysis is based on indicators of business enterprise R&D expenses, gross fixed capital formation (GFCF: machinery, equipment, buildings, land), labour costs and export. The Analytical Business Enterprise R&D Database is constructed "with the objective of creating a consistent data set, that overcomes the problems of international comparability and time discontinuity associated with the official BERD data provided to the OECD by the Member countries" (OECD, ANBERD, 1996; p. 9). Official BERD data covers private, public enterprises and institutes serving such enterprises and "are based on the sum of performers' reports on national territory (i.e. excluding payments to international organisations and other performers abroad)" (OECD, 1998). Problems of international comparability refer to the inclusion of small firms R&D expenses, which are often underestimated, and borderline institutions, which frequently are not allocated to the appropriate manufacturing sector. Moreover classification problems arise between countries which report on a enterprise basis and countries which report on a product field basis especially when there are big diversified firms. ANBERD tries to overcome these problems opting for the inclusion of 'service' firms and industrial research institutes in the manufacture class of the firm they serve and tending to be closer to product field data.

R&D and GFCF are chosen in order to reflect two different aspects of the technological content of the economic activity within industries (see also Magnier, Toujas-Bernate, 1994). In particular R&D expenses can be considered a proxy for technical change based on creation of new knowledge and therefore with a disembodied nature (as, for example, the one provided by industrial research institutes and borderline institutions). At the same time GFCF can index the technological improvements embedded in investment flows. Since the econometric analysis in Section 3.3 and 4 will focus on sectoral specificity in the relation between technological dynamics and export performance it is also appropriate to explore patterns of relative and absolute advantages at a descriptive level. This means enquiring about the characteristics and the stability of patterns of countries' specialisation.

Table A.1 and Table A.2 in the Appendix provide a description of the data set. Sectors are displayed in Table A.1. Table A.2 describes data availability for each sector and country. The choice of the sectors and countries responds to relevance and data availability criteria and guarantees a sufficient degree of diversity in terms of technological content and country characteristics.

3.1 R&D Intensity

It does not exist a unified criterion to make taxonomies out of the idea of sectoral technological intensity. It follows from our previous discussion, however, that, in some sectors, commercial and productive activity is linked more substantially to efforts in research and development of new processes and products and to a more complex technological knowledge base. OECD (1986; p.59) lists a set of characteristics which are normally related to high-technology sectors:

- Need for a strong R&D,
- Strategic importance for governments,
- Very rapid product and process obsolescence,
- High risk and large capital investments,
- High degree of international co-operation and competition in R&D production and worldwide marketing.

Following OECD (1986), we use the first of these criteria and sectors are ordered according to R&D intensity (the ratio of R&D expenditure to production). The period considered runs from 1980 to 1991 and data are grouped in three sub-periods of four years (80-83; 84-87 and 88-91). For each sub-period the average value is calculated.

Tab. 3.1 (a, b and c) shows the average values of R&D intensity in the three different sub-periods for the twelve sectors and ten countries considered[3]. In Tab. 3.2, for each sub-period, the average R&D

[3] In Tab. 3.1 to 3.6 Australia and Netherlands are not considered. R&D intensity in Electronics in Netherlands range from 38% to 66% and R&D intensity in the Electrical Machinery in Australia is between 73% and 109%. These cases represent very interesting outliers, which need further enquiry on the specific characteristics of

intensities for each sector i, weighted by each country's share in total output[4] are displayed. Sectors are divided in high, medium and low technology groups according to the criterion defined by OECD (1986). If the R&D/output ratio is greater than 4% then sectors are high technology (Aircraft, Computer and Office Machinery, Pharmaceuticals, Electronics). If the ratio belongs to the 1%-4% interval, then sectors are medium technology (Chemicals, Electrical and Non-electrical Machinery, Motor Vehicles). Otherwise they are low technology (Textile, Food, Paper and Wood). It can be noted that, for each sector, R&D intensity values are quite stable across country and through time. More precisely the following evidence accounts for sectoral specificity:

1) These categories are stable in the chosen sub-periods (Tab. 3.1). Considering the R&D intensity values for each country in two different sub-periods, correlation coefficients are significantly different from zero[5] (Tab. 3.5 (point 1) shows the correlation indexes between the first and the third sub-period).

2) The analysis of variance shows that the variance between sectors accounts for more than two-third of the total variance in all the three sub-periods. The hypothesis that the mean is constant across sectors is always rejected (Tab. 3.4).

3) The results in Tab 3.5 (point 2) show that sectoral R&D intensity is significantly correlated cross-country. This is upheld in all the sub-periods.

Looking at R&D intensity, then, it turns out that sectoral differences are stronger than differences among countries. The characteristics of sectoral R&D intensities are persistent across countries and through time. The discussion in Section 2 can account for these differences. In particular different technological paradigms imply a sectoral variance of the modes of innovative search, which depends on the characteristics of the technological opportunities and on the variety of potential innovations and ease of achieving them. The development of knowledge bases in aircraft technologies, computers, electronics and pharmaceuticals relies more importantly on research and this affects the organisational rules of the innovative activity. In microelectronics, for example, R&D levels and cumulative R&D are also an important mean of appropriability. Moreover it can be noted that, to a great extent, in the four high technology sectors innovating firms have a larger size (and then a higher likelihood to perform R&D) and innovative activities tend to be concentrated (Malerba, Orsenigo, 1995, 1996). Market structures provide then a possible link between sectoral technological features and R&D intensity.

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these countries. Note also that the values of R&D relative effort, for Electronics in Netherlands and Electrical Machinery in Australia, is in line with the country values in the other sectors. Moreover this analysis does not include Denmark because R&D data are missing in the Motor Vehicles sector and Norway because R&D data are missing in the Aircraft sector.

[4] Sector i R&D intensity weighted averages $= \sum_{j=1}^{10} q_{ij} rd_{ij}$; $rd_{ij} = RD_{ij}/Y_{ij}$; $q_{ij} = Y_{ij} \Big/ \sum_{j=1}^{10} Y_{ij}$; j=1,..10, countries and i=1,..12, sectors.

[5] Here and throughout Section 3 the null hypothesis is rejected at significance level of 15%.

Still this does not rule out country differences, since the ‘within sectors’ variance is one third of the total variance. Country average R&D intensity weighted by sectoral shares on countries’ total output[6] is displayed in Tab. 3.3. A higher value is found in US, UK, Sweden, Germany and France. In Japan, Italy, Finland and Sweden it increases significantly along the three sub-periods. Moreover in all countries average R&D intensity increases between the first and the third sub-period (except from UK which passes from the third position in the first sub-period to the sixth position in the last sub-period). This change is composed of two parts. First, there is an increase of R&D intensity in almost all sectors and this can be seen comparing the first and the last sub-periods in Tab. 3.1 and in the values of sectoral averages in Tab 3.2 (R&D intensity decreases particularly in the Aircraft and Electronics in US and UK and in Computer and Office Machinery in UK). Second, in all countries, sectoral shares on country’s total output tend to shift in the direction of high technology sectors. This circumstance is displayed in Tab. 3.6. These sectoral variations are similar in all G7 countries (excluding Italy). The weights of the textile, chemical, food and non-electrical machinery sectors decrease everywhere while the weights of high technology sectors are augmented (except from the Italian Aircraft, US Computers and Office Machinery and Japanese Pharmaceuticals). The motor vehicle industry and paper manufactures keep on having an increasingly important weight in the manufacture of all the countries considered.

Tab. 3.7 shows an index of countries’ relative R&D effort, which is the amount of R&D expenses in sector i and country j divided for the aggregate R&D expenditure of all countries in the same sector. Note that these indexes are not controlled for the size effect. Absolute levels of R&D expenditures are considered a better indicator when there is an absolute R&D threshold at a firm level in order to produce a new variety of a product[7].

Two third of total R&D is performed in US and Japan (see Tab. 3.8). This is true for all sectors, a part from Pharmaceuticals, Chemicals and Non Electrical Machinery where European countries, in particular Germany, account for an important share of total R&D. The distance in terms of absolute R&D between the US and the other countries is greater in the high-tech, motor vehicles and paper sectors. Relative R&D for Japan shows a 30% increase between the first and the third sub-period. This change is higher than the 40% in Computers and Office Machinery, Electrical Machinery, Electronics, Paper and Aircraft, which still has a very small weight in relative Japanese R&D expenditures.

While Tab. 3.1 shows that sectoral R&D intensity is a quite robust cornerstone in order to grasp differences in the industrial technological content, in Tab. 3.7, conversely, the use of relative indexes

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[6] Country j R&D intensity weighted averages = $\sum_{i=1}^{12} w_{ij} rd_{ij}$; $rd_{ij}=RD_{ij}/Y_{ij}$; $w_{ij} = Y_{ij} \Big/ \sum_{i=1}^{12} Y_{ij}$; j=1,..10, countries and i=1,12, sectors.

[7] R&D intensity, conversely, expresses the relative R&D effort of firms in independently of the country dimension and of the total amount of firms. Rates of variation of relative R&D effort between sub-periods will

allows a direct emphasis on diversity across countries. This diversity depends, firstly, on country size and on the amount of firms active in R&D and on their average dimension. Secondly, as already mentioned, it can indicate superior quality and higher variety of products. Thirdly, as stressed by the literature on National Systems of Innovations, country-specific institutional factors can affect firms' propensity to innovate, and their choices of location of research and innovative activities.

Summing up, it is important to point at the following pieces of evidence. It cannot be rejected the hypothesis that there exist technology-driven differences among sectors accounted for by R&D intensities. These differences are persistent through time and emerge consistently in all countries. Moreover R&D intensity tends to grow in all countries and sectors considered. The growth in R&D intensity in all the G7 countries is also due to the structural shift of sectoral shares of countries' output in the direction of high technology industries. Country specificity is better grasped considering the relative R&D effort, which shows a leading position of the US. US are far ahead in all high technology industries, due also to a size effect, with Japan catching up mainly in the Computer, Electronics and Electrical and Non Electrical Machinery industries.

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be used in the econometric analysis in Section 3.3. Rates of variation of relative R&D intensity will be used as determinant of world market share in Section 4.

Tab. 3.1: *R&D Intensity*.

a) First sub-period: 1980-1983;

		CAN	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	10.518	0.748	12.813	15.719	5.437	7.650	5.206	12.127	14.030	18.477
Computers and Office Machinery		7.295	7.718	5.954	6.459	6.774	3.424	2.170	5.856	11.388	13.480
Pharmaceuticals		3.655	11.089	6.795	8.270	6.874	7.188	1.472	16.885	11.165	10.007
Electronics		12.602	8.600	11.281	7.708	4.543	4.462	1.653	10.187	14.756	13.959
Electrical Machinery	MT	1.359	3.399	1.823	3.230	0.630	3.185	0.517	4.844	2.505	6.007
Chemicals		0.819	0.954	2.151	3.457	1.377	2.819	0.349	1.616	1.974	2.471
Motor Vehicles		0.262	0.356	2.801	2.767	1.748	2.125	0.565	4.352	1.776	4.109
Non Electrical Machinery		0.769	1.979	0.871	2.283	0.268	1.668	0.199	2.786	1.343	1.579
Food	LT	0.169	0.236	0.122	0.151	0.034	0.396	0.045	0.373	0.244	0.254
Paper		0.292	0.353	0.089	0.203	0.011	0.178	0.053	0.537	0.149	0.336
Textiles		0.192	0.152	0.160	0.204	0.001	0.368	0.012	0.245	0.151	0.117
Wood		0.110	0.121	0.060	0.230	0.002	0.196	0.002	0.093	0.067	0.217

b) Second sub-period: 1984-1987;

		CAN	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	11.414	2.197	14.029	21.394	11.901	7.136	20.136	14.463	11.094	21.863
Computers and Office Machinery		9.496	9.039	5.389	5.334	6.051	4.727	4.627	6.547	7.672	16.990
Pharmaceuticals		3.469	12.234	8.015	8.096	6.365	9.048	2.227	24.529	12.138	10.988
Electronics		15.803	9.289	11.454	8.953	6.924	4.615	2.829	12.312	9.275	14.805
Electrical Machinery	MT	1.248	4.035	2.163	3.601	1.082	3.933	0.839	5.454	4.039	2.115
Chemicals		0.962	2.112	2.789	3.682	1.292	4.151	0.511	2.228	2.218	2.936
Motor Vehicles		0.211	0.592	2.992	2.945	1.753	2.579	0.551	5.320	2.548	4.111
Non Electrical Machinery		0.674	2.969	1.143	2.364	0.643	2.324	0.534	3.600	1.176	1.598
Food	LT	0.167	0.352	0.175	0.164	0.052	0.493	0.072	0.401	0.256	0.362
Paper		0.277	0.426	0.114	0.181	0.011	0.294	0.070	0.624	0.133	0.261
Textiles		0.269	0.220	0.183	0.228	0.008	0.441	0.024	0.424	0.148	0.176
Wood		0.124	0.189	0.071	0.370	0.014	0.210	0.015	0.086	0.046	0.150

(Tab. 3.1 continues in the next page)

c) Third sub-period: 1988-1991;

		CAN	*FIN*	*FRA*	*GER*	*JAP*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	10.440	1.452	14.810	22.210	10.064	16.528	12.235	8.031	16.943
Computers and Office Machinery		8.898	6.328	4.529	7.217	7.597	10.711	7.566	5.496	19.418
Pharmaceuticals		5.552	12.689	8.533	9.375	10.967	2.913	24.875	15.562	11.770
Electronics		11.899	13.425	12.336	9.944	4.783	5.604	20.655	5.579	10.329
Electrical Machinery	MT	0.855	4.015	2.323	2.930	4.298	1.422	3.669	3.763	3.088
Chemicals		0.931	3.084	3.182	4.081	5.535	0.664	2.168	2.823	2.950
Motor Vehicles		0.163	1.409	3.150	3.127	3.076	0.732	5.030	2.382	4.781
Non Electrical Machinery		0.615	2.940	1.332	2.203	2.634	0.836	3.820	1.753	1.561
Food	LT	0.149	0.593	0.262	0.142	0.644	0.102	0.445	0.288	0.324
Paper		0.351	0.634	0.106	0.138	0.390	0.106	0.706	0.127	0.346
Textiles		0.310	0.458	0.183	0.218	0.544	0.054	0.518	0.122	0.196
Wood		0.145	0.243	0.072	0.269	0.304	0.070	0.062	0.046	0.180

Tab. 3.2: *R&D Intensity: weighted sectoral averages.*

		80-83	*84-87*	*88-91*
Aircraft	HT	16.339	19.258	15.716
Computers and Office Machinery		9.440	10.492	11.721
Pharmaceuticals		8.295	9.323	10.949
Electronics		9.080	9.341	7.893
Electrical Machinery	MT	3.394	2.881	3.400
Chemicals		2.413	2.904	3.376
Motor Vehicles		2.739	2.976	3.376
Non Electrical Machinery		1.501	1.746	1.966
Food	LT	0.221	0.290	0.334
Paper		0.249	0.238	0.314
Textiles		0.150	0.189	0.268
Wood		0.157	0.149	0.188

Tab. 3.3: *R&D Intensity: weighted country averages.*

	80-83	*84-87*	*88-91*
CAN	0.977	1.162	1.262
FIN	0.849	1.302	1.748
FRA	2.095	2.537	2.888
GER	2.372	2.723	2.937
ITA	0.755	1.039	1.410
JAP	1.859	2.465	3.033
SPA	0.265	0.467	0.764
SWE	2.382	3.152	3.612
UK	2.503	2.409	2.344
US	3.406	4.105	3.737

Tab. 3.4: *Analysis of Variance between and within sectors. Dependent variable: R&D Intensity*.

First sub-period (1980-83), 12 sectors, 10 countries:

Source of Variation.	*df*	*Sum of Squares.*	*Mean Square.*	*F-value.*	*Pr. > F*	*R-Square.*
Model (between sectors).	11	1659.89	150.9	21.14	0.0001	0.68
Error (within sectors).	108	770.92	7.14			
Total.	119	2430.81				

Second sub-period (1984-87), 12 sectors, 10 countries:

Source of Variation.	*df*	*Sum of Squares.*	*Mean Square.*	*F-value.*	*Pr. > F*	*R-Square.*
Model (between sectors).	11	2378.27	216.2	22.19	0.0001	0.69
Error (within sectors).	108	1052.40	9.74			
Total.	119	3430.68				

Third sub-period (1988-91), 12 sectors, 9 countries:

Source of Variation.	*df*	*Sum of Squares.*	*Mean Square.*	*F-value.*	*Pr. > F*	*R-Square.*
Model (between sectors).	11	2260.94	205.54	19.28	0.0001	0.69
Error (within sectors).	96	1023.47	10.66			
Total.	107	3284.41				

Tab. 3.5: *Correlations tables. Varible R&D Intensity (r=Pearson product-moment correlation, P-values are obtained from* $t=r/[(1-r^2)/(n-2)]^{1/2}$. *t comes from a t distribution with n-2 degrees of freedom,* H_0: $r=0$, H_1: $r>0$).

1) Correlation between the first and the third subperiods. (N=12, for Italy N=10, P-values in parenthesis)

	CAN	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*SPA*	*SWE*	*UK*	*US*
r	0.99	0.95	0.99	0.99	0.84	0.96	0.97	0.95	0.76	0.94
P-values	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.003)	(0.0001)	(0.0001)	(0.0001)	(0.004)	(0.0001)

2) Cross-sector Correlation Matrix: first sub-period (N=12. P-values in parenthesis)

	CAN	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*SPA*	*SWE*	*UK*
FIN	0.55								
	(0.06)								
FRA	0.95	0.55							
	(0.0001)	(0.06)							
GER	0.83	0.44	0.94						
	(0.0009)	(0.15)	(0.0001)						
ITA	0.76	0.79	0.83	0.82					
	(0.004)	(0.002)	(0.0009)	(0.0011)					
JAP	0.71	0.61	0.87	0.94	0.85				
	(0.001)	(0.03)	(0.0002)	(0.0001)	(0.0005)				
SPA	0.80	0.27	0.89	0.96	0.74	0.82			
	(0.002)	(0.4)	(0.0001)	(0.0001)	(0.005)	(0.001)			
SWE	0.68	0.76	0.83	0.84	0.86	0.95	0.69		
	(0.01)	(0.004)	(0.0008)	(0.0006)	(0.0003)	(0.0001)	(0.01)		
UK	0.94	0.73	0.96	0.89	0.92	0.86	0.82	0.86	
	(0.0001)	(0.007)	(0.0001)	(0.0001)	(0.0001)	(0.0003)	(0.001)	(0.0003)	
US	0.92	0.60	0.96	0.94	0.89	0.87	0.91	0.82	0.96
	(0.0001)	(0.04)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0.001)	(0.0001)

(Tab. 3.5 continues in the next page)

(Tab. 3.5 continued)

Cross-sector Correlation Matrix: second sub-period (N=12. P-values in parenthesis)

	CAN	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*SPA*	*SWE*	*UK*
FIN	0.60								
	(0.04)								
FRA	0.88	0.58							
	(0.002)	(0.05)							
GER	0.74	0.36	0.94						
	(0.006)	(0.25)	(0.0001)						
ITA	0.85	0.57	0.97	0.95					
	(0.0005)	(0.05)	(0.0001)	(0.0001)					
JAP	0.56	0.76	0.81	0.77	0.82				
	(0.06)	(0.004)	(0.001)	(0.004)	(0.001)				
SPA	0.62	0.11	0.78	0.94	0.86	0.56			
	(0.03)	(0.74)	(0.003)	(0.0001)	(0.0004)	(0.06)			
SWE	0.55	0.79	0.80	0.70	0.78	0.92	0.47		
	(0.06)	(0.002)	(0.002)	(0.01)	(0.0028)	(0.0001)	(0.12)		
UK	0.77	0.80	0.92	0.83	0.92	0.94	0.64	0.93	
	(0.003)	(0.002)	(0.0001)	(0.0009)	(0.0001)	(0.0001)	(0.03)	(0.0001)	
US	0.89	0.61	0.93	0.88	0.98	0.77	0.80	0.71	0.90
	(0.0001)	(0.03)	(0.0001)	(0.0002)	(0.0001)	(0.003)	(0.001)	(0.01)	(0.0001)

Cross-sector Correlation Matrix: third sub-period (N=12. for Italy N=10. P-values in parenthesis)

	CAN	*FIN*	*FRA*	*GER*	*JAP*	*ITA*	*SPA*	*SWE*	*UK*
FIN	0.66								
	(0.02)								
FRA	0.90	0.60							
	(0.0001)	(0.04)							
GER	0.83	0.38	0.95						
	(0.0008)	(0.23)	(0.0001)						
JAP	0.70	0.60	0.79	0.83					
	(0.01)	(0.04)	(0.002)	(0.0009)					
ITA	0.89	0.43	0.98	0.99	0.89				
	(0.0005)	(0.21)	(0.0001)	(0.0001)	(0.0006)				
SPA	0.84	0.22	0.79	0.90	0.71	0.92			
	(0.0006)	(0.49)	(0.002)	(0.0001)	(0.009)	(0.0001)			
SWE	0.76	0.90	0.82	0.66	0.76	0.82	0.45		
	(0.004)	(0.0001)	(0.001)	(0.02)	(0.004)	(0.004)	(0.14)		
UK	0.62	0.75	0.72	0.68	0.92	0.92	0.49	0.90	
	(0.03)	(0.005)	(0.008)	(0.01)	(0.0001)	(0.0001)	(0.1)	(0.0001)	
US	0.88	0.53	0.78	0.82	0.85	0.84	0.89	0.67	0.71
	(0.0002)	(0.08)	(0.003)	(0.001)	(0.0004)	(0.002)	(0.0001)	(0.02)	(0.01)

Tab. 3.6: *Variation in sector i share of gross output in country j between the third and the first sub-period.*

		AUS	CAN	FIN	FRA	GER	ITA**	JAP	NET	SPA	SWE	UK	US
Aircraft	HT	0.184	0.309	0.631	0.210	0.150	-0.228	0.327	0.231	0.570	0.171	0.179	0.145
Comp. And Off. Machinery		-0.160	0.426	1.573	0.480	0.458	1.399	0.661	0.142	0.868	0.096	1.467	-0.032
Pharmaceuticals		0.166	0.450	0.315	0.246	0.101	0.317	-0.033	0.186	0.327	0.693	0.299	0.412
Electronics		-0.028	0.571	0.860	0.280	0.150	0.099	0.376	0.205	0.104	0.040	0.075	0.235
Electrical Machinery	MT	0.017	-0.126	0.101	-0.031	0.071	0.169	0.277	-0.107	-0.173	-0.070	-0.033	0.028
Chemicals		0.005	-0.101	-0.043	-0.063	-0.101	0.085	-0.269	-0.075	0.058	-0.079	-0.052	-0.021
Motor Vehicles		0.040	0.318	0.337	0.179	0.231	0.309	0.086	0.604	0.464	0.185	0.151	0.154
Non Electrical Machinery		-0.104	-0.108	0.098	-0.120	0.067	0.178	-0.079	0.107	-0.098	-0.011	-0.094	-0.173
Food	LT	-0.049	-0.180	-0.062	-0.116	-0.180	-0.073	-0.126	-0.111	-0.059	-0.101	-0.130	-0.088
Paper		0.190	0.022	0.063	0.182	0.074	0.237	-0.029	0.143	0.115	0.036	0.178	0.129
Textiles		-0.057	-0.212	-0.427	-0.164	-0.178	0.064	-0.216	-0.084	-0.253	-0.294	-0.140	-0.192
Wood		0.028	0.040	-0.086	-0.079	-0.118	0.068	-0.182	0.001	-0.128	-0.014	-0.003	0.027

** For Chemicals and Pharmaceuticals data from the second sub-period are used.

Tab. 3.7: *R&D relative effort (Sector i R&D of country j divided by total sector i R&D).*

First sub-period: 1980-1983;													
		AUS	CAN	FIN	FRA	GER	ITA	JAP	NET	SPA	SWE	UK	US
Aircraft	HT	0.01	1.17	0.00	7.22	3.95	1.59	0.76	0.21	0.13	0.43	8.37	76.14
Comp. and Off. Mach.		0.12	1.11	0.13	4.31	3.95	2.31	9.30	0.16	0.14	0.45	5.41	72.59
Pharmaceuticals		0.28	0.77	0.37	7.58	10.65	6.11	18.03	1.50	0.85	1.47	10.89	41.51
Electronics		0.37	2.05	0.20	8.44	9.92	2.14	16.90	1.39	0.30	1.15	11.56	45.59
Electrical Machinery	MT	0.22	0.73	0.41	3.53	15.62	1.84	22.68	4.16	0.55	1.32	5.01	43.93
Chemicals		0.42	0.86	0.21	6.41	20.37	2.98	19.02	3.46	0.52	0.54	6.57	38.64
Motor Vehicles		0.40	0.38	0.02	7.17	15.30	3.93	20.17	0.27	0.74	1.86	3.43	46.34
Non Electrical Machinery		0.43	0.96	0.80	3.90	21.97	1.41	23.72	0.54	0.30	2.63	6.70	36.63
Food	LT	0.94	2.50	0.82	4.60	7.23	1.11	25.85	4.54	1.09	1.64	9.53	40.14
Paper		0.57	5.55	2.75	2.20	5.05	0.25	12.85	0.50	0.50	4.92	4.11	60.75
Textiles		0.23	3.16	0.59	8.13	11.49	0.17	42.69	0.86	0.44	0.69	5.97	25.57
Wood		0.80	3.20	1.18	2.26	15.03	0.16	20.87	0.02	0.05	1.31	2.39	52.74

(Tab. 3.7 continues in the next page)

(…continued from the previous page)

Second sub-period: 1984-1987;

		AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	0.01	1.03	0.01	6.31	3.83	2.06	0.74	0.21	0.34	0.51	5.47	79.47
Comp. and Off. Mach.		0.22	1.28	0.20	3.55	3.39	2.32	13.11	0.26	0.43	0.50	4.46	70.29
Pharmaceuticals		0.52	0.79	0.34	7.72	9.00	5.89	18.22	1.46	0.95	2.12	10.91	42.08
Electronics		0.44	2.53	0.25	7.66	10.24	2.25	18.28	1.49	0.33	1.18	6.63	48.71
Electrical Machinery	MT	0.43	0.72	0.50	4.04	19.48	3.85	35.66	6.30	0.74	1.64	8.93	17.71
Chemicals		0.48	0.90	0.37	6.82	19.49	2.56	21.11	3.25	0.67	0.65	6.71	36.99
Motor Vehicles		0.55	0.36	0.03	5.81	14.78	3.39	20.61	0.31	0.64	2.19	4.07	47.25
Non Electrical Machinery		0.82	0.76	1.11	4.18	22.49	2.84	28.31	0.61	0.61	3.35	5.21	29.69
Food	LT	1.39	1.96	0.94	4.86	5.86	1.26	26.64	3.80	1.26	1.43	7.86	42.75
Paper		0.69	5.70	3.25	2.93	4.62	0.24	20.36	0.52	0.61	6.05	4.04	50.99
Textiles		0.56	3.70	0.60	7.42	10.22	0.79	39.26	0.90	0.59	0.95	5.02	29.98
Wood		1.17	4.56	1.70	2.47	23.17	0.96	19.80	0.16	0.25	1.29	1.76	42.73

Third sub-period: 1988-1991;

		AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	0.04	1.50	0.01	8.87	6.18	2.47	1.32	0.19	0.52	0.45	5.13	73.33
Comp. and Off. Mach.		0.18	1.27	0.14	2.81	4.08	2.19	22.41	0.52	0.70	0.38	3.91	61.41
Pharmaceuticals		0.57	1.11	0.29	6.98	8.53	6.00	17.60	1.37	1.19	2.14	11.97	42.24
Electronics		0.51	2.90	0.44	10.05	13.65	3.19	23.83	1.37	0.87	2.06	4.16	36.98
Electrical Machinery	MT	0.35	0.41	0.44	4.01	15.27	3.40	40.53	4.42	1.04	0.87	6.94	22.30
Chemicals		0.46	0.75	0.44	6.78	18.04	2.23	23.56	3.44	0.73	0.51	7.06	36.00
Motor Vehicles		0.48	0.23	0.05	6.28	15.36	4.37	23.67	0.41	0.84	1.71	3.63	42.98
Non Electrical Machinery		0.69	0.63	0.98	4.36	20.44	3.53	32.25	0.62	0.85	2.98	6.79	25.88
Food	LT	1.69	1.54	1.32	6.61	4.61	1.57	31.41	3.84	1.62	1.35	7.64	36.82
Paper		1.27	5.51	3.41	2.24	2.92	0.09	22.14	0.52	0.72	4.86	3.09	53.23
Textiles		0.66	3.57	0.73	6.13	8.74	1.08	44.09	1.04	1.09	0.83	3.38	28.67
Wood		0.98	4.53	1.78	2.29	15.52	0.91	27.34	0.24	1.11	0.80	1.54	42.96

Tab. 3.8: *R&D relative effort: country averages.*

Sub-periods	AUS	CAN	FIN	FRA	GER	ITA	JAP	NET	SPA	SWE	UK	US
80-83	0.29	1.22	0.25	6.46	11.45	2.50	15.06	1.36	0.41	1.16	7.63	52.20
84-87	0.40	1.31	0.30	6.06	10.92	2.73	16.66	1.40	0.53	1.32	6.15	52.21
88-91	0.42	1.35	0.36	6.81	11.83	3.21	21.15	1.36	0.82	1.35	5.66	45.67

3.2 Absolute Advantages and Revealed Comparative Advantages

In this section the analysis of the nature of sectoral diversity is performed in terms of export indexes. In particular two indexes are calculated: the revealed absolute advantage (consistently with the previous section they are the ratio of export of country j in sector i to sectoral aggregate of all countries, Tab. 3.9) and revealed comparative advantage[8] (RCA: Tab. 3.11). Revealed absolute advantages are used to study world market share of country j in sector i. Conversely RCAs are more appropriate in order to explain trade specialisation of countries and changes in the sectoral allocation of exports due to changes in factor prices and sectoral levels of profits. It is worthwhile noting that RCA_{ij} can increase either, because of an effective improvement of competitiveness in sector i, or because of deterioration in the export performance of the other sectors in the economy of country j.

In Section 3.3 and 4 emphasis will be placed upon sectoral specificity in the relation between technology and world market share dynamics. An index of absolute advantage will then be used in order to relate country j export performance to the technological effort (relative to the other countries) of country j within the same sector. Note that the absolute advantage index is affected by countries' size. Three points can be raised in relation to this. First, theories of technological gap and of innovation systems claim that firms' efficiency distribution is not the same within each country (Dosi et al., 1990; Nelson, 1993). In this case world market shares can be an appropriate index of international sectoral competitiveness because they would reflect this difference across countries in firms' average efficiency levels. Second, Tab. 3.9 shows the existence of sectoral and national specificity and, then, the size effect has a different weight according to different sectors. Moreover there are important differences in world market shares among countries with a similar size. Finally, the normalisation of exports with a size indicator returns an index of countries' trade openness. European countries would have a greater value than, for example, US and Japan.

In the Tab. 3.9 the absolute advantages are shown for two sub-periods: the first (80-83) and the third (88-91). US, Japan and Germany account for more than half of world export market, in both period (Tab. 3.8). US has a clear absolute advantage in the Aircraft sector, US and Germany in Computers and Office Machinery, Pharmaceutical and Chemicals, US and Japan in Electrical and Non Electrical Machinery, Germany and Japan

[8] $RCA_{ij} = \dfrac{\exp_{ij}}{\sum_{j=1,..,12} \exp_{ij}} \Bigg/ \dfrac{\sum_{i=1,..,12} \exp_{ij}}{\sum_j \sum_i \exp_{ij}}$, j=1,..12, countries and i=1,12, sectors.

in the Motor Vehicles sector. In the Electronics sector (TV, Radio and Telecom Equipment) Germany is the export leader, however, in this sector, values of export market share in Germany, US and Japan are very similar. Germany and France have high values of world market shares mainly in five sectors: Electronics, Chemicals, Pharmaceuticals, Food and Wood; Italy in Wood and Textile, UK in Pharmaceutical and Aircraft.

In the two sub-periods world market shares are fairly stable, Spearman correlation coefficients (not reported) are equal to 1 for Food and Electrical Machinery and 0.9 for all other sectors. This circumstance seems to confirm the specific and cumulative character of sectoral success factors. Moreover there is a very high cross-sectoral correlation for each country between the values of absolute advantages in the two sub-periods (Tab. 3.10). Within this general pattern it can be noted, firstly, the decline of the US market shares in all HT sectors with the exception of Electronics, secondly the improvement of Germany in Computers and Office Machinery, Pharmaceutical and Electronics.

The two last columns in Tab. 3.9 display, for each sector, Herfindal indexes and the cross-national standard deviations of world market shares. Variances and Herfindal indexes are quite stable in the two sub-periods and display significant differences among sectors. This result indicates, on the one side, persistence not only in the distribution of absolute advantages but also in the relative distance between countries. On the other side sectoral diversity points at the existence of industry-specific structural features which affect the competitive process and competitiveness improvements.

It is noteworthy that standard deviations and Herfindal indexes are on average lower in the low-technology sectors. Moreover standard deviations increase in three mature sectors such as Textiles, Food and Motor Vehicles and decrease in less mature sectors such as Computer and Office Machinery, Electrical and Aircraft.

Consider now the RCAs in Table 3.11. Their structure is quite different between countries and persistent through time (see Tab. 3.12) and this indicates different patterns of economic specialisation[9]. This circumstance is strengthened by the values of the correlation coefficients in Tab. 3.13, which are not in general significantly different from zero. However it is possible to point at some characteristics of the RCAs distribuions.

The structure of export specialisation tends to be similar in Canada Sweden and Finland. These countries display marked export specialisation in Paper and Textile Manufactures[10]. The correlation coefficient of the RCAs in US and UK is also significantly positive. UK and US reveal a comparative advantage in Aircraft and Computers and Office Machinery and, like France and Germany, in Chemicals and Pharmaceuticals. Thirdly RCAs in France, Spain, Netherlands and Australia are correlated because these countries tend to specialise in

[9] This is a common theme in international economics and is traditionally accounted for by the relative intensity of production factors and by the emergence of firm-level economies of scale and increasing returns. At the same time it can be noted that this circumstance does not contradict the idea that technological knowledge bases are not perfectly transferable. In particular in the high and medium technology sectors a different path of relative specialisation may reflect a differentiated distribution of competence and the emergence of cumulative processes of learning.

[10] Pearson coefficients are considered significantly different from zero at 85% significance level.

Pharmaceuticals and Chemicals (excluding Australia), Food and Wood manufactures. Also Italy’s trade specialisation is similar to the Spanish one because of the RCAs values in the Food and Wood manufactures. Japan shows, like Germany, above average markets shares in Electronics and Motor Vehicles.

The stylised facts highlighted in this section can be summarised as follows:

- US, Germany and Japan share in world export is higher than 0.5. Keeping into account the size effect, these countries have also the highest values of relative R&D effort in all sectors (Tab. 3.7).
- Revealed absolute advantages are fairly stable in the two sub-periods. This confirms the specific and cumulative character of sectoral success factors in each country. Within this framework, in HT sectors, the market shares gain of Germany and the decline of the US are noteworthy.
- Sectoral diversity emerges in the different values of cross-country market shares variance. The dispersion is, on average, lower (but increasing in the two sub-periods) in the LT sectors. In HT and MT sectors, products are often ‘complex systems’. Technical advancements in these sectors stem from the interaction of component and material producers and designers. The systemic features and complexity of the knowledge basis suggest that in these sectors is more likely the emergence of cumulative learning processes and dynamic increasing returns, which increase asymmetry in the competitive performance of countries.
- RCAs show different patterns of export specialisation in different countries, which are stable in the two sub-periods. Export specialisation is similar in UK and US; in Finland, Sweden and Canada, and, finally, in France, Spain and Netherlands.

Tab. 3.9: *Absolute advantages (county j world market share in 12 sectors).*

First sub-period: 1980-1983;															
		AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*	*St. d.*	*Herf.*
Aircraft	HT	0,21	3,39	0,06	8,23	12,13	4,80	0,47	2,24	0,64	0,14	16,56	51,13	14,49	0,31
Comp. and Off. Mach.		0,27	2,87	0,82	7,72	21,27	11,93	13,31	2,40	1,59	2,79	10,24	24,79	8,22	0,16
Pharmaceuticals		0,65	1,11	0,45	17,34	19,47	9,35	3,07	5,36	2,57	2,61	16,07	21,94	8,13	0,16
Electronics		0,26	1,25	0,87	10,80	20,80	10,87	20,02	4,07	2,18	2,23	9,20	17,46	7,71	0,15
Electrical Machinery	MT	0,11	2,67	0,49	5,51	12,42	3,94	41,22	4,56	0,49	2,33	6,48	19,77	11,80	0,24
Chemicals		0,33	3,54	0,62	11,52	21,38	7,34	9,54	9,89	1,93	1,11	10,89	21,90	7,48	0,14
Motor Vehicles		0,20	10,45	0,19	9,49	23,23	5,58	24,65	1,19	2,70	2,57	5,71	14,04	8,47	0,16
Non Electrical Machinery		0,15	3,59	0,16	7,31	12,23	7,07	13,62	3,63	1,08	2,16	10,24	38,77	10,64	0,21
Food	LT	6,23	4,72	0,63	16,17	13,20	7,53	2,13	15,89	4,06	0,71	9,23	19,50	6,47	0,13
Paper		0,27	21,26	10,29	6,77	12,15	4,84	3,31	4,21	2,97	10,06	5,93	17,94	6,30	0,13
Textiles		1,19	20,54	7,89	6,43	13,21	17,51	1,39	2,69	3,07	9,02	3,27	13,80	6,58	0,13
Wood		1,04	1,02	1,64	10,94	14,89	29,54	10,53	4,28	4,46	1,10	8,26	12,30	8,29	0,16
Country share		*0,94*	*5,66*	*1,29*	*9,87*	*18,23*	*9,71*	*14,14*	*5,31*	*2,35*	*2,44*	*8,93*	*21,13*		

Third sub-period: 1988-1991;															
		AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*	*St. d*	*Herf.*
Aircraft	HT	0,21	3,98	0,03	11,85	11,23	3,77	0,63	2,84	1,44	0,75	12,62	50,65	14,14	0,30
Comp. and Off. Mach.		0,29	2,25	0,91	7,16	25,02	12,16	14,10	3,42	1,81	2,88	9,26	20,73	8,18	0,16
Pharmaceuticals		0,80	0,86	0,36	15,18	21,06	6,73	3,13	6,05	3,33	4,19	17,85	20,45	7,98	0,15
Electronics		0,31	1,92	0,70	10,16	23,04	9,25	18,09	4,17	2,59	1,96	8,37	19,43	7,94	0,15
Electrical Machinery	MT	0,19	3,44	0,71	6,19	12,28	3,53	32,67	3,99	0,77	2,04	8,81	25,40	10,40	0,20
Chemicals		0,40	3,54	0,56	12,45	21,93	5,52	8,38	10,53	2,31	1,13	11,32	21,92	7,64	0,15
Motor Vehicles		0,25	11,60	0,27	9,50	23,86	4,98	20,86	1,81	4,70	2,33	5,79	14,05	7,88	0,15
Non Electrical Machinery		0,26	2,80	0,27	6,33	9,67	5,11	19,95	5,53	1,46	1,32	13,69	33,59	9,92	0,19
Food	LT	5,09	4,30	0,29	17,02	12,92	6,97	1,08	16,79	4,02	0,62	9,27	21,64	7,20	0,14
Paper		0,35	19,50	8,10	7,78	14,61	4,49	2,57	5,40	2,54	8,80	6,92	18,94	6,28	0,13
Textiles		0,13	21,58	4,19	7,11	15,48	16,77	1,04	3,85	2,84	6,84	2,99	17,19	7,36	0,14
Wood		1,65	1,01	0,66	12,10	18,43	29,22	5,00	6,15	4,45	0,87	8,64	11,81	8,57	0,16
Country share		*0,82*	*5,83*	*0,99*	*10,10*	*19,12*	*8,43*	*12,97*	*5,92*	*2,82*	*2,26*	*9,10*	*21,63*		

Tab. 3.10: *Correlation between the first and the third sub-period. Variable: country world market share in each sector.*

	AUS	CAN	FIN	FRA	GER	ITA	JAP	NET	SPA	SWE	UK	US
Pearson's Coefficient	0,97	0,99	0,97	0,92	0,95	0,99	0,96	0,99	0,87	0,97	0,89	0,97
t-test (N=12)	(12,03)	(26,48)	(13,71)	(7,68)	(9,21)	(28,48)	(10,55)	(18,63)	(5,66)	(11,95)	(6,09)	(11,81)

Tab. 3.11 *Revealed Comparative Advantages.*

First sub-period: 1980-83.		AUS	CAN	FIN	FRA	GER	ITA	JAP	NET	SPA	SWE	UK	US
Aircraft	HT	0,22	0,60	0,05	0,83	0,67	0,49	0,03	0,42	0,27	0,06	1,85	2,42
Comp. and Off. Mach.		0,29	0,51	0,64	0,78	1,17	1,23	0,94	0,45	0,68	1,14	1,15	1,17
Pharmaceuticals		0,69	0,20	0,35	1,76	1,07	0,96	0,22	1,01	1,09	1,07	1,80	1,04
Electronics		0,27	0,22	0,67	1,09	1,14	1,12	1,42	0,77	0,93	0,91	1,03	0,83
Electrical Machinery	MT	0,12	0,47	0,38	0,56	0,68	0,41	2,92	0,86	0,21	0,96	0,73	0,94
Chemicals		0,35	0,63	0,48	1,17	1,17	0,76	0,68	1,86	0,82	0,46	1,22	1,04
Motor Vehicles		0,21	1,85	0,15	0,96	1,27	0,57	1,74	0,23	1,15	1,05	0,64	0,66
Non Electrical Machinery		0,15	0,63	0,13	0,74	0,67	0,73	0,96	0,68	0,46	0,89	1,15	1,83
Food	LT	6,62	0,83	0,49	1,64	0,72	0,78	0,15	3,00	1,73	0,29	1,03	0,92
Paper		0,29	3,76	7,98	0,69	0,67	0,50	0,23	0,79	1,26	4,12	0,66	0,85
Textiles		1,26	3,63	6,12	0,65	0,72	1,80	0,10	0,51	1,30	3,69	0,37	0,65
Wood		1,11	0,18	1,27	1,11	0,82	3,04	0,74	0,81	1,90	0,45	0,92	0,58

(Tab. 3.11 continues in the next page)

(Tab. 3.11 ...continued)

Third sub-period: 1988-91.		*AUS*	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*
Aircraft	HT	0,26	0,68	0,03	1,17	0,59	0,45	0,05	0,48	0,51	0,33	1,39	2,34
Comp. and Off. Mach.		0,36	0,39	0,92	0,71	1,31	1,44	1,09	0,58	0,64	1,28	1,02	0,96
Pharmaceuticals		0,98	0,15	0,36	1,50	1,10	0,80	0,24	1,02	1,18	1,86	1,96	0,95
Electronics		0,38	0,33	0,71	1,01	1,21	1,10	1,40	0,70	0,92	0,87	0,92	0,90
Electrical Machinery	MT	0,23	0,59	0,71	0,61	0,64	0,42	2,52	0,67	0,27	0,90	0,97	1,17
Chemicals		0,48	0,61	0,56	1,23	1,15	0,65	0,65	1,78	0,82	0,50	1,24	1,01
Motor Vehicles		0,31	1,99	0,27	0,94	1,25	0,59	1,61	0,30	1,67	1,03	0,64	0,65
Non Electrical Machinery		0,32	0,48	0,27	0,63	0,51	0,61	1,54	0,93	0,52	0,59	1,50	1,55
Food	LT	6,18	0,74	0,29	1,68	0,68	0,83	0,08	2,83	1,42	0,27	1,02	1,00
Paper		0,43	3,34	8,16	0,77	0,76	0,53	0,20	0,91	0,90	3,90	0,76	0,88
Textiles		0,16	3,70	4,22	0,70	0,81	1,99	0,08	0,65	1,01	3,03	0,33	0,79
Wood		2,01	0,17	0,67	1,20	0,96	3,47	0,39	1,04	1,58	0,39	0,95	0,55

Tab. 3.12: *Correlation between the first and the third sub-period. Variable: Revealed Comparative Advantages*

	AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*	*US*
Pearson's Coefficient	0,97	0,99	0,97	0,92	0,95	0,99	0,96	0,99	0,87	0,97	0,89	0,97
t-test (N=12)	12,03	26,48	13,71	7,68	9,21	28,48	10,55	18,63	5,66	11,95	6,09	11,81

Tab. 3.13: *Cross-sector correlations. Dependent variable: Revealed Comparative Advantages. (r=Pearson product-moment correlation, P-values are obtained from* $t=r/[(1-r^2)/(n-2)]^{1/2}$. *t comes from a t distribution with n-2 degrees of freedom,* H_0*: r=0,* H_1*: r>0)*

First sub-period 1980-1983 (N=12).

	AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*
CAN	-0,02										
	(0,96)										
FIN	-0,05	0,90									
	(0,88)	(0,0001)									
FRA	0,56	-0,42	-0,37								
	(0,06)	(0,17)	(0,23)								
GER	-0,25	-0,28	-0,38	0,33							
	(0,44)	(0,38)	(0,23)	(0,3)							
ITA	0,06	-0,07	0,12	0,09	0,01						
	(0,84)	(0,82)	(0,71)	(0,78)	(0,98)						
JAP	-0,34	-0,29	-0,36	-0,37	0,20	-0,20					
	(0,27)	(0,37)	(0,24)	(0,23)	(0,52)	(0,52)					
NET	0,83	-0,19	-0,15	0,63	-0,11	-0,11	-0,25				
	(0,0009)	(0,55)	(0,64)	(0,02)	(0,74)	(0,73)	(0,43)				
SPA	0,57	0,26	0,33	0,49	0,05	0,61	-0,41	0,38			
	(0,05)	(0,42)	(0,29)	(0,1)	(0,88)	(0,03)	(0,18)	(0,22)			
SWE	-0,17	0,91	0,95	-0,43	-0,25	0,02	-0,22	-0,29	0,20		
	(0,6)	(0,0001)	(0,0001)	(0,17)	(0,42)	(0,95)	(0,49)	(0,37)	(0,52)		
UK	-0,06	-0,64	-0,56	0,49	0,10	-0,20	-0,34	0,10	-0,33	-0,60	
	(0,86)	(0,02)	(0,06)	(0,1)	(0,75)	(0,54)	(0,28)	(0,75)	(0,29)	(0,04)	
US	-0,18	-0,29	-0,34	-0,16	-0,33	-0,42	-0,23	-0,15	-0,67	-0,37	0,69
	(0,57)	(0,35)	(0,28)	(0,62)	(0,3)	(0,18)	(0,47)	(0,65)	(0,02)	(0,24)	(0,01)

Third sub-period 1988-1991 (N=12).

	AUS	*CAN*	*FIN*	*FRA*	*GER*	*ITA*	*JAP*	*NET*	*SPA*	*SWE*	*UK*
CAN	-0,20										
	(0,54)										
FIN	-0,19	0,82									
	(0,56)	(0,001)									
FRA	0,70	-0,38	-0,36								
	(0,01)	(0,22)	(0,24)								
GER	-0,20	-0,14	-0,15	0,12							
	(0,53)	(0,66)	(0,63)	(0,71)							
ITA	0,14	-0,03	0,01	0,05	0,21						
	(0,67)	(0,93)	(0,97)	(0,88)	(0,51)						
JAP	-0,36	-0,27	-0,32	-0,56	0,08	-0,28					
	(0,24)	(0,39)	(0,3)	(0,06)	(0,8)	(0,37)					
NET	0,86	-0,20	-0,12	0,68	-0,19	-0,03	-0,37				
	(0,0004)	(0,53)	(0,72)	(0,02)	(0,6)	(0,91)	(0,24)				
SPA	0,48	0,13	-0,03	0,54	0,40	0,45	-0,36	0,27			
	(0,11)	(0,68)	(0,92)	(0,07)	(0,2)	(0,15)	(0,25)	(0,4)			
SWE	-0,32	0,81	0,91	-0,37	0,01	-0,02	-0,28	-0,27	-0,01		
	(0,32)	(0,001)	(0,0001)	(0,24)	(0,97)	(0,94)	(0,38)	(0,4)	(0,99)		
UK	0,03	-0,70	-0,48	0,42	-0,09	-0,30	-0,07	0,17	-0,24	-0,37	
	(0,91)	(0,01)	(0,12)	(0,17)	(0,77)	(0,34)	(0,83)	(0,6)	(0,47)	(0,24)	
US	-0,16	-0,24	-0,25	-0,02	-0,58	-0,49	-0,06	-0,12	-0,64	-0,32	0,46
	(0,63)	(0,45)	(0,43)	(0,94)	(0,05)	(0,1)	(0,86)	(0,72)	(0,02)	(0,,32)	(0,13)

3.3 The Relation between Export Market Shares, Investment, R&D Expenditure and Labour Costs. A Cross-country Analysis

In this section a first step is moved in order to explore sectoral diversity in the relation between market shares, investment, R&D expenditure and labour costs and to find out if any significant pattern emerges in this diversity. The following variables are considered:

$REXP_{ij}=EXP_{ij}/\Sigma_j\ EXP_{ij}$	i=1,….., 12 sectors;	j=1,….,14 countries;
$RRD_{ij}=RD_{ij}/\Sigma_j\ RD_{ij}$	i=1,….., 12 sectors;	j=1,….,14 countries;
$RCF_{ij}=CF_{ij}/\Sigma_j\ CF_{ij}$	i=1,….., 12 sectors;	j=1,….,14 countries;
$RLC_{ij}=LC_{ij}/ALC_j$	i=1,….., 12 sectors;	j=1,….,14 countries;

EXP_{ij}: total country j export in sector i (US$-PPP).

RD_{ij}: business enterprise R&D expenditure in sector i and country j (US$-PPP).

CF_{ij}: gross fixed capital formation in sector i and country j (US$-PPP).

LC_{ij}: labour costs per employee in sector i and country j (US$-PPP).

ALC_j: sector i weighted average of LC_{ij}.

Consistently with the previous section, average values in the three sub-periods (80-83, 84-87, 88-90) are calculated. Four sub-samples are built: in the first all sectors are included. There are 149 observations (for each sub-period) according to the number of countries used in each sector, as shown in Tab. A.2. The other three samples are composed by the high (47 obs.), medium (50 obs.) and low technology (52 obs.) sectors.

As already mentioned RD_{ij} and CF_{ij} can be interpreted as two different sources of technological improvements: R&D expenditure can reflect the disembodied nature of innovation and its reliance on the production of new pieces of formal knowledge. GFCF can be considered a proxy for technological advancement embedded in capital equipment (see next section for important caveats). LC is a control variable and can also be excepted to approximate the value of the quality of human capital (see the following section for a discussion).

In Tab. 3.14 correlation coefficients are calculated between $REXP_{ij}$, RRD_{ij}, RCF_{ij}, and RLC_{ij}. In all the four sub-samples, and for all the sub-periods, coefficients' values are very high and significantly different from zero. This reflects mainly the size effect discussed in section 3.1 and 3.2. Notwithstanding some differences emerge in the sub-samples. Technological variables are more highly correlated with export market shares in the high tech sectors. In the medium tech sectors correlation coefficients between $REXP_{ij}$ and RRD_{ij} decrease proportionally more than correlation coefficients between $REXP_{ij}$ and RCF_{ij}. For these technological variables, as expected, the correlation coefficients in the low technology sector are smaller. Finally it is worthwhile noting the positive correlation between RLC and REXP especially in the medium-technology industries.

To perform the regression analysis, the percentage change of the variables between the sub-periods (between the third and the second and between the second and the first) is calculated. This brings about two positive consequences. First, expressing variables in terms of growth rates grasps better the dynamic relation between countries technological relative efforts and competitiveness. Secondly it allows to get rid of the size effect that would also generate problems of multicollinearity between the variables.

Accordingly the following specifications are tested[11]:

$$\Delta REXP_{hj}=\mu_h + \mu_j + \beta\Delta RRD_{hj}+\gamma\Delta RCF_{hj}+\delta\Delta RLC_{hj} +\varepsilon_{hj}; \quad (3.1)$$

$$\Delta REXP_{hj}=\mu_h + \mu_j + \beta_h \Delta RRD_{hj}+\gamma_h \Delta RCF_{hj}+\delta_h \Delta RLC_{hj} +\varepsilon_{hj}; \quad (3.2)$$

Sub-script h refers to the three technological categories (HT, MT, LT) in which sectors are grouped. Consider first specification 3.1. Restrictions on the constant terms are rejected, with respect to country effects and technological classes effects (HT, MT, LT), by the appropriate F-test[12] (respectively $F_{13,276}$=2.27*** and $F_{2,287}$=3.13***). As a result both country and technological class fixed effects are included. In the Tab. 3.15, then, POLS estimates are reported. In column (i) it can be seen that the R&D and capital formation relative effort coefficients are positive and significantly different from zero. At the same time the relative labour costs coefficient, despite showing a negative sign, cannot be considered significantly different from zero. In column (ii) the estimates from the same regression are reported without the inclusion of the RLC variable.

In addition the linear functional form is controlled by a formulation which includes interaction and squared terms. Significant estimates and total marginal effects are reported in column (iii). Three

[11] As it can be noted from Tab. 3.15 and Tab. 3.16 the number of observation amounts to 293 and not 298 as it should be because of the pooling the two sub-samples which incorporate variables'percentage changes between the second and the first sub-period and between the third and the second sub-period (149 obs. each). Five observations are left out. These five variables refer, for the first sub-sample, to the wood industry in Italy, Netherlands and Spain and to textiles in Italy. For the second sub-sample to wood in Spain. In this five cases the values of R&D relative effort growth rates turn out to be much higher than the average. This is because the initial value is very small. This circumstance can be verified in Tab. 3.7. Moreover it can also be noted in Tab. 3.1 for the wood industry in Italy and Spain and, for Textiles, in Italy that the R%D intensity values in the first period are by far the smallest.

aspects are noteworthy: firstly there is a complementarity effect between R&D and investment efforts because the effect of a higher value of ΔRRD on ΔREXP is increased if the value of ΔRCF is higher (and vice-versa). Secondly, the values of the estimated coefficients of the squared terms suggest that, in the case of R&D, the effect of a higher R&D relative effort on world market share dynamic is an increasing function of ΔRRD. Conversely, in the case of RCF, the return, in terms of export shares' growth rates, decreases when values of a change in the capital formation index are higher.

In general the results shown in Tab. 3.15 confirm that countries' relative position in terms of R&D and capital formation plays an important role in the determination of competitiveness gains. However, since the aim of this paper is to enquire sectoral specificity in the relation between these variables, it is necessary to pass to specification (3.2). The evidence that specification 3.1 still explains a low portion of the total variance also suggests exploring slope differences between technological classes. They also suggest a pattern. The marginal effect of ΔRRD on ΔREXP turns out to increase with the value of ΔRRD itself.

Columns (i) in Tab. 3.16 show the estimates of specification (3.2). In columns (ii) the same formulation is used without the inclusion of not statistically significant coefficients. In columns (iii) interaction and squared terms are introduced. The estimated coefficients do not reject the hypothesis that differences in the technological content of sectors affect the relation between technological variables and export market shares. In particular, in the high technology sample, R&D relative effort coefficient is significantly different from zero, while the capital formation parameter is not statistically significant. The opposite occurs in the medium technology case, where estimated γ is significantly different from zero, while estimated β is not. In low technology sectors positive changes in the relative labour cost coefficients seem to play a negative role in the determination of world market shares dynamics (column (i)). However estimated δ cannot be considered statistically different from zero.

The consideration of interaction and squared terms brings about further results. Complementarity between embodied (ΔRCF) and disembodied (ΔRRD) investment emerges both in the high technology and low technology industries and it is absent in the medium technology sectors. Two effects, which seemed to be general in specification 3.1, turn out to be limited at the high technology sectors: in the case of R&D, the effect of a higher ΔRRD on ΔREXP is an increasing function of ΔRRD. In the case of ΔRCF, the return in terms of export market shares decreases with ΔRCF. Finally, always in the high technology industries, there is an interesting interaction between modifications in relative capital formation and changes in the relative labour cost. This means that a higher value of ΔRLC improves the effect of a higher ΔRCF on world marked shares. This circumstance can be interpreted in two ways. On

[12] *, ** and *** indicate a rejection of the null hypothesis at a significance level of 15, 10 and 5 percent,

the one hand, capital formation can be more successful if the quality of human capital improves. The evidence that this interaction is significant only in high technology sectors also supports this point of view. On the other hand an increased level of relative labour costs could foster factor substitution and then capital formation which, in turn, improves export market shares.

Summing up, this exercise confirms the importance of technological variables in the relation with world market shares in two ways. First they are, in general, statistically significant, second the taxonomy of technological classes in terms of R&D intensity seems to be meaningful in disentangling the role played by sectoral diversity in the relation between embodied and disembodied investment and competitiveness.

In the next section the relation between technology and competitiveness is studied more in depth. In particular:

- variables will be normalised of the size effect,
- it will be possible to test a specification for each sector without sectoral pooling,
- the analysis will be dynamic and will keep into account the sectoral structures of time lags.

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respectively.

Tab. 3.14: *Correlation coefficients between REXP, RRD, RCF and RLC (Three sub-periods).*

	Sub-periods	*REXP-RRD*	*REXP-RCF*	*REXP-RLC*
All sectors (N=149)	1	0.72 (0.0001)	0.80 (0.0001)	0.36 (0.0001)
	2	0.65 (0.0001)	0.76 (0.0001)	0.36 (0.0001)
	3	0.70 (0.0001)	0.76 (0.0001)	0.46 (0.0001)
HT (N=47)	1	0.83 (0.0001)	0.87 (0.0001)	0.27 (0.06)
	2	0.80 (0.0001)	0.88 (0.0001)	0.3 (0.04)
	3	0.88 (0.0001)	0.86 (0.0001)	0.37 (0.09)
MT (N=50)	1	0.78 (0.0001)	0.81 (0.0001)	0.54 (0.0001)
	2	0.73 (0.0001)	0.75 (0.0001)	0.50 (0.0002)
	3	0.76 (0.0001)	0.74 (0.0001)	0.61 (0.0001)
LT (N=52)	1	0.43 (0.001)	0.63 (0.0001)	0.38 (0.005)
	2	0.28 (0.005)	0.47 (0.0004)	0.37 (0.007)
	3	0.34 (0.01)	0.54 (0.0001)	0.48 (0.0003)

Tab. 3.15: *POLS Estimates of specification 3.1.*

Dep. Var.	*(i)*	*(ii)*	*(iii)*
ΔRRD	0.08*** (2.49)	0.08*** (2.46)	
ΔRCF	0.06** (1.74)	0.06*** (1.74)	0.10*** (1.99)
ΔRLC	-0.06 (-0.41)		
ΔRRD*ΔRCF			0.11** (1.65)
ΔRRD*ΔRRD			0.07*** (2.71)
ΔRCF*ΔRCF			-0.07*** (-1.98)
$\frac{\partial \hat{E}[\Delta REXP]}{\partial \Delta RRD}$	0.08	0.08	0.02
$\frac{\partial \hat{E}[\Delta REXP]}{\partial \Delta RCF}$	0.06	0.06	0.11
n	293	293	293
F	5.8***	6.56***	5.64***
R_{ADJ}	0.13	0.13	0.15

Notes: Test-t in parenthesis. Levels of significance: *=85%, **=90%, ***=95%. Test of homogeneity of constant term against country and technological classes fixed effects: $F_{13,276}$=2.27*** and $F_{2,287}$=3.13***. Fixed effects included when significantly different from zero. No heteroscedasticity detected in the POLS estimates (White tests). No multicollinearity (Variance inflation numbers and condition number). The calculation of marginal effects follows Greene (1997; p.391-392).

Tab. 3.16: *POLS Estimates of specification 3.2.*

	High Tech. Sectors			*Medium Tech. Sectors*			*Low Tech. Sectors*		
Dep. Var.	*(i)*	*(ii)*	*(iii)*	*(i)*	*(ii)*	*(iii)*	*(i)*	*(ii)*	*(iii)*
ΔRRD	0.12*** (2.4)	0.12*** (2.44)		0.05 (0.86)			0.05 (0.88)		
ΔRCF	0.01 (0.25)			0.17*** (2.16)	0.17*** (2.2)	0.18*** (2.45)	0.07 (0.91)		
ΔRLC	0.0003 (0.01)			0.05 (0.13)			-0.28 (-0.78)		-0.5* (-1.46)
ΔRRD*ΔRCF			0.13** (1.7)						0.38*** (2.43)
ΔRRD*ΔRRD			0.08*** (2.46)						
ΔRCF*ΔRCF			-0.09*** (-2.37)						
ΔRCF*ΔRCL			1.57** (1.91)						
$\frac{\partial \hat{E}[\Delta REXP]}{\partial \Delta RRD}$	0.12	0.12	0.08						0.03
$\frac{\partial \hat{E}[\Delta REXP]}{\partial \Delta RCF}$			0.07	0.17	0.17	0.18			0.04
$\frac{\partial \hat{E}[\Delta REXP]}{\partial \Delta RCL}$			0.20						-0.5
	(1)	(2)	(3)						
n	293	293	293						
F	3.68***	6.23***	6.06***						
R_{ADJ}	0.13	0.14	0.16						

Notes: Test-t in parenthesis. Levels of significance: *=85%, **=90%, ***=95%. Fixed effects included when significantly different from zero. No heteroscedasticity detected in the POLS estimates (White tests). No multicollinearity (Variance inflation numbers and condition number). The calculation of marginal effects follows Greene (1997; p.391-392).

4. Sectoral Specificity in the Relation between Technology and Market Share Dynamics

4.1 The Dynamic Specification

In this section the role, played by sectoral specificity, in the relation between technology and export is studied in a dynamic framework. It is appropriate to emphasise that technological innovation processes are inherently dynamic and that in many empirical studies this feature has been neglected[13]. Here we use a panel-dynamic (DL) specification for each sector in order to extend specification (3.1) and (3.2) and to assess sectoral diversity from two points of view: 1) diverse coefficients' significance and magnitude in different sectors, 2) different structures of time lags.

As in the previous section the 'engines', which affect market share dynamics, are: R&D per employee, Gross Fixed Capital Formation per employee and human capital. The dynamic relation between these variables and world export market shares is studied with a DL specification as follows:

$$X_{i,j,t} = a_i + m_j + t_t + \sum_{l=0}^{m} g_l RDL_{i,j,t-l} + \sum_{l=0}^{n} d_l CFL_{i,j,t-l} + \sum_{l=0}^{g} j_l RLC_{i,j,t-l} + e_{i,j,t}; \qquad (4.1)$$

α_i, μ_j e τ_t correspond to sector i, country j, time t fixed effects.

-$X_{i,j,t}$: is the rate of growth of the ratio of export in sector i, country j at time t to country aggregate in sector i at time t.

-$RDL_{i,j,t}$: is the rate of growth of the ratio of R&D per employee in sector i, country j at time t to country aggregate in sector i at time t.

-$CFL_{i,j,t}$: is the rate of growth of the ratio of GFCF per employee in sector i, country j at time t to country aggregate in sector i at time t.

-$RLC_{i,j,t}$: is the rate of growth of the ratio of labour compensation per employee in sector i, country j at time t to the weighted country average in sector i at time t.

The description of the number of sectors (12), countries (14) and years selected is provided in Tab. A.2 in the Appendix. As stressed in the previous section R&D and GFCF are proxies for the technological vitality of country j in sector i. The former reflects the disembodied nature of technological advancements, the latter approximates the technological improvements which are incorporated in new machinery and equipment. In addition a relative labour cost index is calculated.

[13] Static relationships are estimated in Soete, 1981, Dosi et al., 1990 and Fagerberg, 1988. Dynamic specifications are tested in Amendola et. al, 1993; Magnier, Toujas-Bernate, 1994 and Amable Verspagen, 1995.

Again there are not *a priori* expectations on the sign of cofficient φ because, on the one side, RLC may reflect wage changes in order to attract high quality labour, on the other side, it represents an increased cost for the firms[14].

4.2 Estimation Results

First consider the pooling of the twelve sectors. Pooled Least Squares estimates, shown in Tab. 4.1, do not reject the hypothesis of an important role played by the technological variables. RDL, CFL and RLC estimated parameters are significantly different from zero with a delay of three lags for RDL, zero and three lags for CFL and two years for RLC. POLS estimates do not pass the diagnostic check. First the restriction of homogeneity of slopes is rejected, secondly Breush-Pagan/Godfrey Test (Greene, 1997; p.552) reveals the presence of heteroscedasticity.

The following step is then dividing the sample in three sub-samples composed by high, medium and low technology sectors[15]. In the Tab. 4.1 results are reported just for the first two categories. For the low-technology sectors the estimates do not return values which are significantly different from zero. This is not surprising because the adopted specification does not include important non-technological variables (marketing expenditure, specific price factors) which are probably crucial in traditional sectors. With respect to LT sectors the result, found in the previous section (Tab. 3.16), is lost in specification 4.1. This is probably due to the shorter run character of this latter formulation and on the possible inertia in the effects that parameters φ attempt to embody.

However some important sectoral specificities emerge in Tab. 4.1. RDL estimated coefficient is greater in the case of high technology sectors. It is suggested also that RDL acts with a greater delay than CFL. RLC estimated coefficient is significantly different from zero only in the high tech sectors at time lag 2. The positive sign suggests that human capital plays a role in supporting competitiveness gains in these sectors. These estimates, even if they start providing some introductory evidence on

[14] R&D and GFCF are used as measures technological inputs. The link between R&D and technological output is complex and is only partly grasped in specification 4.1. Firstly R&D expenditure not always translates in tradable processes and products, secondly, as stressed by Fagerberg (1988), capacity constraints at firm level and firms ability to actually exploit R&D output have to be taken into account. Finally in this paper technological spillovers and externalities are not explicitly considered (Pavitt, 1984; Verspagen, De Loo, 1998). Since R&D expenditures are reported on a territorial basis the three variables not only do not take into account technological transfers across macro-sectors, but also underestimate transfers which take place within firms. This problem is partially overcome considering that cross-country variance of these effects is limited in our sample because all countries are advanced. Moreover, as noted by Amendola et al. (1993), acquisition and localisation processes of multinational firms respond to the technological sophistication reflected in the values of the variable chosen in this paper.

[15] This exercise is of course different from the one performed in Section 3.3 variable are normalised for the size effect, there is no averaging across sub-periods and, finally the time dimension is explicitly addressed.

sectoral diversity, incur the following problems: first, heteroscedasticity is detected by the Breush-Pagan/Godfrey Test, second, adjusted R-squared show that a great portion of variance remains unexplained and, finally, the restriction of sectoral homogeneity of the slopes is rejected in two cases out of three.

Both the theoretical discussion in Section 2 and the evidence in Tab. 4.1 suggest continuing the analysis estimating 4.1 separately for each single sector. For each sectoral sample, heteroscedasticity has been detected. As a result two stages FGLS have been used on the following specification:

$$X_{j,t} = \mu_j + \tau_t + + \sum_{l=0}^{m} \gamma_l RDL_{j,t-l} + \sum_{l=0}^{n} \delta_l CFL_{j,t-l} + \sum_{l=0}^{g} \varphi_l RLC_{j,t-l} + \varepsilon_{j,t};$$

j=1,……., M; t=1,…..,T; (4.2)

μ_j e τ_t are country j and time t fixed effects.

The estimates are shown in Tab. 4.2. For each sector a restricted model with homogeneous intercepts has been tested against three models without restrictions on the intercepts (time and country fixed effects, country fixed effects and time fixed effects). This restriction has always been accepted except for the case of Telecommunications Equipment where time-fixed effects have been included. In all the regression autocorrelation error diagnostic is implemented via the Box-Pierce and the Ljung-Box Tests (Greene, 1997, p.595) for one to four years lags. The panel structure of the observations has been taken into account in the construction of these tests.

In Tab. 4.2 sectoral diversity emerges from a double perspective: in the statistical significance of the coefficients and in the time lag structure. In particular RDL coefficient estimates show a regular pattern. They are significantly different from zero in six sectors out of eight. This result confirms the role of relative R&D expenditure in affecting export performance of countries, moreover it reinforces the empirical evidence already available which often is not sectorally disaggregated (Soete, 1981; Fagerberg, 1988; Dosi et al. 1990; Amendola et al. 1993; Amable, Verspagen, 1995). Secondly it is interesting to note the sectoral differences in the time lags necessary for R&D expenditure to affect export market shares. In Aircraft, Telecom Equipment and Motor Vehicle the time lag is three years, in two Pharmaceuticals and Non-electrical Machinery is two years and Electrical Machinery is one year.

In addition it emerges an important regularity. The values of parameters γ, which are significantly different from zero, are correlated with the sectoral R&D intensity. This result suggests that R&D intensity is an important cornerstone not only to understand the technological content of the sectoral activity but also to evaluate the dynamic relation between relative R&D effort and market share dynamics.

It is surprising that coefficients γ are not statistically significant in the case of Computers and Office Machinery and Chemicals. The first is a high tech sector. This non-intuitive result can be caused in the case of Computers and Office Machinery by a high heterogeneity across countries[16]. The hypothesis of different 'national' strategies is confirmed by a regression exercise on selected sub-samples. POLS results on the G5 countries (as in Magnier, Toujas-Bernate, 1994) display a value of estimated γ (at a time lag equal to 3) of 0.28 (significantly positive at the 5% significance level). POLS estimates on the remaining countries do not show a significant statistical relationship between RDL and X.

This result is undoubtedly related to different national patterns of industrial organisation and efficiency in the connectivity between research and economic activity and attributes an important explicative role to different 'national systems of innovations'. The result for the Chemical industry, in turn, is probably affected by the high product heterogeneity of this sector. It has been calculated as a residual (ISIC: 351(Industrial Chemicals)+352(Other Chemicals)-3522(Pharmaceuticals)) and contains basic industrial chemicals, fertilisers and pesticides, synthetic resins, plastic materials and man-made fibres, paints, varnishes, soaps, perfumes and cosmetics.

The dynamic relation between the relative investment effort indicator (CFL) and export market share (X) dynamics shows again a highly sector specific character. At the same time there is not a recognisable pattern in the values of the estimates. The parameters δ are significantly positive in the case of Computers and Office Machinery Electrical and Non-electrical Machinery. It is significantly negative in the case of Electrical Machinery and Chemicals.

The estimates of relative labour cost coefficients are significantly positive in three sectors (Aircraft, Non-electrical Machinery and Motor Vehicles) and, this would support an interpretation in terms of human capital, and negative in Telecommunications Equipment. This latter result is somewhat surprising. As a result, also in this case, POLS regressions have been performed on the sub-sample of the G5 countries and on the sub-sample of the remaining countries. Results confirm what found by Magnier and Toujas-Bernate (1994): in the regression for the G5 countries all the parameters φ cannot be considered significantly different from zero at a significance level of 10%. At the same time the negative estimated impact of RLC on X emerges clearly in the regression analysis for the remaining countries. It has then to be stressed the importance, within diverse sectoral-specific sets of relations, of specific national institutional features, which clearly affect industrial organisation and the competitive process.

5. Conclusions

This paper focuses on a selected number of OECD countries and manufacturing sectors and shows theoretically and empirically the importance of sectoral diversity in the innovative process and in the relation between technology and world market share dynamics. The main hypothesis that underpins this paper is that there are important sectoral differences in the way firms innovate and develop and that these differences originate mainly in the technological domain.

The hypothesis that there exist technology-driven differences among sectors accounted for by R&D intensities cannot be rejected. These differences are persistent through time and emerge consistently in all countries. At the same time country specificity is grasped considering the relative R&D effort, which shows a leading position of the US. US are far ahead in all high technology industries, due also to a size effect, with Japan catching up mainly in the Computer, Electronics and Machinery industries.

At the same time the descriptive analysis of export data shows that US, Germany and Japan have higher market shares in almost all sectors. Keeping into account the size effect, these countries have also the highest values of relative R&D effort in all sectors. Revealed absolute advantages are fairly stable in the two sub-periods. This confirms the specific and cumulative character of sectoral success factors in each country. Within this framework, market shares gain of Germany and the decline of the US in the HT sectors are noteworthy. Sectoral diversity emerges in the different values of cross-country market shares variance. The dispersion is higher (and decreasing in the two sub-periods) in the high-tech sectors (pharmaceutical excluded).

The econometric exercise confirms the importance of technological variables in the relation with world market shares in two ways. First they are, in general, statistically significant, second the taxonomy of technological classes in terms of R&D intensity seems to be meaningful in disentangling the role played by sectoral diversity in the relation between embodied and disembodied investment and competitiveness. In particular a DL specification has been tested in order to evaluate sectoral differences in non-price factors of competitiveness where variables are normalised of the size effect. R&D (per employee) relative efforts play a crucial role in affecting world market share dynamic. Sectoral diversity emerges in the statistical significance of the coefficients and in the time lag structure. Moreover the values of estimated R&D parameters are correlated with the sectoral R&D intensity. This result suggests that R&D intensity is an important cornerstone not only to understand the technological content of the sectoral activity but also to evaluate the dynamic relation between relative R&D effort and market share dynamics. Important country-specific effects also emerge. This reveals that important national institutional and organisational forces are at work as pointed out by the literature on innovation systems.

[16] It is possible that, within the macro-sector considered, there is a variance in sub-products' R&D intensity. Some countries, then, could specialise, more than others, in sub-products with a high research intensity.

Tab. 4.1: *POLS Estimates of specification 4.1.*

	Lags	*All sectors* (b)(c)	*HT* (b)(c)	*MT* (c)
RDL	0			
	1			
	2			
	3	0.03***	0.32***	0.06**
CFL	0	0.05***	0.07**	0.04**
	1			
	2			
	3	0.03**		
RLC	0			
	1			
	2	0.22**	0.42*	
	3			
	n.obs.	1550	444	462
	F	6.27***	10.42***	4.97***
	adjR^2	0.02	0.08	0.04
TESTS	(a)	$F_{66,1477}$ =5.06***	$F_{12,427}$ = 5.36***	$F_{6,453}$ =1.11
	(d)	X(13)=888.34***	X(12)=335.37***	X(12)=138.87***
	(e)	X(11)=1615.90***	X(3)=159.92***	X(3)=42.97***

(a) test of sectoral homogeneity of slope.
(b) autoregressive component is included when signficantly different from zero.
(c) Country and sector fixed effects have been tested. Hypothesis of homogeneity of the intercept rejected.
(d) -(e) Heteroscedasticity: Breush-Pagan/Godfrey Test: countries (d) and sectors (e).
Significativity levels: *: 90%, **: 95%, ***: 99%;

Tab. 4.2: *FGLS estimates of specification 4.2;*

		Aircraft	*Computers Office Machinery*	*Pharm.*	*Telecom Equip.*	*Electrical Machinery*	*Motor Vehicles*	*Chemicals*	*Non Electrical Machinery*
R&D Intensity		15.7	11.7	10.9	7.9	3.4	3.37	3.37	2.0
	Lags	(b)		(b)	(c)			(b)	(b)
RDL	0								
	1					0.12***			
	2			0.18**					0.06*
	3	0.72***			0.17**		0.10*		
CFL	0								0.18***
	1							-0.10***	
	2		0.09**					0.08***	
	3					-0.07*		-0.09***	
RLC	0						1.01*		
	1	1.41**							
	2						0.44*		0.36**
	3				-0.77**				
	n.obs.	90	117	120	117	117	108	120	104
	F	10.41***	3.22**	6.17***	2.74***	5.34***	3.87***	6.27***	7.17***
	$adjR^2$	0.24	0.03	0.08	0.13	0.07	0.14	0.15	0.19
Test L-B	$X_{(3)}$, (4 lag)	6.54	1.31	2.52	4.19	3.46	1.39	3.80	0.55

Significativity levels: *: 90%, **: 95%, ***: 99%;
Autocorrelation diagnostic check: Breush-Pagan and Ljung-Box test for 1 to 4 lags. Only the Ljung-Box test for the fourth lag is reported. The value c such that $Prob[X_3^2 <= c] = 0.95$ is 7.82

Multicollinearity diagnostic check: Condition Number and Variance Inflation Number. Not detected
(b) Autoregressive component is included when significantly different from zero.
(c) The presence of fixed time effect is not rejected by the appropriate F-test

Appendix

Tab. A.1: *Sectors used in Section 3*.

Sectors:	ISIC Rev.2
1. Food (food products manufactures: meat, fish, fruits, sugar etc. ; beverage: wine, spirits, soft drinks etc.; tobacco manufactures).	31
2. Textile (wearing apparel, leather, carpet and rugs, furs and footwear).	32
3. Wood (wood and cork products, furniture).	33
4. Paper (paper and pulp products, printing and publishing).	34
5. Chemicals (pharmaceuticals excluded, industrial chemicals, soap, paints, cosmetics).	351+352-3522
6. Pharmaceuticals (drugs and medicines).	3522
7. Computers and Office Machinery.	3825
8. Non Electrical Machinery (engines, turbines, agricultural equipment, metal and wood machinery).	382-3825
9. Electronics (telecom. equipment semiconductors, TV, radio etc.)	3832
10. Electrical Machinery.	383-3832
11. Motor Vehicles.	3843
12. Aircraft.	3845

Tab. A.2: *Database used in Section 4.*

	Aircraft	*Electronics*	*Computers and Office Machinery*	*Pharm.*	*Chemicals*	*Non Electrical Machinery*	*Electrical Machinery*	*Motor Vehicles*	*Food*	*Wood*	*Paper*	*Textile*	*n. sectors*	*Obs. per country*
Aus		x	x	x	x	x	x	x	x	x	x	x	11	115
Can	x	x	x	x	x	x	x	x	x	x	x	x	12	125
Den		x	x	x	x	x	x		x	x	x	x	10	106
Fin	x	x	x	x	x	x	x	x	x	x	x		11	111
Fra	x	x	x	x	x	x	x	x	x	x	x	x	12	125
Ger	x	x	x	x	x	x	x	x	x	x	x	x	12	125
Ita	x	x	x			x	x	x	x	x	x	x	10	105
Jap		x	x	x	x	x	x	x	x	x	x	x	11	115
Net	x	x	x	x	x	x	x	x	x	x	x	x	12	125
Nor		x	x	x	x	x	x	x	x	x	x	x	11	115
Spa	x	x	x	x	x	x	x	x	x	x			10	97
Swe									x	x	x		3	36
UK	x	x	x	x	x	x	x	x	x	x	x	x	12	125
US	x	x	x	x	x	x	x	x	x	x	x	x	12	125
Countries(n)	9	13	13	12	12	13	13	12	14	14	13	11		1550
Years	82-91	82-90	82-90	81-90	81-90	82-90	82-90	82-90	81-91	81-91	77-90	77-90		
T	10	9	9	10	10	9	9	9	11	11	14	14		
n X T	90	117	117	120	120	117	117	108	154	154	182	154		

	Number of. observations
TOTAL	1550
High Technology	444
Medium Technology	462
Low Technology	644

References

Amable, B., Verspagen B., (1995); The Role of Technology in Market Share Dynamics, *Applied Economics,* v. 27, pp. 197-204.

Amendola G., Dosi G., Papagni E. (1993); The Dynamics of International Competitiveness, *Weltwirtshaftliches Archiv*, v.129, pp. 451-471.

Bijker W.E., Hughes T.P., Pinch T.J. (eds) (1989); *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology*. MIT Press, Cambridge, pp. 51-82.

Breschi S., Malerba F., (1997); Sectoral Innovation Systems: Technological Regimes, Schumpeterian Dynamics and Spatial Boundaries. in Edquist C. (eds), *Systems of Innovation, Technologies, Institutions and Organizations*. Pinter, London, ch. 6, pp.130- 156.

Breschi S., Malerba F., Orsenigo L. (1999); Technological Regimes and Schumpeterian Patterns of Innovation, *The Economic Journal*, forthcoming

Carlsson B. (ed.) (1995); *Technological Systems and Economic Performance: The Case of Factory Automation*. Kluwer Academic Publishers. Dordrecht.

De Liso, N. Metcalfe J. S. (1996); On Technological Systems and Technological Paradigms. Some Recent Developments in the Understanding of Technological Change, in Helmstädter, Perlman, E. (eds), *Technological Progress and Economic Dynamics*, University of Michgan Press, Ann Arbor.

Dosi, G. (1997); Opportunities, Incentives and the Collective Patterns of Technological Change, *The Economic Journal*, 107, pp.1530- 1547.

Dosi, G. (1988); Sources, Procedures and Microeconomic Effects of Innovation. *Journal of Economic Literature*, Vol. 26, pp. 1120-1171.

Dosi, G. (1982); Technological Paradigms and Technological Trajectories. *Research Policy,* n. 11, pp. 129-180.

Dosi, G., Pavitt, K., Soete, L. (1990); *The Economics of Technical Change and International Trade*, Harvester Wheatsheaf, Hertfordshire.

Edquist C., (1997) (ed.), *Systems of Innovation. Technologies, Institutions and Organizations*. Pinter, London.

Fagerberg J. (1988); International Competitiveness, *The Economic Journal*, v. 98, pp. 355-374.

Freeman C. (1995); The 'National System of Innovation in Historical Perspective, *Cambridge Journal of Economics*, vol. 19, n.1, pp. 5-24.

Freeman C. (1987); *Technology Policy and Economic Performance: Lessons from Japan.* Frances Pinter. London.

Greene W.H. (1997); *Econometric Analysis*, Prentice Hall, Upper Saddle River, N.J.

Greenhalg C., (1990); Innovation and Trade Performance in the United Kingdom, *The Economic Journal*, v.100, pp. 105-118.

Gutting, G. (1984), Paradigms, Revolutions and Technology, in: Laudan, R. (1984) (eds); *The Nature of Technological Knowledge. Are Models of Scientific Change Relevant ?,* D. Reidel Publishing Company, Dordrecht. Ch. 3, pp. 47-65.

Hård, M. (1994); Technology as Practice: Local and Global Closure processes in Diesel-Engine Design, *Social Studies of Science*, v. 24, pp. 549-585.

Jaffe A.B. (1989); Real Effects of Academic Research, *American Economic Review*, 79, pp. 957-970.

Klepper S. (1997), Industry Life Cycles, *Industrial and Corporate Change*, Vol. 6 (1), pp. 145-181.

Klepper S. (1996), Entry, Exit, Growth, and Innovation over the Product Life Cycle, *American Economic Review*, 86 (3), pp. 562-583.

Laudan, R. (1984) (eds); *The Nature of Technological Knowledge. Are Models of Scientific Change Relevant?*, D. Reidel Publishing Company, Dordrecht.

Levin R.C. (1988); Appropriability, R&D Spending and Technological Performance, *American Economic Review*, Paper and Proceedings, vol. 78, pp. 424-428.

Levin R.C., Klevorick A.K., Nelson R., Winter S. (1987); Appropriating the Returns from Industrial Research and Development, Brooking Papers on Economic Activity, n. 3, pp. 783-831.

Lundvall B.-A. (ed.) (1992); *National System of Innovation. Towards a Theory of Innovation and Interactive Learning.* Pinter. London.

Magnier, A., Toujas-Bernate, J. (1994); Technology and Trade: Empirical Evidences for the Major Five Industrialized Countries, *Weltwirtshaftliches Archive,* v.130, pp. 494-520.

Magnier, A., Toujas-Bernate, J. (1993); Innovation Technologique et Performance a l'Exportation, in Guellec, D. (ed.), *Innovation et Compétitivité*, INSEE Méthod, N. 37-38, pp.98-123.

Malerba, F. (1992); Learning by Firms and Incremental Technical Change, *The Economic Journal*, 102, pp. 845-859.

Malerba F., Orsenigo L. (1997); Technological Regimes and Sectoral Patterns of Innovative Activities, *Industrial and Corporate Change*, v. 6(1), pp.83-117.

Malerba F. Orsenigo L. (1996); Schumpeterian Patterns of Innovations are Technology Specific, *Research Policy*, 25, pp. 451-478.

Malerba F., Orsenigo L. (1995); Schumpeterian Patterns of Innovations*; Cambridge Journal of Economics*, vol. 19, n.1, pp. 47-65.

Metcalfe J.S. (1995); Technology Systems and Technology Policy in an Evolutionary Framework, *Cambridge Journal of Economics*, vol. 19, n.1, pp. 25-46.

Miozzo M., Montobbio F. (1997); *Industrial Dynamics: Product Cycles and Systems of Innovations*. Paper presented at the ASEAT Conference, UMIST, Manchester.

Nelson R.R. (ed.), (1993) *National Innovations Systems: A Comparative Study,* Oxford, Oxford University Press.

Nelson, R.R. Winter S. (1982); *An evolutionary Theory of Economic Change*, The Belknap Press, Cambridge (Mass.).

OECD (1998); *Basic Science and Technology Indicators*, OECD, Paris

OECD (1997); *Analytical Business Enterprise R&D (ANBERD) Database*, OECD, Paris

OECD (1997); *Structural Analysis Industrial (STAN) Database*, OECD, Paris

OECD (1996); *Analytical Business Enterprise R&D (ANBERD) Database*, OECD, Paris

OECD (1996); *Structural Analysis Industrial (STAN) Database*, OECD, Paris

OECD (1986); Technological Performance and Indurial Competitiveness, in OECD (1986), R&D, Invention and Competitiveness; *OECD Science and Technology Indicators*, n. 2, Cap. 2, pp. 58-76.

Patel P., Pavitt K., (1996); Patterns of Technological Activity: their Measurement and Interpretation, in Stoneman P. (ed.), *Handbook of the Economics of Innovation and Technological Change*. Blackwell. Oxford. Cap. 2, pp. 14-51.

Patel P., Pavitt K., (1994); Uneven (and Divergent) Technological Accumulation among Advanced Countries: Evidence and a Framework of Explanation. *Industrial and Corporate Change*, v.3, n.3, pp. 759-787.

Pavitt, K. (1984); Sectoral Patterns of Technical Change: Towards a taxonomy and a Theory, *Research Policy*, 13, pp. 343-373.

Schumpeter, J.A. (1942); *Capitalism, Socialism and Democracy*. Harper. New York.

Schumpeter, J.A. (1934); *The Theory of Economic Development*, Harvard Economic Studies, Cambridge Mass.

Soete, L. G. (1981); A General Test of Technological Gap Trade Theory, *Weltwirtshaftliches Archiv*, band 117, pp. 638-650.

Utterback, J.M., Abernathy W.J. (1975); A Dynamic Model of Process and Product Innovation, *Omega*, 3, pp. 639-656.

Verspagen B., De Loo, I., (1998); *Technological Spillovers between Sectors and over Time*, Paper presented at 12th Conference on Input-Output techniques, York, May.