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Measurement and Analysis of Technological Competencies of Large Firms

By

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1. Objectives

This report documents the preliminary results of the project concerned with the measurement and analysis of technological competencies within firms. The main aim is to compare large companies from the Triad (Europe, Japan and the USA) in terms of their patterns of *technology diversification* (spread of competencies across technical fields) over time. In particular the report addresses the following questions:

- Have firms become more or less technologically diversified since the 1980's?
- What are main differences in the characteristics of diversifying and non-diversifying firms?
- To what extent are increases in technology diversification associated with (a) growth in the volume of technological activities (measured by R&D expenditures and total patenting) (b) rate of entry into new (or fast-growing) areas (c) economic performance (as measured by sales growth)?

2. Background and Rationale

This project is concerned with the measurement and analysis of technological competencies and their accumulation at the level of the firm. Whilst there is increasing emphasis on the importance of technological competencies, only a limited number of studies have attempted to devise explicit measures of them. The focus here will be on using information on US patenting activities to investigate the extent of the spread of competencies (technology diversity) within firms and how they have evolved over time. The underlying rationale is that the granting of a patent reflects the judgement of the patent examiner that the applicant has the competence to improve technology in a given field, even though it maybe difficult to foresee its degree of usefulness at the time. Other measures used to map competencies have been based on the technical field of qualification of corporate employees, especially engineers (Jacobsson and Oskarsson (1995). However few countries apart from Sweden have collected such comprehensive data on a regular basis.

A major reason for focusing on the activities of *large* firms is that despite the rhetoric on the importance of small firms, large firms are a major source of new technology and innovation.

Although data on formal R&D expenditures exaggerate their share in national technological activities, they make an important contribution especially in the so called 'high technology' sectors (Chemicals and Electronics). Further large firms also contribute to the development of technology (and new products) in other smaller firms such as the suppliers of their production equipment, components and software (Patel & Pavitt 1994). Thus strategic decisions by these firms can have a major impact on the sectoral patterns of technological activities, and competitive performance, of whole countries and industrial sectors.

Our earlier work (Granstrand et. al. (1997) and Patel and Pavitt (1997)) highlighted the following characteristics of technological competencies of large firms:

- They are typically *multi-field* with substantial proportion of activities outside what would appear to be the core fields. A large number of firms in all sectors are active in machinery and process related technologies (instruments and controls, chemical processes, and non-electrical machinery), where they often do not have a distinctive technological advantage, and where smaller firms are particularly active. This reflects both the multi-technology nature of their products, and the knowledge requirements for co-ordinating in-house product innovation with innovation in related production systems and supply chains.
- Each firm has a measurable *profile* of competencies, with varying levels of commitment and competitive advantage in a range of technological fields. In general, firms' technological profiles are *highly stable* over time, reflecting the localised and cumulative nature of technological learning.
- Large firms' technological profiles are *highly differentiated*, according to the products that they make. Firstly firms have significantly different profiles of technological competence to most others. Secondly, in all sectors firms have a higher probability of finding others with similar technological profiles *within* their sector than *outside* their sector. Thirdly, the frequency of technological proximity between firms in different industrial sectors is not evenly spread or random, but reveals 3 distinct groupings:

  + chemicals, pharmaceuticals, and mining and petroleum sectors,
  + machinery and vehicles,
  + electrical and computers.

Moreover this research showed that firms were acquiring new technological competencies over time. The measurable effects of such increasing spread of competencies over time (i.e. technology diversification) have been highlighted by Granstrand (1998): growth of R&D, growth of sales, growth of external technology sourcing and growing opportunities for business diversification. In this project our data only allows us to analyse in some detail the evidence for the first two effects. Thus in section 3, we describe the sample and the data base as well as highlighting the main limitations of our analysis. In section 4 we examine the differing characteristics of firms that have become more diversified, remained stable or become less diversified from the 1980's to the mid 1990's. In particular we focus on the following dimensions: technology leadership, changes in the volume of technological activities, and changes in market shares. Section 5 contains the main conclusions and policy implications.

3. Sample, Data Sources and Limitations

3.1 Population of Firms

Our population is made up of 463 of the world's largest firms according to sales drawn from the Disclosure Global WorldScope database. We have excluded (a) firms which are not technologically active in patenting in the USA in the period 1980 to 1996[1] and (b) those based in countries outside the Triad (e.g. S. Korea, Australia, S. Africa, and Latin America). The data that we have for each firm are its sales, employment, principal sector of activity, country of origin (i.e., country of headquarters), and R&D expenditures, derived from Disclosure and other sources such as Company Reporting. All firms had sales of more than US$ 1,000 million in 1996 and the average level of employment was in excess of 40,000 employees. For a number of companies the country of origin is not immediately obvious and we have made some arbitrary decisions for this report, e.g. ABB is regarded as Swiss, Smithkline Beecham, and Unilever British, and Shell as Dutch.

Table 1 shows the distribution of the 463 firms according to principal product group and region. Thus 34% are of European origin, 37% are US owned, and 29% are Japanese. Within

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[1]These are mainly resource based companies (related to the mining and petroleum industry), and those involved in textiles and in publishing.

Europe the largest contributors are the Germany (43), UK (35) and France (21). Throughout this report we have included Switzerland as a part of Europe as a number of large Swiss companies have widespread activities (technological and economic) within the EU. In terms of industrial sectors, nearly half the firms are in Chemicals, Electronics (including Computers and Telecommunications) and Machinery.

Table 1. Distribution of Large Firms by Nationality and Product Group.

Principal Product Group	*Number of Firms*	*EU*[1]	*JP*	*US*[2]	*Total*
Aerospace	16	25.0	0.0	75.0	100.0
Chemicals	70	30.0	42.9	27.1	100.0
Electrical/Electronics[3]	84	19.0	34.5	46.4	100.0
Food, Drink & Tobacco	18	33.3	11.1	55.6	100.0
Machinery	78	48.7	19.2	32.1	100.0
Materials	18	22.2	50.0	27.8	100.0
Metals	38	42.1	31.6	26.3	100.0
Mining & Petroleum	25	40.0	4.0	56.0	100.0
Motor Vehicles and parts	42	42.9	38.1	19.0	100.0
Paper	16	31.3	6.3	62.5	100.0
Pharmaceuticals	34	38.2	23.5	38.2	100.0
Photography and Photocopy	15	13.3	60.0	26.7	100.0
Rubber & Plastics	9	33.3	44.4	22.2	100.0
Total	463	33.7	29.4	36.9	100.0

[1] Includes 3 Norwegian and 15 Swiss firms
[2] Includes 4 Canadian firms
[3] Includes Computers

3.2 Patent Data

The data set has been compiled from information, provided by the US Patent Office, on the name of the company, the technical field, and the country of origin, of each patent granted in the USA from 1980 to 1996. The main difficulty in using the primary data at the company level is that many patents are granted under the names of subsidiaries and divisions that are different from those of the parent companies, and are therefore listed separately. In addition the names of companies and other institutions are not unified, in the sense that the same company (or institution) may appear several times in the data, with a slightly different name in each case. For the current analysis we have consolidated the 463 firms on the basis of Who

Owns Whom for 1992 and unified all the names for the period 1980-96. This process has enabled us to identify some 4500 different assignee names for these 463 firms.

There is one caveat that needs to be borne in mind when interpreting the results of the analysis below. As our firms are consolidated for one year only: 1992, the time-trend analyses of patenting by firms between 1980 and 1996, reflects the firm as constituted in that year, and does not include any of the changes resulting from (a) the purchases or sales of subsidiaries or divisions since then, or (b) divestments undertaken over the period since 1980. Thus measured changes over time are composed of changes in those parts of the firm retained up to 1992, together with those resulting from acquisitions made up to 1992: in other words, what the firm kept and what it bought, up to 1992. In order to assess the likely bias introduced by this method of consolidation on the trends in technology diversification, we report the results of a limited[2] analysis based on an earlier year of consolidation, 1984, in section 4.4.

3.3 Advantages and Limitations of the Patent Data

Patent statistics have been used frequently by economists and other analysts as a proxy measure of technological activities[3]. Their general advantages compared to other measures, such as R & D expenditures, are that - with the advent of modern information technology - they are readily available over long time periods; they can be broken down in great statistical detail, according to firm, technical field and geographical location; and they capture technological activities undertaken outside R & D departments, such as design activities in small firms, and production engineering in large firms. Their main general disadvantage is that, like other routine measures of technological activities, they do not measure satisfactorily one of the major fields of technological growth, namely, software.

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[2] Limited because we only have information for 323 of the 463 firms.
[3] See Patel and Pavitt (1995) for a more detailed discussion.

4. Patterns of Technological Diversification

4.1 Measures Used

In this paper, we report on research using the technological fields of US patenting as the basic units of competence. For the US patent examiner, the granting of a patent reflects the judgement that the applicant has the competence significantly to improve technology in a given field. The 34 technical classes used in our analysis are based directly on the US patent classification. Thus we construct the following measures:

1. Number of Technical Fields (out of 34) in which a firm is active.
2. Proportion of patents that are in 'core' technologies. This measure was used in our earlier analyses (Patel and Pavitt (1997)) where we identified fields of *distinctive* or *core* competence as those commanding both high shares of corporate technological resources, and a strong revealed technology advantage compared to the competition. Table 1 in the Annex contains the list of core technical fields in the various product groups.
3. Involvement in fast-growing technical fields. For the analysis of involvement in fast-growing subfields we have identified the 1,000 (out of a total of around 100,000 in the USPC) technological sub-classes with the highest absolute increase in patenting from 1980-84 to 1992-96. Their combined share of total patenting increased steeply from 4% to 15% of total US patenting over this period. A relatively high proportion of these fast growing fields are to be found in electronics and chemical technologies, but cases can be identified in all technological fields. The underlying assumption is that these reflect the fields of greatest technological opportunity. Thus for each company the indicator we calculate is the proportion of a company's total patents that are in these fields.

4.2 Extent of Technology Diversity

Table 2 shows the extent of technology diversity amongst our firms in the period 1991-96 as measured by the proportion of patents outside 'core' technical fields in different product groups. Thus Aerospace firms are amongst the most diversified, with nearly three-quarters of all patents outside their 'core' technical fields (Aerospace; General non-electrical machinery; Power plants), and Pharmaceuticals firms the least (18% outside the 'core' technical fields:

Organic chemicals; Drugs and Bioengineering). The analysis by nationality shows that US firms are more diversified than the firms based in Japan and Europe, with the biggest differences in Aerospace, Chemicals, Food, Drink and Tobacco, and Motor Vehicles. However in other industries such as Electronics, Machinery, Metals and Mining there is a great deal of similarity across regions in the level of diversity.

Table 2. Proportion of Total Patents Outside 'Core' Technical Fields

Product Group	***EU Firms***	***Japanese Firms***	***US Firms***	***Average For Product Group***
Aerospace	57.0		77.2	74.0
Chemicals	25.1	32.8	38.4	31.1
Electrical/Electronics	35.7	32.3	37.0	34.7
Food, Drink & Tobacco	36.0	47.1	50.9	43.2
Machinery	58.8	56.9	60.1	58.8
Materials	43.6	59.1	33.9	52.1
Metals	62.2	59.0	67.8	62.1
Mining & Petroleum	41.5	41.4	41.0	41.2
Motor Vehicles and parts	60.8	53.0	72.0	62.4
Paper	66.8	52.1	56.6	57.7
Pharmaceuticals	23.7	9.8	16.4	17.8
Photography and Photocopy	37.2	45.3	55.0	48.9
Rubber & Plastics	65.7	50.9	38.6	50.0
All 463 Firms	39.3	39.8	45.4	42.1

4.3 Changes in Technological Diversity

One of the key issues addressed in this report is changing technological diversity over time. Table 3 shows the numbers of firms (from Europe, Japan and the USA) whose technological diversity increased, decreased and remained stable over the period 1980 to 1996. Just under half the firms (48%) have been increasing the range of technical fields in which they patent, and only 17% have been refocusing their range of patenting activities, while the remaining 35% have stayed stable. There are some differences according to nationality with more than two-thirds of Japanese firms increasing diversity and only around 6% showing an opposite trend. Of the refocusing firms more than 50% are of American origin. Amongst the European firms, the proportion of stable firms is slightly higher than average (42% compared to 35%) and the proportion of increasing diversifiers is lower (41% compared to 48%). However, care needs to be taken in interpreting these differences by nationality. They may partly reflect the method of measurement we are using, since we are comparing trends in *domestic* patenting by US firms, with *international* patenting by Japanese firms at precisely the time that they were reaching the world technological frontier.

Table 3. Changes in Firms' Technological Diversity by Product Group and Region: 1980-85 to 1991-96.

	Europe			Japan			USA			Total		
Number of Firms	***Inc***	***Dec***	***Stab***	***Inc***	***Dec***	***Stab***	***Inc***	***Dec***	***Stab***	***Inc***	***Dec***	***Stab***
Aerospace	3	0	1	0	0	0	7	1	4	10	1	5
Chemicals	9	2	10	19	2	9	7	2	10	35	6	29
Electrical/Electronics	5	4	7	21	1	7	16	8	15	42	13	29
Food, Drink & Tobacco	3	2	1	0	0	2	3	1	6	6	3	9
Machinery	21	5	12	12	0	3	11	6	8	44	11	23
Materials	1	1	2	7	1	1	0	4	1	8	6	4
Metals	5	3	8	10	1	1	4	5	1	19	9	10
Mining & Petroleum	4	2	4	1	0	0	1	6	7	6	8	11
Motor Vehicles and parts	3	5	10	14	1	1	5	1	2	22	7	13
Paper	2	0	3	0	0	1	6	2	2	8	2	6
Pharmaceuticals	4	3	6	0	2	6	5	3	5	9	8	17
Photography & Photocopy	2	0	0	6	0	3	2	1	1	10	1	4
Rubber & Plastics	2	0	1	2	1	1	1	1	0	5	2	2
All Product Groups	64	27	65	92	9	35	68	41	62	224	77	162

Notes
A Firm is deemed to be active in a technical field if it has 5 or more patents in that field in each time period.
Inc: Firms where the number of technical fields (out of 34) of activity have ***increased by 2 or more***
Dec: Firms where the number of technical fields (out of 34) of activity have ***decreased by 2 or more***
Stab: Firms where the ***change*** in the number of technical fields (out of 34) of activity has been ***1,0 or -1***

4.4 Effect of Acquisitions and Divestments

As we have consolidated our companies (see section 3.2) for one year only, 1992, these inter-firm differences in trends in technology diversity can possibly be explained by differences over the period in acquisitions and divestments. One way of assessing the extent of this effect is by comparing the above results (in Table 3) with those obtained by utilising company structures as they existed in an earlier period. We have gathered such information on the basis of *Who Owns Whom* for 1984 for 323 of the 463 companies in our database. Thus redoing the analysis[4] in Table 3 for these companies shows:

- for more than 40% of companies (139 out of 323) the number of technical fields of activity remain the same.

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[4] i.e. comparing the number of technical fields on the basis of patents granted in 1980-85 to company as it existed in 1984 to those granted in 1991-96 to company as it existed in 1992.

- for 48 companies (15% of total) there is a change in the categorisation of technological diversity (between *increasing*, *decreasing* and *stable*). The biggest single category within this group comprises of firms that were identified as *stable in* Table 3: 19 of them are now classified as *increasing* and 12 as *decreasing*. Changes also occur for 9 of the firms previously identified as *decreasing* in technological diversity: 5 now become *increasing* and 4 *stable*. In the previously *increasing* category, 7 companies become *stable* and 1 becomes *decreasing.*

These results show that the categorisation reported in Table 3, and subsequent analyses based on it in section 4.5, under-represents the extent of increasing technological diversity when a more careful account is taken of acquisitions and divestments over time.

4.5 Characteristics of Diversifying, Refocusing and Stable Firms

In this section we examine the differences in the characteristics firms according to whether they increased their technological diversity (*diversifiers*), decreased their technological diversity (*refocusing* firms), or remained stable (*stable* firms) as defined above. In particular we analyse firms according to:

- *Technology leadership* as measured by *R&D intensity* and *shares in fast-growing technical fields*;
- Changes in the *volume of technological activities* as measured by changes in *R&D* and *patent shares within each product group*;
- Changes in *market shares* as measured by changes in the *shares of sales within each product group*.

4.5.1 Technology Leadership and Diversification Patterns

Table 4 shows the differences in average R&D intensity and Table 5 shows the variation in the average share of patenting in fast-growing technologies across the 3 categories of firms. The main points to emerge from this analysis are:

- *Diversifiers* are amongst the technology leaders (as measured by above average R&D intensity) in Aerospace, Electronics, Food, Drink and Tobacco and Metals.
- *Diversifying* firms have a higher proportion of activity fields of high technological opportunity (as measured by the proportion of patenting in fast growing technical fields)

Table 4. R&D Intensity and Diversification Patterns

R&D as a % of Sales: Average for 1991-96	IncDiv	ReFoc	Stable	Average for Product Group
Product Group				
Aerospace	6.2	3.7	3.9	5.2
Chemicals	3.3	3.2	5.0	4.4
Electrical/Electronics	6.5	4.4	5.7	6.0
Food, Drink & Tobacco	1.3	0.5	0.8	1.0
Machinery	2.7	2.4	4.0	3.2
Materials	2.3	2.6	2.2	2.4
Metals	1.6	1.1	1.2	1.4
Mining & Petroleum	0.5	0.9	0.8	0.8
Motor Vehicles and parts	3.6	3.8	4.7	4.3
Paper	0.9	1.7	0.9	0.9
Pharmaceuticals	10.4	10.5	10.5	10.5
Photography & Photocopy	5.6	6.9	7.0	6.0
Rubber & Plastics	2.1	3.1	3.0	2.6
All Product Groups	4.2	2.6	4.4	4.1

Table 5. Fast-Growing Technical Fields and Diversification Patterns

%Total Patenting in FG Fields: 1991-96	IncDiv	ReFoc	Stable	Average for Product Group
Product Group				
Aerospace	11.5	10.6	10.8	11.1
Chemicals	14.6	12.0	17.2	16.1
Electrical/Electronics	28.8	20.0	25.4	26.7
Food, Drink & Tobacco	14.3	11.6	12.1	12.6
Machinery	9.8	5.1	8.5	9.0
Materials	18.2	11.3	12.3	15.9
Metals	12.1	10.2	8.6	11.3
Mining & Petroleum	11.6	7.6	11.8	10.3
Motor Vehicles and parts	17.1	12.6	16.9	16.9
Paper	14.5	8.3	14.7	14.4
Pharmaceuticals	31.9	28.6	31.1	30.3
Photography & Photocopy	22.8	18.9	23.0	22.9
Rubber & Plastics	15.3	15.9	27.5	17.0
All Product Groups	21.9	15.9	20.3	20.7

- compared to *stable* and *refocusing* firms, especially in Electronics, Food, Drink and Tobacco and Materials, Machinery.
- In terms of R&D intensity, *stable* firms are amongst the industry leaders in aggregate and in Chemicals, Machinery and Motor Vehicles. In Chemicals they also have the highest shares of patenting in fast growing technologies.
- In general, *refocusing* firms as a group have lower R&D intensity and a lower share of patenting in fast-growing technical fields compared to the other two categories of firms. This is the case in 6 (out of 13) product groups in terms of R&D intensity and 11 in terms of shares of patenting in fast growing areas.

4.5.2 Changing Volume of Technological Activities and Diversification Patterns

In Table 6 we examine the changes in the proportion of R&D expenditures attributable to each of the 3 categories of firms from 1986-90 to 1991-96 and in Table 7 we do the same in terms of US Patenting. The main points to emerge from this analysis are:

- Both in aggregate and in most of the product groups, *diversifying* firms increased their share of total technological activities (R&D and Patenting), largely at the expense of *stable* firms.
- In terms of R&D, the biggest increases for *diversifying* firms were in Aerospace, Electronics and Food, Drink and Tobacco. In terms of patenting the largest increases for these firms were in Materials and Electronics.
- In Aerospace and Electronics industries, s*table* firms saw a large decline in their share of R&D. On the other hand in the Machinery sector they increased their share.
- There was a relatively small decline in the volume of technological activities of the *refocusing* firms in most industries. Exceptions in terms of R&D were Mining and Petroleum and Pharmaceuticals.

Table 6. Changes in the Distribution of R&D Expenditures by Diversification Type: 1986-90 to 1991-96.

Change in Share	IncDiv	ReFoc	Stable
Aerospace	13.3	-4.1	-9.1
Chemicals	1.0	0.0	-1.0
Electrical/Electronics	8.8	-0.9	-8.0
Food, Drink & Tobacco	8.8	-4.6	-4.1
Machinery	-5.8	-2.1	7.9
Materials	4.8	-3.9	-0.9
Metals	4.9	-1.3	-3.6
Mining & Petroleum	-0.1	4.1	-4.0
Motor Vehicles and parts	2.0	1.7	-3.7
Paper	1.4	-0.9	-0.5
Pharmaceuticals	-0.4	1.1	-0.7
Photography & Photocopy	3.6	-0.7	-2.9
Rubber & Plastics	10.3	-10.6	0.3
All Product Groups	4.2	-0.2	-4.0

Table 7. Changes in the Distribution of Patenting by Diversification Type: 1986-90 to 1991-96.

Change in Share	IncDiv	ReFoc	Stable
Aerospace	4.0	-1.1	-2.9
Chemicals	5.8	-1.6	-4.2
Electrical/Electronics	13.1	-4.3	-8.8
Food, Drink & Tobacco	4.3	-4.9	0.6
Machinery	8.0	-5.9	-2.1
Materials	17.9	-16.9	-1.0
Metals	9.9	-6.7	-3.1
Mining & Petroleum	1.4	1.0	-2.5
Motor Vehicles and parts	-2.8	-1.8	4.6
Paper	10.1	-5.7	-4.4
Pharmaceuticals	7.0	-2.9	-4.0
Photography & Photocopy	5.3	-1.2	-4.0
Rubber & Plastics	10.1	-8.1	-2.0
All Product Groups	8.4	-3.9	-4.5

4.5.3 Evolution of Market Shares

In Table 8 we analyse how the patterns of technological diversification relate to economic performance, measured as the change in market[5] share within each product group from 1986-90 to 1991-96. The contrast between the 3 categories of firms is very clear:

- The *diversifying* group increased their market share in all product groups except Machinery. The highest gains were in Electronics, Metals, Photography and Photocopying and Rubber and Plastics.
- *Refocusing* firms lost market share in all product groups, but especially in Mining and Petroleum, Metals, Materials and Electronics.
- *Stable* firms show a mixed pattern with increases in some industries (Aerospace, Food, Drink and Tobacco and Machinery) and decreases in others (Photography and Photocopying, Electronics and Motor Vehicles).

Table 8. Changes in the Distribution of Sales by Diversification Type: 1986-90 to 1991-96.

Change in Share	IncDiv	ReFoc	Stable
Aerospace	0.4	-2.5	2.1
Chemicals	2.0	-0.4	-1.6
Electrical/Electronics	5.5	-2.9	-2.7
Food, Drink & Tobacco	0.0	-1.9	1.9
Machinery	-1.0	-0.9	1.9
Materials	3.0	-3.0	0.0
Metals	4.3	-3.8	-0.5
Mining & Petroleum	2.6	-4.0	1.4
Motor Vehicles and parts	3.0	-0.1	-2.9
Paper	2.7	-2.1	-0.6
Pharmaceuticals	0.9	-1.4	0.6
Photography & Photocopy	4.5	-0.4	-4.1
Rubber & Plastics	5.9	-5.5	-0.4
All Product Groups	3.2	-2.3	-0.9

[5] The market is defined as the total sales for all the firms in the product group.

4.5.4 Firm Level Relationships

The above analysis has been based on firms grouped according to their pattern of technology diversification, thereby neglecting any variations at the firm-level. Thus in this section we examine the relationship between changes in technological diversity (measured by changes in the number of fields of activity) and growth in R&D, sales and volume of patenting at the firm level. Table 9 reports the rank (Spearman) correlations between these variables.

For the sample as a whole there is a weak and statistically insignificant correlation between R&D growth and technology diversification. This also applies across all sectors with the exception of Electronics. However increasing diversity is positively associated with sales growth especially in Chemicals, Electronics, and Metals. The strongest relationships are to be found between increases in the volume of patenting and changes in diversity.

Table 9. Rank Correlations between Changes in Technological Diversity and Growth in R&D, Sales and Volume of Patenting

Principal Product Group	**Number of Firms**	**R&D Growth**	**Sales Growth**	**Change in Patent Shares**
Spearman Rank Correlations				
Aerospace	16	0.11	0.06	0.65**
Chemicals	60	0.00	0.28**	0.39**
Electrical/Electronics	71	0.27**	0.42**	0.43**
Food, Drink & Tobacco	16	0.39	0.03	0.46
Machinery	50	-0.24	-0.10	0.54**
Materials	17	0.36	0.42	0.44
Metals	27	0.34	0.37**	0.64**
Mining & Petroleum	23	0.08	0.28	0.25
Motor Vehicles and parts	33	-0.03	0.24	0.05
Paper	12	0.03	0.09	0.56
Pharmaceuticals	34	-0.04	0.08	0.62**
Photography and Photocopy	15	0.36	0.49	0.18
Rubber & Plastics	7	0.30	0.45	0.79**
All Firms	381	0.08	0.18**	0.36**

** indicates that the correlation coefficient is significantly different from zero.

4.5.5 Technical Fields of Increasing Activity

In this section we examine the technical fields in which the *diversifying* firms have increased their activity. Table 10 lists the main technical fields in which their patent share increased by more than 1% over the period 1980-85 to 1991-96. It confirms the findings of our previous research (Patel and Pavitt (1997)), that firms from a number of different product groups are increasingly becoming involved in materials and 'high-tech' areas such as computing technology. Indeed for the Motor Vehicles and Machinery firms the largest increases in patent shares have been in computers. However, firms are also increasing their activities in some of the 'traditional' (non high-tech) technologies such as those related to production: chemical processes and instrumentation.

Table 10. Main Technical Fields where 'Diversifiers' increased their Patent Share

Product Group					
Aerospace	Instruments	Semiconduct.	Materials	Oth. Transport	Plastics
Chemicals	Materials	Phtog & Phtoc	Semiconduct.	Drugs & Bio.	
Electronics	Computers	Semiconduct.	Instruments	Telecoms	
Food, Drink & Tob.	Drugs & Bio.	Medical	Spec. Mach..	Misc. Metal Pr.	
Machinery	Computers	Materials	Telecoms	Semiconduct.	Plastics
Materials	Materials	Image&Sou	Telecoms	Chem. Proc.	Spec. Mach.
Metals	Semiconduct.	Materials	Computers	Telecoms	Instruments
Mining & Petroleum	Misc. Metal Pr.	Materials	Chem. Proc.	Instruments	
Motor Vehicles	Computers	Oth. Transport	Instruments	Semiconduct.	
Paper	Materials	Computers	Organic Chem.	Chem. Proc.	
Drugs & Bio.	Drugs & Bio.	Medical	AssHandApp	Chem. Proc.	
Photography & Phot.	Image&Sou	Computers	Semiconduct.	Chem. Proc.	Materials
Rubber & Plastics	Misc. Metal Pr.	Spec. Mach..	Chem. Proc.	Metal Working	Non-Ele Mach.

5. Conclusions

The main findings of the above analysis of the technological diversification patterns of nearly 500 large technologically active firms based in Europe, Japan and the US can be summarised as follows:

- Increasing technological diversification has become a more common phenomenon in the 1990's amongst firms in all product groups and nationalities;
- As a group, *increasing diversifiers* have expanded the volume of their technological activities, have a much higher than average proportion of these

activities in areas of high technological opportunity, and have increased their market share;

- On the other hand *refocusing firms* have a low proportion of their technological activities in fast-growing areas and have seen a decline in their share of technological activities. Their market share in all product groups has declined;
- At the firm level, there is a statistically significant positive relationship between increasing technological diversity and growth in the volume of sales and patenting.
- Amongst the technologies that are becoming more important are both the (so-called) ‘high-tech’ areas and the more ‘traditional technologies’.

These findings indicate that despite the emphasis on ‘refocusing’ as a business strategy, large firms are becoming more diversified in terms of their technological competencies in the 1990’s and this process has gone hand in hand with growth in their volume of sales.

From a national (or European) perspective, this acquisition of an increasing range of technological competencies by large firms provides the necessary variety needed to explore and exploit a fuller range of product markets. Finally these results have implications for technology support policies which need to take into account the increasing importance of a wide range of technologies (such as materials and instrumentation) and not just those related to computing and IT.

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Annex Table 1. Core Technical Fields for each Product Group

Product Group	**'Core Technical Fields'**
Aerospace	Aerospace; General Non-electrical machinery; Power plants.
Chemicals	Organic Chemicals; Agricultural Chemicals; Drugs and Bioengineering
Electrical/Electronics	Telecommunications; Semiconductors; Electrical devices; Computers; Image and sound equipment
Food, Drink & Tobacco	Food and Tobacco; Chemical processes; Drugs and Bioengineering
Machinery	General Non-electrical machinery; Metallurgical and metal working equipment; Chemical apparatus; Vehicles engineering; Mining machinery; Specialized machinery;
Materials	Materials
Metals	Metallurgical and Metal Treatment processes ; Materials; Metallurgical and metal working equipment
Mining & Petroleum	Organic Chemicals; Inorganic Chemicals; Mining machinery
Motor Vehicles and parts	Vehicles engineering; General Non-electrical industrial equipment; Other Transport equipment
Paper	Materials (inc glass and ceramics); Specialized machinery
Pharmaceuticals	Organic Chemicals; Drugs and Bioengineering
Photography and Photocopy	Photography and photocopy ; Instruments and controls;
Rubber & Plastics	Plastic and rubber products; Organic Chemicals; Materials