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R&D-intensive SMEs in Europe: What do we know about them?

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[1] IRMA activities correspond to the implementation of the approach set out in "Investing in research: an action plan for Europe" (COM, 2003) and in further Communications of the Commission: "More Research and Innovation – Investing for Growth and Employment – A common approach", COM (2005) 488 final, "Implementing the Community Lisbon Programme: A policy framework to strengthen EU manufacturing – Towards a more integrated approach for industrial policy", COM (2005) 474 final.

Abstract

The importance of SMEs in Europe's innovation process can be seen in both the academic and the political arena. Adopted in June 2008, the 'Small Business Act' for Europe reflects the Commission's political will to recognise the central role of SMEs in the EU economy and was the first to put in place a comprehensive SME policy framework for the EU and its Member States. One of its main aims is to promote growth among SMEs by helping them to tackle problems that hamper their development. This kind of policy calls for a more in-depth look into the nature of the SME population in Europe.

Several attempts have been made in recent years to draw taxonomies of firms, but mostly they do not control for size effects within the defined groups of firms. The purpose of this paper is to typify different groups of R&D-intensive SMEs distinguished according to their inputs into the innovation process. In particular, we draw attention to SMEs that contribute the most to the industrial R&D investment in the EU. To do so, we run a cluster analysis on a sample of top European R&D SME investors based on a unique dataset made up of the different waves of the *European R&D Investment Scoreboard.*

The results show that several clusters of R&D-intensive SMEs can be defined by certain characteristics, but that the diversity between clusters calls for a more careful understanding before developing measures to support European R&D-intensive SMEs.

For companies labelled as 'corporate laboratories' according to the cluster analysis, it would be legitimate to question support for R&D, as these firms do not seem to have significant problems in finding investors that believe in their business model. On the other hand, e.g. the 'Gazelles' do in fact grow, but struggle with the high capital investment needed to become and remain large. In this case, it seems it would be more effective to focus on the weaknesses (physical expansion) of these firms rather than supporting their strengths (knowledge, R&D).

JEL Classification: O33

Keywords: SMEs; innovation inputs; cluster analysis

1 Introduction

The role of small and medium enterprises (SMEs) in the innovation process has become one of the main components of European policy. In terms of R&D and innovation policies in Europe, the European Commission has two broad objectives to achieve the goals set in the 3 % Action Plan:[1] (1) to increase the total amount of creative work undertaken in the EU, and (2) to raise the productivity of (new/existing) knowledge. To do so, a mix of policy measures is commonly used. However, given the diversity of business environments and the importance of SMEs for Europe's economy,[2] the general principle of '*think small first*' has been adopted as a policy maxim. In contrast, 'The recent situation in European Member States can be characterised by the general absence of specific policies that discriminate and exclusively address R&D activities in SMEs,' as pointed out by an Expert Group[3] on SMEs in 2004. Indeed, '…most programmes, measures and initiatives in Member States' R&D and innovation policies already address SMEs as part of the national business enterprise sector', but do not focus explicitly on SMEs and their R&D activities.

Analysing *Drivers and Impacts of Corporate Research and Development* [R&D] *in Small and Medium-Sized Enterprises* seems to be an equally important and challenging business.[4] On the one hand, SMEs are major pillars of any economy in terms of output, employment, technological change, etc., and anything thought to be generally important for their dynamics has to be taken seriously as it will affect, in turn, sectoral, regional and national economic development. On the other hand, the importance of corporate R&D activities is on the increase for any individual firm, as innovative/technological advantages may help cope with increasing competitive pressure due to globalisation. Although usually associated with large-scale companies, more emphasis needs to be placed on the particular drivers and impacts of corporate R&D in SMEs. Thus, the diversity of SMEs is a challenge for which many aspects

1 See http://europa.eu.int/comm/research/era/3pct/index_en.html for information on the 3 % Action Plan. However, the 3 % target set in Barcelona should not be seen in isolation, but as one key component in achieving the overarching objective set in Lisbon of Europe becoming the most competitive and dynamic knowledge-based economic region in the world by 2010.

2 In the EU-25, about 23 million SMEs provide employment for 66 % of the private sector. Thus, small firms (< 50 employees) make up at least 95 % of the total jobs in SMEs and 50 % of the total value added in the EU-25 (OECD, 2005). A company is considered to be an SME if it is an independent unit with fewer than 250 employees and a turnover ≤€50m or a total balance sheet ≤€43m (European Commission, 2006d).

3 The *Expert Group* has undertaken analyses of the situation and problems SMEs in Europe are facing. The results are outlined in two reports: SME and Research (Gallup Organisation, 2006); Design Measures to Promote growth of young research-intensive SMEs and start-ups (OMC-SME Expert Group, 2006).

4 The general question of whether any public R&D is a complement or substitute for private R&D is not tackled in this paper. See David, Hall and Toole (2000) for a review of econometric evidence in this regard or Lokshin et al. (2006) for a more recent consideration.

have to be taken into account, such as restricted capabilities and resources in SMEs, diseconomies of scale concerning R&D activities, the stage of the firm's life cycle, etc.[5]

Characteristic sector patterns seem to be prominent, but R&D-intensive SMEs are specific in every sense and treating them in relation to everyone is certainly not the right approach. The classification of industries implicitly assumes that these are (more or less) uniform entities with respect to the innovativeness of firms. The classification procedure reflects the diversity of an industry with respect to the innovation strategies pursued by its firms. Moreover, it allows the different innovation modes to co-exist, which, at a certain point in time, are equivalent in terms of economic performance. Research has mainly been devoted to establishing taxonomies to describe different ways of operating in terms of innovative behaviour (Pavitt, 1984; Malerba and Orsenigo, 1996; Legler, 1982; Schulmeister, 1990; Hatzichronoglou, 1997; Peneder, 1999; among others). However, these taxonomies focus more on the characteristics of larger firms and do not distinguish between different size segments.

Taking into account some of the ideas summarised above, we analyse a fairly specific group of firms. They are SMEs included in the list of top R&D investors in Europe for the period 2002-2006 and include both manufacturing and services firms. Looking at this novel dataset, we draw a number of conclusions about the characteristics of these top SME contributors to European R&D investment. Looking more closely at this group of firms, by means of a cluster analysis, we draw conclusions in terms of internal characteristics and sectoral categorisation. We also compare our results against established taxonomies. We conclude with a number of policy recommendations. Thus, the paper seeks to add to what is commonly known about R&D-intensive SMEs in Europe. Furthermore, it tackles the questions of why it is so important to examine companies of this kind and what recent empirical evidence suggests in terms of such companies' R&D investment trajectories and patterns of firm dynamics.

As a starting point, section two provides a synopsis of what we already know about R&D-intensive SMEs and what blind spots are evident. Since lack of data appears to be the reason for some of these blind spots, the availability as well as strengths and limitations of the datasets are discussed briefly in section three, with particular emphasis on the EU Industrial R&D Investment Scoreboard. Given this empirical framework, SMEs in the top 1 000 R&D investors in Europe are investigated in terms of patterns of individual business concepts,

[5] Moreover, when considering 'R' & 'D' in SMEs with respect to a company's life cycle, innovation can usually be found first. Subsequently, SMEs usually pursue 'D' in the sense of developing incremental innovations in a certain product and/or process and, then, 'R' activities are occasionally performed, either by the SME itself or outsourced.

particular firm dynamics and trajectories of their R&D investments, and benchmarked against the corresponding sector/large-scale company trends. The results of this analysis are presented in section four. Section five concludes the study including some considerations for policy-makers and outlines further avenues of research in this field.

2 Literature review

There has been a long debate dating back to the economist Joseph Schumpeter[6] about the role of small and large firms in technological progress and innovation. While the pioneering role of large enterprises with their R&D units was stressed by academics and policy-makers during the eighties, in the nineties the role and impact of SMEs was rediscovered. The empirical evidence shows many examples of highly successful innovations that stemmed from small enterprises and have revolutionised entire industries. Start-up companies, young entrepreneurs, university spin-offs and small highly innovative firms have often produced major technological breakthroughs and left the R&D efforts and innovation strategies of large global corporations in their slipstream. Indeed, SMEs act as important vehicles for knowledge spillovers; their ideas, competencies, products, strategies, innovations and technologies are frequently acquired, accessed and marketed by larger enterprises. They often create new markets and meet new consumer demands.[7]

It is a fact that SMEs are a key source of dynamism, innovation and flexibility in advanced industrialised countries, and also in emerging and developing economies. They account for up to 99 % of the total number of enterprises in EU economies (depending on the country), generate about two-thirds of employment, and are the main source of job creation.[8] Thus, studying SMEs and their attitude to 'R' & 'D', common trends (growth patterns, sector composition/trends), and the problems they face is crucial understanding the EU economy's position in terms of corporate R&D (for more details, see Ortega-Argilés and Voigt, 2009). Looking at R&D-intensive SMEs, therefore, puts the spotlight on SMEs that are at the forefront in terms of corporate innovation and technological progress and, in turn, are the key subject of

6 Joseph A. Schumpeter, *Capitalism, Socialism, and Democracy* (New York, 1942).

7 For a more detailed discussion, see, for example, European Commission, 2006a.

8 In the EU-25 economies, 23 million SMEs provide employment for 66 % of the private sector. Thus, micro-enterprises (0 to 9 employees) account for 70-90 % while the category of small firms (0 – 49 employees) constitute at least 95 % of the total jobs in SMEs. They also generate more than half of the total value added of the EU-25 (OECD, 2005). This evidence was the main reason for introducing the general EU principle '*Think small first*' (European Commission, 2006f).

any techno-economically focused study.[9] However, given the importance of R&D-intensive SMEs, as outlined above, our systematic and explicit knowledge of them is surprisingly poor. Indeed, the picture that emerges regarding the R&D activities of SMEs is somewhat fragmented and often not much more than anecdotal evidence. Unfortunately, this is even more so for R&D-intensive SMEs.

In general, evidence suggests that R&D activities in SMEs are mostly short-term and often carried informal. These activities relate to the acquisition, adaptation and improvement of existing technologies. Moreover, since research projects are sometimes non-separable and demand certain critical levels of scale, SMEs find it difficult to launch R&D projects (European Commission, 2006a). Investment in R&D and innovation is risky and it is often very difficult to predict how successful the result will be. Galbraith (1952) asserts that small firms do not have the time to spend on R&D because it is too costly and risky whereas large firms can spread the risk over a large number of R&D projects. He concludes that larger firms are more capable than smaller firms of minimising the costs associated with R&D. Large enterprises, with established brands and channels to market, can spread their risk through diversification of their research and innovation activities – an option not open to SMEs, who might stand or fall on the success or failure of a single product or service. Lee and Sung (2005), for example, have analysed general causalities between firm size and corporate R&D. Referring to Schumpeter's legacy, the authors stressed that firm diversity in technological competence is crucial, rather than differences in industry-specific characteristics. According to a formal model of business R&D, the R&D intensity of a profit-maximising firm is determined jointly by firm-specific technological competence and consumer preference regarding quality and price. However, firm size apparently affects firm R&D intensity not directly, but through its influence on firm-specific technological competence.[10]

Thus, as regards the size of firms, Schumpeter (1942) emphasised the positive influence of size on innovation, while a number of theoretical studies claim that larger companies have

[9] It should be noted that highly R&D- and/or technology-intensive companies are not necessarily the fastest growing firms in a certain market. Indeed, high-growth-potential SMEs (so-called Gazelles), in principle, can be found in any sector. Accordingly, high growth in SMEs is not exclusively related to companies that are R&D-intensive and/or engaged in high-tech industries. For a more detailed analysis, see, for example, OMC-SME Expert Group 2006, p. 151 ff, or the following web page: http://www.higrosme.org.

[10] The authors showed in particular that (1), in general, the size–R&D relationship is less-than-proportional or inverted U-shaped, especially for low-technological-competence firms; (2) however, the common less-than-proportional relationship disappears, and a more-than-proportional relationship becomes increasingly likely for firms with high levels of technological competence, possibly due to competence-enhancing, learning economies of scale and/or scope in R&D; (3) firms with larger accumulated R&D experience are, all things being equal, less likely to exhibit the common less-than-proportional relationship; (4) among industries, a greater within-industry departure from the proportional size–R&D relationship is expected for industries with seemingly high, rapidly changing technological-opportunity conditions.

potential factors such as economies of scale, lower risk, a larger market and greater opportunities for appropriation (Fernández, 1996), which enable them to perform sophisticated R&D projects and to benefit from innovations born of these activities. However, empirical studies often do not provide such a clear picture. Some find a positive relationship between size and innovation, where large-scale firm research has become the prevailing form of organisation of innovation because it is most effective in exploiting and internalising the tacit and cumulative features of technological knowledge (Pavitt, 1986; Scherer, 1992; Scherer and Ross, 1990; Love et al., 1996; Cohen and Klepper, 1996; among others), but this significant (positive) influence is not confirmed by others (e.g. Mansfield, 1964; Griliches, Hall and Pakes, 1986; Acs et al., 1991) who report that small firms have an innovative advantage in highly innovative industries and in highly competitive markets or find that 'the pattern of R&D investment within a firm is essentially a random walk'. Evidence suggests, however, that most of the advantages of larger firms are due to the higher accessibility to finance and infrastructure, whereas in smaller firms the advantages centre on the flexibility and adaptability to any new environment. Hence, the advantages of large-scale companies are physical whereas smaller companies can capitalise more on flexibility.

Although this may explain the existence of SMEs that perform formal R&D (presumably complementing other innovation activities as part of their business strategies) it does tell us how some SMEs even manage to base their entire business on R&D activities, i.e. appear to be particularly R&D-intensive. There seem to be specific factors governing this type of company that need to be studied in greater depth.

Regarding sectoral disparities in innovative behaviour, many innovation and technology studies support the conjecture that (a) at any given point in time, technological opportunities vary according to the sectors and the degrees of development of the various paradigms under which they work, and (b) this is an important part of the explanation of why commitment to innovative investment varies across sectors. Another reason for inter-industry differences in R&D investment relates to the different *modes of innovative search* that each paradigm entails. For example, in some technologies (e.g. electronics, drugs) innovation involves laboratory research and/or complex development and testing of prototypes. In other technologies (e.g. non-electrical machinery) innovation is much more informal and not recorded as the result of 'investment' in R&D.[11]

[11] These and other causes and explanations for potential sectoral disparities in innovative behaviour can be found in Dosi (1988).

3 Drawing a new taxonomy for European R&D-intensive SMEs

3.1. Previous attempts: established taxonomies

Among the best known taxonomies of sectors are the taxonomies by Pavitt (1984) and Malerba and Orsenigo (1996). These focus only on manufacturing sectors and do not distinguish between different size classes.

Legler (1982), Schulmeister (1990) and Hatzichronoglou (1997) focused their taxonomies on the differentiation in the technological level of the sector (high-tech, medium-tech and low-tech). In particular, the works by Legler and Schulmeister (1990) moved a step further and combined the groups of high, medium and low-tech sectors with a deeper view of factor inputs such as capital investment, labour costs and research expenditures.

The research issues outlined at the outset of this part will be tackled by empirical analysis, as presented in this section. Thus, as a starting point, it has to be investigated whether and to what extent R&D-intensive SMEs differ from other (more large-scale) R&D-intensive companies? All R&D-intensive SMEs seem to be quite specific in that the vast majority of SMEs do not perform any formal R&D at all (see discussion above in section 2). However, whether and how there might be specifics in R&D-intensive companies attributable to firm size still needs to be looked into. Furthermore, for an understanding of common development patterns of R&D-intensive SMEs it seems to be promising to identify in which emerging sectors they play a crucial role. All these points will be illustrated below by descriptive statistics. We then try, in separate subsections, to establish common patterns of sector and firm dynamics, of individual firm trajectories and any potential spatial effects in terms of R&D-intensive SMEs.

In this paper we want to focus on the knowledge intensity or input intensity of R&D. There are two examples of sectoral taxonomies that also characterise groups of firms by their input into the innovation process. The OECD (2001) developed a taxonomy based on knowledge intensity, where the most relevant dimensions and variables of the cluster analysis are R&D and human resources input (skill levels). The analysis is based on the cut-off points of indicators in a sample of small firms from the ANBERD STAN dataset. It is important to note that the industry classification is only based on groups of sectors (high-tech manufacturing, low-tech manufacturing and Knowledge Intensive Business Services (KIBS) and traditional services).

Peneder (2002) created a new taxonomy of manufacturing industries based on typical combinations of factor inputs, not only R&D and physical capital but also human capital. The difference between his paper and ours is that he did not focus only on SMEs or include services in the analysis. He found many pronounced structural differences related to intangible factors of production.

As reported in many papers (Kahn et al, 2003; Jong and Marsili, 2006) in recent years, there has been a lack of specific studies on sectoral disparities and innovative behaviour in small and medium enterprises. In the past, the literature suggested that innovation was not really related to SMEs, because of the lack of information on innovative activities by this population of firms. Subsequently, evidence showed that SMEs are an engine of growth and that they also contribute to innovation. It is true that established taxonomies have focused more on larger firms and that smaller firms appear not to be represented in these objective taxonomies. Some authors, for example, argue that SMEs have limited resources and capabilities for conducting in-house R&D activities (Hausman, 2005) and limited external contacts (Srinivasan et al., 2002). In order to overcome such disadvantages, public assistance has frequently been advocated and a variety of intermediary institutions for innovation have been adopted by national governments. A further point to take into account is that the diversity of firms is even greater in this segment of firm population.

However, the literature focusing on disparities in groups of firms and in particular in innovative behaviour or internal characteristics of innovative firms has come up with examples where the target population has been SMEs and their innovative activities. The examples from the literature on cluster analyses focusing on SMEs only look a one single country. It is worth remembering the huge difficulty obtaining data on this particular segment of firm population and even more so data on their investment in R&D.

Wood (1995) applies a factor and cluster analysis to a specially constructed database of UK SMEs. The paper identifies different types of SME innovators based on indicators of their innovation ‘outputs’. These groups are then compared in terms of their use of a variety of ‘inputs’ to innovation. In terms of policy implications, it seems clear that policies supporting the transfer of knowledge and skills to SMEs are likely to promote the incidence and extent of innovative activity in the sector. In addition, measures that enable smaller firms to sustain adequate levels of R&D expenditures for R&D are likely to be an important means of promoting innovation in the SME sector. R&D appears to be a vital input to innovation not only in SMEs that introduce novel innovations. Even firms which do not report novel innovations can be involved in substantial R&D expenditure.

The most similar paper to this research is the one by De Jong and Marsili (2006), who apply a factor and cluster analysis to propose an empirical taxonomy of the innovative firms at the bottom of the size distribution, based on a new survey of 1234 small and micro-firms in the Netherlands, in both manufacturing and services. These firms differ not only in their innovative activities, but also in their business practices and strategies, such as management attitude, planning and their external approach to achieving innovation. The authors compared their results with Pavitt's taxonomy and described a more diverse pattern of innovation of small firms than in Pavitt's taxonomy, a pattern that is shared by both manufacturing and service firms. The paper shows that taxonomies can be effectively used to map differences in the rates, sources and nature of innovation against differences in the business strategies of innovative firms. The results do not show a clear-cut relationship between industrial sectors and clusters of firms. Although this may partly reflect the high level of aggregation of sectors used in the analysis, the taxonomy seems to support the existence of different 'strategic groups'. Even if the degree of diversification may be expected to be less problematic for small firms than for large firms, the patterns observed at firm level may in fact be average differences at a lower level of aggregation. Our analysis differs from this one, in the fact that we address conclusions for Europe in general focussing our analysis on highly R&D investors.

In brief, our paper attempts to develop a sectoral taxonomy for R&D-intensive firms. Given the importance of SMEs in Europe and in the innovation process, we base our analysis on an special dataset of R&D intensive SMEs and cover both manufacturing and services. From our descriptive analysis we then go a step further trying to analyse more in depth which are the characteristics and potential defined groups of SMEs among the top European R&D investors, an aspect that has been neglected to some extent by the literature. Our study is interesting in order to shed some light on the population of high R&D intensive SMEs, and it will contribute to the definition of some specific policies that support SMEs in their struggle to become large companies, which traditionally seems a difficulty in Europe as compared to the US.

3.2. Data

The amount of available information on European firms, e.g. broken down by company size classes and activities, is surprisingly low. Admittedly, some data are available, and EUROSTAT, the OECD and others have recently made notable efforts to improve the data availability on SMEs. However, particularly as regards small and micro-enterprises (together they account for about 50 % of the EU-25 value added), these databases are rather fragmented and often no more as anecdotal evidence. Unfortunately, this applies even more so where company activities are a point of interest, e.g. R&D activities of SMEs.

Data for this analysis are obtained from the different editions (2004 - 2007) of the EU Industrial R&D Investment Scoreboard (the *Scoreboard* for short). The Scoreboard collects data from the latest audited company reports and accounts that had been published up to 1 August the previous year. It also encompasses data for the previous three reporting years. The Scoreboard lists companies whose registered offices are located within the EU and the same number with registered offices outside the EU. These companies are considered to be the top R&D investors for each of their respective EU and non-EU groups.

We based our analysis only on the EU, mainly because of a clear problem of SME representativeness. For example, taking 2006 as the base year, there are 133 SMEs[12] among the top 1000 EU Scoreboard companies. Among the 'non-EU' top R&D investors only 10 SMEs could be found on the 2007 Scoreboard (all from North America: 9 x USA, 1 x Canada; and all from the biotech (9) or pharmaceutical (1) sectors). The reason why there are far less SMEs in this sub-sample ('rest-of-the-world') obviously relates to the differences in sample coverage when focusing on the main R&D investors globally rather than EU-wide only. This tends to result in small and medium-sized companies being crowded out with rising geographical coverage. Accordingly, any direct comparison of sectoral distribution between the EU and the 'rest-of-the-world' [RoW] sample in terms of SMEs would be misleading due to the sample size and coverage bias and is therefore disregarded in this study.

Finally, pooling several annual editions of the EU R&D Investment Scoreboard gave us a longitudinal sample of 1209 R&D-intensive companies (unbalanced panel), comprising 203 firms classified as SMEs at at least one of the observed points in time during the period 2000–

[12] According to the European Commission (2006d), a company is considered to be an SME if it is an independent unit with fewer than 250 employees <u>and</u> a turnover ≤ €50m <u>or</u> a total balance sheet ≤ €43m (the latter is not taken into account for lack of information on Scoreboard company balance sheets).

2006. See Table 1 and 2 for the corresponding descriptive statistics, broken down according firm classes.

Table 1 suggests that R&D-intensive SMEs are mainly linked to five emerging sectors only whereas large-scale R&D-intensive companies can basically be found in any sector of economic activity. Thus, the analysis of R&D-intensive SMEs will concentrate on these five sectors in particular, namely Electronic & Electrical Equipment, Healthcare Equipment & Services, Pharmaceuticals & Biotechnology, Software & Computer Services, and Technology Hardware & Equipment.

Table 1. Sector alignment according to company size class (pooled Scoreboard sample)

ICY CLASS	*LARGE*		*SMEs*		*ALL*
Sector of activity	**Freq**	**%**	**Freq**	**%**	**Freq**
Oil & Gas Producers	10	0.99			10
Oil Equipment, Services & Distribution	8	0.80	2	0.99	10
Chemicals	55	5.47	1	0.49	56
Forestry & Paper	11	1.09			11
Industrial Metals	17	1.69			17
Mining	16	1.59	2	0.99	18
Construction & Materials	34	3.38			34
Aerospace & Defence	29	2.88			29
General Industrials	25	2.49			25
Electronic & Electrical Equipment	79	7.85	16	7.88	79
Industrial Engineering	95	9.44	3	1.48	95
Industrial Transportation	15	1.49			15
Support Services	32	3.18	1	0.49	33
Automobiles & Parts	49	4.87	4	1.97	53
Beverages	5	0.50			5
Food Producers	43	4.27			43
Household Goods	36	3.58			36
Leisure Goods	7	0.70	2	0.99	9
Personal Goods	19	1.89	1	0.49	20
Tobacco	2	0.20			2
Healthcare Equipment & Services	29	2.88	15	7.39	44
Pharmaceuticals & Biotechnology	63	6.26	65	32.02	128
Food & Drugs Retailers	8	0.80			8
General Retailers	18	1.79			18
Media	24	2.39	2	0.99	26
Travel & Leisure	14	1.39	3	1.48	17
Fixed Line Telecommunications	19	1.89			19
Mobile Telecommunications	3	0.30			3
Electricity	19	1.89	2	0.99	21
Gas, Water & Multi-utilities	11	1.09			11
Banks	22	2.19			22
Nonlife Insurance	9	0.89	1	0.49	10
Life Insurance	3	0.30			3
General Financial	21	2.09	3	1.48	24
Software & Computer Services	107	10.64	53	26.11	160
Technology Hardware & Equipment	49	4.87	27	13.30	76
Total	**1006**	**100**	**203**	**100**	**1209**

From Table 2 it can be seen that common firm characteristics are quite different between R&D-intensive SMEs and large-scale R&D-intensive companies, suggesting significant firm size effects. Apart from differences attributable to the pure company size (such as number of employees, net sales, capital expenditures, R&D investment, etc.) some common patterns stand out. For example, R&D-intensity tends to be higher in small firms (not surprising given the underlying sample selection of the largest nominal investors in R&D). Moreover, the operating profits of R&D-intensive SMEs – in contrast with large companies – appear on average even to be negative, given the high standard deviation in terms of both R&D intensity and net profit rates, which, in turn, suggests significant diversity, particularly among SMEs. On the other hand, the standard deviations in terms of R&D investment, net sales and capital expenditures of SMEs seem to be comparably low, suggesting a rather uniform picture in this respect.

Table 2. Descriptive statistics of firm characteristics according to company size classes

	Large Firms		*SMEs*		*ALL Firms*	
Variable	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
R&D investment	152.46	532.38	9.58	9.90	129.09	489.78
Employees	21794.05	48248.30	168.34	173.13	18267.38	44855.70
Net Sales	595.75	1685.01	3.73	6.50	512.68	1575.74
Operating Profits	435.47	1970.55	-51.62	1333.87	351.71	1885.38
Capital Expenditures	333.04	1048.85	1.56	3.49	273.93	959.15
R&D Intensity	6.32	15.47	1089.90	6806.44	157.09	2654.43
No of individuals	**1006**		**203**		**1209**	

From the descriptive analysis we can draw important conclusions. First, R&D-intensive SMEs are special: they differ from 'normal' SMEs and from other R&D-intensive companies not only in terms of R&D investments. Second, SMEs, sectoral specifics appear to be prominent among R&D-intensive, which is all the more reason for a more detailed analysis of this particular group. A cluster analysis can shed some light on the different groups of R&D-intensive SMEs, possibly highlighting business concepts and sectoral specifics. Support measures should therefore be sector-specific, and tailored to particular types of companies (discussed in the sections 4 and 5 on policy implications).

3.3. Clustering variables

The variables that form the basis for this cluster analysis are grouped according to Cesaratto and Mangano (1993) and Cesaratto et al. (1995), but – due to the nature of the available data – are approximated slightly differently:

1. Input: input into research is R&D investment
2. Innovation output: sales
3. Firm performance: increase in sales and number of employees

The selection of these variables implies that no distinction is made *ex ante* by country, region or sector. As with Cesaratto et al., we do not consider the specific industrial sector to which a firm belongs. This means that a firm is assigned to a group in which its individual innovation characteristics match rather than to a group which matches the innovation characteristics of the industry to which it belongs. This will lead to clusters of firms with similar profiles active in different sectors and countries (corresponding effects to be tested ex post).
We used cluster analysis techniques to construct groups of R&D intensive SMEs. These techniques are sensitive to the variables used, especially when it comes to SMEs where there is a problem with accessibility to data.

Variables were selected on the basis in different aspects relating to the innovative nature and internal characteristics of firms in the sample. Table 3 shows the combination of variables that were used in the analysis.

Table 3. Variables list

Dimension	***Variable***	***Description***
Innovative Input	R&D Investment	This is the cash investment funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies.
	R&D intensity	This is the ratio between R&D investment and net sales of a given company or group of companies.
Innovative Output	Net sales	Sales after taxes
	Operating profit	Profit (or loss) before taxation, plus net interest cost (or minus net interest income) and government grants, les gains (or plus losses) arising from the sale/disposal by businesses of fixed assets.
Firm performance	Annual employee change Annual net sales change Annual profit change	Growth over the previous year, expressed as a percentage: 1 yr growth = 100*((C/B-1); where C= current year amount and B=previous year amount. 1 yr growth is calculated only if data exist for both the current and the previous year. At aggregate level, 1 yr growth is calculated only by aggregating those companies for which data exist for both the current and the previous year.

Other internal characteristics	Capital expenditures	Physical capital input – capex is expenditure used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings. In accounts capital expenditure is added to an asset account (i.e. capitalised), thus increasing the asset's base. It is disclosed in the accounts as additions to tangible fixed assets.
	Company age	Number of years since the constitution of the firm. Own elaboration based on company website information.
	Industry sector	Based on the ICB Industry Classification System. The level of dis-aggregation is generally three-digit level. It includes services and manufacturing industries.
	Number of employees	Labour input – number of employees is the total consolidated average employees or year-end employees if average not stated
	Market capitalisation	This is the share price multiplied by the number of shares issued at a given point in the year. Market capitalisation data have been extracted from both the Financial Times London Share Service and Reuters. The gross market capitalisation amount is used to take account of those companies for which not all the equity is available on the market.

Source: Own table based partly on glossary of definitions of the 2007 EU Industrial R&D Investment Scoreboard (European Commission, 2008)

The common patterns of R&D-intensive SME sector and firm dynamics, as outlined in the section above, will now be underpinned by means of a closer look at individual firm trajectories. Figures 1 and 2 illustrate micro-level sector alignments of individual firm behaviour in terms of R&D activities. Thus, looking at SMEs in the given sample in terms of their investment in R&D / R&D staff and the corresponding operating profits is of particular interest. From figures 1 and 2 two main points arise:[13] (1) differences between sectors persist even if micro-level data are considered and (2) the particular business strategy of rent seeking over an entire life cycle of a company, however, applies mainly to Pharmaceutical & Biotechnology companies, although not exclusively to them, evidence suggests that companies aligned to other sectors also pursue that kind of strategy.

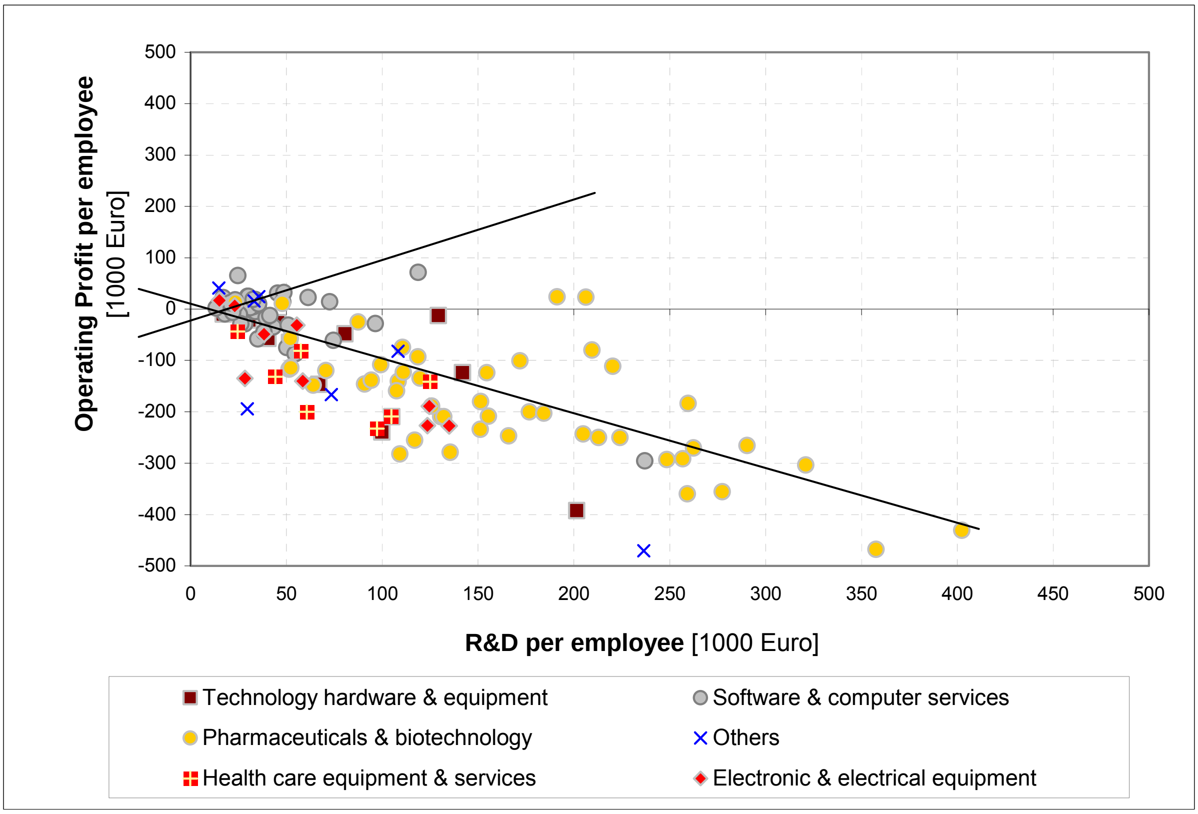
Figure 1 depicts investment in R&D and operating profits of SMEs, both normalised per employee. Thus, companies that appear along the grey line with a positive slope are considered to follow a rather sustainable investment path with respect to their R&D activities since operating profits refer 1:1 to investments in R&D (operating profit in t_0 ~ investment in R&D in t_0). In contrast, companies along the gray line with a negative slope report operating losses corresponding to about 1:1 of the amount invested in R&D (meaning losses in t_0 ~ investments in R&D in t_0). The charts suggest clustering companies according to their behaviour in terms of R&D investment. There is evidence that above a certain threshold[14]

[13] Note that only companies from the Scoreboard sample were considered here that are classified as SMEs in 2006 (in total 133), the figures 1 and 2 refer to a static consideration of year 2006 and, therefore, incorporating any other (bigger) companies would have slewed the emerging picture.

[14] This refers to expenditures on R&D and corresponding operating losses of about €150 000/employee.

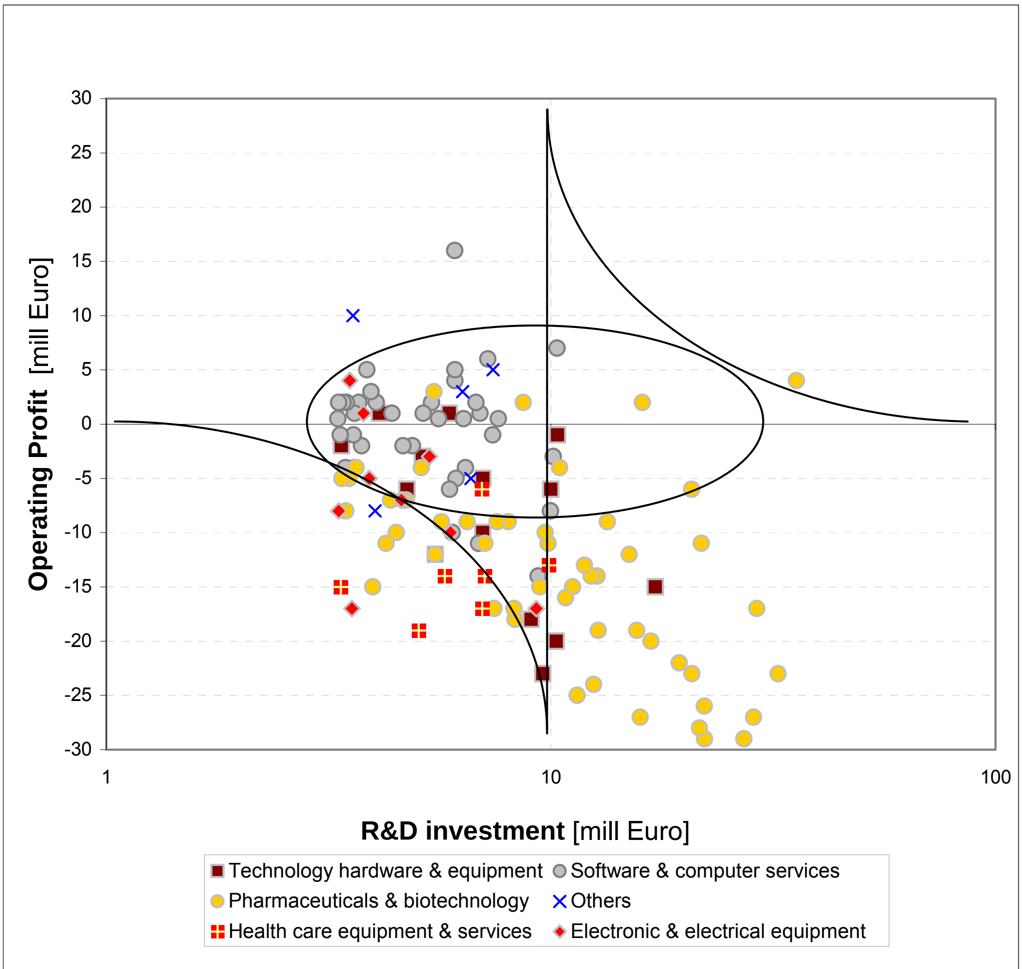
companies are almost exclusively in the Pharmaceutical & Biotechnology sector, which supports the theory of a particular business model applied in R&D-intensive SMEs belonging to this sector. But, as also suggested above, there is evidence that companies belonging to other sectors may follow this same example, but only up to a certain point (see diversity of companies along the line, but below the threshold). This in turn supports the hypothesis that firm level behaviour in R&D-intensive SMEs is sector-specific, e.g. in terms of interpretation of the cross-correlation matrix. If this can be confirmed by further analysis the findings would have implications for policy measures in support of R&D in SMEs, as this is supposed to differentiate between sectors.

Figure 1. R&D per employee vs. Profit per employee (SMEs from selected sectors), year 2006.



The same picture emerges in Figure 2, illustrating investments in R&D and operating profits in absolute terms. In the quadrant referring to high R&D investments R&D and high operating losses, SMEs are thus almost exclusively from the Pharmaceutical and Biotechnology sector (companies along the grey line with a negative slope in Figure 1 above the threshold). In contrast, companies in the bottom left-hand corner of Figure 2 report comparably low R&D investments together with high operating losses. This suggests two different interpretations, on the one hand, it would be seen that for some firms to engage in R&D is not the company's core business, and on the other, we could think that these companies, given the fact that these firms are by definition "top R&D investors", could be struggling with other problems, like suffering some financial problems that affect the high level of R&D and the operating profits (turning out to be losses). In turn, SMEs found in the oval in the centre of the graph report significant R&D spending and fairly sustainable profit figures (expenditures in R&D >> losses), meaning that these companies apply a common and sustainable business model and will therefore stay in the market and also among the SB companies even in the mid/long run, given that they manage to follow a steady company growth path.

Figure 2. R&D investment vs. operating profits (SMEs for selected sectors), year 2006.



In general, interpretation of the cross-correlation matrix[15] and the evidence emerging from Figures 1 and 2 suggest characteristic company clusters among R&D-intensive SMEs, distinguished according to business concept, sector of belonging and/or company

[15] The cross-correlation matrix can be provided upon request to the authors, the main conclusions out of it are presented at the paper.

development strategy. A cluster analysis is therefore run in order to validate this hypothesis, and to check for (potentially) distinctive types of innovating SMEs out of the cluster characteristics and any possible implications for support policies.

The main purpose of cluster analysis is to produce a classification scheme of individual observations based on a heuristic method for the exploration and identification of underlying patterns in the data. In our particular analysis, the clusters will allow us to see whether it is possible to identify distinctive types of innovating firms by the kind of internal characteristics they report, based on the input variables of the innovation process. As Peneder (1999) points out, the main idea of clustering is to divide a specific data profile into segments by creating maximum uniformity within and maximum distance between groups of observations.

From a methodological viewpoint, cluster analysis is a tool for exploring the structure of data, as opposed to the traditional ex ante sector classifications that are widely used. The core of cluster analysis is the process of grouping objects into clusters, to the effect that objects from the same cluster are similar and objects from different clusters are dissimilar. Objects can be described in terms of measurements (e.g. attributes, features) or by relationships with other objects (e.g. pair-wise distance, similarity). Subsequently, firms will be clustered into groups on the basis of the variables characterising the different research-intensive SME profiles.

3.4. Method

3.4.1. Standardising the data

The selected variables are ratio-scale. This might lead to difficulties due to the characteristics of the available data. Milligan and Cooper (1988) showed that standardisation methods involving division by range offer the best recovery of the underlying cluster structure. We therefore applied the method mentioned, for example, by Anderberg (1973):

$Z = X / (Max(X) – Min(X))$

3.4.2. (Dis-)similarity measures

Inter-object similarity is a measure of resemblance between objects to be clustered, and therefore fundamental to cluster analysis (Hair et al., 1998). For this research, we apply Euclidean distance measures to measure inter-object similarity. This reflects the similarity as the proximity of observations to one another across the variables in the cluster variate. The distance measure is actually a dissimilarity measure, in that it represents the distance between two objects. A fairly large value means a lesser similarity.

3.4.3. Selecting a cluster algorithm and determining the number of clusters

When the variables are selected and the similarity matrix is calculated, the algorithm for the cluster formation has to be selected. The crucial question is what set of rules are the most useful for placing similar firms in a cluster. We proceeded as follows:

Hierarchical cluster algorithms:

- Agglomerative algorithms start with each observation considered as a separate cluster and then clustered on the basis of (dis-)similarity measures.
- Divisive clustering algorithms start with one cluster containing all observations and splitting up into several groups on the basis of (dis-)similarity measures.

Partition clustering algorithms:

- Breaks the observations into a distinct number of non-overlapping groups.
- The number of clusters must be defined beforehand.
- Two methods:
    1. Kmeans: each observation is assigned to the group whose mean is closest.
    2. Kmedians: as with kmeans, but with medians instead of means.

Partition clustering algorithms are more suitable for larger datasets, but must be performed various times in order to find the optimal number of clusters.

For this analysis, various hierarchical cluster methods were used first to check for the optimal number of clusters, given the dataset. Although the results of the Caliński-Harabsz and Duda-Hart stopping rules varied appreciably, 3 groups would appear to be the minimum and 10 the maximum. Subsequently, we applied the kmeans clustering algorithms on the dataset, forming three to ten groups with the Caliński-Harabsz stopping rule to compare the clustering outcomes. The optimal outcome during this exercise is four clusters. The results are presented in Table 4.

4 Results

As Table 4 illustrates, applying key company parameters such as R&D intensity, performance and firm dynamics as variables for clustering[16] produces four fairly uniform clusters among R&D-intensive SMEs, which can be characterised as follows.

Table 4 shows the results of the cluster analysis that was applied to these four factors and how the cluster centre values vary across the clusters and factors. If the purpose is to identify the distinctive features of the clusters in terms of their scores for the different factors, however, an easier way is to analyse the variation between groups.

Firms in the ***'Growing SMEs'*** cluster *(cluster A)* – as per Table 4 – are SMEs with fairly straightforward company behaviour in terms of R&D spending and company development. Indeed, R&D investment and net sales are all average (meaning close to the sample mean). Companies belonging to this cluster, on average, face operating losses, although these are fairly low compared to their investments in R&D. Firms in this cluster differ enormously in the average number of employees, the standard deviation being higher than in the other clusters. However, company size has shown above average growth in terms of employment and net sales. They appear to be high-risk companies with losses and enormous variability in profits (operating profits change annually), and seem to be at the stage prior to becoming a gazelle, with high employment change. Companies in this particular cluster have the lowest R&D per employee, which may be due to the fact that the sector composition is highly diverse. Companies in this cluster cover all sectors, meaning that there are no sector specifics in this cluster. Pharma & Biotech (although relatively lower than in total), Software & Computer Services, Electronics and Healthcare are relatively overrepresented compared to other clusters.

Firms in the ***'Niche producers'*** cluster *(cluster B)* can be distinguished from all other clusters as being more likely to be niche market producers than research-intensive. Firms belonging to this cluster do not appear to have high growth in sales and employment and, in terms of innovative behaviour, seem to focus on low-risk strategies (no losses, R&D expenditure apparently taken from current business). As is often the case in low-risk enterprises, it is easier for them to survive in the market, having the oldest average company age. In general, companies belonging to this cluster can be characterised as steady – but R&D-intensive –

[16] Namely, R&D intensity of the firm (R&D per employee, 2006), company performance (net sales in 2006), and company dynamics (annual average change of (i) employment and (ii) net-sales).

niche market producers, being well established in their market segments, managing to increase their net sales, but not growing in terms of employment. The comparably high average company age suggests that the niches the companies are operating in tend to be rather steady too. The sectoral composition of the cluster is mainly composed of Software (both in absolute numbers and in relative overrepresentation) and Pharma (although relatively underrepresented).

Firms in the ***'corporate laboratories'*** cluster (cluster C) are characterised by their non-productive nature, being made up of corporate laboratories as rent-seeking business entities with R&D investments at the same level as operating losses. Firms in this particular cluster have very low net sales (often = 0) and the smallest company size in terms of employees. These companies are also the youngest companies in the sample. As 85 % of companies in this cluster operate in the Pharma/Biotech sector, the hypothesis of significant sector specifics and particularities in terms of business models can be confirmed. This particular cluster is composed in the main of science-based firms, and is similar to the 'science-based' Pavitt taxonomy, in which investments in innovative search are quite high; it includes firms from the drugs and bioengineering industries.

Table 4. Cluster descriptions

CLUSTER		*A*		*B*		*C*		*D*		*Total*	
Name (No of companies)		**'Growing SMEs' (56)**		**'Niche producers' (62)**		**'Corporate labs.' (33)**		**'Gazelles' (19)**		**170**	
		Mean	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Innovative input	R&D investment (million €)	8.0	4.3	7.2	4.4	20.5	16.1	19.9	23.8	11.5	12.5
	R&D per employee (100 000€)	0.3	0.3	0.6	0.4	6.6	7.1	0.5	0.4	1.1	1.7
Output	Net sales (million €)	27.7	26.2	27.4	19.8	7.7	10.7	156.3	308.3	38.2	111.1
	1yr net sales change	169.1 %	755.6	20.4 %	83.6	127.3 %	465.0	3464 %	11768.1	475 %	4014.3
Firm performance	Operating profit (million €)	-7.16	12.7	-0.7	16.7	-21.0	18.0	-23.0	162.8	-9.3	55.8
	1yr Operating profit change	976.2 %	6948.2	15.5 %	113.7	-2.0 %	12.1	16444.3 %	69835.4	2164.7 %	23688.9
	1yr Employee change	29.9 %	10.6	-0.3 %	9.4	7.1 %	18.1	127.8 %	67.6	25.4 %	45.9
General characteristics	Employees	178	107	169	74	80	64	526	612	195	271.2
	Market capitalisation (million €)	132.0	131.8	119.1	152.5	255.6	425.7	902.5	1368.7	233.6	541.7
	Company age (# years)	13	6	21	25	11	10	13	23	16	18
	Capital expenditures (million €)	1.8	2.1	1.5	2.1	1.2	2.8	5.4	6.3	2.0	3.2
Sectoral composition of the cluster	Pharma/Biotech	13		14		31		6		64	
	Software/Comp. Serv.	17		25		1		3		46	
	Technology hardware	5		9		1		1		16	
	Electronics	9		5				1		15	
	Healthcare equipment	8		4						12	
	Others	4		5				8		17	

Firms in cluster D can be defined as '***R&D-based Gazelles'***.[17] Companies in this cluster are characterised by very fast firm development. Indeed, they are only in the sample as they were categorised as SMEs between 2003 and 2006, but have since grown beyond this threshold, as can be seen from the average number of employees (521 in 2006). This make them look like labour-intensive companies but they also have higher physical capital requirements than other clusters. Investment in R&D as well as average net sales in this cluster are the highest among SMEs in the sample, both of which are deemed to reflect size. Also notable are the enormous annual growth rates of net sales and employment, which clearly distinguish these companies from others. Interestingly, these R&D-based Gazelles can be found in all sectors, suggesting that there is no single sector that particularly promotes R&D-intensive company growth.[18] The cluster covers mainly Pharma and Software, as expected, but many other sectors, too. The sectoral composition of the cluster may be down to the fact that successful firms belong to science-based sectors. The Pharma and Biotech industries base their production on inputs from scientific advances and formalised research. High scale economies and a complex labour intensive production system are determinants of their growth and continuity (Dosi, 1988). This finding appears to be in line with the recent economic literature on the subject, mostly based on US firms and hardly on European ones (see, for example, Henkreson and Johansson, 2008; Acs, Parsons and Tracy, 2008). Moreover, finding such success stories (fast-growing Gazelles, ex-SMEs) on the Scoreboard for European companies appears to be a significant message, suggesting in general that it is indeed possible to achieve rapid company growth based on corporate R&D activities and to be based in Europe. Thus, the statement that 'R&D performing SMEs in the US spend about 7-8 times as much on R&D as their counterparts in Europe' might refer more to structural differences in the European and the US economies than to differences in firm behaviour (at least as far as in both cases R&D-intensive ex-SMEs are concerned), as Ortega-Argilés and Brandsma (2009) pointed out. It is interesting to note that this cluster appears to have high capital expenditures. Firms belonging to this cluster invest in infrastructure in order to cope with high growth. This opens up the issue of complementarities in investments benefiting firms' performance and growth. This is also the least populated cluster, showing the difficulties SMEs have in successfully changing up in size class.

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17 Typically 'Gazelles' are defined as small companies with extraordinarily high growth rates over several years. To be more precise, the OECD applies the following definition: enterprises, being employers for a period of up to 5 years, with average annual growth in employees (turnover) greater than 20% a year, over a 3-year period and with 10 employees at the beginning of the observation period.

18 Hoelzl and Friesenbichler (2008) argue that Gazelles appear to be primarily an economic not a technological phenomenon. Therefore, clear sector specifics should not be expected anyway.

In general, the cluster analysis shows that (with some exceptions in terms of the 'corporate labs' cluster) successful R&D-intensive SMEs can operate in any sector as can be seen in table 5 as a summary of the results obtained by the cluster analysis. Hence, evidence suggests that there is no common success pattern among R&D-intensive SMEs, but more a series of sector specifics, particular business concepts, niche strategies, etc., meaning that policy measures – designed to support these companies as they grow – need to be equally diverse. This calls for a radical rethink, as current measurements tend to be somewhat uniform and (if at all) might distinguish only between large-scale companies and SMEs or differentiate according to 'R&D performed by the company' or not.

Table 5 Summary of the results

"Growing SMEs" (56 firms)	"Niche Producers" (62 firms)
■ Moderate growing firms ■ Company behavior: highly risky! ■ High heterogeneity in firm size ■ Losses! Notable Employee change! ■ All sectors equally represented each sector ≥ 10% - No sector specifics!	■ Steady firm growth ■ Company behavior: neutral to risk ■ More mature firms – Efficient size for them? ■ No profits and negative Employee change! ■ Mixture in the sectoral composition but 41% Software and 25% Pharma/Biotech
"Corporate laboratories" (33 firms)	**"Gazelles" (19 firms)**
■ R&D gambler "corp. laboratory" ■ Company behavior: highly risky! ■ Smallest in size! ■ Low sales and high losses ■ 85% Pharma and Biotech firms!! – Sector specifics! Science-based firms!	■ R&D-based Gazelles- Exponential growth ■ Company behavior: highly risky! ■ Biggest in size! ■ Exponential growth (profits and employees) ■ Sector heterogeneity (39% Others, 33% Pharma/Biotech and 17% Software)

5 Conclusions & Further avenues of research

In recent years several attempts have been made to draw taxonomies of firms, but they do not really distinguish between size classes within groups of firms. This paper set out to explore what different groups of R&D-intensive firms can be found in Europe based on their inputs into the innovation process. In particular, we have drawn attention to SMEs and their major contribution to innovation in the EU.

Two main messages emerge from the empirical evidence: (1) the biggest investors in R&D among SMEs are not necessarily the fastest growing companies, even if only R&D-intensive companies are considered, and (2) any support for a given sector or sub-sector should focus only on the dominant types of companies and their respective business models if it is to be effective. The benefits of complementarity of investments must also be taken into account, as our analysis shows that fast-growing SMEs with a high level of capital expenditures compared to other clusters do not have such high growth in performance. This underlines the need for tailored support to meet the requirements of all kinds of R&D-intensive companies, be they small or big, fast or slow growing or not attempting to grow at all.

The differences between the groups also raise the issue of whether public support is necessary for all R&D-intensive SMEs. As can be seen in the cluster consisting of 'corporate laboratories', it would be legitimate to question support for R&D, since these firms do not have problems finding (private) investors that believe in them. On the other hand, we can see that some firms, mainly in the 'Gazelles' cluster do in fact grow, but struggle somewhat to become a large firms due to the high investment needed in physical capital needed to become and remain large. Would it be more effective to support the weaknesses (physical expansion) of these firms rather than their strengths (knowledge, R&D)? These questions go beyond the purpose of this paper, but the idea of different strategies and stages in which SMEs operate is a first step towards more effective public policies.

In the meantime, more research needs to be done on this topic. Expanding the dataset will make for a more accurate distinction according to the sector to which firms belong. Expanding the time series will ensure more accuracy in terms of trend patterns, and including a spatial dimension will teach us more about different strategies in different regions. Increasing the variables like patents accounts or other types of firm characteristics could improve the analysis. A comparison of EU firms with their counterparts in, for example, the US and Japan will contribute to our understanding of worldwide R&D strategies.

References

ACS Z, ISBERG S (1991): 'Innovation, firm size and corporate finance. An initial inquiry,' *Economic Letters*, 35:323–326

ACS, Z.J., W. PARSONS and S. TRACY (2008): High-impact firms: Gazelles revisited. SBA Report. Washington D.C., SBA Office of Advocacy.

CESARATTO, S.; MANGANO, S (1993): 'Technological profiles and economic performance in the Italian manufacturing sector' *Economics of Innovation and New Technology* 2, 237-256.

CESARATTO, S.; MANGANO, S.; MASSINI, S. (1995): 'New Dimensions on Division of Labor: The case of Italy (1981-85), in DeBresson, C. (ed.) *Economic Independence and Innovative Activity: An input-output Analysis,* Edward Elgar, Aldershot.

DAVID, P.A.; HALL, B.H.; TOOLE, A.A (2000): Is public R&D a complement or substitute for private R&D? a review of the econometric evidence. In: Research Policy, Volume 29, Issue 4-5, April 2000, Pages 497-529.

DE JONG, J.P.J. AND MARSILI, O. (2006) The fruit flies of innovations: A taxonomy of innovative small firms, *Research Policy,* 35, 213-229.

DOSI, G. (1988): Microeconomic Effects of Innovation, *Journal of Economic Literature,* 26, 1120-1171.

European Commission (2005a): 'Key Figures 2005 on Science, Technology and Innovation. Towards a European Knowledge Area'.

European Commission (2006a): Reporting Intellectual Capital to Augment Research, Development and Innovation in SMEs. Report to the Commission of the High Level Expert Group on RICARDIS. In: Encourage corporate measuring and reporting on research and other forms of intellectual capital.

European Commission (2006b): 'RICARDIS: Reporting Intellectual Capital to Augment Research, Development and Innovation in SMEs'.

European Commission (2006c): 'SMEs in FP6- Sharing in Europe's future', DG RTD (ed.), Brussels.

European Commission (2006d): 'SMEs in STREPs under FP6', DG RTD (ed.), Brussels

European Commission (2008): 2007 EU Industrial R&D Investment Scoreboard.

FERNÁNDEZ, E. (1996): Innovación, tecnología y alianzas estratégicas: factores clave de la competencia. Madrid: Biblioteca Civitas Economía y Empresa.

GALBRAITH (1952): American Capitalism: The Concept of Countervailing Power, New York: Houghton Mifflin.

GALLUP ORGANISATION (2006): 'SME Access to Finance in the New Member States', FLASH EUROBAROMETER, n.184.

GRILICHES, Z.; HALL, B. and A. PAKES (1986): 'The value of Patents as Indicators of Inventive Activity', NBER working paper, num. 2083.

HAIR, J.F.; ANDERSON, R.E.; TATHAM, R.L.; BLACK, W.C. (1998): Multivariate Data Analysis, fifth ed. Prentice Hall, Englewood Cliffs, NJ.

HATZICHRONOGLOU, T. (1997): Revision of the High-Technology Sector and Product Classification, STI Working Paper 1997/2, OECD, Paris.

HAUSMAN, A. (2005): 'Innovativeness among small businesses: theory and propositions for future research,' *Industrial Marketing Management* 34(8), 773-782.

HENKRESON, M. and D. JOHANSSON (2008): Gazelles as Job Creators. A survey and interpretation of evidence, IFN Working paper No 733, Research Institute of Industrial Economics, Stockholm.

HÖLZL, W. and K. FRIESENBICHLER (2008): Final Sector Report Gazelles. Europa Innova Sector report. Vienna: WIFO.

KAHN, K., FRANZAK, F., GRIFFIN, A., KOHN, S., MILLER, C. (2003): Editorial. Identification and Consideration of emerging research questions. *Journal of Product Innovation Management,* 20, 3, 193-201.

LEE, C.Y.; SUNG, T. (2005): Schumpeter's legacy: A new perspective on the relationship between firm size and R&D, In: *Research Policy,* Vol. 34, Issue: 6, Pages: 914-931.

LEGLER, H. (1982): 'Zur Positionierung der Bundesrepublik Deutschland in Internationalem Wettbewerb,' Forschungsberichte des niedersächsischen Instituts für Wirtschaftsforschung, 3.

LOKSHIN, B.; BELDERBOS, R.; CARREE, M. (2006): Internal and External R&D: Complements or Substitutes? Evidence from a Dynamic Panel Data Model. In: Katholieke Universiteit Leuven, Faculty of Economics and Applied Economics, Department of Managerial Economics, Strategy and Innovation, OR 0604.

LOVE JH, ASHCROFT B, DUNLOP S (1996): 'Corporate structure, ownership and the likelihood of innovation,' *Applied Economics*, 28:737–746.

MALERBA, F. and L. ORSENIGO (1996): Schumpeterian Patterns of Innovation are Technology-Specific, *Research Policy* 25(3), 451-478.

MANSFIELD, E. (1964): 'Industrial research and development expenditures: determinants, prospects and relation of size of firm and inventive output,' *Journal of Political Economy,* 72:319–340.

MILLIGAN, G.W., and M.C.COOPER (1987): 'Methodology review: clustering methods,' *Applied Psychological Measurement,* 11(4), 329-354.

OECD (2001): Science, Technology and Industry Scoreboard, OECD, Paris.

OECD (2005): SME and Entrepreneurship Outlook 2005.

OMC-SME Expert Group (2004): 'SME and Research. In: Report of the CREST expert-group operating within the First Cycle of the Open Method of Coordination for the Implementation of the 3 % Action Plan.' Released June/2004.

OMC-SME Expert Group (2006): 'Design measures to promote growth of young research-intensive SMEs and start-ups. In: Report of the expert-group operating within the Second Cycle of the Open Method of Coordination for the Implementation of the 3 % Action Plan.' (Forthcoming >>> draft report will be presented at the Expert Group meeting 16/17 Nov. 2006, Madrid).

ORTEGA-ARGILÉS, R.; A. BRANDSMA (2009): 'EU-US differences in the size of R&D intensive firms: Do they explain the overall R&D intensity gap?', IPTS Working Papers on Corporate R&D and Innovation, num. 02/2009, European Commission, Institute for Prospective Technological Studies Technical Report.

ORTEGA-ARGILÉS, R.; M. PIVA; L. POTTERS AND M. VIVARELLI (2009) Is corporate R&D investment in high-tech sectors more effective? Some guidelines for European Research Policy, IZA Discussion Paper Series, n. 3945

ORTEGA-ARGILÉS, R.; L. POTTERS; M. VIVARELLI (2008) The Productivity Impact of R&D Investment: Evidence from European Microdata, Jena Economic Research Papers, n. 2008 – 050, ISSN 1864-7057.

ORTEGA-ARGILES, R.; VOIGT, P. (2009): Business R&D in SMEs. *IPTS Working paper on Corporate R&D and Innovation,* num. 07/2009.

PENEDER, M. (1999): 'Intangible Investment and Human Resources: The New WIFO taxonomy of manufacturing industries,' WIFO Working Papers, 114.

PENEDER, M. (2002): 'Intangible Investment and Human Resources,' *Journal of Evolutionary Economics*, 12, 107-134.

PAVITT, K. 1984. 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', Research Policy, 13, 343-373.

PAVITT, K. 1986. 'Chips and Trajectories': How Will the Semiconductor Influence the Sources and Directions of Technical Change?' in *Technology and the human prospect.* Ed.: R. MacLeod London: Francis Pinter. ,

SCHERER FM, ROSS DR (1990): Industrial market structure and economic performance. Houghton Mifflin Co., 3rd ed.

SCHERER, FM (1992): 'Schumpeter and plausible capitalism,' *Journal of Economic Literature,* 30(3): 1416-1433.

SCHREYER, P. (2000) High-growth Firms and Employment, OECD STI Working Paper 2000/3.

SCHUMPETER, J.A. (1942): Capitalism, Socialism and Democracy. New York: Harper.

SCHULMEISTER, S. (1990): Das technologische Profil des österrichischen Außenhandels, WIFO-Monatsberichte, 63 (12), 663-675.

SRINIVASAN, R., LILIAN, G., RANGASWAMY, A. (2002): 'Technological Opportunism and radical technology adoption: an application of e-business,' *Journal of Marketing,* 66, 3, 47-61.

STANLEY, M., N. AMARAL, S. BULDYREV, S. HAVLIN, H. LESCHHORN, P. MAASS, M. SALINGER and H. STANLEY (1996): Scaling behavior in growth companies. In: Nature, 379, pp. 804 – 806.

WOOD, E. (1997): 'SME Innovator Types and Their Determinants' ESCR Centre for Business Research, University of Cambridge, Working paper num. 72.

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Title: R&D-intensive SMEs in Europe: What do we know about them?

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Technical Note

Abstract

The importance of SMEs in Europe's innovation process can be seen in both the academic and the political arena. Adopted in June 2008, the 'Small Business Act' for Europe reflects the Commission's political will to recognise the central role of SMEs in the EU economy and was the first to put in place a comprehensive SME policy framework for the EU and its Member States. One of its main aims is to promote growth among SMEs by helping them to tackle problems that hamper their development. This kind of policy calls for a more in-depth look into the nature of the SME population in Europe.

Several attempts have been made in recent years to draw taxonomies of firms, but mostly they do not control for size effects within the defined groups of firms. The purpose of this paper is to typify different groups of R&D-intensive SMEs distinguished according to their inputs into the innovation process. In particular, we draw attention to SMEs that contribute the most to the industrial R&D investment in the EU. To do so, we run a cluster analysis on a sample of top European R&D SME investors based on a unique dataset made up of the different waves of the *European R&D Investment Scoreboard.*

The results show that several clusters of R&D-intensive SMEs can be defined by certain characteristics, but that the diversity between clusters calls for a more careful understanding before developing measures to support European R&D-intensive SMEs.

For companies labelled as 'corporate laboratories' according to the cluster analysis, it would be legitimate to question support for R&D, as these firms do not seem to have significant problems in finding investors that believe in their business model. On the other hand, e.g. the 'Gazelles' do in fact grow, but struggle with the high capital investment needed to become and remain large. In this case, it seems it would be more effective to focus on the weaknesses (physical expansion) of these firms rather than supporting their strengths (knowledge, R&D).