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Rinaldo Evangelista, Tore Sandven, Giorgio Sirilli and Keith Smith

Innovation expenditures in European industry

Rinaldo Evangelista, Tore Sandven, Giorgio Sirilli and Keith Smith
STEP group
Storgt. 1
N-0155 Oslo
Norway
and
ISRDS, Research Council of Italy, Rome

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STEP group

Studies in technology, innovation and economic policy
Studier i teknologi, innovasjon og økonomisk politikk

Storgaten 1, N-0155 Oslo, Norway
Telephone +47 2247 7310
Fax: +47 2242 9533
Web: http://www.step.no/

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Summary

1. This report uses data from the *Community Innovation Survey* to explore expenditures on innovation by European firms. It analyses the level and structure of three types of innovation investment across European industry: R&D, non-R&D expenditures (such as design activities), and capital investments linked to the innovation of new products.

2. Although we have long had good data on R&D, we have lacked data on the other main categories of innovation expenditure. This is a serious problem, since one of the most important themes of modern innovation analysis has been the importance of non-R&D inputs to innovation. A related issue is expenditure on the acquisition of capital and intermediate goods, embodying new technologies. This type of investment, which is linked to both product and process change, has long been recognised as a key 'carrier' of technological advance.

3. The *Community Innovation Survey* has been the first major attempt to collect data on important categories of non-R&D inputs to innovation, and it offers us the first opportunity to explore – across European economies and across European industries – the extent of resource commitment of this type, and some of its patterns.

4. The report distinguishes between three types of innovation expenditures. First, there are R&D expenditures, or, more precisely, current expenditures on R&D. Second, there are current innovation expenditures which are not comprised under the heading R&D, that is current non-R&D innovation expenditures. These include product design, trial production, training and tooling-up, acquisition of products and licences, market analysis and other expenditures. Third, there are investments in relation to innovation, as for instance the acquisition of new technology through investment in new machinery and equipment. This report is a quantitative exploration of some of the issues which can be examined with such data.

5. After discussing the data itself, we provide in Chapter One a general overview of the structure and characteristics of innovation expenditures across European industry. We then turn, in Chapter Two and Three to a more technical analysis of the data.

6. The analysis seeks to explore two main issues:

- Can we identify industry-specific features of the *level* of innovation expenditures in European? That is to say, when we look at an industry, is the extent or intensity of innovation expenditure consistent across countries in Europe, or do these levels vary across countries?
- How does the *composition* of innovation inputs vary across industries, and is such variation consistent across countries in Europe?

7. The primary results are:

- Innovating firms commit significant resources to innovation, ranging from 7-8% or turnover in traditional industries to 12-15% in high-tech sectors
- The composition of innovation expenditures varies, with between 10 to 25% made up of R&D, roughly 30% comprising non-R&D expenditures, and between 40 and 60% comprising investment expenditures
- The levels of innovation expenditure (measured in terms of innovation expenditures as a proportion of turnover) are very similar across European industries in different Member States. The intensity of innovation expenditure reflects features of the industry, rather than country-specific features.
- There is considerable inter-industry variation in the composition of innovation expenditures. Industries can be seen in terms of different structures of innovation expenditures, and these differences in the composition of innovation expenditures are similar across countries.

8. These questions may have implications for European policy. The data confirms the importance of non-linear models of innovation as a basis for policy analysis. This has implications for the balance of effort between the provision of R&D (historically the most important aspect of innovation support) and the provision of non-R&D services or support related to the wide range of other activities which must be undertaken if innovation is to succeed. But the results may also be relevant for wider issues. For example, one of the basic problems for European innovation policy is to distinguish between the appropriate levels for policy action. What, for example, should be the tasks or areas of responsibility of the European Commission vis-a-vis the Member States? Such questions depend on the characteristics of innovation processes in Europe. Do industries in Europe have significant features in common? Is the structure of innovation inputs similar in the same industry across Europe? Or are there country-specific features (perhaps reflecting different national innovation systems)? If there is a common European level, then we may be able to identify - at least in a broad way – commonalities of innovation input where problems may arise which are appropriate arenas for European action. On the other hand, if innovation at industry level is characterised by strong country-specific features, then policies directed to specific industries or activities might best be undertaken at Member State level. This data strongly shows the importance of industry-level effects, rather than country-level effects: European industries appear to have strong commonalities in terms of innovation expenditures.

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CHAPTER ONE: Innovation expenditures: policy issues, data and overview

This report uses data from the *Community Innovation Survey* to explore expenditures on innovation by European firms. It analyses the level and structure of three types of innovation investment across European industry: R&D, non-R&D expenditures (such as design activities), and capital investments linked to the innovation of new products.

How is innovation related to such expenditures? In the long run the survivability and growth of firms depends critically on innovation performance, as does the growth of welfare in the economy as a whole. Innovation in turn depends on the ability to learn, to develop and market new and changed products, and to improve production processes and organization. The learning capabilities which underpin innovation performance depend on two kinds of resource commitment by firms.

On the one hand there is the creation and maintenance of intangible assets: human capital, skills, new organizational forms, exploration and creation of markets, and so on. These assets require the commitment of resources - to training, R&D, product design, organization skills and capabilities and so on. Although we have long had good data on R&D, we have lacked data on the other main categories of innovation expenditure. This is a serious problem, since one of the most important themes of modern innovation analysis has been the importance of non-R&D inputs to innovation. On the other hand, there is expenditure on the acquisition of capital and intermediate goods, embodying new technologies. This type of investment, which is linked to both product and process change, has long been recognised as a key ‘carrier’ of technological advance. Of course we have long had investment data for firms and industries, but the data here is perhaps the first to isolate such investment specifically associated with innovation.

Both these kinds of resource commitment are investment in the strict sense - that is, they involves the use of finance in the present period or periods to create assets which will deliver benefits over future time periods. A major problem in innovation analysis is that most of the assets which are thus created are intangible - they are not capitalised in the balance sheet of the firm, and are often treated for accounting purposes as current expenditures which impact on current profitability. Unlike R&D, neither accounting systems nor statisticians have systematically collected data on the major categories of non-R&D investment in innovation. This means that we do not have good data on the extent to which innovating firms commit resources to intangible investment, or on the main types of intangible investment which they undertake; nor have we been able to explore inter-industry differences in the ways firms commit resources to innovation. This has, as we shall argue below, important implications for innovation policy.

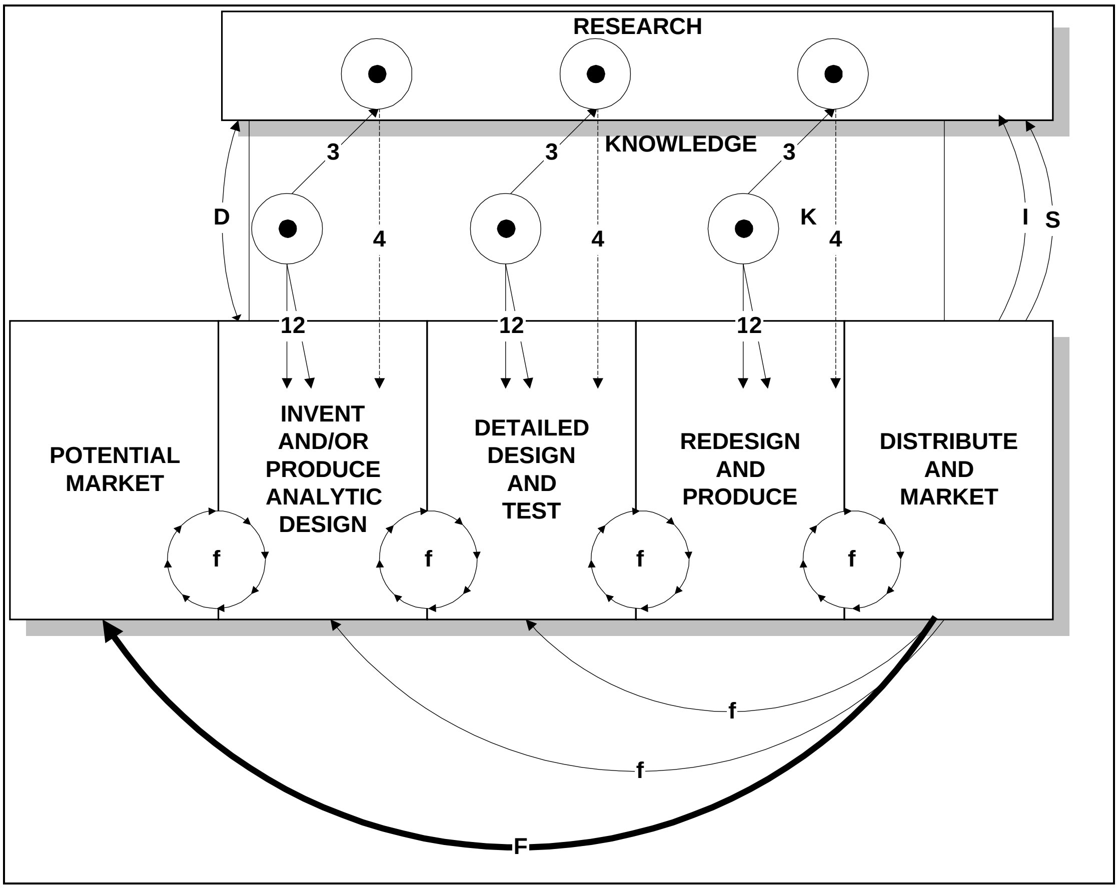
At the present time, many national policies for innovation, and even to some extent the major Community RTD programmes, remain more or less based on the idea that firms face only one problem in innovation, namely the scale and finance of R&D. But the extreme diversity of innovation processes at both industry and firm level suggests that firms undertake a wide variety of activities in innovation, many of which require the commitment of significant resources. An important issue for innovation and technology policy is to reflect this more complex view of innovation-related investments, with a more subtle and differentiated mix of objectives and instruments corresponding to the real characteristics of innovation processes. The starting point for this can only be a wider range of models of innovation processes.

Most of the policy debate is still affected by the so-called "linear model" of innovation. In this model, innovation is a process which occurs in a roughly linear progression from research to invention to innovation and then diffusion of new techniques. Within the research process there is a similar progression, from basic scientific knowledge, to technological knowledge to practical engineering (which is seen as a form applied science). The linear model implies a causal relation which justifies treating R&D as a basic input for innovation activity as a whole. The linear model has been widely criticised for two reasons: first the innovation process is seen as a progression between separate stages rather than in terms of interactions and feedbacks between different innovative functions; secondly, it places an overemphasis on R&D, rather than on non-R&D inputs to innovation.

The most commonly-used alternative model of innovation is the so-called ‘chain-link’ model developed by Kline and Rosenberg; this model is dicussed breifly here, since it had a strong influence on the design of the *Community Innovation Survey* (CIS) which supplies the data for the following analysis. The chain-linked model of innovation conceptualises innovation in terms of interaction between market opportunities and firm’s knowledge base and capabilities, and suggests that no simple progression takes place. In the innovation process it is often necessary to go back to earlier stages in order to overcome difficulties in development. A key element in determining the success of innovation is the continuous interaction between marketing and the invention/design stages. The basic model is structured as indicated in Figure 1.1 below.

The main point here is not simply the feedbacks, but the idea that such activities as design, prototype development and testing, and market research all require resources within specific innovation projects. One of the basic ideas of the *Community Innovation Survey*, therefore, was to seek to collect data on such categories of expenditure. But these categories in themselves clearly do not exhaust non-R&D innovation expenditures. Two other types of expenditure appear to be particularly important. These were, firstly, expenditure on training related to the development and introduction of new products, and secondly, capital expenditures (on new machinery and equipment) related to new products.

Figure 1.1 - The chain-link model of innovation



The previously available data for innovation and technology analysis clearly does not cover such expenditures. Such data is essentially of three types. Firstly, there is data on R&D inputs, collected in the OECD economies according to the procedures and categories described in the OECD "Frascati" Manual. Secondly, there is patent data, the most important body of which consists of the records of the US Patent Office and the European Patent Office. Thirdly, there is bibliometric data on patterns of scientific publications and citations.

The fundamental limitations of these data sources are well known. R&D numbers measure only an input, which has no necessary relation to innovation outcomes. There are many examples of successful innovating companies and industries which perform relatively little R&D. As we shall show below, non-R&D inputs are in fact quantitatively more significant then R&D across all industries. Patent data is limited by variations in firms' and industries' propensity to patent; moreover it tells us only about the invention phase of the innovation process, and little about commercialisation and hence the economic value or economic impact of an invention. Bibliometric data tells us much about the changing shape of fundamental research, and increasingly about scientific the innovation process, but it is not in itself an innovation output indicator.

The necessity to extend the range of technology and innovation data gave rise in 1992 to the adoption of a new OECD statistical manual, the “Oslo” Manual, which attempted to present a coherent framework for the development of new innovation indicators with an explicit theoretical foundation, which could provide a basis for international comparability. The Manual was developed out of a heterogeneous set of more or less independent surveys carried out by various researchers in the 1980s and was based on the chain-linked model of innovation described above. The OECD methodology was subsequently developed by EUROSTAT and DG-XIII (European Innovations Monitoring System) within the European Commission, and implemented on a EU-wide basis using a common questionnaire (“EC Harmonised Questionnaire); this survey was known as the CIS action. EUROSTAT has now built a comprehensive firm-level database with the CIS data, which contains data on almost 41,000 European firms.

The CIS survey primarily collects data on activities related to product and process innovation in manufacturing, and on outputs of new or improved products within the sales profiles of firms. But it also collects data on expenditures on innovation, of the types noted above.

CIS was designed, therefore, to address two main sets of issues. The first one has to do with the general structure of innovation processes, at the level of all European industry as well as across main typologies of firms and industries. What are the main non-R&D inputs to innovation, and how important are they? How extensive is inter-industry and intra-industry variation in innovation inputs, and how does such variation affect the innovative performance of firms? What are the primary objectives of R&D, and what are the dimensions of external collaboration in R&D? Over the last two decades there has been a large amount of literature on the heterogeneous nature of innovation activities and on its firm and sector specific characteristics. The CIS data base allows to explore such issues on the basis of a very large sample, raising the possibility of describing the profile of the ‘innovation structures’ across European industry.

The second set of issues, and the most ambitious one, has to do with the way national innovation patterns of European countries differ from each other and the determinants of such heterogeneity. Do industries in Europe have significant features in common? Is the structure of innovation inputs similar across countries and across industries of different countries? Are there country-specific features? These questions have very relevant policy implications. If there is a sufficiently common European innovation structure, then we may be able to identify, at least in a broad way, appropriate areas for European action. On the other hand, if innovation both at country and industry level is characterised by strong country-specific features, then policies directed to specific industries or activities might best be undertaken at Member State level.

This chapter addresses basically the first set of issues mentioned above, analysing the CIS data on the number of innovating firms and innovation expenditure in European manufacturing industry. Later chapters seek to explore industry-specific features using rather more complex technical approaches to the data.

The CIS data set of course has both strengths and weaknesses. The primary weakness lies in the methodology and the survey procedures which have been used, which sharply limit international comparisons. The methodology and the data collection process of course also have inherent limitations (Archibugi et al., 1995) and it must be recognised that the data set is still in the development stage. The data used for the present analysis are "micro aggregations" of the original data carried out by EUROSTAT to protect confidentiality. The results of the present analysis should therefore be considered provisional; however we think that they teach us important lessons.

In the following section a description of the CIS data set and the methodology used for the empirical analysis of this paper is discussed. Section 3 analyses the data on the percentages of innovating firms at the level of all European manufacturing industry and across main industrial sectors and firm size classes. Section 4 is dedicated to the analysis of the main components of innovation expenditures, while section 5 the technological profile of industries and main firm size classes will be analysed looking at the amount of resources devoted by firms to innovation.

2. The data base and survey methodology

The CIS data base is made of data at the firm level on 40,817 firms of 13 European countries: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Norway, Portugal, Spain, The Netherlands and The United Kingdom. In the table below shows data on the coverage of the surveys, the number of firms which returned the questionnaire, and the response rate, along with some additional information on the features of the surveys.

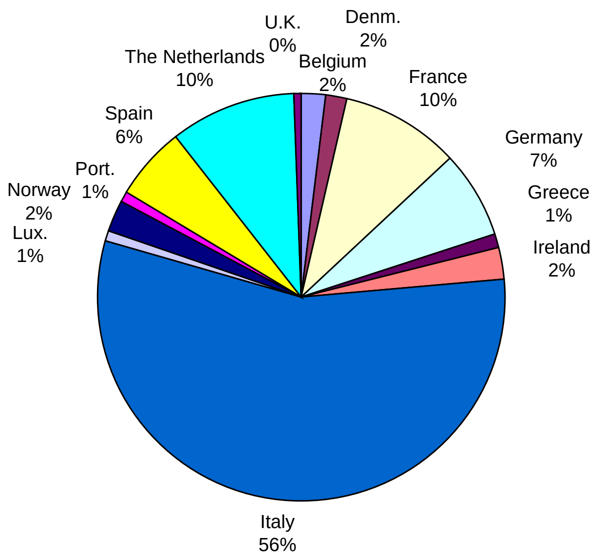
Table 1.1 - Characteristics of the Cis data-base

Countries	1 Census/Survey	2 Sectors covered Manuf/Services	3 Cut-off point n. of empl.	4 Resp. rate	5 Realized sample (*) n. of firms	6 % on total	7 Additional features affecting the comparability of data
Belgium	Survey	M	>9	38%	748	1.8%	Low response rate
Denmark	Survey	M	>19	51%	674	1.7%	
France	Survey	M	>19	75%	3879	9.5%	No data on innovation
Germany	Survey	M&S	>4	22%	2918	7.1%	
Greece	Survey	M&S	No	92%	399	1.0%	Sample biased towards innov.firms
Ireland	Census	M	>9	33%	999	2.4%	Low response rate
Italy	Census	M&S	>19	64%	22788	55.8%	
Luxembourg	Census	M	No	79%	372	0.9%	
Norway	Survey	M	>5	52%	982	2.4%	
Portugal	Survey	M&S	No	70%	410	1.0%	Only innovative firms
Spain	Census	M	>19	13%	2372	5.8%	Survey stopped after 2 weeks
The Netherlands	Survey	M&S	>9	50%	4094	10.0%	
United Kingdom	Survey	M	>25	4%	182	0.4%	Extremely low response rate
Total sample					40817	100%	

Source: Archibugi et al., 1995
(*) as contained in the CIS data-set

National samples differ in survey procedures: three countries (Spain, Italy, Ireland) carried out censuses, while the other carried out sample surveys. The coverage was not homogeneous across countries. In some cases (Germany, Greece, Italy, The Netherlands and the United Kingdom) service sectors have also been included along with manufacturing industries (column 2). Different cut-off points in terms of firm size have been applied in the various surveys (column 3). The response rates varied sharply across the countries, ranging from 79% of Luxembourg to 4% of the U.K (column 4); thus only realtively few countries are comparable, and we have not used all of the data. Differences in the type of the survey, coverage, and response rates are reflected in the number of returned questionnaires as shown in column 5. The last column (7) sets forth other characteristic of national surveys. More in particular: the French data-set does not contain data on innovation expenditures; the Spanish survey was stopped after two weeks from start, leading to a very low response rate; the Greek sample is likely to be biased towards innovative firms; the Portuguese sample contains only innovative firms; the response rate in U.K. was so low to make unreliable the data collected.

Figure 1.2 - National shares of the European sample of responding firms



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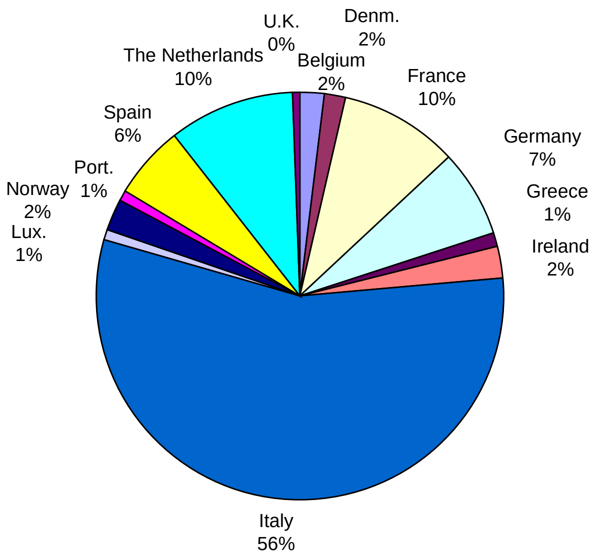


shows the size of the national samples of the CIS data-base. Italian firms represent 50% of the total European sample. France and the Netherlands contribute 10%, while the German sample counts for 7% of total sample.

In order to improve comparabiltiy, in this chapter we have analysed a sub-sample which is comprised of:

- firms with more than 19 employees;
- manufacturing firms.

The coverage of countries varies with the type of indicator, and is specified in the text. The analysis of the number of innovating firms is conducted on the following ten countries: Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, Norway, Spain and The Netherlands. The data on the innovation expenditure refer to the following nine countries: Belgium, Denmark, Germany, Ireland, Italy, Luxembourg, Norway, Spain, and The Netherlands.

Profiles and regularities in firms' innovation patterns across countries, industries and firm size classes are analysed focusing on the following dimensions of innovation activities:

- The percentage of innovating firms over the total number of firms. Innovating firms have been defined as those which have introduced at least one product or process innovation over the period 1990-1992.

- 'Innovation intensity', measured as the ratio between innovation expenditure and sales. R&D intensity is analysed separately.

- The distribution of innovation expenditures in terms of R&D, non-R&D activities (patents and licences, production design, trial production and marketing) and investment.

The statistical analysis on the number of innovating firms has been carried out using the raising factors (weights) provided by EUROSTAT in order to reproportionate the national sample to the populations from which the samples have been drawn. The percentages of innovating firms in Section 2 of this paper refer to the estimates for the whole population of firms.

The above procedure has not be used for the analysis of the data on innovation expenditures because of the large number of missing values in the relevant questionnaire section. The reproportioning to the statistical population would yield highly distorted estimates. We therefore confine ourselves to the sample reponses.

In the harmonised questionnaire the expenditure of innovation was defined as the sum of expenditures incurred by the firm the during a given year - 1992 - for six items. These were:

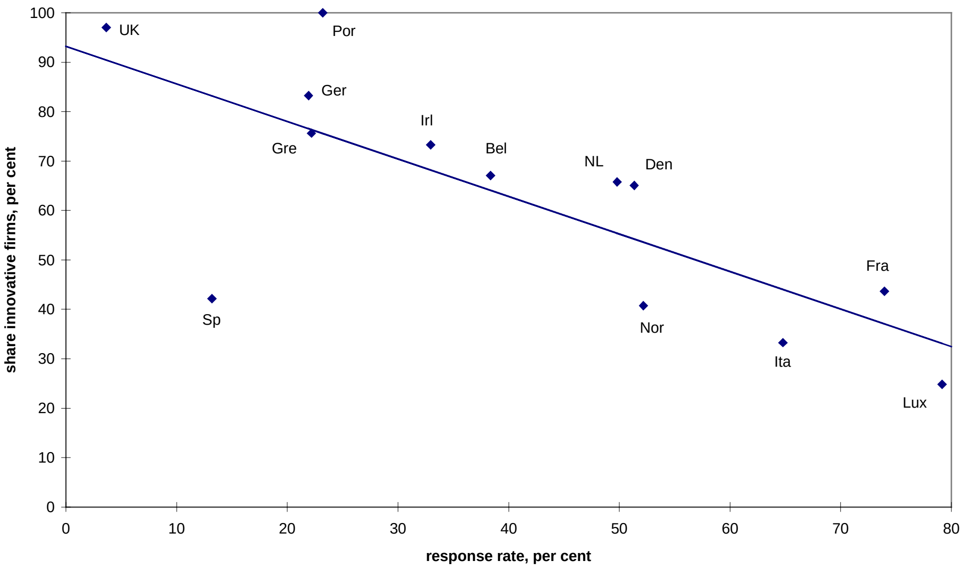
1) R&D,
2) patents and licences,
3) production design,
4) trial production and tooling up,
5) marketing,
6) investment in plant, machinery and equipment).

It should be noted that, because the data was collected for one year, 1992, there is no direct correlation between innovations introduced and their expenditure both in terms of amount of reosurces involved and of timing.

In Sections 4 and 5 of this chapter simple average values of the shares of innovation expenditures and intensity of innovation expenditure have been computed for the whole European sample (13 countries). The average values are calculated summing up the percentages of the of some 8,729 manufacturing firms which have filled out the innovation expenditure section of the questionnaire. This implies that all firms have been attributed the same weight. Moreover, the averages are biased in favour of the countries with a larger sample. It must be note that there appears to be a general problem of sample bias within the data, due to the fact that samples with higher response rates generally report lower proportions of innovation firms, as Figure 1.3 indicates. Much of our approach in later chapters in concerned with eliminating the effects of this bias.

Figure 1.3 - Response rate (x-axis) and share of the firms accounted for by innovative firms (y-axis)

Response rate (x-axis) and share of the firms accounted for by innovative firms (y-axis)



3. How many innovating firms?

Figure 1.4 shows the percentage of innovative firms across the different size classes. The figures are the result of a re-proportioning of the sample to the national statistical population. Data refer to all European countries, with the exclusion of U.K, Portugal and Greece. Overall 53%, of firms of European manufacturing firms have introduced either a process or a product innovation during the 1990-92 period.

Figure 1.4 shows a positive correlation between firms size and percentage of innovative firms. 45% of firms with less than 30 employees have introduced either a product or a process innovation, while this percentage increases to 90% for firms with over 1,000 employees. This pattern holds basically for all the European countries (Figure 1.5). The data for Germany, Ireland and Belgium are in line with this pattern, although the low response rate for these countries almost certainly makes their averages biased.

Figure 1.4 - Percentage of innovating firms across firm size classes (values re-proportionated to the population of European firms)

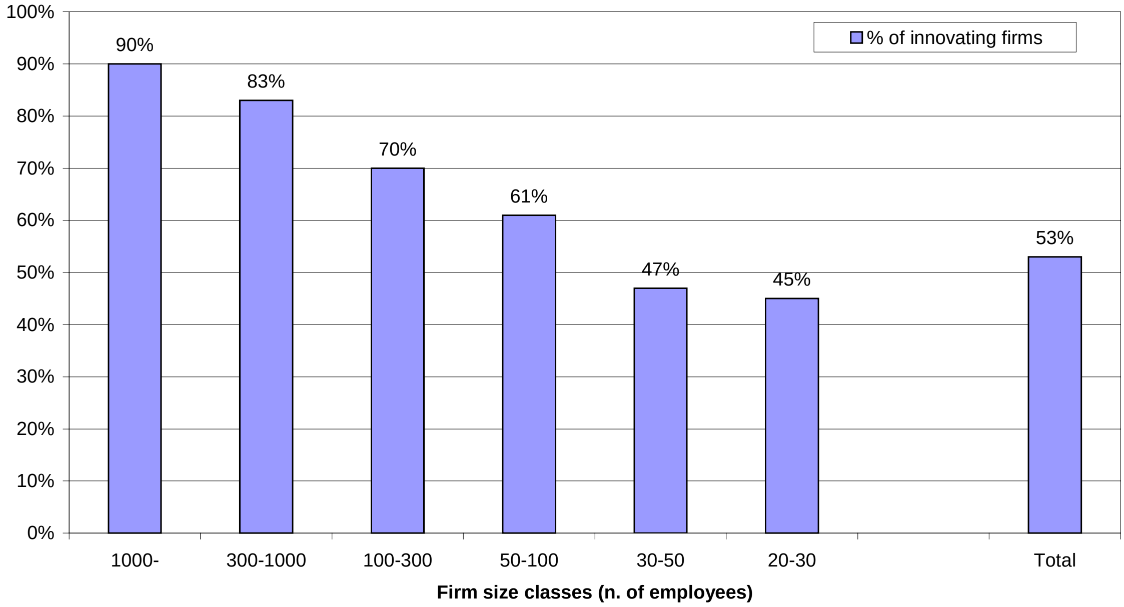


Figure 1.5 - Percentage of innovative firms across firm size classes and countries (values reproportionated to the population of European countries)

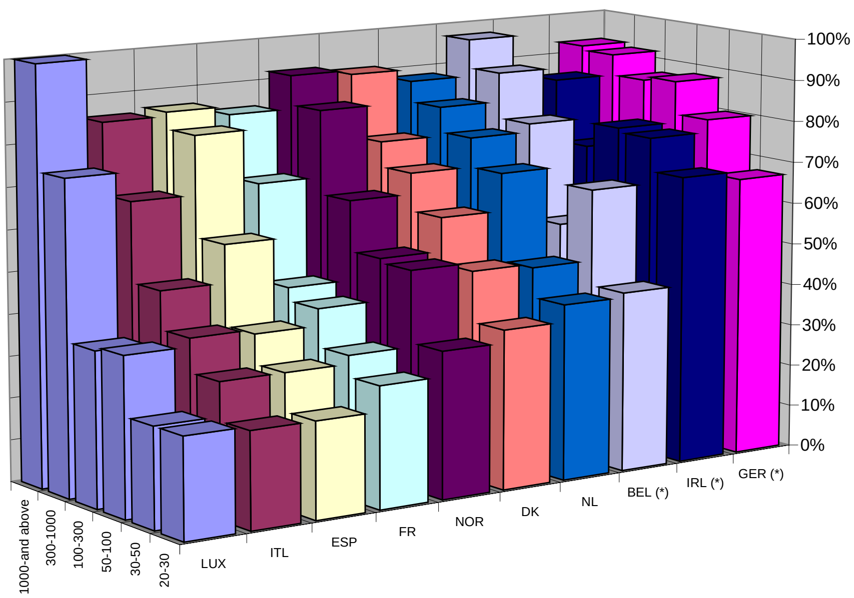
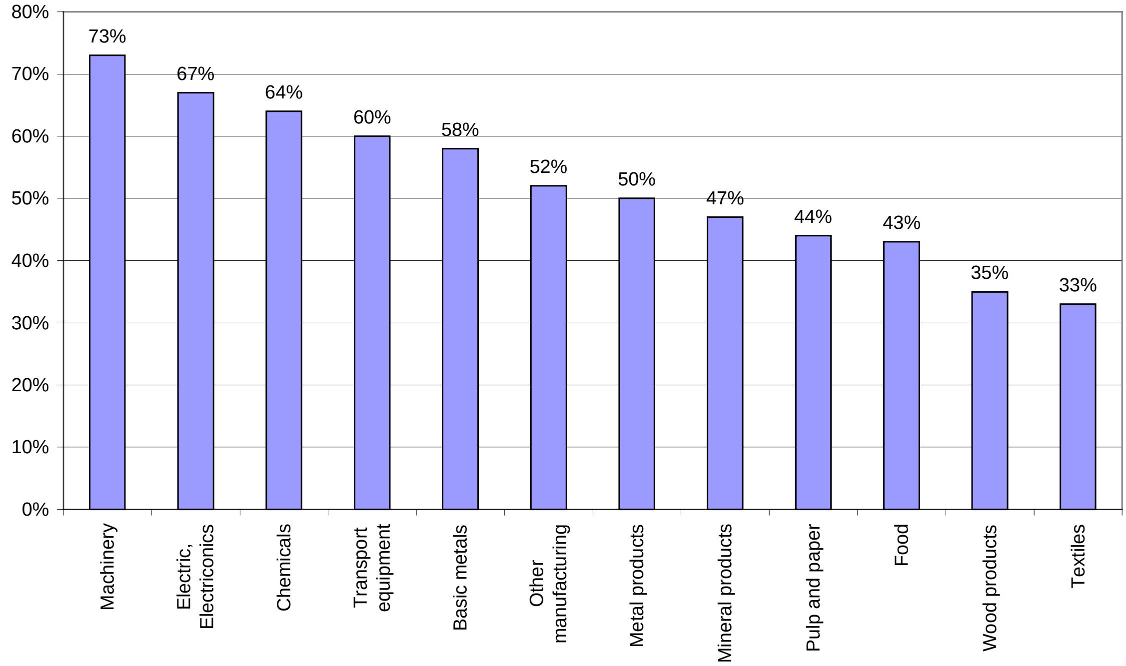


Figure 1.6 shows the same information broken down by industrial sectors. In industries such as machinery, electronics and chemicals some two thirds of firms innovate, while in traditional sectors like consumer goods, textiles, wood products, food, the share is about one third.

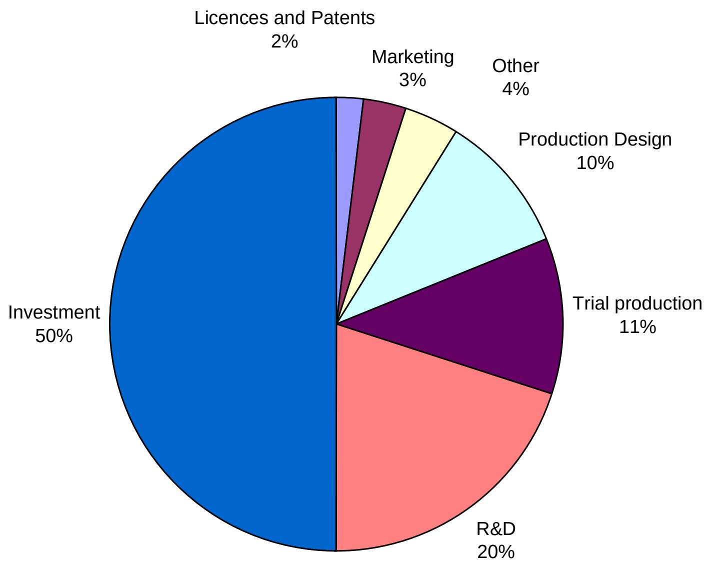
Figure 1.6 - Percentage of innovating firms across industries (values reproportionated to the population of European firms)



4. The break down of innovation expenditures

The multiform nature of innovative activities and their sectoral specificity have been underlined in a vast amount of literature (Pavitt, 1984; Kline and Rosenberg, 1986; von Hippel, 1988; Archibugi et al., 1991), which has confirmed the existence of a multiplicity of closely interdependent sources of innovation. Besides activities generating new technological knowledge, special attention has also been attached to processes of technology adoption and diffusion (both embodied and disembodied), a necessary condition widely acknowledged for technology to express its economic effects to the full (OECD, 1996, Evangelista, 1996).

Figure 1.7 - Break-down of innovation expenditures (all European sample - average values on 8729 innovating firms)

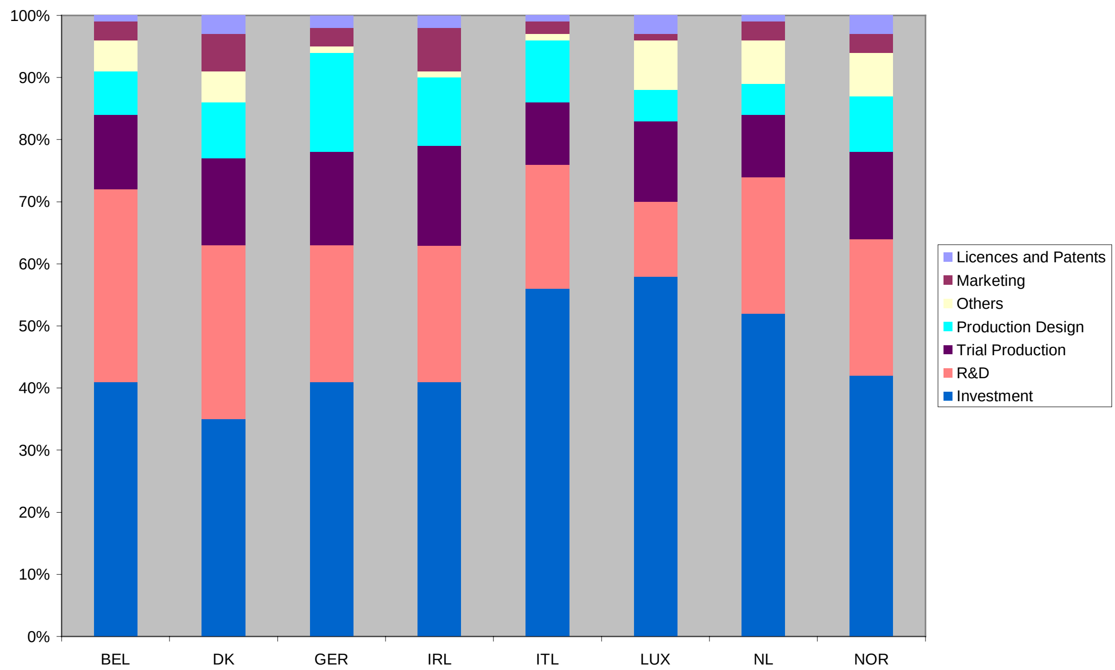


The relevance of the different innovation sources can be analysed looking at the breakdown of expenditure incurred by manufacturing firms in introducing innovations.

Figure 1.7 shows average values of the shares of innovation expenditures using the whole European sample (13 countries). As already mentioned, these figures are biased in favour of the countries with a higher sample size. In particular, it should be pointed out that the data of the following Figures are heavily affected by the size of the Italian sample which weighs some 50%; however figures for the various countries show substantial coherence of profiles.

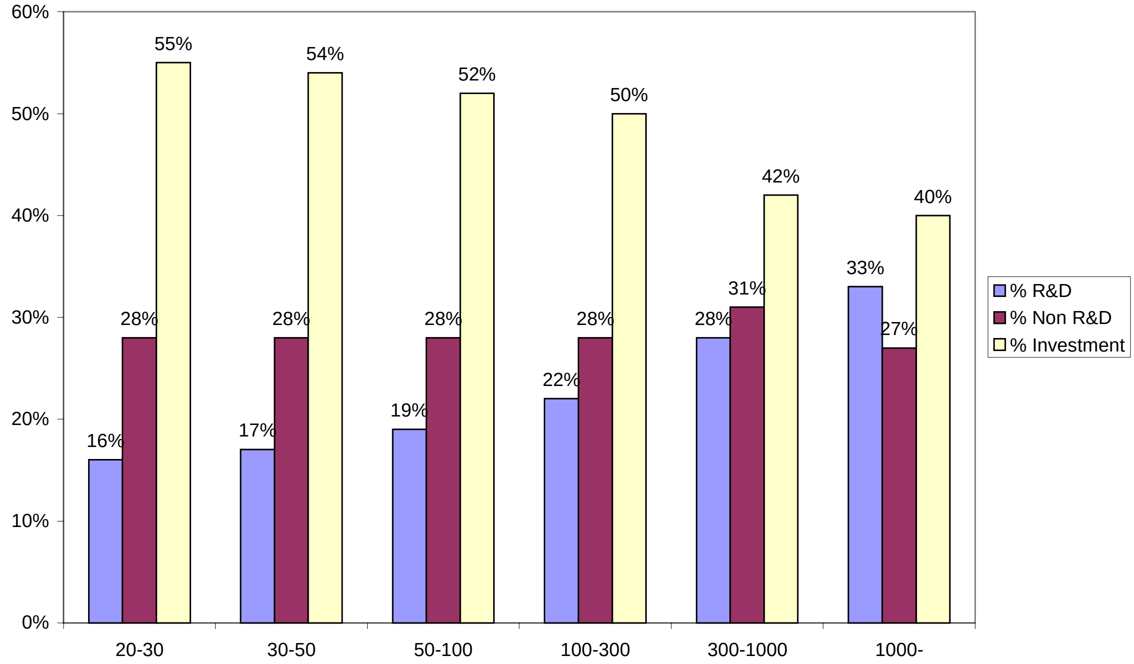
The picture which emerges from Figure 1.7 is very clear-cut. Industrial innovative processes consist, first and foremost, of the purchase and use of technologies embodied in plant, machinery and equipment which represent 50% of total expenditure on innovation. The internal technological efforts and capabilities of firms devoted to R&D, design and trial production are respectively 20%, 10% and 11%. The acquisition of “disembodied” technology through patents and licences accounts for 2%, while 2% is spent for marketing. The same pattern emerges looking at the break-down of innovation expenditures of the various European countries (Figure 1.8). The ranking of the different innovation sources, in terms of their relative importance, does not change significantly.

Figure 1.8 - Break-down of innovation expenditures across countries (average values on 8729 innovating firms)



The importance of the different sources of innovation in business strategies is, however, strongly influenced by firm size. Figure 1.9 highlights the prevailing tendency for small firms to innovate by acquiring machinery and plants, against the greater propensity of large firms to generate internally new technologies. For firms with fewer than 30 employees, R&D activities account for 16% of total innovation expenditure against a percentage of 33% in the case of firms with more than 1,000 employees. Data on investment show an opposite pattern. Innovative investments of small and medium-sized firms account for more than 50% of total innovation expenditures. The other components of innovation do not appear systematically correlated to firm size.

Figure 1.9 - Break-down of innovations across firm size (average values on 8729 innovating firms)



The mix of innovative activities appears rather similar across countries (Figure 1.10 and Figure 1.11).

Figure 1.10 - Share of R&D in innovation expenditures across firms size classes and countries (average values on 8729 innovating firms)

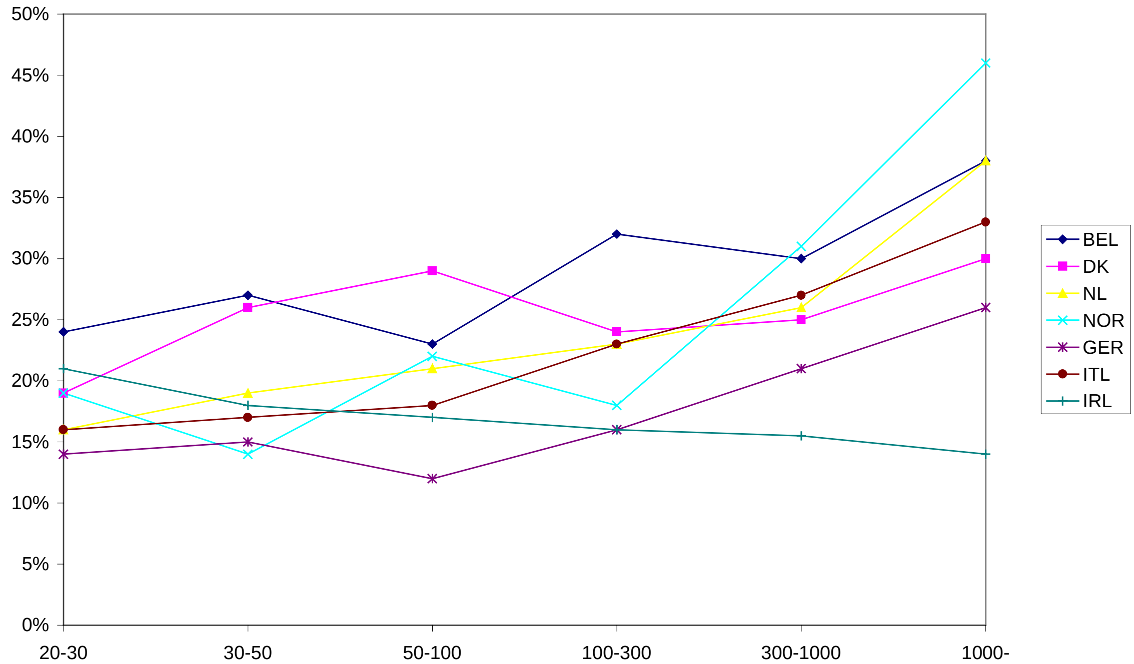
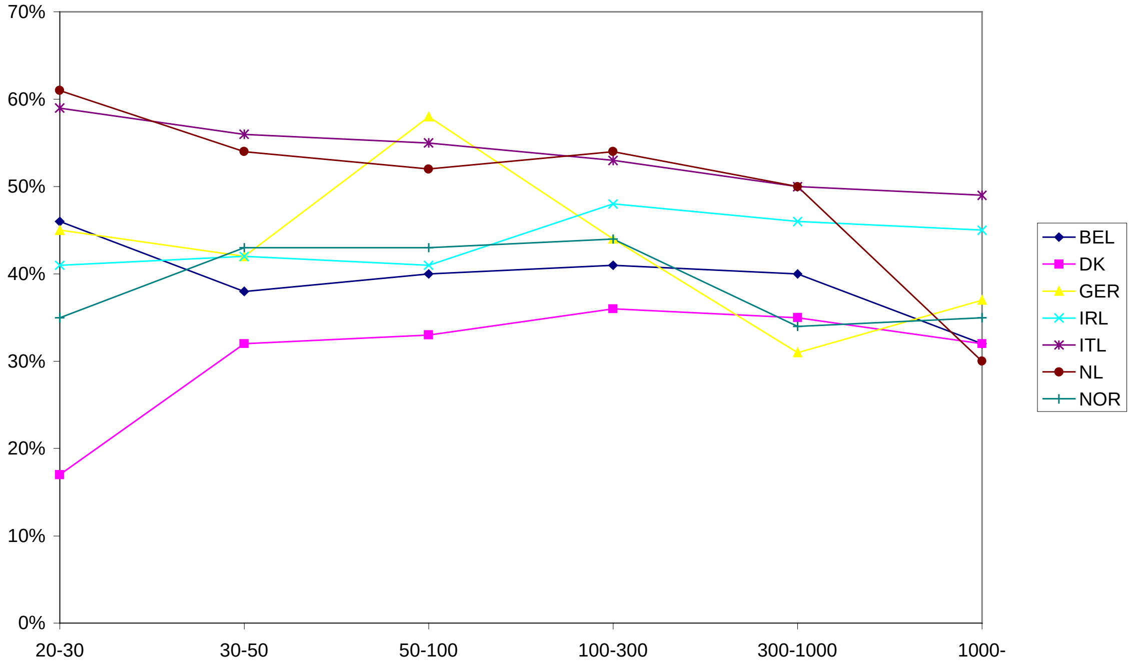


Figure 1.11 - Share of investment in innovation expenditures across firms size classes and countries (average values on 8729 innovating firms)



The distribution of the breakdown of innovation expenditure by industrial sector is reported in Figure 1.12. The data suggests that the distribution of innovation expenditure differs widely across industrial sectors.

Figure 1.12 - Break-down of innovation expenditures across industries

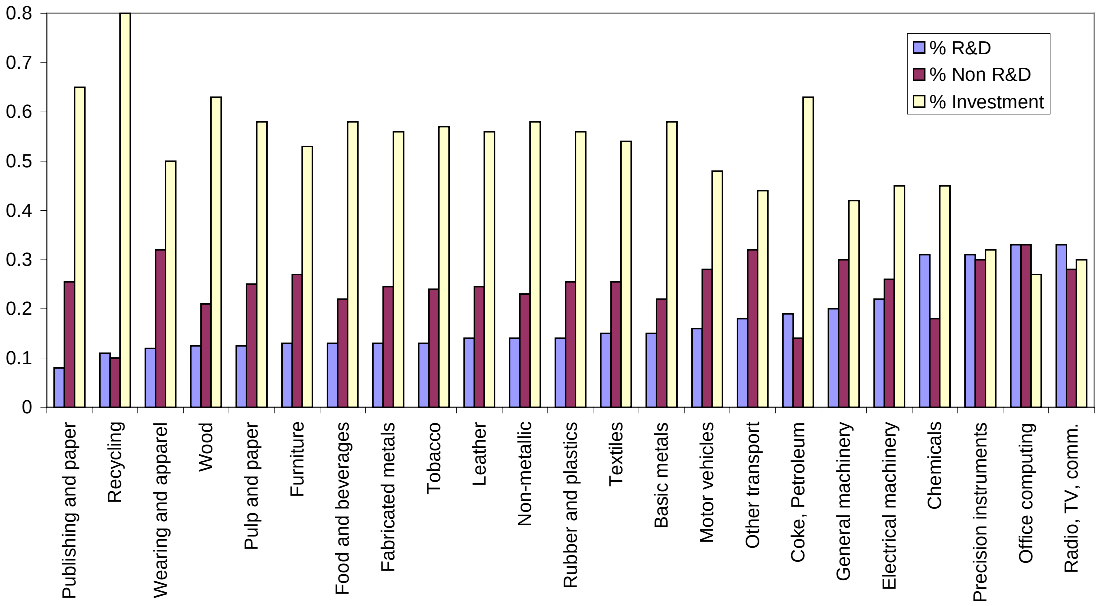


Figure 1.12 allows the identification of sectors traditionally defined as science-based in which the activities aimed at generating new technological knowledge play an

important role. Among the sectors in which firms allocate (on average) over 20% of total innovation expenditure to R&D, we find the following sectors: radio-TV and communications, office machinery and computers, precision instruments, chemicals, electrical machinery and general machinery. On the other hand, the acquisition of new machinery and plant is the main source of technology (above 50% of total innovation expenditures) for most traditional consumer good sectors, such as wearing and apparel, wood, furniture, leather, textiles and fabricated metal, along with 'process based industries' such as food, pulp and paper, recycling, and capital-intensive sectors such basic metals, motor vehicles, non metallic products, coke and petroleum, rubber and plastics.

The share of non-R&D innovation expenditures (including the acquisition of patents and licences, expenditures for production design activities, trial production and marketing) varies to a much lesser extent across industries, ranging between 25% and 30% of the total innovation expenditures. The exceptions are recycling, coke and petroleum and chemicals, which show much lower percentages. The data analysed in the Figure 1.12 will, in subsequent chapters, be complemented with inter-country comparisons of national sectoral profiles.

The picture provided by the previous Figures reaffirms the view that innovation does not only consist of R&D but it is the result of various technical and commercial activities. On the other hand, it should be underlined that the quantification of the expenditure is simply an indicator of the expenditure, and that these percentages do not necessarily reflect on a one-to-one basis the relative importance of the single activities within a integrated process. A case in point is marketing which weighs for only 2%; this does not mean that it has only a marginal importance; what we learn from the results is that, on the contrary, the knowledge of the market is part of the overall strategic innovation process even though its unit expenditure is low.

5. Innovation intensity

In this section an analysis is made of innovation intensities measured by the percentages of sales devoted to total innovation expenditure and R&D.

The relationship between innovation intensity and firm size has been dealt with over the last two decades by a vast amount of empirical literature. Two models of industrial and technological development have often been contrasted: on the one hand, the model based on large firms, characterised by radical innovations centred on R&D activities; on the other, the model of industrial organisation based on small firms, characterised by informal innovative activities but technologically 'creative' nonetheless (for an overview, cf. Cohen and Levin, 1989).

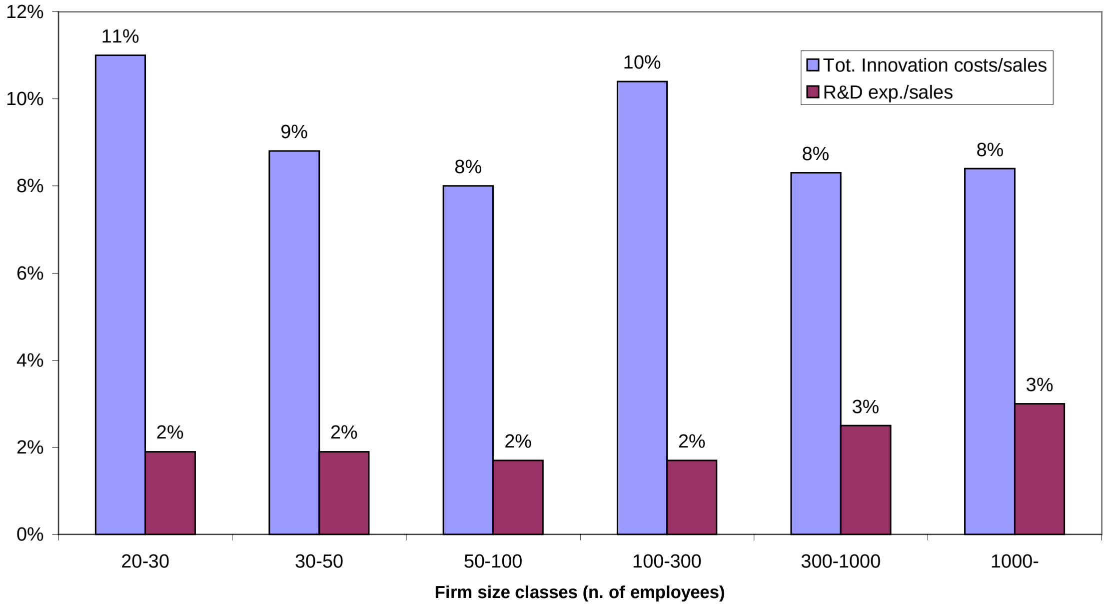
In empirical work, the analysis of the role that small and medium-sized firms play in technological change has been approached in two different ways by comparing the innovation intensity of large and small firms, considering either only firms which innovate, or both innovating and non-innovating firms. Cohen and Levin's overview (1989) stressed that most analyses had followed the first methodological approach and neglected non-innovative firms. The most distinctive feature of this literature is its inconclusiveness. First and foremost, most of the samples used in econometric studies are conspicuously non-random. Secondly, many early studies of firms confined their attention to the 500-1,000 largest firms in the manufacturing sector while, in general, firms which do not do any R&D were not included in samples.

The CIS Survey allows to analyse the relationship between innovation and firm size on the basis of both methodologies outlined above. Figure 1.13 and

Figure 1.14 show the average innovative intensities of different firm size classes taking into account two groups: firms which have introduced innovations over the period 1990-1992 (Figure 1.13), and firms which have returned the questionnaire, independently of whether they had introduced innovation or not innovation (

Figure 1.14). The indicators of the two Figures are the ratio between total innovation expenditure and sales, and R&D expenditure and sales.

Figure 1.13 - Innovative intensity across firms size classes (average values on 8729 innovating firms)



The data in Figure 1.13 show that there is no clear correlation between firm size and intensity of total innovation expenditure. In other words when firms introduce innovations, they invest amounts of money in the range of 8% to 10% of their sales independently of their size. Large firms (those with more than 300 employees), however, are more R&D intensive than the smaller ones. This result is consistent with other studies which, on the basis of much smaller samples have analysed the relationship between innovation and firm size (taking into account innovating firms without considering firms which do not introduce innovations) (Pavitt et al.,1987; Acs and Audretsch, 1990),

Figure 1.14 - Innovative intensity across firms size classes (average values - sample of both innovationg and non-innovating firms)

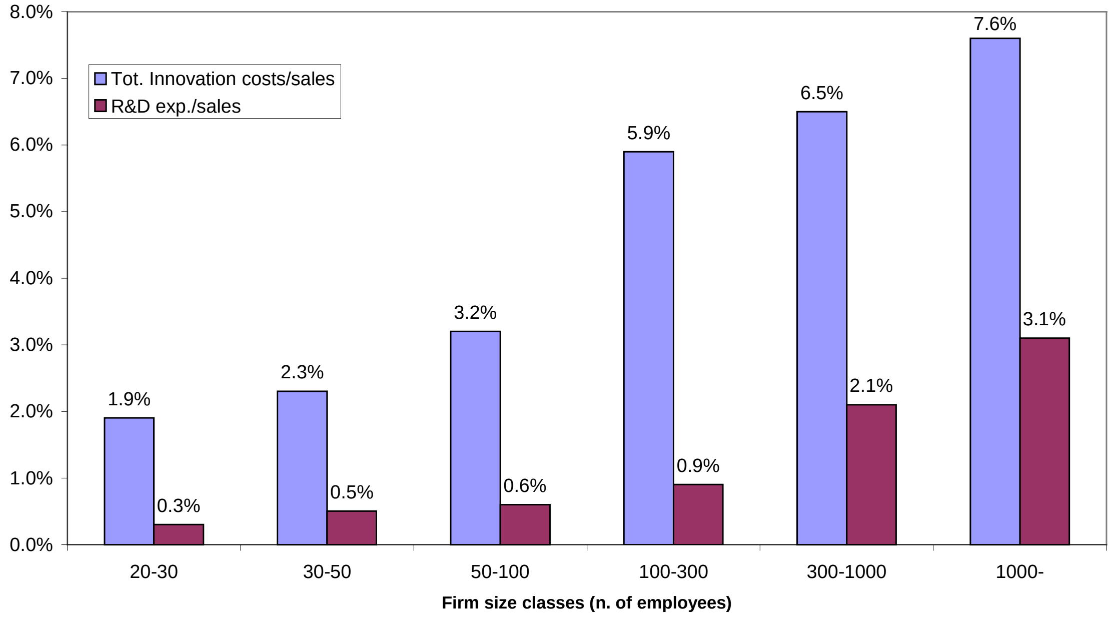


Figure 1.14 shows the average values of the percentage of total innovative expenditures and R&D expenditure on sales, computed on the basis of all responding firms. A positive relationship between innovation intensity (in a broad sense) and firm size emerges clearly. The average percentage of sales devoted to total innovation expenditure is 7.6% in the case of the firms with more then 1,000 employees while for firms with less then 30 employees it is only 1.9%. This difference has to do with the fact that, although small innovating firms are not less innovative than large firms, they are not representative of the overall population of small firms. According to

Figure 1.14, the percentage of small firms which are innovating is smaller than for large ones. Even greater differences in the innovative intensity between large and small firms can be found when the R&D intensity indicator is examined.

Figure 1.15 shows the average innovative intensity calculated on innovating firms alone broken down by industrial sector (the methodology is the same as Figure 1.13). Sectors are ranked according to their average innovation intensity. The industrial sectors in which firms devote to innovation activities shares of their sales above 10% include tobacco (19.3%), radio-TV and communication equipment (15.4%), precision instruments (12.8%), office computing (12.7%), publishing (11.5%). Tobacco surprisingly appears as the most innovative industry. The R&D intensity varies widely across sectors, confirming the variety and diversity in innovative inputs across industries.

Figure 1.15 - Innovative intensity across industries (average values on 8729 innovating firms)

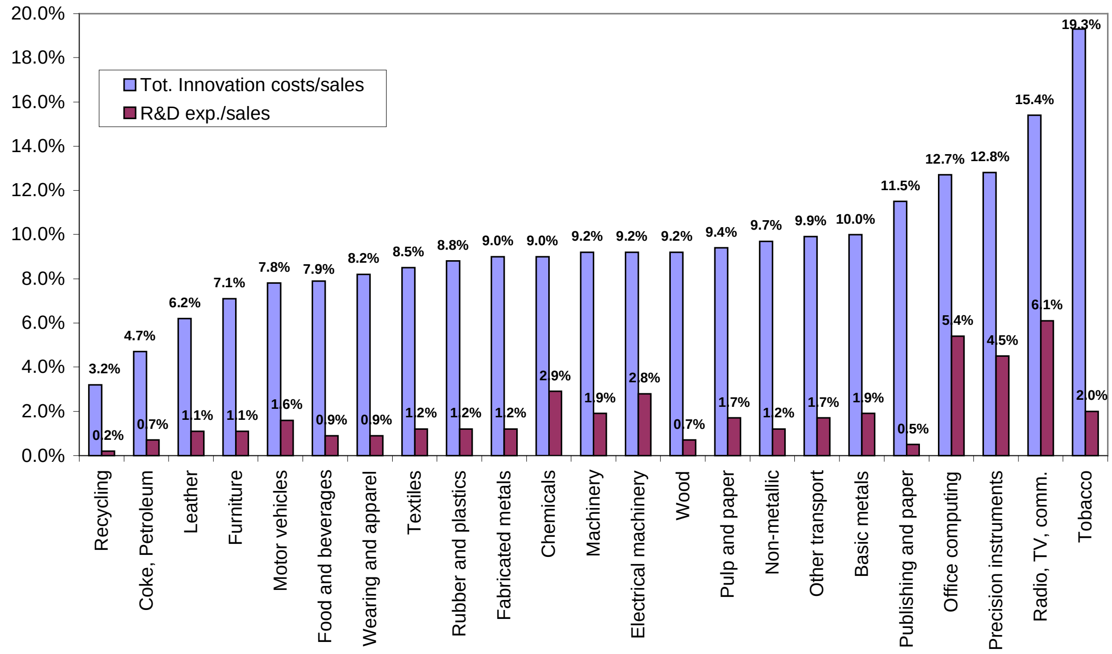


Figure 1.16 - Innovative intensity across industries (average values - sample of both innovationg and non-innovating firms)

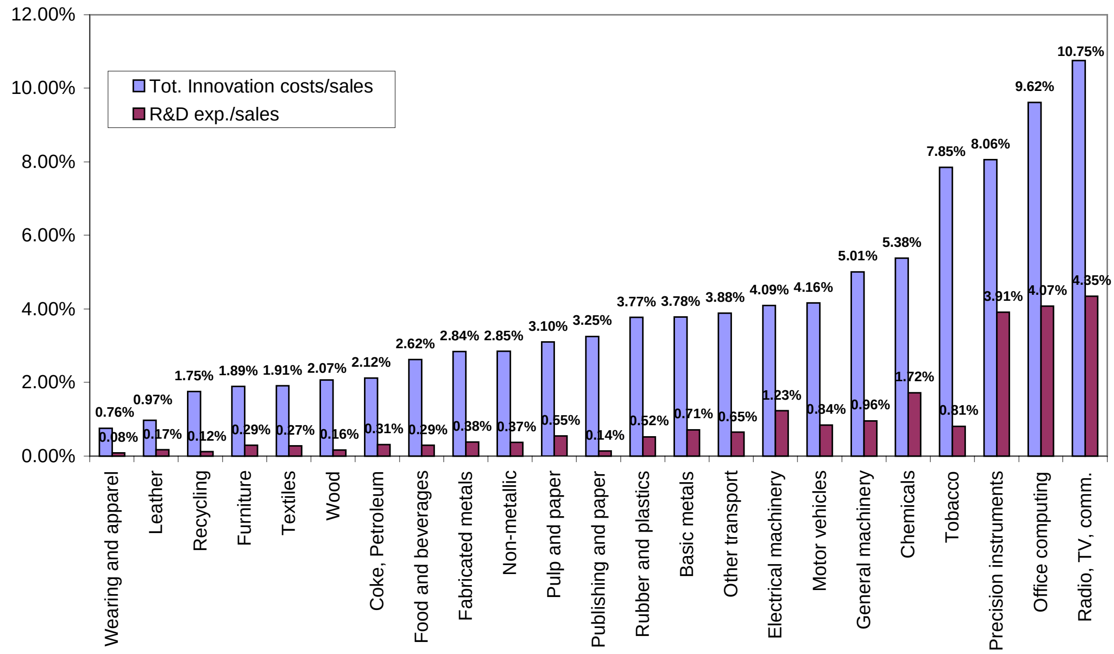


Figure 1.16 shows the same indicators of Figure 1.15 calculated for all firms covered by the survey (both innovating and non innovating). The ranking changes rather considerably for the industries which are shown in the right hand side of Figure 1.15

and Figure 1.16. Sectors such as tobacco, publishing and paper, basic metals, other transport appear to spend less on innovation, when non-innovative firms are taken into account along with the innovating ones. These are the sectors where the number of non innovating firms is relatively large. The traditional consumer good sectors remain in the left hand side of Figure 1.16 showing that their low innovative profile depends on the small percentage of innovating firms and on their small innovative efforts.

6. Main findings

The main findings of this chapter may be summarised as follows:

- Some 50% of European firms have introduced a product or process innovation during the period 1990-1992;

- The share of innovating firms varies between industrial sectors and firm size. The percentage of innovating firms is higher for large firms than in smaller ones in all countries. In high-tech sectors the share is two thirds and for traditional ones is one third;

- The largest part of firms' expenditure for innovation is linked to the adoption and diffusion of technologies through machinery and equipment, which absorbs 50% of firms' innovation expenditures;

- R&D activities are an important component of firms' technological activities which account, on average, for 20% of the total expenditure; other innovative activities, such as design and trial production, play an important role; expenditure-wise, the acquisition of 'disembodied' technology through patents and licences emerges as a secondary innovation component when compared to the other technological sources.

- The mix of innovation inputs, especially R&D and investment, is strongly correlated with firm size, while it displays little change across countries and great variation across industries.

- The ratio of innovation expenditure to total sales for innovative firms varies across industries, ranging from 7 to 8% for traditional sectors, to 12 to 15% for high-tech sectors;

- The innovation intensity of innovating firms does not change across firms size: the innovation investment varies between 8% to 10% of sales.

CHAPTER TWO: Understanding *innovation intensity*: levels of innovation expenditure

This chapter explores inter-industry and inter-country patterns of *innovation expenditure intensity*, meaning total innovation expenditures as a proportion of sales, measured in per cent. This indicator is thus closely similar to the familiar indicator for R&D intensity. The aim is firstly to analyse whether industries have similar levels of innovation expenditures intensity across Europe, and whether cross-industry structures of innovation expenditures are similar, then to analyse the effect of firm size on such expenditures. Behind this analysis is the more general question of whether particular European industries are similar with respect to such indicators, or whether there is substantial inter-country variation (perhaps because of the effects of different national innovation systems) within industries.

This chapter is based on a smaller sub-set of the CIS database than the previous chapter; the analysis focuses on those countries which asked exactly similar questions on innovation expenditures within the CIS survey, and those countries which received relatively good response rates. This leaves us with data from seven countries: Belgium, Denmark, Germany, Ireland, Italy, the Netherlands and Norway. This data covers both innovating and non-innovating firms (i.e those who report no innovation expenditures at all); it was collected for the year 1992.

Including firms which report no innovation activity, we have 30,142 firms. The distribution of these firms across the seven countries are shown in the table below

Table 2.1: CIS: Countries with usable innovation expenditures data

	N	per cent
Belgium	737	2.4
Denmark	664	2.2
Germany	2380	7.9
Ireland	999	3.3
Italy	22445	74.5
Netherlands	2009	6.7
Norway	908	3.0
Total	30142	100

As we see, the total sample is very much dominated by the Italian sample. We will have to take this into account in statistical analyses; methods for this will be discussed below.

How does the sample break up by industry and size class? We have divided the manufacturing sector into 12 industries (NACE 2-digit level). In the table below these industries are listed, and the distribution of the 30,142 firms across the seven countries and 12 industries is shown:

Table 2.2: CIS – innovation expenditures sample by industry

Industry	Bel	Den	Ger	Irl	Ita	NL	Nor	Total
Food, beverages, etc.	98	90	118	150	1500	228	173	2357
Textiles, clothing	109	30	124	90	5485	134	47	6019
Wood products	16	14	28	27	622	68	66	841
Pulp and paper	23	27	57	29	496	78	22	732
Chemicals	104	80	360	176	1746	237	40	2743
Mineral products	48	36	107	50	1486	101	40	1868
Basic metals	20	18	87	16	643	41	23	848
Metal products	78	66	252	96	2874	296	99	3761
Machinery	59	110	537	79	2713	273	78	3849
Transport equipment	32	31	157	23	748	110	89	1190
Electrical, electronic etc	58	81	395	155	1721	157	54	2621
Other	92	81	158	108	2411	286	177	3313
Total	737	664	2380	999	22445	2009	908	30142

It can be seen that most of the cells have reasonably large numbers of firms; the cell with fewest observations contains 14 firms. This is *wood products* in Denmark. In general, however, we have enough data for statistical work.

Likewise, we have classified the firms in six size classes, based on number of employees at the end of 1992. The table below shows how the size classes are defined as well as the distribution of the 30,142 firms across the seven countries and six size classes.

Table 2.3: CIS – innovation expenditures sample by firm-size class

Size class: number of employees	Bel	Den	Ger	Irl	Ita	NL	Nor	Total
30 or less	220	73	614	435	9084	408	490	11324
30-50	102	102	219	159	5985	282	82	6931
50-100	70	152	319	174	3952	569	124	5360
100-300	140	213	504	162	2534	513	146	4212
300-1000	139	101	443	60	707	198	52	1700
more than 1000	66	23	281	9	183	39	14	615
Total	737	664	2380	999	22445	2009	908	30142

Once again there are a resonable number of observations across the cells; here the cell with fewest observations contain only 9 firms, for firms with more than 1000 employees in Ireland. In Norway there are only 14 observations in this size class.

THE UNEVEN DISTRIBUTION OF INNOVATION EXPENDITURES

Before turning to the analysis itself it is important to emphasize a particular characteristic of this data, which is significant in itself, but which also has important implications for statistical analysis. This is that activity is very unevenly distributed among the firms within the sample. In this respect the innovation expenditures data is very similar to other data within the CIS survey; innovation outputs are also very asymmetrically distributed among firms, for example. The substantive point here, which probably has important policy implications, is that there is a very great deal of variety and heterogeneity among firms.

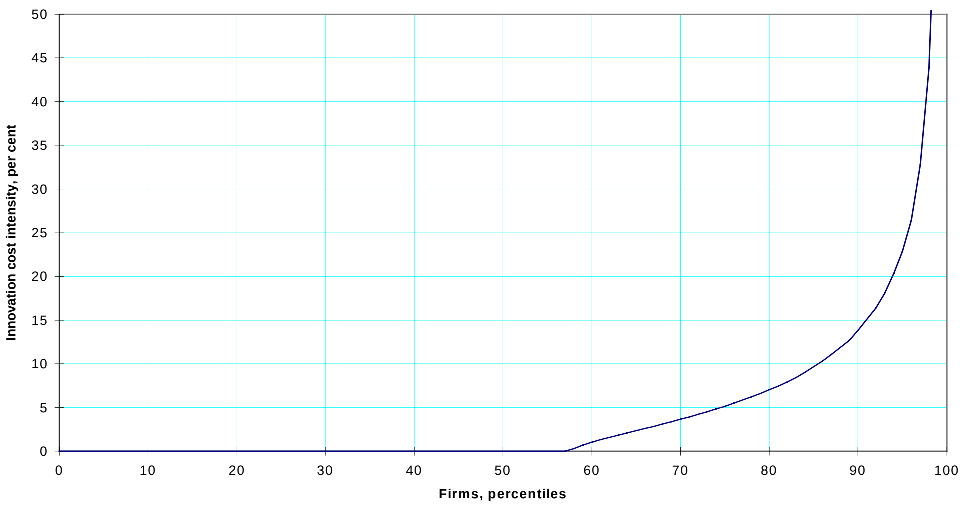
Either because of data error, or because some firms in an establishment phase have innovation-related expenditures far in excess of turnover, this indicator gives a very few observations at the very top of the distribution which have values that are extreme relative to the bulk of the firms in the sample. These extreme values at the top represent a serious problem for the study, because they will make nonsense of any statistical analysis based on means and variances. Besides, they are in general either not credible or not relevant to the study. For these reasons, we will not allow the most extreme values. More specifically, we have chosen not to accept intensity values of more than 200 per cent; an intensity value of more than 200 per cent is simply set to 200 per cent.

Even this, however, leaves us with a very uneven distribution, as the figure below indicates. Here we see that almost 60 per cent of the firms (57.6 per cent, to be precise) have no innovation expenditures at all, the 6th decile has about 1 per cent intensity, the 7th about 3.7 per cent, the 8th 7 per cent and the 9th 13.8 per cent. This can be compared to the 71.5 per cent of the 99th percentile.Thus, the variation in innovation expenditures among firms is quite very substantial, even when we take account of their variation in size (which we do by relating these expenditures to the total production of the firms, as measured by the sales figures). This is a basic fact about innovation expenditures.

However, an equally basic fact about innovation expenditures is that this variation is very greate *also inside among firms in the same industry and of the same size*. Let us briefly illustrate this by means of regression analysis and ANOVA (analysis of variance).

As will be explained below, when analysing differences across industries and size clases in innovation expenditure intensity, we will use the *log* of the intensity values. However, since we want to include the firms with no innovation expenditures in the analysis, and since the log of 0 is not defined, we will use the log of the intensity values, expressed in per cent, + 1. In this way the log value of zero innovation expenditure intensity also becomes zero.

Figure 2.1 - Innovation expenditure intensity (y-axis) and firms ranked by innovation expenditure intensity, percentiles



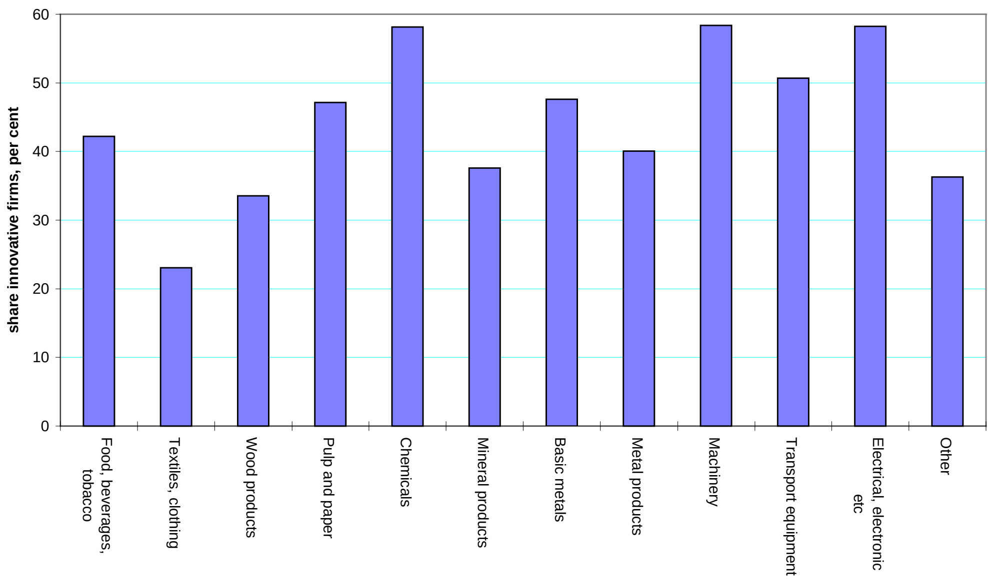
We may thus try to explain the variance in innovation expenditures intensities (in their log version) among all the 30,142 firms by means of three independent variables. If we use a regression analysis with six dummy variables for the seven countries, 11 dummy variables for the 12 industries and five dummy variables for the six size classes, we have a model which uses 22 degrees of freedom (6 + 11 + 5). This model gives an R^2 of only 0.14.

If instead we use a three-way ANOVA, we ideally get a model which uses 503 degrees of freedom (7 x 12 x 6 - 1). However, because some of the cells turn out to be empty, the degrees of freedom actually used are 473. Compared to the former model, this model also includes all the interaction terms. Nevertheless, the R^2 only increases to 0.17. This means that 83 per cent of the variance in the data is found *inside* the groups defined by belonging to both the same country *and* the same industry *and* the same size class simultaneously. The general point here is that firms differ strongly with respect to one another when it comes to innovation expenditures (and, as noted above, all other innovation indicators including innovation outputs and R&D).

Are there variations across industries and size classes?

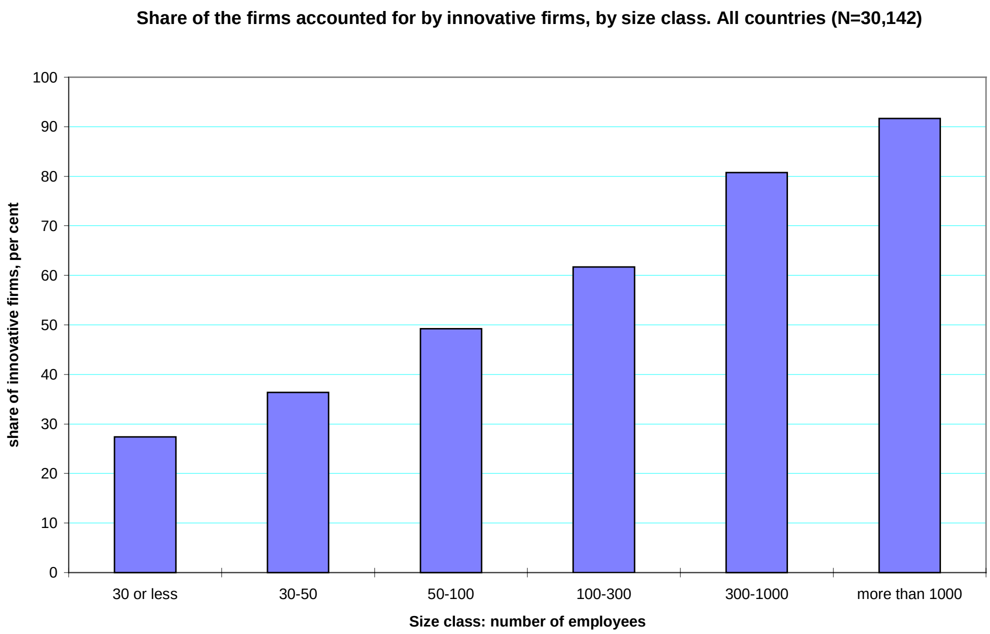
What proportion of the sample is made up of innovating firms, meaning firms that either introcue new products within the survey period, or commit resources to innovation. Our overall sample of 30142 firms contains 12795 (or 42.4%) which are innovative according to this definition. Figure X shows how this breaks down across industries.

Figure 2.2 - Share of the firms accounted for by innovative firms, by industry. All countries (N=30,142)



Across size classes there is a clear tendency (as emphasized in the previous chapter) for the proportion of innovating firms to rise with size. Since this tendency is so marked, it has an important implication for the analysis which follows. This is that the results for any industry and country will be affected by the size distribution of firms with the industry/country. This means that it will be important to control for size classes in the analysis.

Figure 2.3 - Share of the firms accounted for by innovative firms, by size class. All countries (N=30,142)

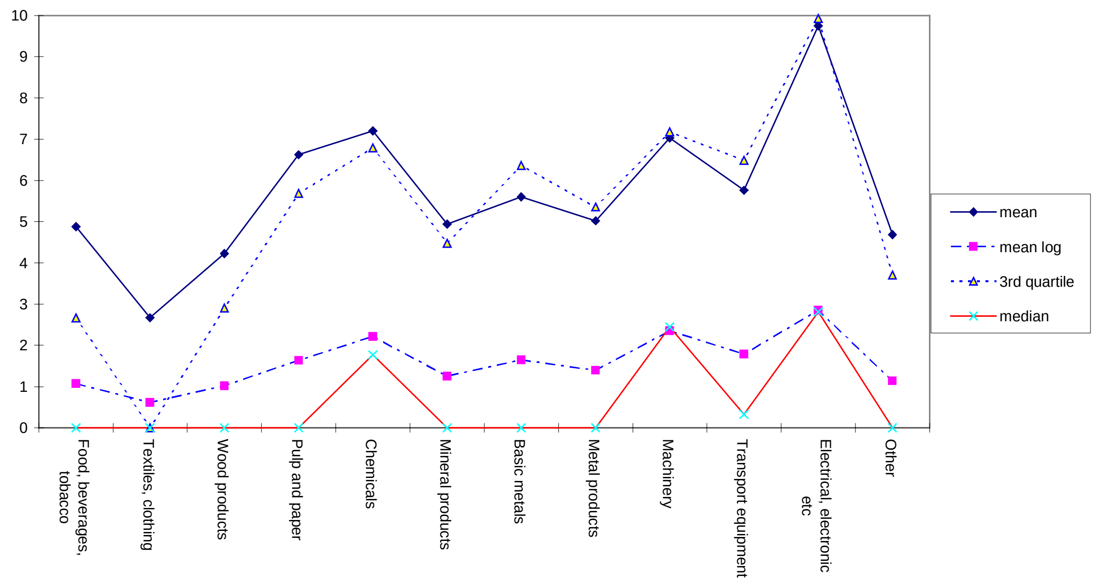


MEASURING THE TYPICAL INNOVATION EXPENDITURE INTENSITY OF INDUSTRIES AND SIZE CLASSES

We turn now to an examination of innovation expenditure intensities across Europe. Since the distributions are far from normal, however, there is a special problem of how to express the typical innovation expenditure intensity of each industry and size class. It is not at all clear that the mean or average is the most adequate measure here. Instead, they are highly skewed and unequal, with a large proportion of firms having zero expenditures and many others having quite small values, while a small proportion at the top have very high values and some have quite extreme values.

In the figure below we have shown the typical innovation expenditure intensity in each of the 12 industries for all the firms in the seven countries together. We have simply put the 30,142 firms together and only classified them according to industry, not taking the country variable into account.

Figure 2.4 - Total innovation expenditure intensity by industry, including firms with zero expenditures, all seven countries



The figure shows four different measures of the typical innovation expenditure intensity in each industry: the mean, the third quartile, the median and the intensity corresponding to the mean of the log to the innovation expenditure intensity values.

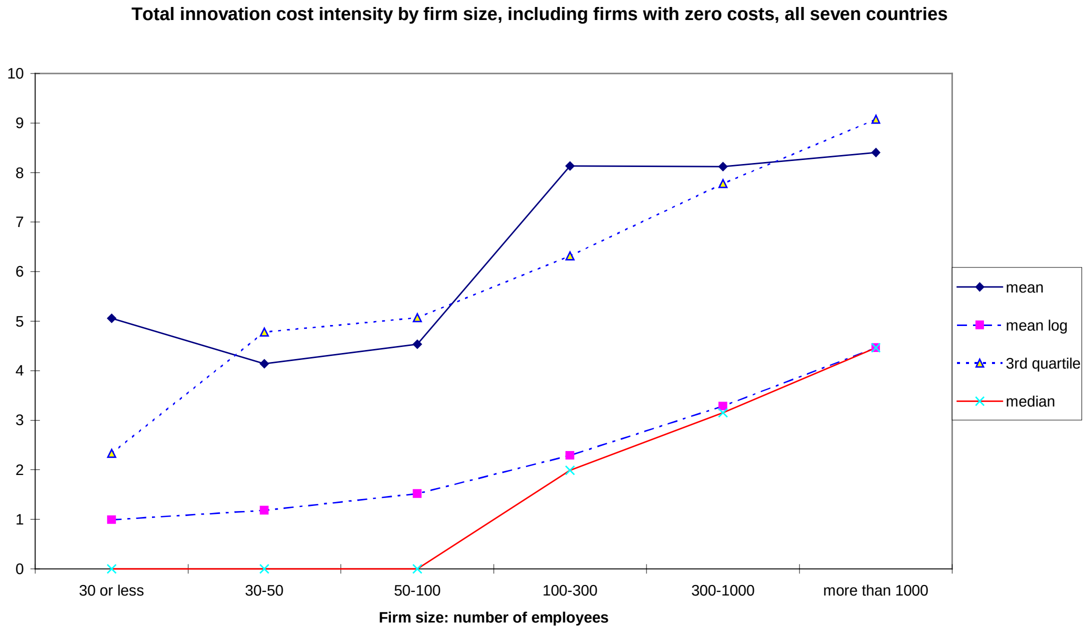
In a normal distribution the mean equals the median. One indicator of the skewness and inequality of the distributions we are dealing with here is that the mean is invariably much higher than the median. In fact, only four of the 12 industries have a median which is above zero, which means that in eight of the 12 industries more than half of the firms have no innovation expenditures. Furthermore, in more than half of the industries the mean is also higher than the *third quartile* and, remember, this is even after we have removed the most extreme values by setting innovation expenditure intensities higher than 200 per cent to 200 per cent. In one industry, Textiles and Clothing, even the third quartile is zero.

We should explain the fourth measure used in the figure, the mean of the log of the intensity values. The values in the figure are calculated in the following way. First we have the intensity values, where unity is one per cent. Since there are very many zero values and the log is not defined for zero, we have first to each intensity value added 1. Then we have taken the log of the intensity value + 1. Of these log values we have then calculated the mean for each industry. Then these mean log values are transformed back to intensity values again. It is the latter values which are shown in the figure. When highly skewed distributions are transformed to log values they will often approach normal distributions. This, of course, does not happen in the present case, given the very high share of zero values. However, we note that for two of the industries the mean of the log values is approximately equal to the median.

In general, the four different measures seem to give roughly the same picture of the differences across industries in innovation expenditure intensities. However, the median only distinguishes among the four most innovation expenditure intensive industries, since in the eight other industries more than half the firms have no innovation expenditures (the median is thus zero)

In the next figure we have used the same four measures to characterize the typical innovation expenditure intensity of each of the six size classes.

Figure 2.5 - Total innovation expenditure intensity by firm size, including firms with zero expenditures, all seven countries



The general picture which emerges here is that of an increasing innovation expenditure intensity with firm size. However, this is not so clear when measured by the mean of each distribution. This is probably due to the fact that the mean is much more sensitive to atypical extreme values than the other measures, which are more stable in relation to extreme values. We also see that the median is zero for the three size classes up to 100 employees and then increases consistently with increasing firm size; the meaning of this is simply that within these size-classes a majority of the firms are not innovating at any particular time according to the indicator used here. The mean of the log seems to be the measure which is the most stable of the four, increasing more smoothly with firm size than the others. Notice also that as firm size increases, the median approaches the mean of the log values (transformed back to intensities).

In the following we choose to use the mean of the log values, transformed back to intensities, as our measure of the typical innovation expenditure intensity in each industry and size class. This is because it is more stable in relation to extreme values than the mean of the raw intensities. As we have noted, the *median* will often not distinguish between groups because of the large share of zero values. When we use the mean of the log values, we see that we get an expression which reflects more what happens towards the middle of the distributions than when we use the third quartile or the ordinary mean, which reflect more what happens towards the high intensity end of the distributions.

We will now look closer at the differences in innovation expenditure intensities across industries and across size classes, taking the country dimension into account.

ANALYSIS: DIFFERENCES IN INNOVATION EXPENDITURE INTENSITY ACROSS INDUSTRIES

We will now look at the typical innovation expenditure intensity in each industry in each of the seven countries. Our measure is still the mean of the log of the intensity values (+ 1), transformed back again to intensity values. These typical values by industry and country are shown in the table below.

Table 2.4 - Innovation expenditure intensities by industry and country

	Bel	Den	Ger	Irl	Ita	NL	Nor
Food, beverages, etc.	2.9	0.9	3.8	1.8	0.8	2.1	0.6
Textiles, clothing	2.0	0.9	3.3	3.4	0.5	1.2	0.6
Wood products	0.7	1.6	3.3	3.0	0.9	1.4	0.7
Pulp and paper	2.5	0.8	3.7	3.7	1.3	2.6	1.8
Chemicals	4.3	3.0	6.5	3.2	1.4	3.5	2.0
Mineral products	2.5	2.3	6.2	3.2	0.9	2.4	0.7
Basic metals	4.2	1.9	5.9	6.9	1.2	1.8	1.2
Metal products	3.2	1.7	5.0	3.0	1.1	1.6	0.6
Machinery	2.7	2.6	7.2	3.8	1.7	3.5	1.7
Transport equipment	2.5	1.2	4.9	5.0	1.5	2.0	0.6
Electrical, electronic etc	5.9	5.3	9.8	6.1	1.7	4.7	3.5
Other	1.8	0.9	4.9	2.4	1.0	1.3	0.8

Our interest here is to examine the differences across industries, to see if a consistent pattern across industries emerges when we look at the differences across industries in all the seven countries. First, however, what clearly emerges in the table above is a general difference in the level of innovation expenditure intensities across countries. To be better able to compare industries, we should control for these differences across countries in the general level of innovation expenditure intensities.This is all the more pertinent because we have reason to believe that these general differences across countries in large part are due to differences in the implementation of the survey, to differences in bias, across countries. Trying to control for country is thus in this case in large part an attempt to control for distortions in the instrument of measurement.

Controlling for country effects: a non-technical explanation
When we explore differences in innovation expenditure intensities across firms in Europe, we have to take into account the fact that this intensity varies not just between firms, but also that the same industry may have a different average R&D intensity across countries. So two firms in different countries may differ not just because of differences in commitment to R&D, but because of industry differences between the countries. The statistical technique described below seeks to compensate for these country differences by constructing a ’base-line’ European average for each industry, against which firms can be compared irrespective of country.

Controlling for country effects: Statistical techniques
The way we have controlled for the country variable is the following. The analysis is performed on the log of the intensity values (+1). We have made a regression analysis with dummy variables for the countries. Then, for each observation in the data set, we have found the estimated value on the basis of the values of the country variables. Then we have found the residual between the observed value and the estimated value. To this residual we have added the overall mean, i.e. the mean of all the observations irrespective of values on any variable. Then we have taken the mean of the resulting values for each industry in each country. Lastly, these means are transformed back from log values to intensity values.

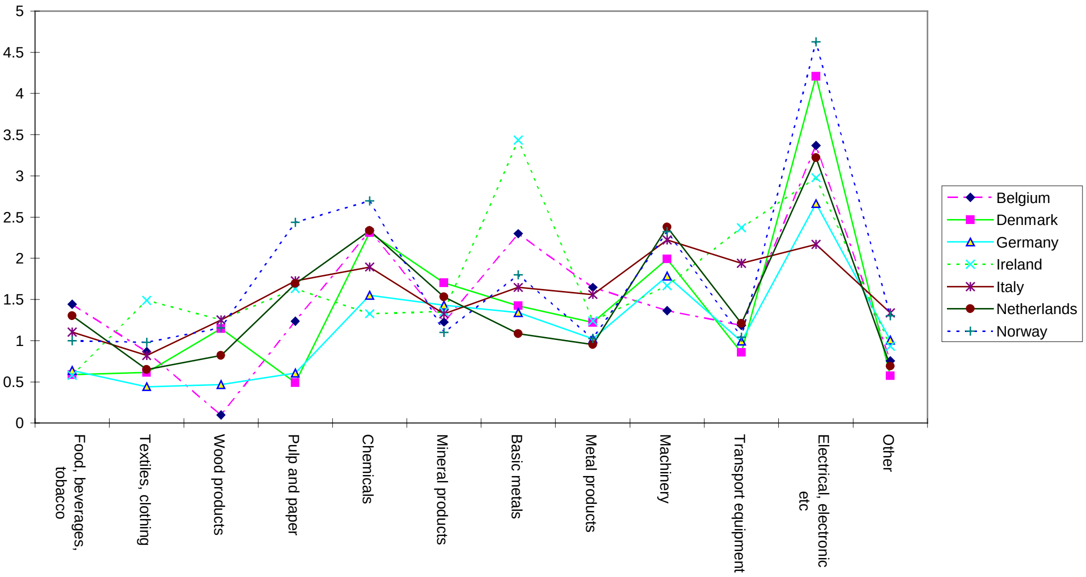
These innovation expenditure intensities by country and industry when country has been controlled for are shown in the table below.

Table 2.5 - Innovation expenditure intensities, controlling for country variation

	Bel	Den	Ger	Irl	Ita	NL	Nor
Food, beverages, etc.	1.4	0.6	0.6	0.6	1.1	1.3	1.0
Textiles, clothing	0.9	0.6	0.4	1.5	0.8	0.6	1.0
Wood products	0.1	1.1	0.5	1.3	1.3	0.8	1.2
Pulp and paper	1.2	0.5	0.6	1.6	1.7	1.7	2.4
Chemicals	2.3	2.3	1.6	1.3	1.9	2.3	2.7
Mineral products	1.2	1.7	1.4	1.4	1.3	1.5	1.1
Basic metals	2.3	1.4	1.3	3.4	1.6	1.1	1.8
Metal products	1.6	1.2	1.0	1.2	1.6	1.0	1.0
Machinery	1.4	2.0	1.8	1.7	2.2	2.4	2.3
Transport equipment	1.2	0.9	1.0	2.4	1.9	1.2	1.0
Electrical, electronic etc	3.4	4.2	2.7	3.0	2.2	3.2	4.6
Other	0.8	0.6	1.0	0.9	1.3	0.7	1.3

The same intensities by country and industry, controlling for country, are also shown graphically in the figure below. We see that there still are differences across countries, but there is no longer a difference in the general level of innovation expenditure intensity across countries. Rather, the differences across countries which emerge here are differences in the *profiles* of innovation expenditure intensities across industries.

Figure 2.6 - Total innovation expenditure intensity by industry and country, adjusting for country: mean log



A comment on this way of controlling for country should be made. Notice that the variation in intensity across industries is much less in Italy than in the other countries. This reflects that Italy has a much lower level than many of the other countries, and this in turn in large part reflects that Italy has a much higher share of firms without innovation expenditures than many of the other countries. This probably reflects the fact that the Italian sample is much more representative than most of the other countries.

Given that the level in Italy is lower, the differences across industries become smaller in Italy, even when the differences in *relative intensity* across industries should be of the same magnitude as in the other countries. However, controlling for country by means of the *residuals* which we have done only controls for the general level, not the differences in inter industry variation.

From the profiles of the differences in innovation expenditure intensity across industries in each of the seven countries we can try to define an overall profile of differences across industries, and see if this profile is one which emerges with consistency from the seven country profiles in spite of the differences across countries that may exist in the profiles.

We propose one main definition of the profile of innovation expenditure intensities across industries when we take the profiles of all the seven countries into account.

This profile is defined by giving each of the 12 industries an innovation expenditure intensity equal to the mean of the seven country values for the industry.

To check whether the profile which emerges by this definition is unduly influenced by extreme values for some of the countries we propose two additional definitions of the overall profile which the profile emerging from the main definition can be compared against. The first of these additional definitions give the profile which emerges when we give each of the 12 industries an innovation expenditure intensity equal to the *median* of the seven country values for the industry. The second is simply the profile across industries which emerges when all firms in all countries are pooled. In all these cases the intensities are controlled for country as explained above.

The overall profiles of innovation expenditure intensities across industries which emerge from these three definitions are shown in the table below.

Table 2.6 - Industry innovation expenditure intensities

	Mean	Median	Total
Food, beverages, etc.	1.0	1.0	1.0
Textiles, clothing	0.8	0.8	0.8
Wood products	0.9	1.1	1.1
Pulp and paper	1.4	1.6	1.6
Chemicals	2.1	2.3	1.9
Mineral products	1.4	1.4	1.3
Basic metals	1.9	1.6	1.6
Metal products	1.2	1.2	1.4
Machinery	2.0	2.0	2.1
Transport equipment	1.4	1.2	1.6
Electrical, electronic etc	3.3	3.2	2.5
Other	0.9	0.9	1.2

Across all of the European countries analysed here, these three measures appear to be closely related. This is best seen graphically as in the figure below.

We see that the profiles emerging from these three definitions look roughly similar. Note that the variation across industries emerging from the all firms pooled definition is less than for the other definitions. This is to be expected, as the Italian sample will weigh very much according to this definition and the variation across industries in the Italian sample is smaller than for the other countries, for reasons explained above.

Figure 2.7 - Three definitions of overall industry intensity profile: mean and median of countries and all firms

Let us try to test the consistency of the profiles which emerge from these three definitions by means of the correlations between them. We proceed in the following way. Each industry now has three different values, the value resulting from the mean of the countries, the value resulting from the median of the countries, and the value resulting from all firms in all countries pooled. This gives 12 observations and three variables. The correlation matrix for these three variables is shown in the table below.

Table 2.7 - Industry expenditure profiles: correlation among indicators

	Mean	Median	All firms
Mean	1	0.98	0.93
Median	0.98	1	0.92
All firms	0.93	0.92	1

These correlations seem reasonably high, meaning that the overall profile does not seem to be too dependent upon the particular definition which happens to be chosen.

Let us now see how the profile of each country correlates with the overall profile. Again each of the industries becomes an observation, and we now get seven country variables in addition to the three variables from above. The correlations are shown in the table below. We show the correlation of each country profile with all three definitions of the overall profile, but focus our main attention on the main definition of the overall profile (the mean of the countries).

Table 2.8 - Country innovation expenditure profiles – correlation with 'European' profile

	Mean	Median	All firms
Belgium	0.89	0.83	0.75
Denmark	0.93	0.92	0.83
Germany	0.93	0.88	0.89
Ireland	0.66	0.54	0.58
Italy	0.79	0.78	0.95
Netherlands	0.90	0.94	0.89
Norway	0.93	0.96	0.85

We see that most of the country profiles correlate quite strongly with the overall profile as defined by the mean of the countries, our main definition. Ireland is an exception, with a correlation coefficient (*r*) of only 0.66. Also Italy has a lower correlation coefficient than the other countries, 0.79. The other countries have correlation coefficients from 0.89 to 0.93. Not surprisingly, Italy has a very high correlation with the all firms pooled definition of the overall profile (0.95).

Let us now test the consistency of the overall profile of innovation expenditure intensities across industries by means of Analysis of Variance (ANOVA). We use the innovation expenditure intensities by industry from the table above. This gives seven observations for each industry, one for each country. We use industry as the independent (class) variable, which has 12 categories, with seven observations in each. The definition of the overall profile here automatically becomes our main definition, the mean of the seven values for each industry. The ANOVA tests whether these mean values are significantly different from each other. The results areas follows:

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	38.55	11	3.5045	13.27	0.0001
Within	19.0104	72	0.2640		
Total	57.5605	83			
R2	0.67				

As we see, the probability that the differences of the mean industry values which we observe should be drawn from a population with no differences between the mean industry values is less than 0.0001, which means that industry has an effect which is significant at the 5 per cent significance level by a very wide margin. The R^2 is 0.67, which we regard as high.

The overall industry means, of the mean of the log of the intensity values when country has been controlled for, transformed back to intensity values, are shown in the following table, with industries ranked according to innovation expenditure intensity. The table also shows which industry values are significantly different from each other at the 5 per cent level, given the overall significance of industry differences.

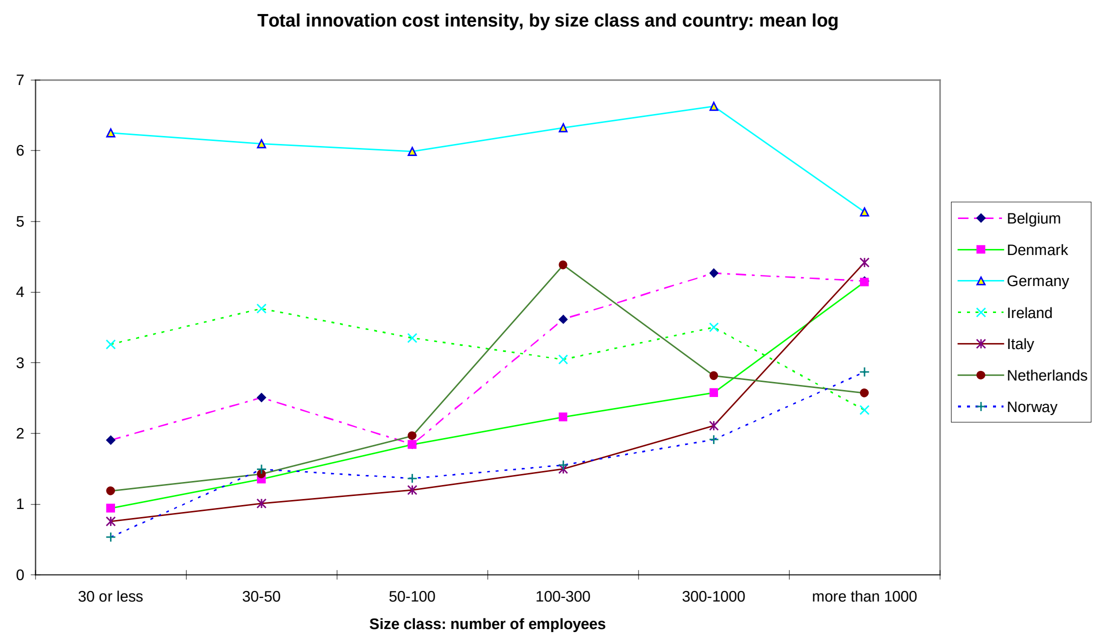
Table 2.9 - Industry means – innovation expenditure intensity

Electrical, electronic etc	3.3	a	
Chemicals	2.1	b	
Machinery	2.0	b	c
Basic metals	1.9	b	c
Pulp and paper	1.4	d	c
Mineral products	1.4	d	c
Transport equipment	1.4	d	c
Metal products	1.2	d	
Food, beverages, tobacco	1.0	d	
Other	0.9	d	
Wood products	0.9	d	
Textiles, clothing	0.8	d	

ANALYSIS: DIFFERENCES IN INNOVATION EXPENDITURE INTENSITY ACROSS SIZE CLASSES

We now turn to the differences in innovation expenditure intensities across size classes, taking the differences across countries into account. We still use the mean of the log of the intensity values (+1), transformed back to intensity values. The figure below shows these intensities by country and size class.

Figure 2.8 - Total innovation expenditure intensity, by size class and country: mean log



Again, the general differences in the level of intensities across countries are evident. As we argued above, it is probable that these differences across countries are due to a large extent to differences in the implementation of the survey across countries, to the varying degrees of bias in the samples across countries. To be better able to compare size classes, we should control for these general differences across the countries.

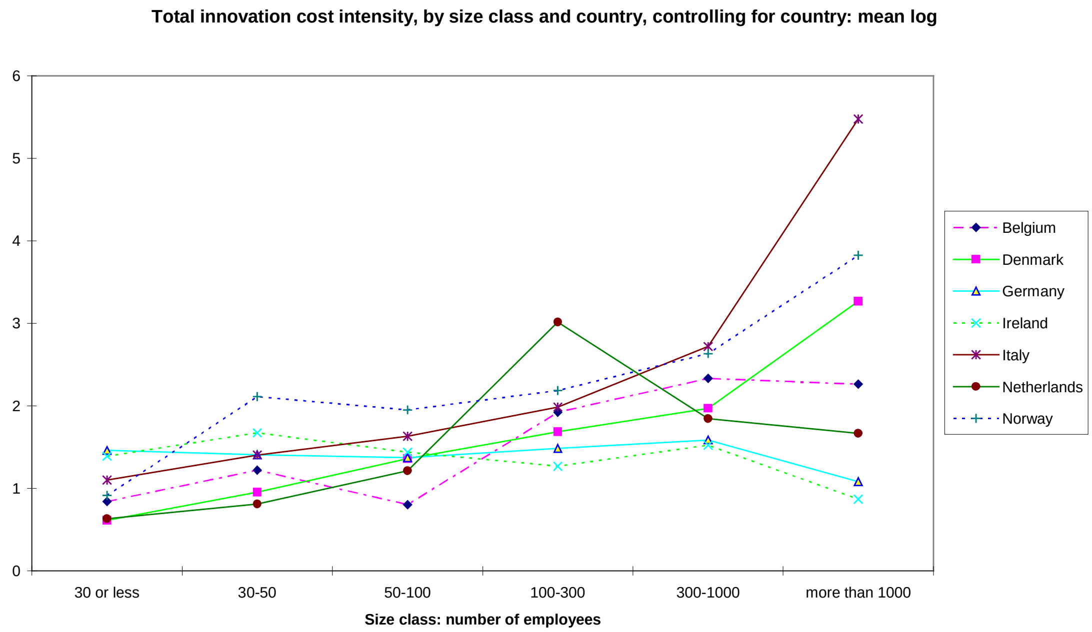
However, the figure also suggests that the differences in the degree of bias of the samples across countries are not independent of size class, and that we have a more complex pattern. It would seem that the differences in bias are especially serious among the small firms and much less serious among the largest firms. Taking this into account, however, is probably impossible here; it would involve introducing too many assumptions into the analysis. We therefore control for country in the same way as we did when we analysed differences across industries above. The innovation expenditure intensities by country and size class, controlling for country differences, are shown in the table below.

Table 2.10 - Innovation expenditure intensities by country and size class

Size class: number of employees	Bel	Den	Ger	Irl	Ita	NL	Nor
30 or less	0.8	0.6	1.5	1.4	1.1	0.6	0.9
30-50	1.2	1.0	1.4	1.7	1.4	0.8	2.1
50-100	0.8	1.4	1.4	1.4	1.6	1.2	1.9
100-300	1.9	1.7	1.5	1.3	2.0	3.0	2.2
300-1000	2.3	2.0	1.6	1.5	2.7	1.8	2.6
more than 1000	2.3	3.3	1.1	0.9	5.5	1.7	3.8

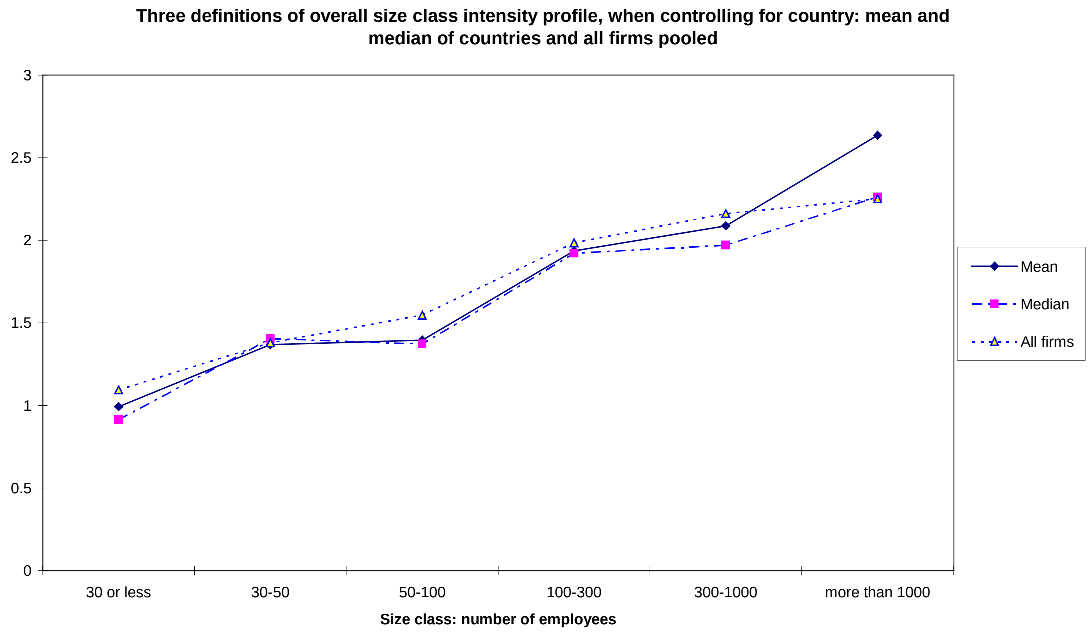
The same innovation expenditure intensities by country and size class, controlling for country, are also shown graphically in the figure below.

Figure 2.9 - Total innovation expenditure intensity, by size class and country, controlling for country: mean log



Again we ask whether these profiles accord with an all-Europe measure; are the profiles similar across countries? Again, we use three definitions of the overall profile of intensities across size classes. The mean of the country values is our main definition, but we also compute the median of the country values and the size class values for the firms of all countries pooled. The three versions of the overall profile of innovation expenditures by size class as they emerge from these three definitions are shown in the figure below.

Figure 2.10 - Three definitions of overall size class intensity profile, when controlling for country: mean and median of countries and all firms pooled



Again, the three definitions seem to give very similar profiles, which means that the overall profile which emerges does not seem to be too dependent on the particular definition chosen. The measure move closely together: the correlation coefficients are very high (ranging from .96 to .98) confirming the impression we get from inspection of the graph.

Let us now look at the correlation of each country profile with the overall profile. The table below shows the correlation coefficients for all three definitions of the overall profile.

Table 2.11 - Correlation of country profiles with overall profile

	Mean	Median	All firms
Belgium	0.91	0.93	0.93
Denmark	0.97	0.91	0.90
Germany	-0.47	-0.35	-0.25
Ireland	-0.69	-0.57	-0.55
Italy	0.91	0.82	0.79
Netherlands	0.61	0.70	0.73
Norway	0.95	0.92	0.87

Concentrating on our main definition, the mean of the country values, four of the country profiles correlate very strongly with the overall profile. This applies to Belgium, Denmark, Italy and Norway. Here there is a clear tendency for innovation expenditure intensity to increase with firm size. For the Netherlands the correlation is not so strong.

However, for Germany and Ireland the correlation is clearly negative, with a slight tendency for innovation expenditure intensity to *decrease* with firm size. However, there is reason to believe that this is largely due to differences in bias across the samples, and that for instance in the German sample the innovative firms are much more overrepresented relative to their share in the population among the small firms than among the large firms.

In the same way as we did in the case of the intensity profile across industries above, let us test the consistency of the overall profile of innovation expenditure intensities across size classes by means of an Analysis of Variance (ANOVA). We use the innovation expenditure intensities by size class, controlled for country, from the table above. This gives seven observations for each size class, one for each country. We use size class as the independent (class) variable, which has six categories, with seven observations in each. The definition of the overall profile here automatically becomes our main definition, the mean of the seven values for each size class. The ANOVA tests whether these mean values are significantly different from each other. The results are summarized in the table below.

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	12.4325	5	2.4865	3.99	0.0056
Within	22.4534	36	0.6237		
Total	34.8859	41			
R^2	0.36				

The probability that the differences of the mean intensity values by size class which we observe should be drawn from a population with no differences between these mean values is 0.0056, which means that size class has an effect which is significant at the 5 per cent significance level by a quite wide margin. The R^2 is 0.36.

The overall size class means, of the mean of the log of the intensity values when country has been controlled for, transformed back to intensity values, are shown in the following table, with size classes ranked according to innovation expenditure intensity. The table also shows which size class means are significantly different from each other at the 5 per cent level, given the overall significance of size class differences.

Table 2.12 - Innovation expenditure intensity by size class

more than 1000	2.6	a	
300-1000	2.1	a	b
100-300	1.9	a	b
50-100	1.4	c	b
30-50	1.4	c	b
30 or less	1.0	c	

The table confirms the tendency for innovation expenditure intensity to increase with firm size.

In the case of differences in innovation expenditure intensity across *size classes*, we can also treat the size class variable as a quantitative variable, coding the less than 30 employees class as 1, the 30-50 employees class as 2, and so on up to the more than 100 employees class as 6. This way we can test for *linearity* through linear regression. We thus have the same 42 observations as in the analysis of variance, with the same size class variable and the same mean innovation expenditure intensities, controlled for country. The only difference is that whereas in the ANOVA we treat the size variable as a nominal variable, in the regression analysis we treat it as a quantitative variable.

When we correlate these two variables, we get $r = 0.58$. This gives an R^2 of 0.34, which is practically the same as with the ANOVA, where it was 0.36. Of course, the R^2 of a linear correlation can never be higher than the R^2 of the corresponding ANOVA. However, the correlation (bivariate regression) analysis uses fewer degrees of freedom than the ANOVA, so that the correlation result is actually slightly more significant than the ANOVA result, the probability value being 0.0001.

Thus we get further confirmation of the tendency for innovation expenditure intensity to increase with firm size.

DIFFERENCES IN INNOVATION EXPENDITURE INTENSITY ACROSS INDUSTRIES, TAKING THE ASSOCIATION BETWEEN INDUSTRY AND FIRM SIZE INTO ACCOUNT

When examining the distribution of innovation expenditure intensity across both industries and size classes, we have controlled for country in order to be better able to assess the effects of industry and firm size. The main concern when controlloing for country was to try to control for some of the distortions rising from differences in the implementation and quality of the survey across countries. But even if we had not suspected any such distortions, controlling for country would have been an essential ingredient in an analysis of the determinants of innovation expenditure intensity.

In the same manner, controlling for firm size becomes important when we analyse differences across industries. Let us explain a bit closer the meaning of this. In what follows, we do not discuss the country dimension and use mean values which have *already been controlled for country*. Let us again look at Table 2.12 above where the overall innovation expenditure intensity means by industry are listed. The table is reproduced below; the question now is, to what extent are the inter-industry differences a reflection of different firm-size structures?

Table 2.13 - Industry innovation intensities

Electrical, electronic etc	3.3
Chemicals	2.1
Machinery	2.0
Basic metals	1.9
Pulp and paper	1.4
Mineral products	1.4
Transport equipment	1.4
Metal products	1.2
Food, beverages, tobacco	1.0
Other	0.9
Wood products	0.9
Textiles, clothing	0.8

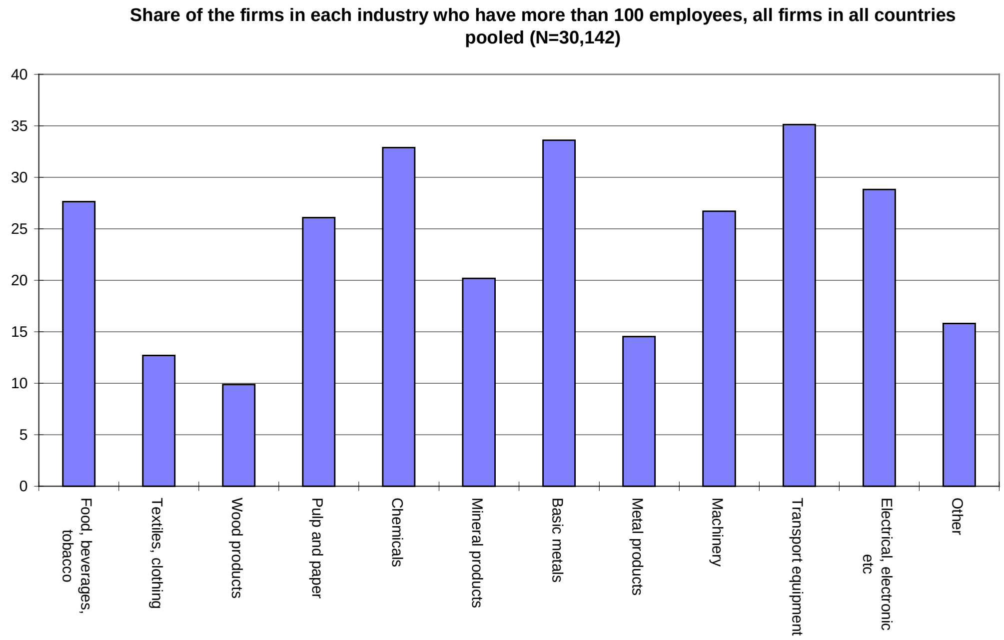
To illustrate the effects of firm size structures, let us focus on two of the industries, *basic metals* and *metal products*. We see that for *basic metals* we found an innovation expenditure intensity of 1.9 per cent, while the corresponding intensity for *metal products* is 1.2 per cent. Thus, the *difference* between the typical innovation expenditure intensity of the two industries is 0.7 percentage points. However, we have already seen from the examination of differences across innovation expenditures across *size classes* that size class has an effect on innovation expenditure intensity: innovation expenditure intensity very clearly increases with firm size.

Now, might not the difference in innovation expenditure intensity between *basic metals* and *metal products* to a large extent reflect differences in the firm size structure between the two industries?

To get a rough indication of differences in the firm size structure across industries, let us divide the firms into only two size classes. We choose 100 employees as the dividing line: the small firms become those with 100 employees or less, the large firms those with more than 100 employees. As the overall profile of innovation expenditure intensity by firm size shows, firms with more than 100 employees typically have a substantially higher innovation expenditure intensity than firms with less than 100 employees.

In the figure below we show the share of the firms in each industry accounted for by firms with more than 100 employees for all the 30,142 firms in all the countries pooled.

Figure 2.11 - Share of the firms in each industry who have more than 100 employees, all firms in all countries pooled (N=30,142)



This figure indicates that there is substantial variation in firm size structure across industries. Specifically, by this simple measure it appears that the firms tend to be much larger in the *basic metals* industry than in the *metal products* industry, the share of the firms accounted for by firms with more than 100 employees being almost 35 per cent in the former industry, less than 15 per cent in the latter. In other words, given that the firms in the former industry generally are larger than the firms in the latter, we would also expect that the former industry typically had higher a higher innovation expenditure intensity than the latter.

But how is this? Are the differences in the typical innovation expenditure intensity between the two industries simply due to the difference in firm size structure, or do we also find differences in mean innovation expenditure intensity between the two industries when we compare *firms of the same size*? To answer this we must, in other words, control for firm size.

The way we do this is exactly the same as we have done when we control for country, only that now we control for *both* country *and* firm size. By means of a regression analysis we estimate the expected values of each observation on the basis of country and firm size, with the seven countries represented by six dummy variables and the six size classes represented by five dummy variables. From the observed values we transform these estimated values to get the residual values. The point is now to examine whether there are systematic differences across industries for these *residual* values, i.e. after the effects of country and firm size have been taken into account. To express these residual values so that the become of the same order of magnitude as the original values, we add the overall mean. Then we find the mean by industry of the resulting values. This whole analysis is done on the *log* of the intensity values (+ 1). Lastly, we transform the resulting values back to intensity values again.

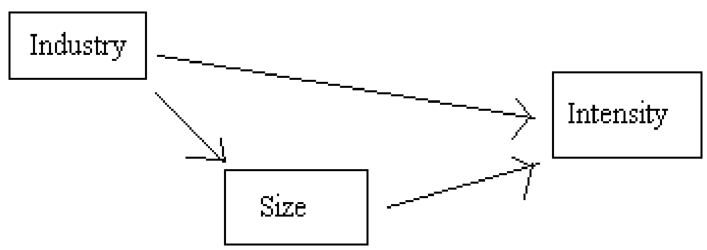
When we control for size class (and country) in this way, we get the mean innovation expenditure intensities by industry presented in the table below:

Table 2.14 - Industry innovation expenditure intensities

Electrical, electronic etc	3.2
Machinery	1.9
Chemicals	1.9
Basic metals	1.7
Mineral products	1.4
Metal products	1.3
Pulp and paper	1.3
Transport equipment	1.3
Wood products	1.0
Other	1.0
Food, beverages, tobacco	0.9
Textiles, clothing	0.9

Concentrating on our two industries, now basic metals has a mean innovation expenditure intensity of 1.7 per cent while metal products has a mean intensity of 1.3 per cent. In other words, the difference between the two industries is now 0.4 percentage points, while when we did not control for firm size it was 0.7 percentage points. That is, of the 0.7 percentage points difference between the industries, 0.4 percentage points are due to the basic metals industry having a higher mean intensity than the metal products industry even when we compare firms of the same size, while the remaing 0.3 percentage points are due to the fact that the firms in the basic metals industry generally are larger than the firms in the metal products industry.

How are we to interpret this? Let us consider the following very simple causal model of what influences the innovation expenditure intensity of firms, as follows:



This model simply says that the industry to which the firm belongs, and the firm's size, influence its innovation expenditure intensity; but also industry influences size.

There may of course be influences in the other direction, as well as influences from variables not included in the model, but let us not consider this here and just assume that the above very simple model summarizes the main direction of the causal effects.

Given this causal model, the difference between of 0.7 percentage points in mean innovation expenditure intensity between the basic metals and the metal products industries are to be understood as the total effect on innovation expenditure intensity of belonging to the basic metals as opposed to the metal products industry. This is the bivariate relationship between industry and intensity, the relationship we get when we do not control for size. This total effect can be decomposed into two separate effects. First there is a direct effect, of 0.4 percentage points, which is the relationship between industry and intensity we get when we control for size. Second, there is an indirect effect through firm size, of 0.3 percentage points, which we here find as a residual, but which we will also get by multiplying the bivariate relationship between industry and size by the relationship between size and intensity when industry has been controlled for.

This effect does not in fact mean that firm size structures are in fact important across Europe. Here we have simply illustrated the principle. In fact it turns out that the results we get when controlling and not controlling for firm size are almost identica. Basic metals and the metal products industries is perhaps the case, together with a couple of others, where we get the clearest effect of controlling for firm size. By and large the differences between the results we get when we do not and when we do control for firm size are very small. All tables and graphs we get when we control for firm size are only marginally diffeent from the ones presented above where only country is controlled for; these are not reported here for reasons of space.

Thus, we conclude that controlling for firm size does *not* alter in any important way the results from the analysis of differences in innovation expenditure intensity across industries presented above.

DIFFERENCES IN INNOVATION EXPENDITURE INTENSITY ACROSS SIZE CLASSES, TAKING THE ASSOCIATION BETWEEN FIRM SIZE AND INDUSTRY INTO ACCOUNT

In the same way as we can control the differences in innovation expenditure intensity across *industries* for differences across *size classes*, we can also control the differences across *size classes* for differences across industries. In any case we assume that *country* has already been controlled for.

Given the simple causal model presented above, however, where firm size influences intensity and industry influences both intensity and firm size, the interpretation of controlling the effects of firm size for industry becomes different from the interpretation of controlling the effects of industry for firm size. The bivariate relationship between firm size and intensity, presented in the analysis of differences in innovation expenditure intensity across size classes above, we now see as containing a *spurious* component, reflecting the fact that both firm size and intensity are influenced by a variable which is prior in the causal sequence. The direct effect of firm size and intensity, the one we get when we control for industry, is to be interpreted as the *total* effect of firm size on intensity, the *difference* between the bivariate effect and this direct effect being the spurious component.

However, it turns out that when we control for industry, the results become only marginally different from the results we get when we do not control for industry, presented above. We will therefore not present the results when controlling for industry here. They do not alter the conclusions from the analysis alredy presented.

CONCLUSION

The aim of this chapter has been to assess whether innovation expenditure intensities are similar at industry level across Europe. If these intensities are different across European countries, perhaps reflecting the different characteristics of innovation systems, then we would have some evidence for the absence of a 'European level' in industry organization, and possibly an argument for focusing policy actions at national levels. On the other hand, if intensities are similar across Europe, we can think in terms of commonalities at the European level.

These issues are complicated by differences in the quality of data across countries, and by the need to control for the effects of different industrial structures and size-class structures within and across industries. After doing this, we arrive at two clear results:

- Firstly, innovation expenditure intensities appear to be industry-specific: that is, these intensities reflect characteristics of the industry rather than the country in which a firm finds itself.
- Secondly, the inter-industry profiles (that is, the structure of relative innovation intensities across industries) are remarkably similar across European industries.

Just as country characteristics do not appear to affect innovation intensities at industry level, neither do firm-size structures. Industry effects appear to be far more important than either country effects or firm-size effects. Industries across Europe share common challenges across Europe, and react with common intensities of innovation investment at an aggregate level. The question remains as to whether the composition of investments is also similar. It is to this we turn in the following chapter.

CHAPTER THREE: The composition of innovation expenditure

We turn now to the *composition* of innovation expenditures, looking at the extent to which the internal structure of innovation expenditures is consistent across European industries. We distinguish among three different components of innovation expenditures, namely: (i) R&D expenditures; (ii) current innovation expenditures which are not R&D expenditures, of which there are (for most countries) six different categories in the survey. We will call these for short 'non R&D expenditures'; (iii) investment expenditures related to innovations.

When we analyse the composition of innovation expenditures we have to restrict ourselves to firms which report that they have innovation expenditures, of course. In addition, we have to have data which allow the full breakdown of total innovation expenditures into the three different components. We thereby end up with 12,206 firms in our sample for the analysis of the composition of innovation expenditures. The distribution of these 12,206 firms across the seven countries are shown in the table below.

Table 3.1 - Firms with innovation expenditures

	N	per cent
Belgium	489	4.0
Denmark	429	3.5
Germany	1410	11.6
Ireland	730	6.0
Italy	7464	61.2
Netherlands	1319	10.8
Norway	365	3.0
Total	12206	100

Although Italy dominates this sample also, the domination is not so strong as in the case of innovation expenditure intensities, including also firms with no innovation expenditures. The reason is that the share of innovative firms is generally lower in Italy than in the other countries, this largely reflecting bias in the survey samples.

The following table shows how these 12,206 firms are distributed across the seven countries and the 12 industries.

Table 3.2 - Firms with innovation expenditures, by industry and country

Industry	Bel	Den	Ger	Irl	Ita	NL	Nor	Total
Food, beverages, etc.	66	49	62	101	468	151	65	962
Textiles, clothing	61	14	65	71	1069	62	13	1355
Wood products	7	9	9	15	179	37	16	272
Pulp and paper	14	13	28	20	190	55	15	335
Chemicals	84	65	205	137	777	192	27	1487
Mineral products	26	23	57	36	441	73	16	672
Basic metals	15	12	59	13	244	29	15	387
Metal products	49	41	124	61	960	177	25	1437
Machinery	44	82	369	56	1328	218	42	2139
Transport equipment	23	18	100	19	309	67	33	569
Electrical, electronic etc	49	68	245	131	782	118	34	1427
Other	51	35	87	70	717	140	64	1164
Total	489	429	1410	730	7464	1319	365	12206

There are significant numbers of firms in each cell, but it should be noted that we have very few observations in the *wood products* industry, with only seven observations in Belgium and only nine in Denmark and Germany.

The firms are distributed by country and the six size classes as follows:

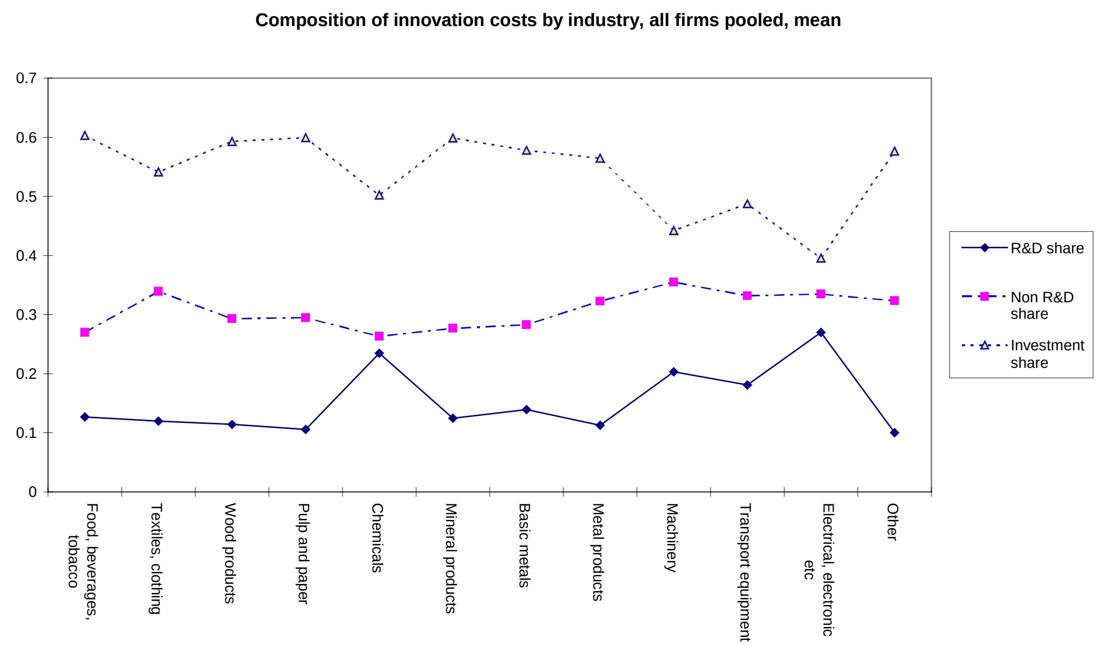
Table 3.3 - Firms with innovation expenditures by country and size class.

Size class: number of employees	Bel	Den	Ger	Irl	Ita	NL	Nor	Total
30 or less	91	25	0	276	2032	164	105	2693
30-50	63	55	25	121	1909	150	39	2362
50-100	38	96	266	140	1622	397	68	2627
100-300	111	155	435	128	1264	404	95	2592
300-1000	125	77	418	57	481	167	45	1370
more than 1000	61	21	266	8	156	37	13	562
Total	489	429	1410	730	7464	1319	365	12206

Notice that there are no valid observations in the less than 30 employees size class for Germany; for Ireland there are only eight observations in the more than 1000 employees class.

We begin with the composition of the innovation expenditures by industry and size class. Our measure here will simply be the *mean* in each group, looking first at these distributions (i.e shares in each category) for all firms of all countries pooled. We start with the composition of innovation expenditures by *industry* for all countries pooled. This is shown in the figure below.

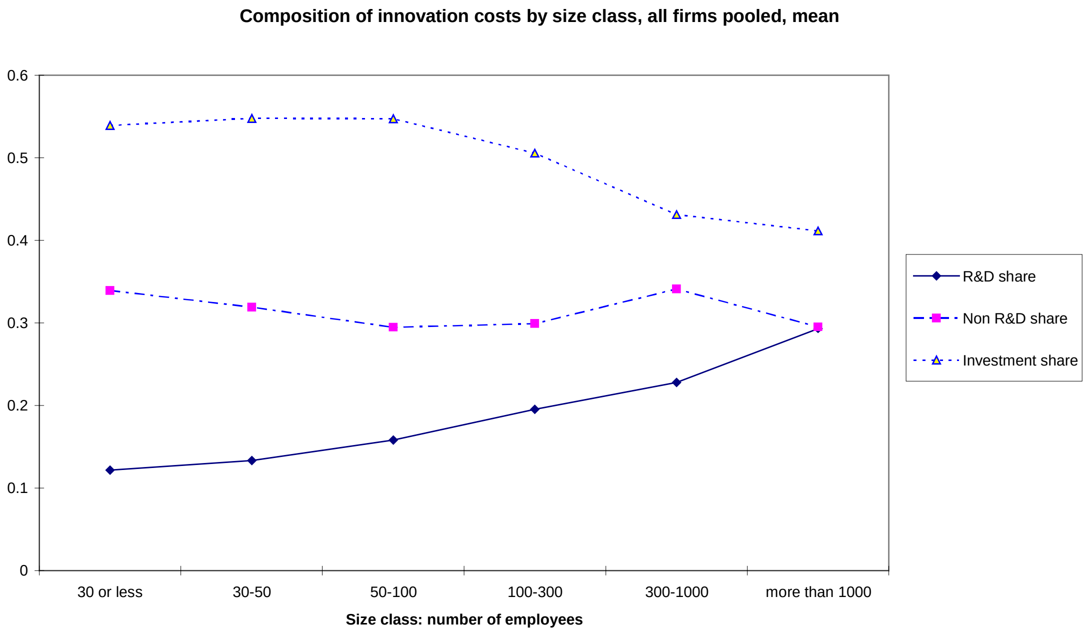
Figure 3.1 - Composition of innovation expenditures by industry, all firms pooled, mean



There is some variation in the share of R&D expenditures across industries, with especially electrical, electronics, etc. and chemicals having high shares. To this variation across industries there roughly seems to correspond a variation in the opposite direction for the share of *investment* expenditures, while non R&D expenditures seem to vary somewhat less across industries. The mean R&D share by industry varies between about 0.1 and 0.25, the mean non-R&D share is generally close to 0.3, while the mean investment share varies between 0.4 and 0.6, roughly.

The next figure shows the composition of innovation expenditures by *size class* for all countries pooled.

Figure 3.2 - Composition of innovation expenditures by size class, all firms pooled, mean



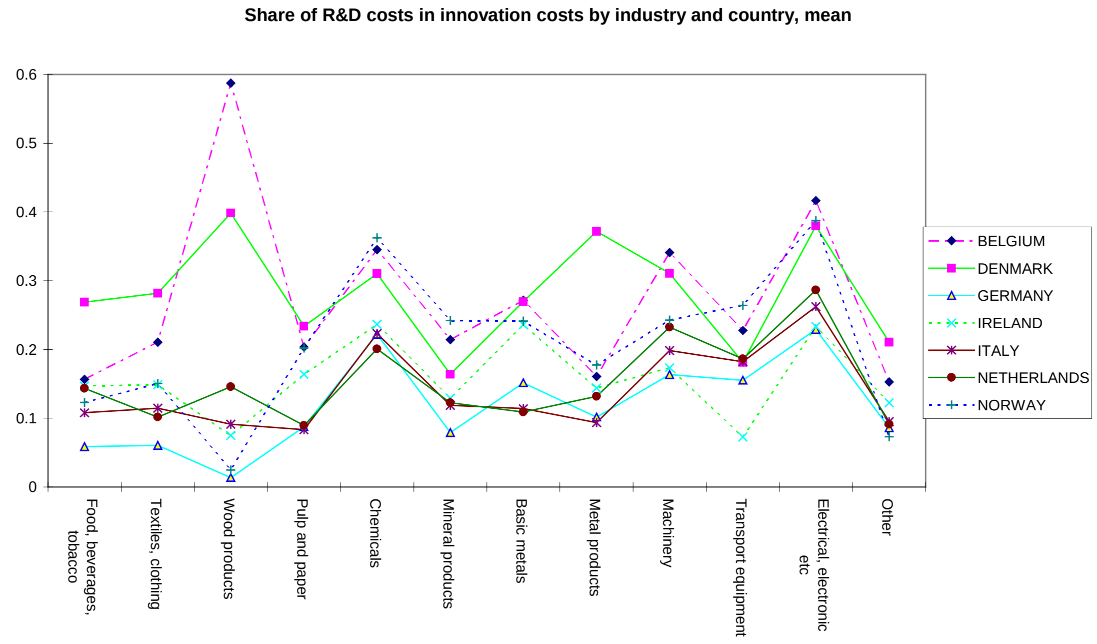
The data suggests that there is a clear relationship between firm size and the share of *R&D expenditures*, with this share *increasing* consistently with firm size. To this there seems to correspond, though less clearly, a *decrease* in the share of *investment* expenditures with firm size. Again, the share of non R&D expenditures seems to vary less, and there seems to be no linearity to the variation.

COMPOSITION OF INNOVATION EXPENDITURES BY INDUSTRY

We will now look closer at the variation *across industries* in the shares of the different expenditure components, taking the country dimension into account. Do we in general recognize the pattern we found for all countries pooled also for each of the different countries, so that we can say that there is a consistent profile across industries in spite of the differences across countries, or are the differences across countries too large for a conclusion concerning a general profile across industries to be sustainable?

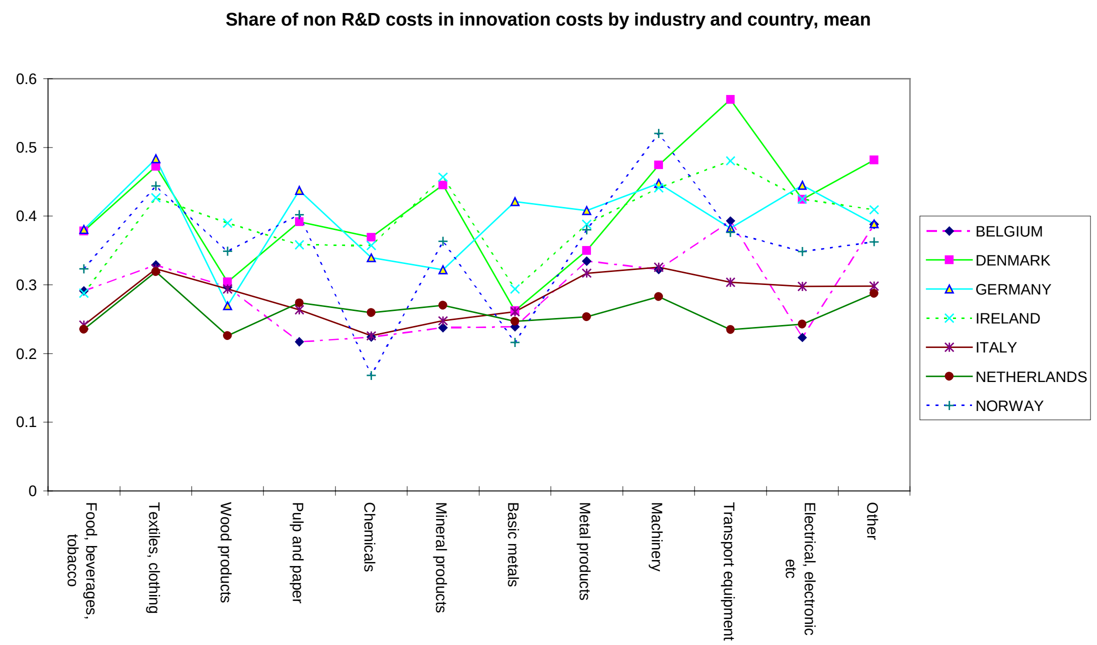
Let us first briefly look at the mean share of *R&D expenditures* in innovation expenditures by industry and country. This is shown in the figure below.

Figure 3.3 - Share of R&D expenditures in innovation expenditures by industry and country, mean



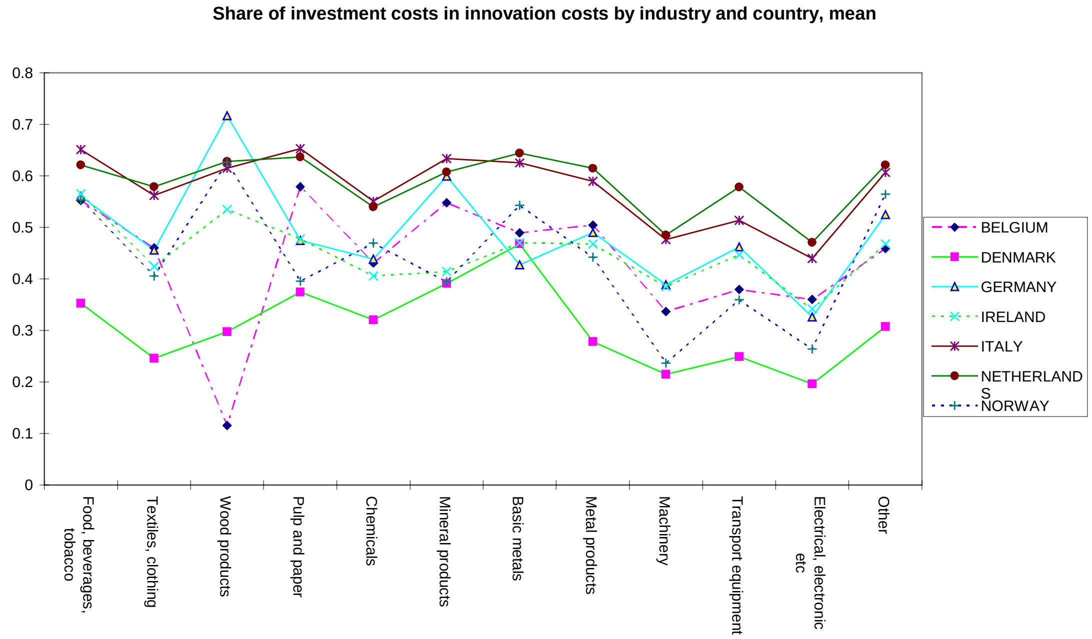
In the same way, the next figure shows the mean share of *non R&D expenditures* in innovation expenditures by industry and country.

Figure 3.4 - Share of non R&D expenditures in innovation expenditures by industry and country, mean



Finally, we show the mean share of *investment expenditures* in innovation expenditures by industry and country in the following figure.

Figure 3.5 - Share of investment expenditures in innovation expenditures by industry and country, mean



While these figures suggest that the shares move in similar ways across countries, the issue is clearly complicated by differences in level. As with the intensity variable analysed in the previous chapter, it is necessary to take account of country effects if we are to analyse the industry profiles, and we turn to this in the next section.

COMPOSITION OF INNOVATION EXPENDITURES BY INDUSTRY, CONTROLLING FOR COUNTRY

We control for country in the same way that we did when we analysed the intensity of innovation expenditures above. By means of a regression analyses with dummy variables we estimate the share of each expenditure component for each firm in the sample on the basis of their value on the country variable (the country dummy variables) only. Then we find the residuals, and lastly add the overall mean to these residuals. We then take the mean of the values which then result, by industry and country. In the following sub-sections we analyse the cross-industry profiles in turn for R&D, non-R&D expenditures, and investment expenditures.

The share of R&D expenditures in total innovation expenditures, controlling for country

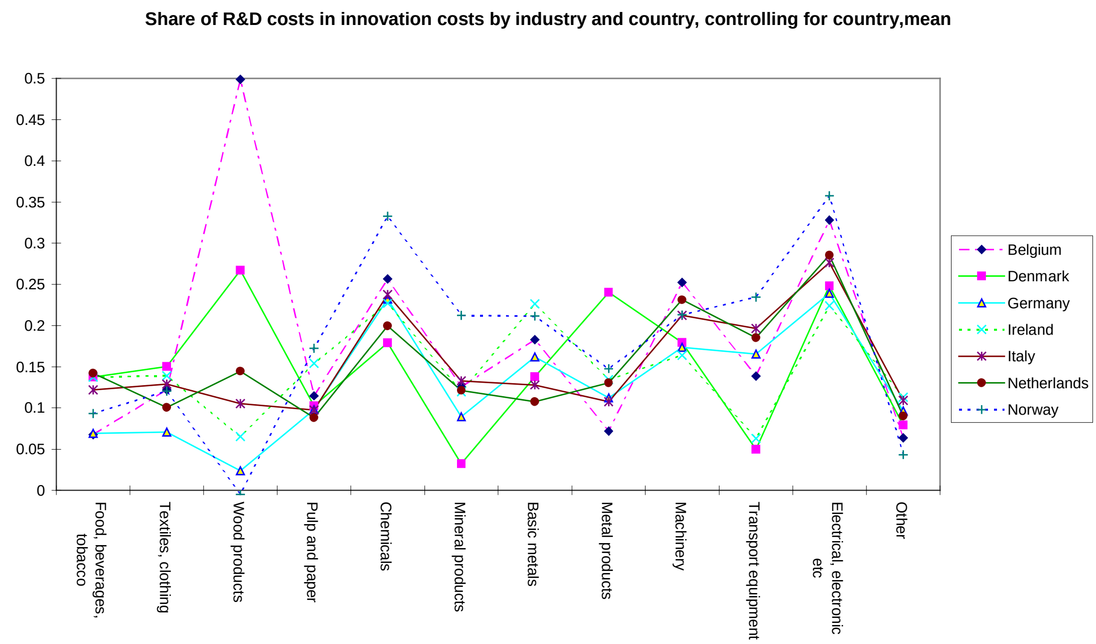
The table below shows the mean share of R&D expenditures in total innovation expenditures by industry and country, when controlling for country.

Table 3.4 - Share of R&D in innovation expenditures, by industry and country

	Bel	Den	Ger	Irl	Ita	NL	Nor
Food, beverages, etc.	0.07	0.14	0.07	0.14	0.12	0.14	0.09
Textiles, clothing	0.12	0.15	0.07	0.14	0.13	0.10	0.12
Wood products	0.50	0.27	0.02	0.07	0.11	0.14	-0.01
Pulp and paper	0.11	0.10	0.10	0.15	0.10	0.09	0.17
Chemicals	0.26	0.18	0.23	0.23	0.24	0.20	0.33
Mineral products	0.13	0.03	0.09	0.12	0.13	0.12	0.21
Basic metals	0.18	0.14	0.16	0.23	0.13	0.11	0.21
Metal products	0.07	0.24	0.11	0.13	0.11	0.13	0.15
Machinery	0.25	0.18	0.17	0.16	0.21	0.23	0.21
Transport equipment	0.14	0.05	0.17	0.06	0.20	0.19	0.23
Electrical, electronic etc	0.33	0.25	0.24	0.22	0.28	0.29	0.36
Other	0.06	0.08	0.10	0.11	0.11	0.09	0.04

The following figure shows the same adjusted mean shares graphically.

Figure 3.6 - Share of R&D expenditures in innovation expenditures by industry and country, controlling for country, mean



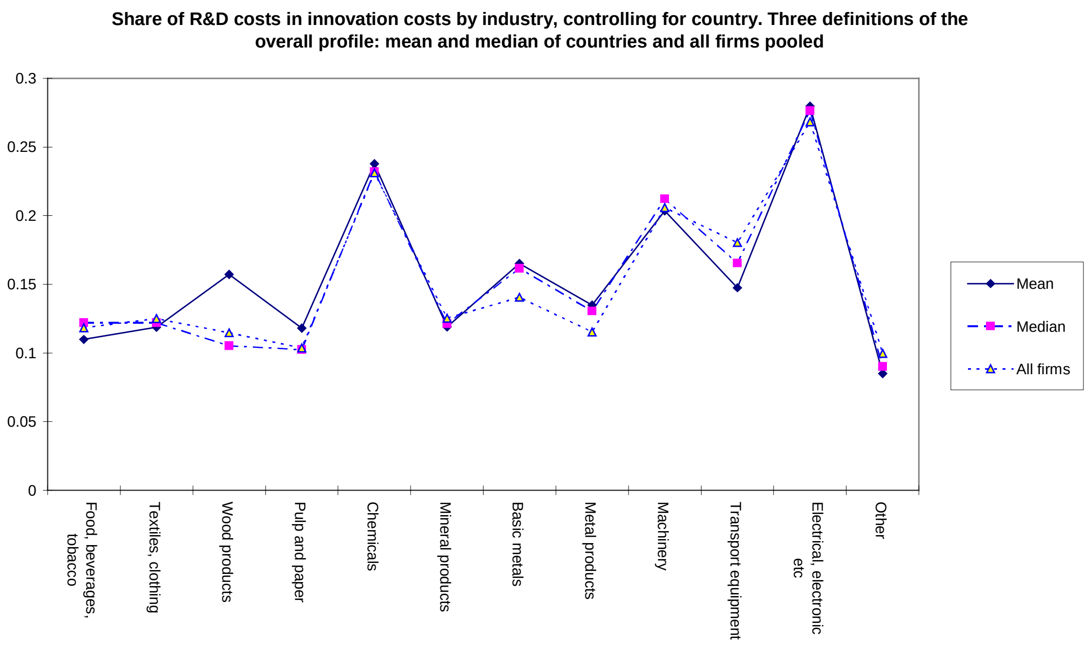
What is immediately striking here is the very large variation in mean shares across countries in the *wood products* industry. This industry is rather special, however, because for some of the countries the number of valid observations here are quite few. For Belgium, which has the mean value which deviates the most from the others, we have only 7 valid observations for this industry, while for both Denmark and Germany we have only 9. Notice also that for Norway the share if R&D

expenditures in the *wood products* industry is actually slightly *negative*. This is not a mistake but a result of controlling for country.

In the same way as we did when analysing innovation expenditure intensities above we will define an overall profile of the variation in the share of R&D expenditures in total innovation expenditures across industries. Again we have three different versions of this overall profile. The main definition is the mean of the country values. In addition, we have the median of the country values for each industries and the mean value for each industry when the firms of all countries are pooled.

The overall profiles which emerge from these three definitions are shown graphically in the following figure.

Figure 3.7 - Share of R&D expenditures in innovation expenditures by industry, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



We see that the irregular variation in the *wood products* industry leads to a quite substantial discrepancy between our main definition of the share of R&D expenditures and the two other definitions for this particular industry.

These three definitions of the overall profile correlate closely with each other, as the following correlation matrix indicates:.

Table 3.5 - Correlation among R&D share indicators

	Mean	Median	All firms
Mean	1	0.95	0.94
Median	0.95	1	0.98
All firms	0.94	0.98	1

The correlation coefficients of the profile of each country with the overall profiles emerging from the three different definitions are shown in the next table.

Table 3.6 - Country correlations with overall profiles

	Mean	Median	All firms
Belgium	0.62	0.40	0.43
Denmark	0.55	0.37	0.31
Germany	0.81	0.91	0.89
Ireland	0.63	0.66	0.55
Italy	0.89	0.96	0.99
Netherlands	0.88	0.91	0.93
Norway	0.76	0.86	0.84

Note that Belgium, which is the most conspicuous outlier in the *wood products* industry, and also Denmark, which also has a quite deviant value in this industry, both have a much higher correlation with the *mean* definition of the overall profile than with the *median* definition. Given that the median is more resistant to outliers than the mean, we should perhaps here concentrate on the *median* definition. Here we see that Germany, Italy, the Netherlands and Norway correlate quite strongly with the overall profile, Ireland has a more modest correlation coefficient, while this coefficient is quite low for Belgium and Denmark.

Let us, in the same way as we did above for innovation expenditure intensities, test the consistency of the overall profile of the share of R&D expenditures in total innovation expenditures across industries means of an Analysis of Variance (ANOVA). We use the R&D shares by country and industry from the table above. This gives seven observations for each industry, one for each country. We use industry as the independent (class) variable, which has 12 categories, with seven observations in each. The definition of the overall profile here automatically becomes our main definition, the mean of the seven values for each industry. The ANOVA tests whether these mean values are significantly different from each other. The results are summarized in the following table.

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	0.2535	11	0.02305	5.29	0.0001
Within	0.3137	72	0.00435		
Total	0.5673	83			
R^2	0.45				

As we see, the probability that the differences of the mean industry values which we observe should be drawn from a population with no differences between the mean industry values is less than 0.0001, which means that industry has an effect which is significant at the 5 per cent significance level by a very wide margin. The R^2 is 0.45.

The overall industry means, of the mean of the R&D shares when country has been controlled for, are shown in the following table, with industries ranked according to the share of R&D expenditures in innovation expenditures. The table also give a rough indication of which industry values are significantly different from each other at the 5 per cent level, given the overall significance of industry differences.

Table 3.7 - R&D shares of innovation expenditures: industry means

Electrical, electronic etc	0.28	a		
Chemicals	0.24	a	b	
Machinery	0.20	c	b	
Basic metals	0.17	c	b	d
Wood products	0.16	c		d
Transport equipment	0.15	c		d
Metal products	0.13	c		d
Mineral products	0.12			d
Textiles, clothing	0.12			d
Pulp and paper	0.12			d
Food, beverages, tobacco	0.11			d
Other	0.08			d

However, we shall remember the problems with the *wood products* industry, where especially the Belgian value was an outlier. In fact, if we run the ANOVA without Belgium, the R^2 increases from 0.45 to 0.56, the probability still being 0.0001. And if we instead bring Belgium back in but exclude the *wood products* industry, this increases R^2 even more, from 0.45 to 0.66.

The share of non R&D expenditures in total innovation expenditures, controlling for country

We now turn to the mean share of non-R&D expenditures in innovation expenditures by industry and country, controlling for country. The method of analysis is exactly the same as the one employed for the share of R&D expenditures, above.

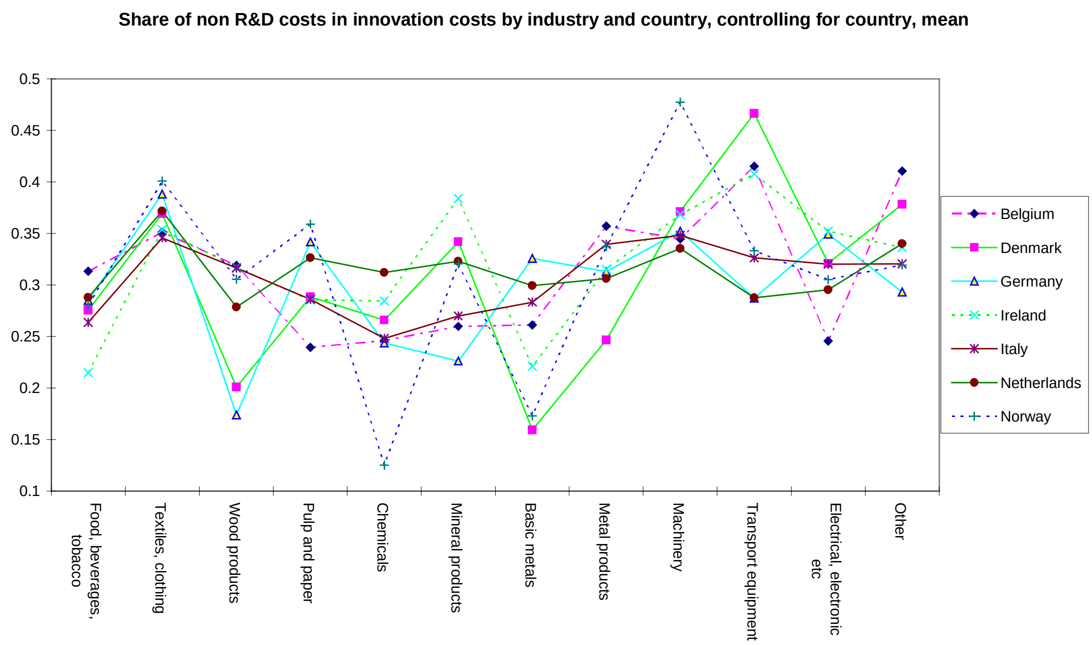
The mean share of non R&D expenditures by industry and country, when controlling for country, are shown in the table below.

Table 3.8 - Shares of non-R&D expenditures in innovation expenditures, by country and industry

	Bel	Den	Ger	Irl	Ita	NL	Nor
Food, beverages, etc.	0.31	0.28	0.29	0.21	0.26	0.29	0.28
Textiles, clothing	0.35	0.37	0.39	0.35	0.35	0.37	0.40
Wood products	0.32	0.20	0.17	0.32	0.32	0.28	0.31
Pulp and paper	0.24	0.29	0.34	0.29	0.29	0.33	0.36
Chemicals	0.25	0.27	0.24	0.28	0.25	0.31	0.13
Mineral products	0.26	0.34	0.23	0.38	0.27	0.32	0.32
Basic metals	0.26	0.16	0.33	0.22	0.28	0.30	0.17
Metal products	0.36	0.25	0.31	0.32	0.34	0.31	0.34
Machinery	0.34	0.37	0.35	0.37	0.35	0.34	0.48
Transport equipment	0.42	0.47	0.29	0.41	0.33	0.29	0.33
Electrical, electronic etc	0.25	0.32	0.35	0.35	0.32	0.30	0.31
Other	0.41	0.38	0.29	0.34	0.32	0.34	0.32

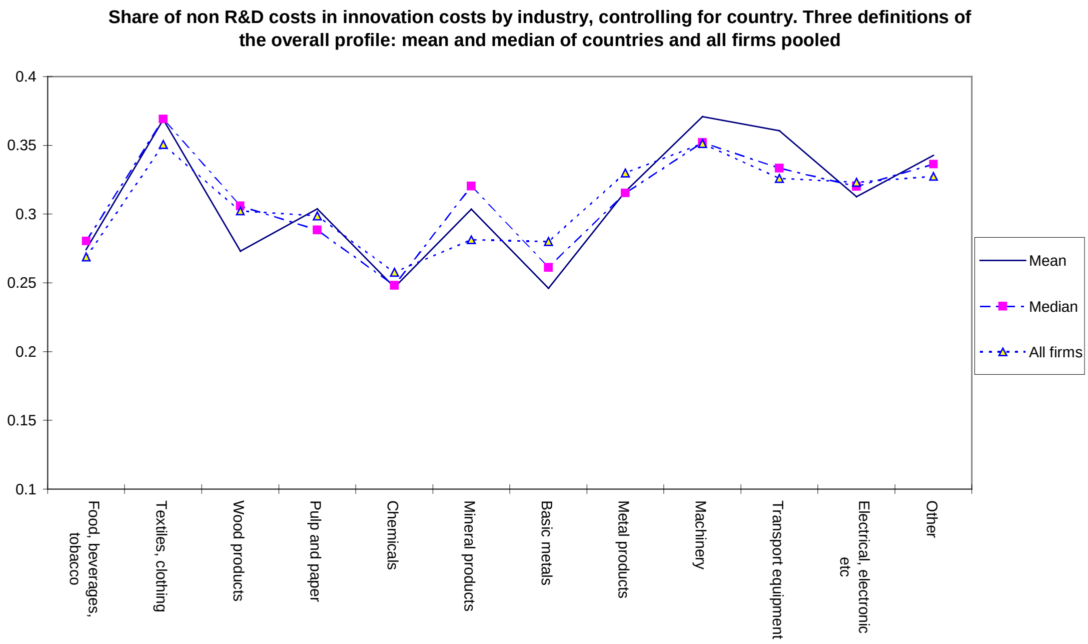
The same profiles across industries are shown graphically in the figure below.

Figure 3.8 - Share of investment expenditures in innovation expenditures by industry and country, controlling for country, mean



As explained above, from these profiles we get three different versions of the overall profile, based on three different definitions of the total: the mean and median of the country values, and the mean of all the firms of all countries pooled by industry. These are shown in the following figure:

Figure 3.9 - Share of non R&D expenditures in innovation expenditures by industry, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



Again we check for consistency by examining the correlations among the three definitions of the overall profile. The correlation matrix is shown in the table below.

Table 3.9 - Non-R&D expenditure shares: correlations among indicators

	Mean	Median	All firms
Mean	1	0.94	0.90
Median	0.94	1	0.90
All firms	0.90	0.90	1

Also these correlation coefficients are high and significant. The correlation coefficients of each of the country profiles with each of the three versions of the overall profile are shown in the next table.

Table 3.10 - Country correlations with overall profiles, non-R&D expenditure shares

	Mean	Median	All firms
Belgium	0.67	0.63	0.62
Denmark	0.83	0.70	0.54
Germany	0.51	0.38	0.56
Ireland	0.75	0.77	0.63
Italy	0.80	0.83	0.97
Netherlands	0.55	0.54	0.47
Norway	0.85	0.86	0.81

Taking the *mean* definition as the main definition, we generally see lower correlation coefficients than in the case of the share of R&D expenditures, as well as in innovation expenditure intensities. No countries have correlation coefficients with the overall of more than 0.90, only three countries have coefficients of 0.80 or more (Norway, Denmark and Italy). Again we test the effect of industry by means of ANOVA, in the same way as explained above. The results are given in the table below.

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	0.1515	11	0.01377	5.80	0.0001
Within	0.1710	72	0.00237		
Total	0.3226	83			
R^2	0.47				

Once again, the probability that the differences of the mean industry values which we observe should be drawn from a population with no differences between the mean industry values is less than 0.0001, which means that industry has an effect which is significant at the 5 per cent significance level by a very wide margin. The R^2 is 0.47.

The overall industry means, of the mean of the non R&D shares when country has been controlled for, are shown in the following table, with industries ranked according to the share of non R&D expenditures. The table also shows which industry values are significantly different from each other at the 5 per cent level, given the overall significance of industry differences.

Table 3.11 - Non-R&D expenditures – shares of total innovation expenditures, by industry

Machinery	0.37	a		
Textiles, clothing	0.37	a		
Transport equipment	0.36	a	b	
Other	0.34	a	b	
Metal products	0.32	a	b	c
Electrical, electronic etc	0.31	a	b	c
Pulp and paper	0.30	d	b	c
Mineral products	0.30	d	b	c
Food, beverages, tobacco	0.27	d		c
Wood products	0.27	d		c
Chemicals	0.25	d		
Basic metals	0.25	d		

When we do not take the special problems of the *wood products* industry into account, it may from the ANOVA seem that industry is equally important in influencing the share of both R&D expenditures and non R&D expenditures in total innovation expenditures. However, remember that when we excluded the *wood products* industry in the R&D share case, R^2 rose from 0.45 to 0.66, which is quite high. This probably reflects reality better. It is also consistent with the correlation coefficients between the country profiles and the overall profile generally being higher in the R&D expenditures share case than in the non R&D expenditures share case.

The share of investment expenditures in total innovation expenditures, controlling for country

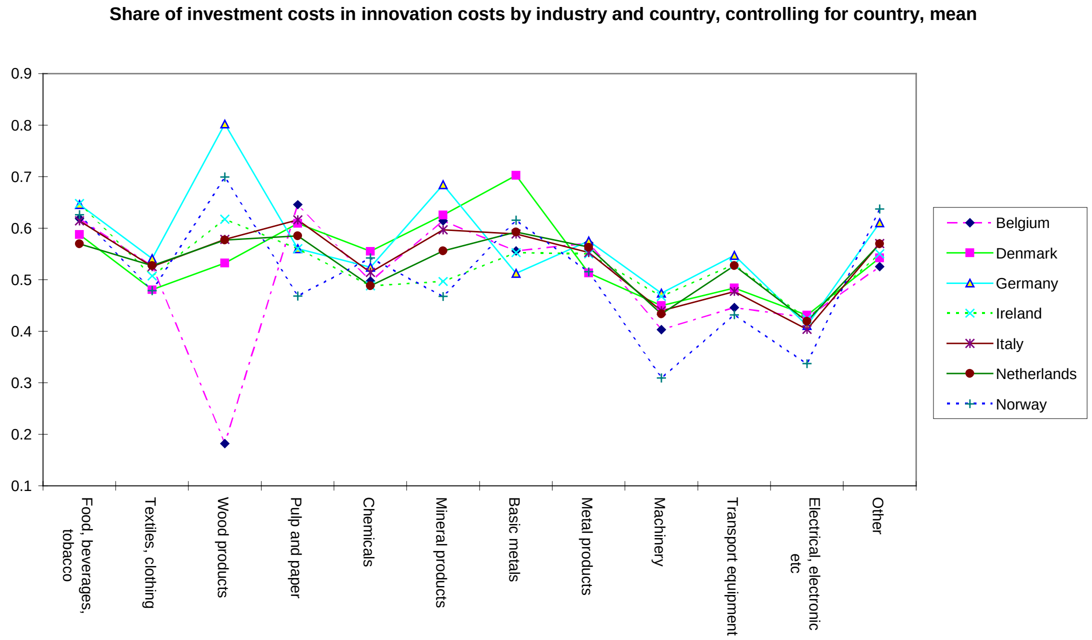
Lastly, we turn to the mean share of investment expenditures in innovation expenditures by industry and country, controlling for country. The mean share of investment expenditures by industry and country, when controlling for country, are shown in the table below.

Table 3.12 -Shares of investment expenditures in total innovation expenditures, by industry and country

	Bel	Den	Ger	Irl	Ita	NL	Nor
Food, beverages, etc.	0.62	0.59	0.65	0.65	0.61	0.57	0.63
Textiles, clothing	0.53	0.48	0.54	0.51	0.53	0.53	0.48
Wood products	0.18	0.53	0.80	0.62	0.58	0.58	0.70
Pulp and paper	0.65	0.61	0.56	0.56	0.62	0.59	0.47
Chemicals	0.50	0.56	0.52	0.49	0.51	0.49	0.54
Mineral products	0.61	0.63	0.68	0.50	0.60	0.56	0.47
Basic metals	0.56	0.70	0.51	0.55	0.59	0.59	0.62
Metal products	0.57	0.51	0.58	0.55	0.55	0.56	0.52
Machinery	0.40	0.45	0.47	0.47	0.44	0.43	0.31
Transport equipment	0.45	0.48	0.55	0.53	0.48	0.53	0.43
Electrical, electronic etc	0.43	0.43	0.41	0.42	0.40	0.42	0.34
Other	0.53	0.54	0.61	0.55	0.57	0.57	0.64

These same shares are also shown graphically in the following figure.

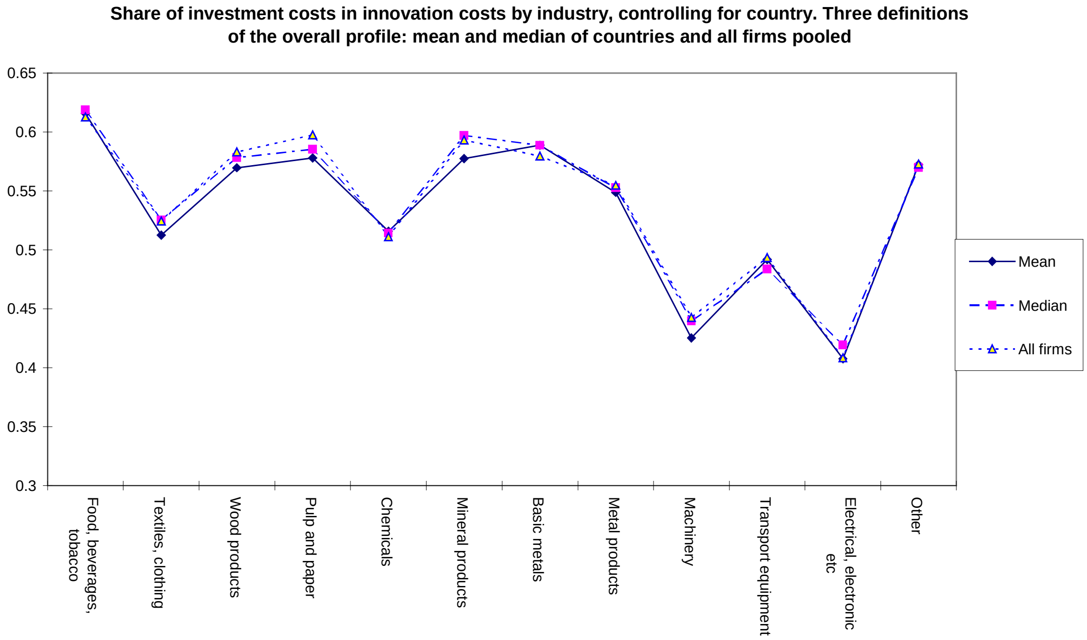
Figure 3.10 - Share of investment expenditures in innovation expenditures by industry and country, controlling for country, mean



Since we had very large variation across countries in the *wood products* industry for the share of *R&D expenditures*, but not any exceptional variation for the *non R&D expenditures*, we quite expectedly get very large variation again for the share of *investment expenditures* in this industry. Again, we should remember that a number of the countries have very few valid observations in this industry, in particular Belgium, which is the most marked outlier.

Again we get three different versions of the overall profile of the shares across industries. The shares of each industry in the total according to each of the three definitions are given in the following figure:.

Figure 3.11 - Share of investment expenditures in innovation expenditures by industry, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



As we see, the large deviation of Belgium in the *wood products* industry is balanced by a couple of also quite large deviations (Germany and Norway) in the opposite direction, so that also in this industry the mean of the countries becomes approximately equal to the median. In general, all three definitions give almost identical values in all the industries. This is reflected in the very high correlation coefficients among the three different versions of the overall profile. The correlation matrix is given in the table below.

Table 3.13 - Investment profiles: correlations among indictors

	Mean	Median	All firms
Mean	1	0.99	0.99
Median	0.99	1	0.99
All firms	0.99	0.99	1

The correlation coefficients of each country profile with the overall profile are as follows:.

Table 3.14 - Investment expenditures: correlations between country and overall profiles

	Mean	Median	All firms
Belgium	0.40	0.40	0.39
Denmark	0.81	0.81	0.78
Germany	0.69	0.71	0.73
Ireland	0.82	0.79	0.81
Italy	0.98	0.99	0.99
Netherlands	0.94	0.93	0.94
Norway	0.82	0.78	0.77

Belgium has a low correlation coefficient with the overall profile. Italy and the Netherlands have very high correlation coefficients, Denmark, Ireland and Norway quite high, and Germany medium. Lastly, we again test the effect of industry by means of ANOVA, as explained above. The results of this analysis are as follows:

	Sum of Squares	DF	Mean square	F-ratio	Prob.
Between	0.3280	11	0.0298	5.90	0.0001
Within	0.3640	72	0.0050		
Total	0.6920	83			
R^2	0.47				

As we see, the probability that the differences of the mean industry values which we observe should be drawn from a population with no differences between the mean industry values is less than 0.0001, which means that industry has an effect which is significant at the 5 per cent significance level by a very wide margin. The R^2 is 0.47.

The overall industry means, of the mean of the investment expenditure shares when country has been controlled for, are shown in the following table, with industries ranked according to the share of investment expenditures in innovation expenditures. The table also shows which industry values are significantly different from each other at the 5 per cent level, given the overall significance of industry differences.

Table 3.15 - Investment expenditures – shares of overall innovation expenditure – Industry means

Food, beverages, tobacco	0.62	a		
Basic metals	0.59	a	b	
Pulp and paper	0.58	a	b	c
Mineral products	0.58	a	b	c
Other	0.57	a	b	c
Wood products	0.57	a	b	c
Metal products	0.55	a	b	c
Chemicals	0.52		b	c
Textiles, clothing	0.51		b	c
Transport equipment	0.49	d		c
Machinery	0.43	d	e	
Electrical, electronic etc	0.41		e	

However, it is important here to remember the problems with the *wood products* industry, and with Belgium in particular. This means that one should not put too much trust in the share for the *wood products* industry in the table above. In fact, if we leave out Belgium, we get an R^2 of 0.65, and if we instead keep Belgium in but leave out the *wood products* industry, we get an R2 of 0.70, which are both quite high. In both cases the probability of no industry differences is 0.0001.

17. ANALYSING COMPOSITION OF INNOVATION EXPENDITURES BY SIZE CLASS

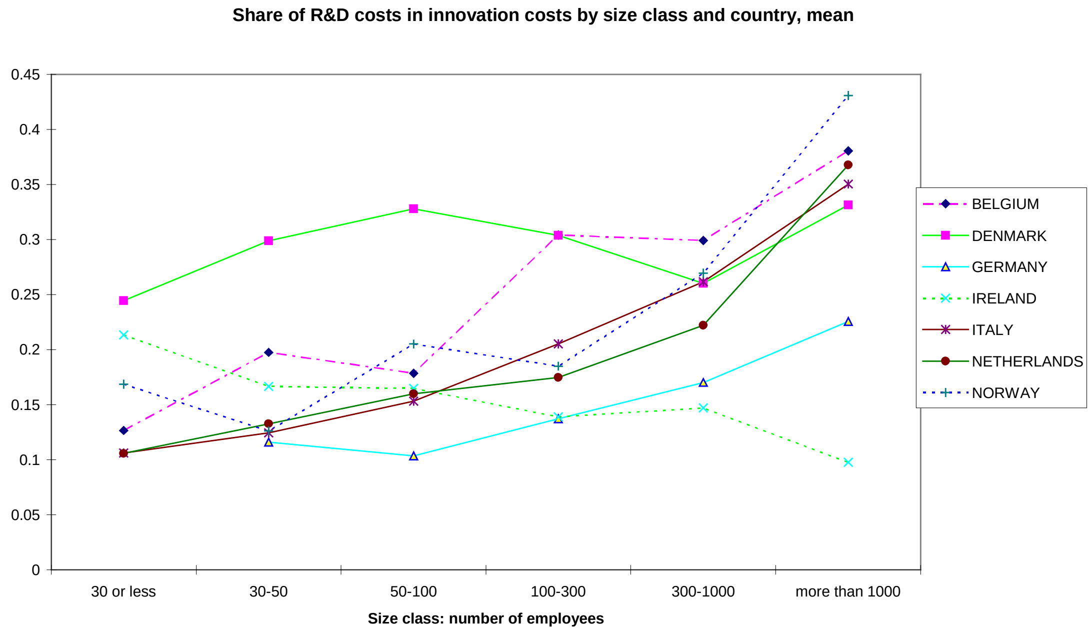
Above we presented data showing the R&D expenditures share, the non R&D expenditures share and the investment expenditures share by size class for the firms in all countries pooled. Here we got the impression that there was a clear tendency for the share of *R&D expenditures* in innovation expenditures to *increase* with firm size, a somewhat weaker tendency for the share of *investment expenditures* to *decrease* with firm size, and no clear tendency for the share of *non R&D expenditures*.

Let us now see if these impressions are confirmed when we look closer at the composition of innovation expenditures across size classes, bringing the country dimension into the picture.

First we will briefly show the share of each expenditure component by country and industry when we do *not* control for the general level of the shares in each country, that is when we do not take account of country effects.

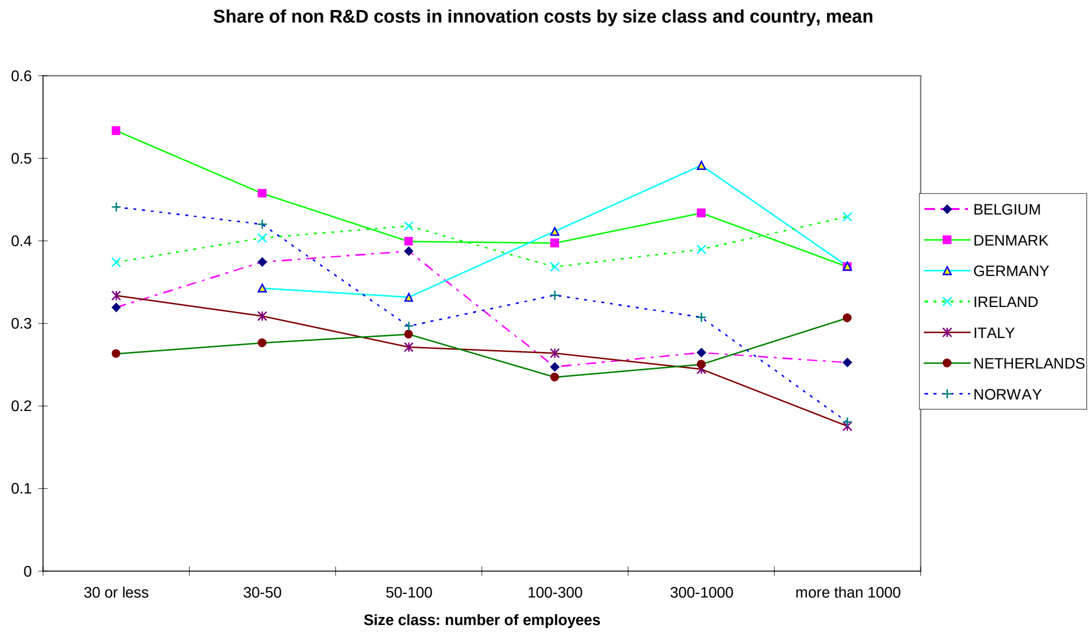
We start with the share of R&D expenditures in innovation expenditures by country and size class, when country is *not* controlled for. These mean shares are shown in the figure below.

Figure 3.12 - Share of R&D expenditures in innovation expenditures by size class and country, mean



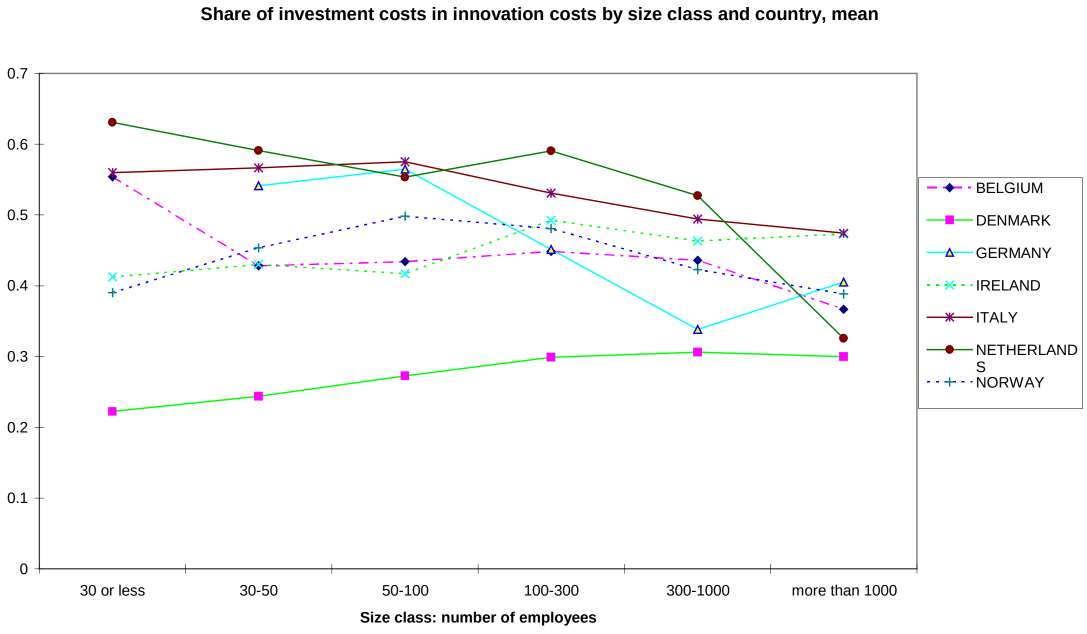
Notice that for Germany we have no valid observation on the *composition* of innovation expenditures for the smallest firms, the 30 or less employees size class. Thus, for Germany we only have five size categories when analysing the *composition* of innovation expenditures, cf. also the table further above. Next comes the share of non R&D expenditures in innovation expenditures by country and size class, when country is *not* controlled for. These shares are shown in the following figure.

Figure 3.13 - Share of non R&D expenditures in innovation expenditures by size class and country, mean



Lastly, in the following figure we show the share of investment expenditures in innovation expenditures by country and size class, when country is *not* controlled for.

Figure 3.14 - Share of investment expenditures in innovation expenditures by size class and country, mean



Again, it is quite evident that there are differences across countries in the general level of the shares of the different expenditure components, irrespective of size class. To what extent these differences reflect genuine differences across the countries and to what extent they represent distortions due to differences in the implementation of the survey across countries, is difficult to say. There is no reason to doubt, however, that there are such distortions present to an important degree. But again, whatever the answer to this question, we should control for differences in the general level in the shares of the different expenditure components across countries, in order to better able to analyse the differences across size classes. We turn now to this issue.

COMPOSITION OF INNOVATION EXPENDITURES BY SIZE CLASS, CONTROLLING FOR COUNTRY

We control for country in exactly the same way as explained above, in the case of the analysis of innovation expenditure intensity, and in the case of differences in the composition if innovation expenditures across *industries*.

The share of R&D expenditures in total innovation expenditures, controlling for country

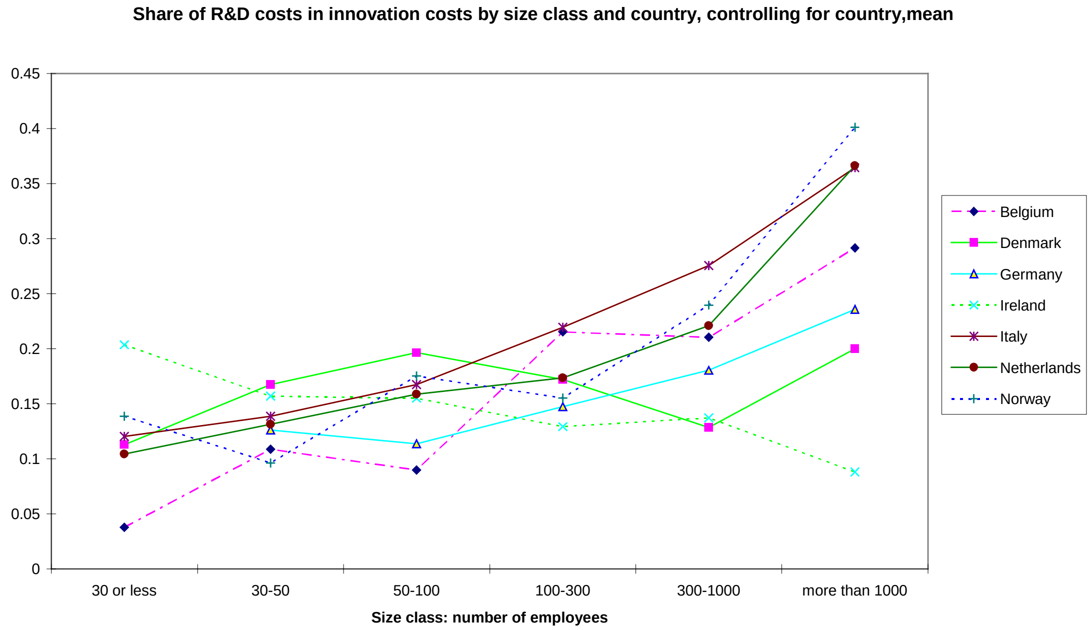
We start with the share of R&D expenditures. The table below shows the share of R&D expenditures in innovation expenditures by country and size class, controlling for country.

Table 3.16 - Share of R&D in total innovation expenditures, by country and firm size-class

	Bel	Den	Ger	Irl	Ita	NL	Nor
30 or less	0.04	0.11	---	0.20	0.12	0.10	0.14
30-50	0.11	0.17	0.13	0.16	0.14	0.13	0.10
50-100	0.09	0.20	0.11	0.16	0.17	0.16	0.18
100-300	0.22	0.17	0.15	0.13	0.22	0.17	0.16
300-1000	0.21	0.13	0.18	0.14	0.28	0.22	0.24
more than 1000	0.29	0.20	0.24	0.09	0.36	0.37	0.40

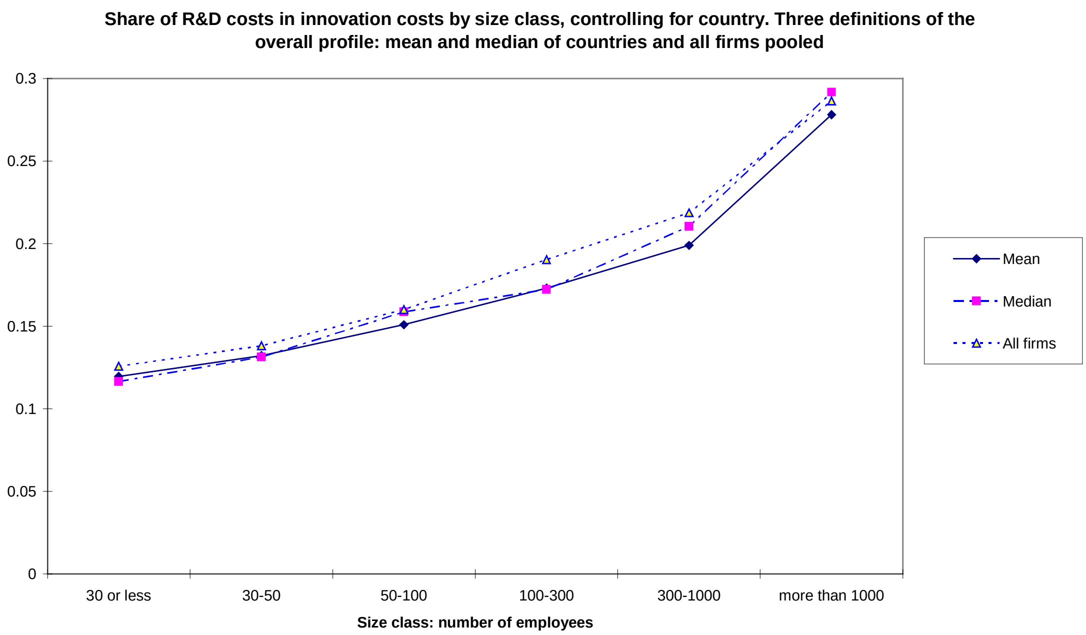
The same shares of the R&D expenditures are also shown graphically in the following figure.

Figure 3.15 - Share of R&D expenditures in innovation expenditures by size class and country, controlling for country, mean



Again, we define three different versions of the overall profile across size classes. Our main definition is the mean of the country values for each size class. In addition, we have the median of the country values and the mean of the firms of all countries pooled. The overall profiles which emerge from these three definitions are shown in the following figure:.

Figure 3.16 - Share of R&D expenditures in innovation expenditures by size class, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



The figure gives a strong impression of an increase in the share of R&D expenditures in innovation expenditures by firm size. Moreover, the three versions of the overall profile are almost identical, as is also indicated by the correlation matrix in the following table.

Table 3.17 - R&D shares in total innovation expenditures – correlation among indicators

	Mean	Median	All firms
Mean	1	1.00	1.00
Median	1.00	1	0.99
All firms	1.00	0.99	1

The next table shows the correlation of each country profile with each of the three versions of the overall profile.

Table 3.18 - Correlation of country profiles with overall profiles

	Mean	Median	All firms
Belgium	0.92	0.91	0.94
Denmark	0.46	0.47	0.43
Germany	0.97	0.97	0.97
Ireland	-0.91	-0.91	-0.92
Italy	0.99	0.99	1.00
Netherlands	0.99	0.99	0.98
Norway	0.96	0.97	0.94

As we see, five of the seven country profiles correlate very strongly with the overall profile. These are for Belgium, Germany, Italy, the Netherlands and Norway. However, there are deviant cases here. In the Danish case, the correlation coefficient is very moderate. And then Ireland has a profile which is practically the exact opposite of the overall profile, the correlation coefficient being almost -1.

Lastly, we test the consistency of the overall profile by means of ANOVA, in the same way as we have done earlier. Remember that for Germany there is no observation for the less than 30 employees class, so the total degrees of freedom become 40, of which the six size classes (the class variable) uses 5. The results of the analysis are shown in the table below.

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	0.1137	5	0.0227	6.37	0.0003
Within	0.1249	35	0.0035		
Total	0.2387	40			
R^2	0.48				

The probability that the differences of the mean size class values which we observe should be drawn from a population with no differences between the mean size class values is 0.0003, which means that size class has an effect which is significant at the 5 per cent significance level by a very wide margin. The R^2 is 0.48.

The overall size class means, of the mean of the R&D shares when country has been controlled for, are shown in the following table, with size classes ranked according to the share of R&D expenditures in innovation expenditures. The table also gives a rough indication of which size class values are significantly different from each other at the 5 per cent level, given the overall significance of size class differences.

Table 3.19 - R&D shares of total innovation expenditures, by size class

More than 1000	0.28	a	
300-1000	0.20	b	
100-300	0.17	b	c
50-100	0.15	b	c
30-50	0.13	b	c
30 or less	0.12		c

As we see, the mean share of R&D expenditures in innovation expenditures increases without exception as we go from the smallest firms through the middle categories to the large firms.

In the case of differences in the shares of the different expenditure components across *size classes*, we can also treat the size class variable as a quantitative variable, coding the less than 30 employees class as 1, the 30-50 employees class as 2, and so on up to the more than 100 employees class as 6. This way we can test for *linearity* through ordinary linear correlation (regression). We thus have the same 41 observations (five for Germany and six for each of the other countries) as in the analysis of variance, with the same size class variable and the same mean share of R&D expenditures, controlled for country. The only difference is that whereas in the ANOVA we treat the size variable as a nominal variable, in the regression analysis we treat it as a quantitative variable.

When we correlate these two variables, we get $r = 0.65$. This gives an R^2 of 0.42, which is almost as high as we got with the ANOVA, where it was 0.48. However, the correlation (bivariate regression) analysis uses fewer degrees of freedom than the ANOVA, so that the correlation result is actually slightly more significant than the ANOVA result, the probability value being 0.0001. Thus, we can conclude that there is a very clear tendency for the share of R&D expenditures in total innovation expenditures to increase with firm size which persists despite variation in the profiles across countries. And we should remember that the results of the ANOVA and correlation analyses emerge despite the presence of one case, namely Ireland, which deviates almost maximally from the general pattern. Considering this, the R^2 and correlation coefficient we get seem high.

The share of Non R&D expenditures in total innovation expenditures, controlling for country

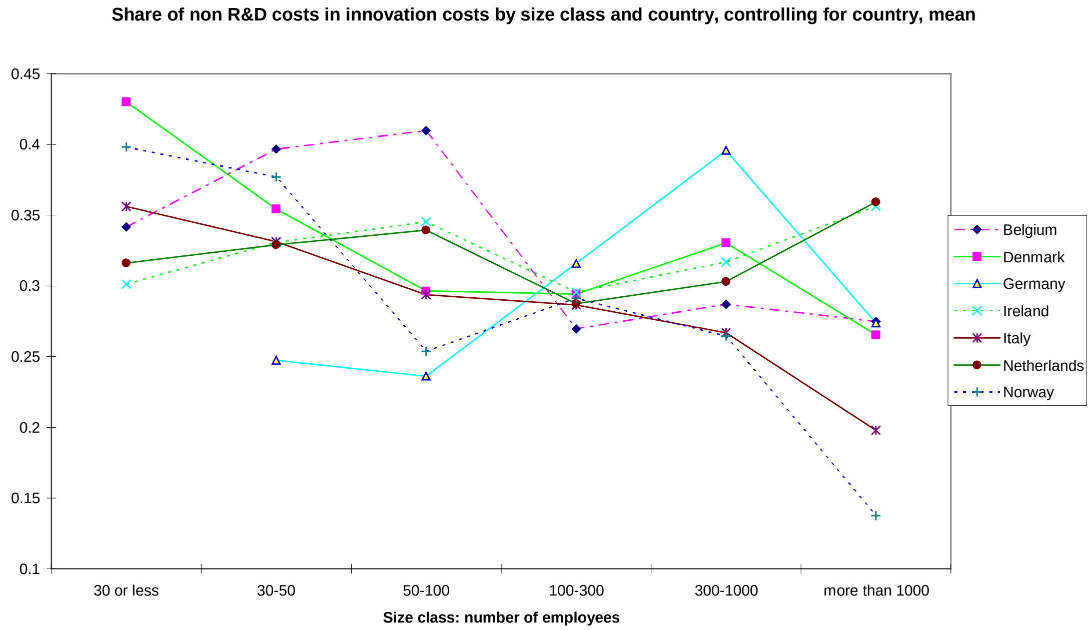
Next we look at the share of non R&D expenditures in innovation expenditures by size class. The table below shows the mean shares by industry and country when controlling for country.

Table 3.20 - Shares of non-R&D expenditures in total innovation expenditures, by size class

	Bel	Den	Ger	Irl	Ita	NL	Nor
30 or less	0.34	0.43	---	0.30	0.36	0.32	0.40
30-50	0.40	0.35	0.25	0.33	0.33	0.33	0.38
50-100	0.41	0.30	0.24	0.35	0.29	0.34	0.25
100-300	0.27	0.29	0.32	0.30	0.29	0.29	0.29
300-1000	0.29	0.33	0.40	0.32	0.27	0.30	0.26
more than 1000	0.27	0.27	0.27	0.36	0.20	0.36	0.14

The same mean shares are shown graphically in the following figure.

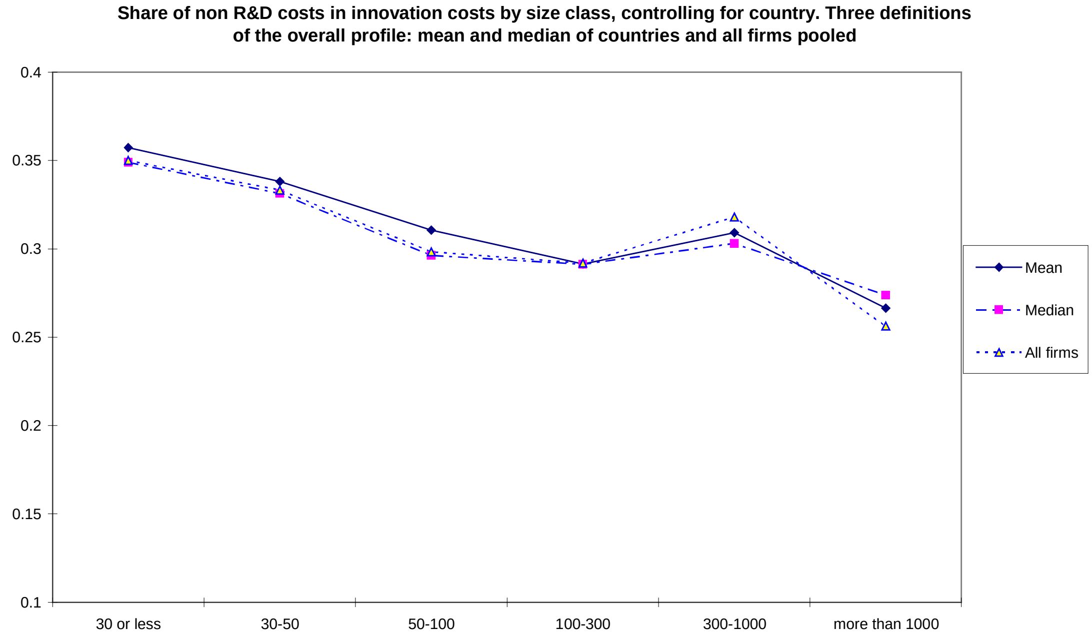
Figure 3.17 - Share of non R&D expenditures in innovation expenditures by size class and country, controlling for country, mean



The immediate impression we get here is that there is more variation across countries inside each size category relative to the variation across size categories than in the share of R&D expenditures case examined above.

As before, we construct three different versions of the overall profile, shown in the following figure.

Figure 3.18 - Share of non R&D expenditures in innovation expenditures by size class, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



In spite of all the variation in the across countries inside each size category, the three versions of the overall profile which emerge look quite similar. This impression is confirmed by the correlation matrix presented in the table below.

Table 3.21 - Non-R&D expenditure shares by size class – various indicators

	Mean	Median	All firms
Mean	1	0.98	0.97
Median	0.98	1	0.96
All firms	0.97	0.96	1

When we compute the correlation coefficients of each of the country profiles with each of the versions of the overall profile, we find some significant variation, as the following table indicates:

Table 3.22 - Non-R&D expenditure shares - correlations with overall profile

	Mean	Median	All firms
Belgium	0.60	0.49	0.46
Denmark	0.94	0.97	0.93
Germany	-0.14	-0.11	0.14
Ireland	-0.45	-0.48	-0.57
Italy	0.94	0.91	0.92
Netherlands	-0.25	-0.25	-0.42
Norway	0.93	0.93	0.94

This table confirms the impression of substantial variation across countries inside size classes. Three country profiles, Denmark, Italy and Norway, correlate very strongly with the overall profile. But one country profile, Belgium, correlates only moderately, and three country profiles, Germany, Ireland and the Netherlands, actually correlate *negatively*.

Let us again test the consistency of the overall profile by means of ANOVA, with size class as the independent variable:

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	0.0345	5	0.0069	2.46	0.0523
Within	0.0984	35	0.0028		
Total	0.1330	40			
R^2	0.26				

The probability that the differences of the mean size class values which we observe should be drawn from a population with no differences between the mean size class values is 0.0523, which means that size class has an effect which is *not* significant at the 5 per cent significance level. The R^2 is 0.26.

The following table shows the overall size class means of the share of non R&D expenditures in innovation expenditures when country has been controlled for, ranked according to these shares.

Table 3.23 - Non-R&D expenditure shares by size class

30 or less	0.36
30-50	0.34
50-100	0.31
300-1000	0.31
100-300	0.29
more than 1000	0.27

As this table and the table and figure for the overall profile above show, there seems to be a certain tendency for the mean to decrease by firm size, the exception being that the 300-1000 employees category has a share which is higher than the 100-300 category. Let us also in this case test for linearity by means of ordinary correlation, using size class as a quantitative variable with values from 1 to 6. When we do this, we find that $r = -0.47$, which gives an R^2 of 0.22. This is almost as high as in the ANOVA case. However, the regression uses fewer degrees of freedom, so that this correlation coefficient is actually significant at the 5 per cent level by a fairly wide margin, the probability of a zero correlation in the population being 0.002. Thus, in spite of the variation across countries inside size classes, there seems to be a tendency, although a rather weak one, for the share of non R&D expenditures in innovation expenditures to *decrease* with firm size.

The share of investment expenditures in total innovation expenditures, controlling for country

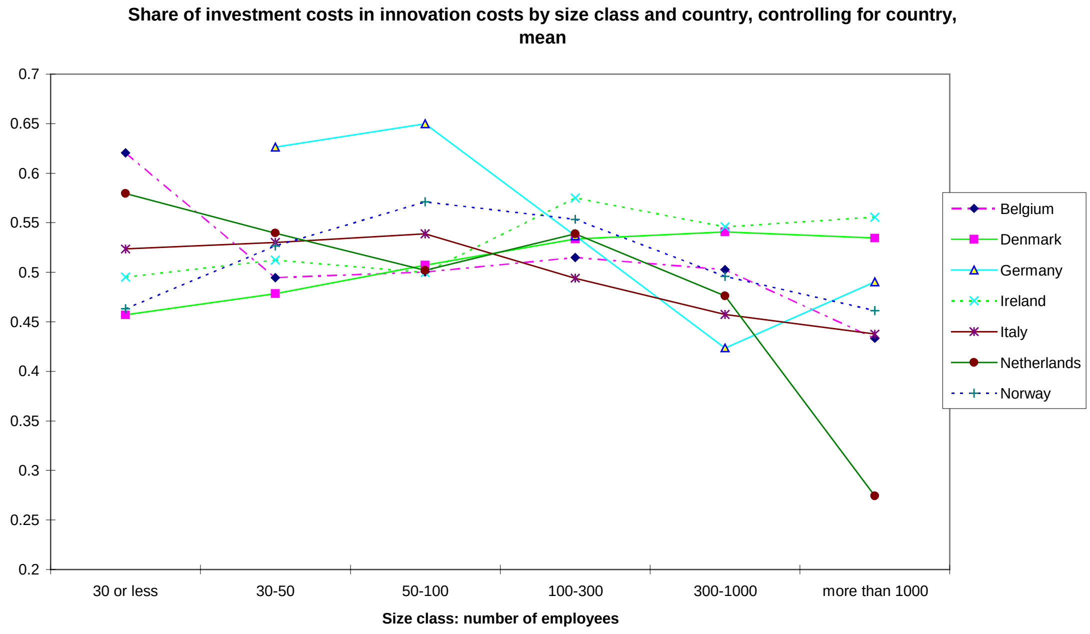
Lastly, we look at the share of investment expenditure in innovation expenditures across size classes. The table below shows the mean share of investment expenditures in innovation expenditures by country and size class when controlling for country.

Table 3.24 - Investment expenditure shares by country and size class

	Bel	Den	Ger	Irl	Ita	NL	Nor
30 or less	0.62	0.46	---	0.50	0.52	0.58	0.46
30-50	0.49	0.48	0.63	0.51	0.53	0.54	0.53
50-100	0.50	0.51	0.65	0.50	0.54	0.50	0.57
100-300	0.52	0.53	0.54	0.58	0.49	0.54	0.55
300-1000	0.50	0.54	0.42	0.55	0.46	0.48	0.50
more than 1000	0.43	0.53	0.49	0.56	0.44	0.27	0.46

The same mean shares are also shown graphically in the following figure.

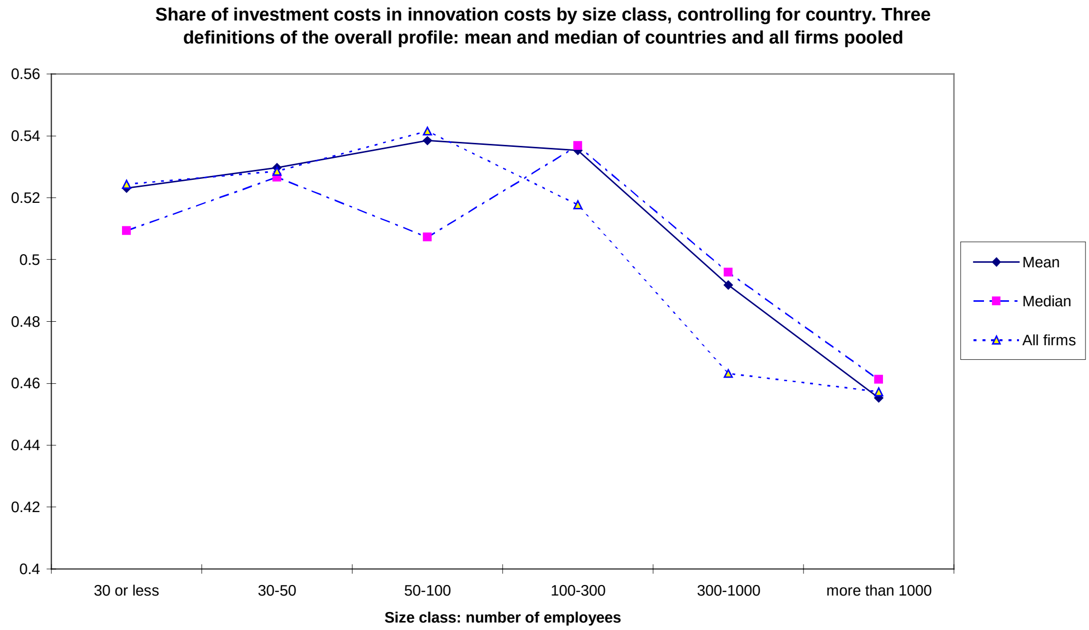
Figure 3.19 - Share of investment expenditures in innovation expenditures by size class and country, controlling for country, mean



This figure gives an impression that there is quite substantial variation across countries inside size classes.

As before, we define three versions of the overall profile across size classes. These are shown in the figure below.

Figure 3.20 - Share of investment expenditures in innovation expenditures by size class and country, controlling for country. Three definitions of the overall profile: mean and median of countries and all firms pooled



Here we see that appears to be substantial variation among the three different versions. Let us look at the correlation between these three profiles. The correlation matrix is as follows:

Table 3.25 - Investment shares: correlations among indicators

	Mean	Median	All firms
Mean	1	0.91	0.93
Median	0.91	1	0.75
All firms	0.93	0.75	1

We see that the correlation coefficient between the *median* and the *all firms pooled* definitions of the overall profile is only 0.75. The correlation of each country profile with each of the three definitions of the overall profile is given in the table below.

Table 3.26 - Investment shares: correlations between country profiles and over-all profiles

	Mean	Median	All firms
Belgium	0.54	0.46	0.50
Denmark	-0.48	-0.33	-0.65
Germany	0.71	0.47	0.91
Ireland	-0.42	-0.10	-0.59
Italy	0.90	0.69	0.97
Netherlands	0.89	0.88	0.76
Norway	0.72	0.64	0.62

The correlation coefficients are generally not high. Let us concentrate on our main definition, the mean of the country values. Two of the coefficients are high, two are moderate, one is quite low and two are negative. The impression of a consistent profile is not strong. Again we test the consistency by means of ANOVA, with class as the independent variable. The results are shown in the table below.

	Sum of squares	DF	Mean square	F-ratio	Prob.
Between	0.0369	5	0.0073	2.15	0.0827
Within	0.1206	35	0.0034		
Total	0.1576	40			
R^2	0.23				

The effect of size class here is *not* significant at the 5 per cent significance level, the probability that the differences of the mean size class values which we observe should be drawn from a population with no differences between the mean size class values being 0.0827.

The mean values in question are given in the following table, with size classes ranked by these mean values.

Table 3.27 - Investment expenditure shares by size class

50-100	0.54
100-300	0.54
30-50	0.53
30 or less	0.52
300-1000	0.49
more than 1000	0.46

As this table and the figure above graphing the overall profile show, there seems to be a certain tendency for the share of investment expenditures in innovation expenditures to decrease with firm size. The relationship does not appear to be linear, though. Rather, there is no difference in the means among the four size categories up to the 100-300 employees category, but then the mean drops with the 300-1000 employees category and further down with the more than 1000 employees category. Let us nevertheless correlate the size variable, treated as a quantitative variable, with the share of investment expenditures in innovation expenditures for all the 41 observations. We then find that $r = -0.37$. This gives an R^2 of 0.13, which is quite low, and also markedly lower than the R^2 of the ANOVA. However, because the regression analysis uses fewer degrees of freedom, this correlation coefficient is nevertheless significant at the 5 per cent level, the probability of getting a coefficient this high from a population with no relationship between the variables being 0.0184. Had we tried a non-linear specification of the relationship, we would no doubt have found a stronger association between the variables, but in the present context this would very much have had the quality of an ad hoc adaptation.

We conclude that we find little or no relationship between firm size and the share of investment expenditures in innovation expenditures when we take account of the variation in profiles across countries.

DIFFERENCES IN THE COMPOSITION OF INNOVATION EXPENDITURES ACROSS INDUSTRIES AND ACROSS SIZE CLASSES, TAKING THE ASSOCIATION BETWEEN INDUSTRY AND FIRM SIZE INTO ACCOUNT

In the same way as we did when analysing innovation expenditure intensities, we can control the differences across industries for size class, and we can control differences across size classes for industry. This will then give the *direct effects* of industry and size class, respectively. Given the same kind of very simple causal model, where both industry and firm size influences the composition of innovation expenditures, and where industry influences firm size, controlling for firm size must be interpreted differently from controlling for industry. In the case of differences across industries, the bivariate relationship between industry and composition of innovation expenditures represents the total effect of industry on the composition of innovation expenditures. When we control this relationship for firm size, we get the direct effect of industry. The total effect (the bivariate relationship) can then be decomposed into a sum of the direct effect and an indirect effect, which goes through the effect of industry on firm size and of firm size on the composition of innovation expenditures.

In the case of the differences in the composition of innovation expenditures across size classes, the bivariate relationship contains a spurious component. When we control this relationship for industry, we get the direct effect, and in this case the direct effect equals the total effect.

Let us again use the two industries basic metals and metal products as an example. We focus on the share of R&D expenditures in total innovation expenditures. We have seen that this share is 0.17 for basic metals and 0.13 for metal products. Thus, R&D expenditures accounts for 4 percentage points more of total innovation expenditures in basic metals than in metal products. However, we have also seen that the share of R&D expenditures in total innovation expenditures increases with firm size, and that in basic metals tend very clearly to have larger firms than metal products. Thus, it is highly likely that part of the difference in the share of R&D expenditures between the two industries expresses differences in firm size structure between the two industries. In fact, when we control for size class, we find that the share of R&D expenditures in both industries is 0.15. Thus, the direct effect of belonging to basic metals as opposed to metal products is zero. This means that all of the total effect of 4 percentage points difference represents an indirect effect which goes through the influence of industry on firm size and of firm size on the composition if innovation expenditures.

However, it turns out that controlling the differences in the composition of innovation expenditures across industries for firm size, and controlling the differences in the composition of innovation expenditures across size classes for industry, gives results which only marginally deviate from the results already presented when this control is not performed. This is especially so in the case of controlling differences across size classes for industry.

CONCLUSIONS

We have seen that in spite of differences across the countries, there are clear differences across industries in the *composition* of innovation expenditures. When we look at the mean share out of total innovation expenditures which each of the expenditure components account for by country and industry, controlling for country, we find that industry accounts for 45 per cent of the variance in the share of R&D expenditures, 47 per cent of the variance in the share of non R&D expenditures, and 47 per cent of the variance in the share of investment expenditures. Thus, industry appears equally important in all three cases.

However, we saw that there were specific problems connected to the *wood products* industry, where we had very few observations and very deviant composition figures for some of the countries. The results we get when we *exclude* the *wood products* industry therefore probably make more sense than the ones we get when we include this industry. When we *exclude* the *wood products* industry, we find that R^2 increases considerably for two of the three components. For the share of R&D expenditures in total innovation expenditures it increases from 0.45 to 0.66, for the share of non R&D expenditures only from 0.47 to 0.49, and for the share of investment expenditures from 0.47 to 0.70.

Thus, both for the share of R&D expenditures and the share of investment expenditures, R^2 is quite high, while it is somewhat lower for the share of non R&D expenditures. This confirms our first impression that there is more consistent variation across industries in the share of R&D expenditures and the share of investment expenditures than in the share of non R&D expenditures.

However, also for the share of non R&D expenditures in total innovation expenditures the differences across industries seem quite consistent, and perhaps more consistent than what we would suppose from our first impression. Thus, even if the variation across industries is considerably smaller in the case of the share of non R&D expenditures than in the case of the other expenditures components, this variation is still quite consistent considering the variation across countries in the individual industries.

Turning to the impacts of size class, we have seen that there is a very clear tendency for the share of R&D expenditures in innovation expenditures to increase with firm size. There appears to be a slight decrease by firm size for the two other expenditure components. But, of course, since the share of R&D expenditures in innovation expenditures increases quite consistently with firm size, the share of the sum of non R&D expenditures and investment expenditures must decrease by size class. Now, since this tendency for decrease by size class is not very clear for any of the two components, it seems quite obvious that both should decrease moderately, given the increase in the R&D share. This means that the only important pattern here is the increase by firm size in the share of R&D expenditures, with no clear pattern for the other two components over and above what must follow from the increase in the share of R&D expenditures.

In the previous chapter we saw that the intensity of innovation expenditures was primarily an industry-level phenomenon, relatively unaffected by national location or by firms size. This chapter has shown that similar conclusions can be drawn from a study of the internal composition of innovation expenditures. There are significant differences between industries, reflecting the fact that industries innovate in different ways, and commit different patterns of resources to innovation; it is especially important to note the quantitative importance of non-R&D and investment expenditures, as compared with R&D as an innovation input. More generally, European industries have much in common in committing resources to innovation – there is a European level to innovation, in which the resources used are shaped by industry characteristics, rather than by specifically national characteristics.

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Fax: +47 2242 9533
Web: http://www.step.no/

STEP-gruppen ble etablert i 1991 for å forsyne beslutningstakere med forskning knyttet til alle sider ved innovasjon og teknologisk endring, med særlig vekt på forholdet mellom innovasjon, økonomisk vekst og de samfunnsmessige omgivelser. Basis for gruppens arbeid er erkjennelsen av at utviklingen innen vitenskap og teknologi er fundamental for økonomisk vekst. Det gjenstår likevel mange uløste problemer omkring hvordan prosessen med vitenskapelig og teknologisk endring forløper, og hvordan denne prosessen får samfunnsmessige og økonomiske konsekvenser. Forståelse av denne prosessen er av stor betydning for utformingen og iverksettelsen av forsknings-, teknologi- og innovasjonspolitikken. Forskningen i STEP-gruppen er derfor sentrert omkring historiske, økonomiske, sosiologiske og organisatoriske spørsmål som er relevante for de brede feltene innovasjonspolitikk og økonomisk vekst.

The STEP-group was established in 1991 to support policy-makers with research on all aspects of innovation and technological change, with particular emphasis on the relationships between innovation, economic growth and the social context. The basis of the group's work is the recognition that science, technology and innovation are fundamental to economic growth; yet there remain many unresolved problems about how the processes of scientific and technological change actually occur, and about how they have social and economic impacts. Resolving such problems is central to the formation and implementation of science, technology and innovation policy. The research of the STEP group centres on historical, economic, social and organisational issues relevant for broad fields of innovation policy and economic growth.