

# How firms innovate: R&D, non-R&D, and technology adoption

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**How firms innovate: R&D, non-R&D, and technology adoption**

**Can Huang, Anthony Arundel and Hugo Hollanders**



# HOW FIRMS INNOVATE: R&D, NON-R&D, AND TECHNOLOGY ADOPTION

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## **Abstract:**

Non-R&D innovation is a common economic phenomenon, though R&D has been the central focus of policy making and scholarly research in the field of innovation. An analysis of the third European Community Innovation Survey (CIS-3) results for 15 countries finds that almost half of innovative European firms did not perform R&D in-house. Firms with weak in-house innovative capabilities and which source information from suppliers and competitors tend to innovate through non-R&D activities. In contrast, firms that engage in product innovation, find clients, universities and research institutions an important information source for innovation, or apply for patents or use other appropriation methods are more likely to perform R&D. However, non-R&D performers do not form a consistent block, with several notable differences between firms that use three different methods of innovating without performing R&D. Many of these determinants also influence the share of total innovation expenditures that are spent on non-R&D innovation activities. Furthermore, an analysis of the determinants of the share of each firm's total innovation expenditures for non-R&D activities shows that the factors that influence how innovation expenditures are distributed is generally consistent across sectors and European countries.

**Key Words:** Non-R&D innovation, Technology adoption, Community Innovation Survey, CIS, R&D, Innovation

**JEL Classification:** O31, O32, O33, L13, L60

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## 1. INTRODUCTION

Firms innovate through a wide range of activities, including the acquisition of new process technologies, incremental engineering to increase productivity, the combination of existing knowledge in new ways, and investment in R&D to increase the stock of knowledge and to apply this knowledge to create new or improved products and processes. Yet the majority of scholarly research and policy documents on innovation focus almost entirely on R&D, ignoring other methods that firms use to innovate (Arundel, 2007). This focus on R&D is reflected in the structure of innovation support programmes. A study using data on the expenditures of national European programs to support innovation, estimated that approximately 95 percent of all such funding in Europe was directed to supporting R&D, with less than 5% of funding available to innovative firms that do not perform R&D (Arundel, 2007).

The central role of R&D in innovation research and policy is supported by the value of R&D to technological innovation. R&D is the source of many productivity enhancing innovations and is essential to the competitiveness of fast-growing medium- and high-technology industries such as pharmaceuticals, automobiles, computers, communications, instruments, and machinery. R&D is also critical to the absorptive capacity of a firm and an industry (Cohen and Levinthal, 1989, 1990). The application of R&D to produce technologically advanced products for export can also improve the terms of trade at the national level. In addition, R&D activities create a demand for high caliber human resources, which provides an impetus to develop and improve educational systems, leading to potential benefits throughout an economy.

Although R&D provides many advantages, it is not useful by itself. In order to create economic benefits, the results of R&D must be incorporated into products and processes that reach the market and these products or processes must be widely adopted – in other words R&D must lead to innovation and to the diffusion of productivity-enhancing technologies. The rapid adoption of new technologies partly explains why national investments in R&D are not strongly correlated with average incomes. Ireland, the United Kingdom, Australia and The Netherlands have R&D intensities that are below the average for OECD countries, but enjoy similar or even higher per capita incomes than that of countries that are major R&D performers, such as Sweden, Finland and Germany.

In addition to innovating through developing new products and processes through R&D or by acquiring new technology, firms can innovate through three types of creative activities that do not require R&D (Arundel *et al.*, 2008). First, firms can make minor modifications or incremental changes to products and processes, relying on engineering knowledge (Kline and Rosenberg, 1986; Nascia and Perani, 2002). Hansen and Serin (1997) note that the innovation process in low- and medium-technology sectors is often less formal and more related to adaptation and learning by doing, based on design and process optimization, rather than formal R&D. Second, many imitative activities, including reverse engineering, do not require R&D (Kim and Nelson, 2000). A variant of this approach is for firms to adopt innovations developed by users, which von Hippel argues is increasingly common (von Hippel, 2005; Gault and von Hippel, 2009). Third, firms can combine existing knowledge in new ways, which can include industrial design and engineering projects (Grimpe and Sofka, 2009; Evangelista *et al.*, 2002).

Innovating without performing R&D is widespread. After population weighting, the 2007 Innobarometer survey of 4,395 innovative European firms found that 52.5% of these firms innovated without performing R&D or contracting out R&D (Arundel *et al.*, 2008).<sup>1</sup> Due to the high share of firms that innovate without performing R&D, the factors that influence firms to innovate without drawing on R&D are of relevance to our understanding of innovation and the development of innovation policy. In this paper, we take a closer look at the options available to firms that innovate without performing R&D in-house and we examine the factors that influence firms to allocate part of their innovation budget to non-R&D innovation activities.

We use data for a sample of 14,931 manufacturing and service sector firms that responded to the third European Community Innovation Survey (CIS-3). Innovative firms are classified into four mutually exclusive groups. The first group consists of firms that perform R&D in-house (in-house R&D performers). The remaining three groups of non-R&D performing firms includes firms that contract out R&D (contract R&D performers), firms that conduct some creative activities in-house, but do not perform R&D (non-R&D innovators), and firms that only report acquiring new technology from other firms (technology adopters).

The analytical results show that firms with a low level of in-house innovative capabilities, demonstrated by small firm size, an absence of staff with tertiary education, and a lack of exports, are more likely than other firms to innovate without performing R&D. These results are consistent for firms in both the manufacturing and service sectors. However, there are also many

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<sup>1</sup> The high share of innovative firms that do not perform R&D was not due to high rates of technology adoption. Only 11.2% of non-R&D performing innovative firms were pure technology adopters that did not report creative innovative activities in-house.

differences in the factors that influence the method of innovation used by firms that do not perform R&D in-house. For example, suppliers and competitors are an important information source for non-R&D innovators, but not for firms that contract out R&D or for firms that are technology adopters. These and other differences suggest that a simple contrast between innovative firms that do and do not perform R&D in-house is insufficient for understanding innovation.

## **2. THEORETICAL CONTEXT AND HYPOTHESES**

The seminal work on the choice between innovating through R&D or through non-R&D activities is by Veugelers and Cassiman (1999). In their paper, firms can choose to ‘make’ an innovation through in-house R&D or they can decide to ‘buy’ an innovation through contracting out R&D, licensing inventions, using consultancy services, or obtaining new technology either through purchasing another firm or by hiring new employees. Of note, there is no option for ‘making’ an innovation in-house without performing R&D. In addition, Veugelers and Cassiman exclude the direct purchase of new technology because of its high prevalence in both the ‘make’ and ‘buy’ firms.

Similar to Veugelers and Cassiman, we assume that firms can choose different methods of innovating, but we include a more complex set of four options. The main choice is between innovating through R&D and innovating through other methods. The R&D option includes two choices: R&D can be performed in-house (in-house R&D performers) or only contracted out to other firms or organizations (contract R&D performers). The non-R&D option also includes two

choices. Firms can conduct creative, in-house activities that do not require R&D, such as production engineering or design work (non-R&D innovators). Alternatively, they can only innovate through buying advanced machinery, computer hardware and software, or licenses from other firms or organizations. The latter firms are defined here as technology adopters.

The four categories of innovative firms are aligned along an unobserved scalar variable of in-house innovative capability. We assume that firms that innovate in-house through R&D have the highest level of in-house innovative capabilities, while firms that only innovate through technology adoption have the lowest level of innovative capability, at least during the three years covered by the third CIS survey. Contract R&D performers and non-R&D innovators are assumed to have moderate levels of in-house innovative capabilities. It is difficult to determine which of these latter two types of firms are more innovative. In most cases contracting out R&D could require some level of in-house expertise or absorptive capacity (Cohen and Levinthal, 1990) to fully describe the problem or to implement the results, but non-R&D innovators could use advanced engineering and other competences that exceed the capabilities of contract R&D performers.

We expect different sets of factors to influence the firm's choice on *how* it innovates.

Furthermore, all firms, including firms that perform R&D, can choose to spend part of their innovation budget on innovation activities that do not require R&D. The share of the innovation budget spent on non-R&D activities is likely to vary across a range of factors. The next section identifies factors that could influence 1) how firms innovate and 2) the share of their innovation budget spent on non-R&D activities.

## 2.1 Indirect and direct measures of innovative capabilities

One of the primary determinants of how firms innovate and how they allot their innovation budgets to different innovative activities is likely to be their capabilities to finance, manage, and develop technological and organizational innovations. We use direct and indirect measures in this paper to gauge the general abilities of firms to finance and manage innovation. Two indirect measures or proxies of each firm's general capabilities are firm size and export status.

Most of the research on the effect of firm size on innovation has focused on R&D. Schumpeter (1950) was among the first to hypothesize that large firms in a mature capitalist economy generate a disproportionately large share of a society's technological advances, presumably through R&D.

There are several possible explanations for the effect of firm size on how firms innovate and particularly on their decision to perform R&D in-house. Compared to small firms, large firms possess substantially more internally-generated funds that they can invest in risky R&D projects and they can benefit from the economies of scale in R&D activity. Empirical research has consistently found that the prevalence of any in-house R&D increases with firm size, although the relationship between the amount invested in R&D as a share of total revenues (R&D intensity) and firm size can be complex. For instance, Cohen *et al.* (1987) find that the relationship between firm size and R&D intensity varies by sector. In a recent study, Lee and Sung (2005) contend that size influences firm-specific technological competences that can be of value to both R&D and other methods of innovating.

Rammer *et al.* (2009), based on the results of an analysis of innovation survey data for Germany, identified several reasons why large firms possess higher internal capabilities than small firms and are thus more likely to engage in R&D. First, R&D often requires high initial investments in laboratory equipment and advanced instruments and large fixed costs over time. Small firms are more likely to lack the internal sources of finance for both the initial costs (creating an entry barrier) and for the fixed costs over time. They may face barriers to raising capital from external sources because of a lack of collateral and a record of past successful R&D projects. R&D projects are also risky, with many failing. Small firms can lack the financial resources to maintain a portfolio of several R&D projects to hedge against the risk of failure.

A second indirect measure of innovative capabilities is whether or not the firm exports. Tomiura (2007) analyzed a dataset of 118,300 Japanese manufacturing firms and found that exporters, on average, are more active in innovation than non-exporters, own more patents and declare more R&D expenditure. Firms are unlikely to export goods and services unless they have sufficient capabilities in organizational learning and innovation to enter and compete in foreign markets where they lack experience. Exporters can need to adapt products to local market conditions, offer customized applications, and take advantage of new market opportunities through rapid new product development (Filatotchev and Piesse, 2009). Export activities can also directly influence how firms innovate through feedback effects. Exposure to a wider range of technologies than those available in the domestic market can give exporting firms an edge over domestic rivals, encouraging them to invest in R&D activities (Girma *et al.*, 2008; Harris and Li, 2009).

Two direct measures of innovative capabilities are available from innovation surveys: in-house innovation activities and the skills of the human capital employed by the firm. Firms can develop innovations without external assistance, develop innovations by collaborating with other firms or organizations such as universities, or they can largely acquire new technology developed by other firms (OECD, 1997). Firms that can develop innovations in-house, with or without R&D, are likely to have higher innovative capabilities than firms that only acquire new technology developed by others (Arundel, 2007).

Human capital has long been considered as a critical resource in firms. The technological and innovative capabilities of a firm's labor force depend on the educational level, training, and experience of its employees and managers (Hitt *et al.*, 2001) and the ability of managers to effectively use these skills to solve problems (Herrera *et al.*, 2010). Educated and experienced employees are an essential prerequisite for high-level innovative activities to generate new knowledge and absorb existing knowledge. Employees with advanced education, training, and experience are particularly important in science-based industries (Luo *et al.*, 2009).

Based on the literature on the relationship between innovation and the capabilities of a firm, we make the following prediction:

Hypothesis 1: Firms with lower innovative capabilities (small firms, firms that do not export, firms that lack highly skilled staff, and firms that do not have in-house innovation activities) will

be more likely to innovate through non-R&D activities and spend a higher share of their innovation budget on these activities.

## **2.2 Product and process innovation**

Product and process innovations have different characteristics which can influence how they are developed. Product innovation is the introduction of new or significantly improved goods or services, while process innovation is the introduction of a new or significantly improved production or delivery method (OECD, 1997). Process innovations can include improvements to service operations, logistics, work and information flows, and equipment (Reichstein and Salter, 2006). Compared with process innovation, product innovation more often involves R&D (Rouvinen, 2002; Mairesse and Mohnen, 2005). In contrast, process innovation often requires the participation of external suppliers (von Hippel, 1988; Rouvinen, 2002; Cabagnols and Le Bas, 2002) and can frequently involve innovative activities that do not require R&D, such as the purchase of advanced machinery, computer hardware and software, the acquisition of patents and licenses, investment in training, and other procedures such as design and production engineering. In line with these arguments, we test the following hypothesis:

Hypothesis 2: Product innovators are more likely than process innovators to perform R&D, while process innovators are more likely to engage in non-R&D activities and spend more of their overall innovation budget on these activities.

### **2.3 Information sources as proxies for technological opportunities**

The methods that a firm uses to innovate and how it allocates its innovation budget could be affected by differences in technological opportunities. Technological opportunities differ because the scientific and technological know-how relevant for each industry advances at different paces and with varying degrees of difficulty. Even within a sector, technological opportunities can vary due to differences in specific markets. There are three different sources of technological opportunities: advances in scientific understanding and technique; technological advances in other industries and in other institutions in the economy; and an industry's technological advances in one period that open up new technological opportunities for the next (Klevorick *et al.*, 1995). Firms operating in an environment with high-level technological opportunities will have greater incentives to invest in R&D because of a higher probability of inventing commercially successful processes or products (Nieto and Quevedo, 2005; Vega-Jurado *et al.*, 2008).

Differences in technological opportunities at the level of the firm can be identified from the types of information sources that the firm draws on to innovate. Firms that source information from universities or research institutions are likely to face greater technological opportunities than firms that source information from suppliers, and thus have higher R&D intensity. Klevorick *et al.* (1995) and Levin *et al.* (1985) found a positive correlation between sourcing information from universities and government research laboratories and R&D expenditures, but Klevorick *et al.* did not find a positive correlation between strong links with suppliers and R&D expenditures. Klevorick *et al.* (1995) suggested that R&D by universities and government research institutes

could complement industrial R&D, while the R&D of equipment suppliers partly substitutes for the R&D of other private firms.

Pavitt (1984) argued that most innovations in supplier-dominated sectors such as textiles, leather and footwear come from suppliers of equipment and materials. Firms that source innovations from suppliers are therefore expected to spend the majority of their innovation expenditures on purchasing advanced machinery and equipment. In contrast, science-based firms in sectors such as pharmaceuticals or information technology produce a relatively high proportion of their own technology, often through R&D. Levin *et al.* (1985) report similar results, with R&D intensities increasing with greater reliance on public sector research. Evangelista *et al.* (1997), using the second European Community Innovation Survey results for 22,000 Italian manufacturing firms, found that science-based firms active in office machinery and computers, radio, TV and telecommunications, pharmaceuticals and precision instrument sectors allocated more than 50 percent of their innovation expenditure to R&D. In comparison, supplier-dominated and production-intensive firms in wood, textiles, leather and footwear, food and metal products, printing and publishing, paper, rubber and plastic and motor vehicles spent more than 50 percent of their innovation budgets on non-R&D activities such as purchasing new machinery.

Firms can also obtain information to support their innovative activities from their competitors and from open sources such as professional conferences, meetings and journals. However, the impact of these sources on technological opportunities and how firms choose to innovate, and the proportion of their budget spent on non-R&D activities, is ambiguous. Information obtained from competitors and from open sources could replace in-house R&D or it could create

spillovers that lead to new technological opportunities, enhancing the benefits of conducting in-house R&D.

In line with the above arguments, we assume that how firms innovate and the share of their innovation budget spent on non-R&D activities will vary by their technological opportunities. These will vary both across sectors and within sectors. We use sector dummies to control for differences in technological opportunities across sectors, while the types of information sources used by the firm are assumed to capture firm-specific differences in technological opportunities. We develop a third hypothesis based on the types of information sources that firms use:

Hypothesis 3: Firms sourcing information from suppliers will tend to innovate through non-R&D activities and spend more of their overall innovation budget on these activities, while firms that source information from universities and research institutions will tend not to do so.

## **2.4 Appropriability**

A precondition for the decision to invest in financially expensive and riskier innovation activities such as R&D is a reasonable expectation of being able to appropriate innovation investments through higher prices for new or improved products or through lower production costs. Common strategies for increasing the level of appropriability include the use of patent protection, trademarks, copyright, secrecy, lead-time advantages over competitors, design complexity, and the ownership of specialized complementary marketing and manufacturing assets (Arundel and Kabla, 1998; Cohen *et al.*, 2002). Ceccagnoli (2009) argued that strong appropriability

conditions, for instance through patent protection and ownership of specialized complementary assets, have a large and positive impact on a firm's economic performance. This could feed back into higher investments into creative innovative activities, particularly R&D.

Patenting is frequently viewed in the theoretical literature as the most effective appropriation method, but the effectiveness of patents is limited by the opportunities for competitors to invent around a patent, the cost of a patent versus other appropriation methods such as secrecy or lead-time advantages, and the speed of technological change. The interplay of these factors results in large variations in the effectiveness of patents across industries and firm size, as shown in survey research in the United States (Levin *et al.*, 1987; Cohen *et al.*, 2002) and in Europe (Arundel and Kabla, 1998; Arundel, 2001). Patents appear to be most valuable to R&D intensive firms and science-based small firms (Leiponen and Byma, 2009).

The use of strategies to increase appropriability is expected to increase with the level of investment in activities that produce novel innovations. Therefore, non-R&D performers, particularly technology adopters, are expected to use fewer appropriability strategies than R&D performing firms.

Based on the above arguments, we propose the following hypothesis:

Hypothesis 4: Firms that use patents or other appropriation methods (industrial designs, trademarks, copyright, secrecy, design complexity, or lead-time advantages) to increase

appropriability are less likely to innovate through non-R&D activities and will spend a smaller share of their overall innovation budget on these activities.

## **2.5 Risks from innovation investments**

Another factor that should influence how firms innovate is the riskiness of investments in innovation. This can involve both economic risks and information risks, such as when there is a lack of good information on potentially useful technical solutions.

On average, innovation projects that do not involve R&D should be less financially risky than R&D based innovation projects. The least risky activity should be technology adoption because firms can obtain relatively complete information on the characteristics of existing technologies that were developed by other firms. Similarly, some in-house activities that do not require R&D, such as modifying existing production lines to reduce costs, are likely to be low risk, while design or incremental improvements could involve moderate risk, due to difficulties in estimating consumer responses or potential markets. The riskiest activity is expected to be R&D, since R&D projects can be difficult to budget and can fail completely. This could also be true of R&D that is contracted out.

The riskiness of an innovation project could be increased by a lack of information on available technology for solving a problem. Firms facing a lack of technological information could be forced to invest in R&D. Alternatively, when plentiful information is available on a possible technology, firms could forego risky investments and innovate through investing in advanced

machinery and equipment or through licensing in other patented technology. We expect firms that report a high level of importance for a lack of information to be more likely to invest in R&D. Firms that source information from their clients, such as on the types of enhanced products that they would like to buy, should experience a decline in market risk (von Hippel, 1988; Lundvall, 1988) and consequently be more willing to invest in R&D. Therefore, hypothesis 5 is as follows:

Hypothesis 5: Firms that face high economic risks from innovation should be more likely to invest in less risky methods of innovation that do not involve R&D, while firms that face a lack of information on technologies, or a decline in market risk, should be more likely to invest in R&D.

### **3. DATA, METHDOLOGY AND VARIABLES**

#### **3.1 Data**

In this study we use data from the third European Community Innovation Survey (CIS) to test the five hypotheses. The survey collected data on the innovative strategies of European firms active in manufacturing and in selected service sectors from 1998 to 2000, inclusive, and on their innovation expenditures for 2000. As with the first and second Community Innovation Surveys<sup>2</sup>,

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<sup>2</sup> The first and second CIS surveys were limited to technological innovation, as defined by the Oslo Manual. The third CIS, used in this study, introduced five questions on non-technological innovation, covering strategic, management, organizational and marketing changes, plus aesthetic changes to product design. None of these forms of innovation require R&D. Respondents to the third CIS that only innovated through non-technological innovations are excluded from this study in order to clearly identify the importance of non-R&D forms of innovation to firms that could also choose to conduct R&D.

the third CIS is based on the Oslo Manual (OECD, 1997) which provides methodological guidelines for defining and measuring innovation and innovative activities.

This study uses micro-aggregated, anonymized data from the third CIS that prevents the identification of individual firms (Eurostat, 2005). We evaluated the reliability of the micro-aggregated data by running a preliminary set of identical regressions on both the anonymized and non-anonymized data. The latter can only be accessed at the Eurostat offices in Luxembourg, which creates a serious constraint for ongoing data access. We found no substantive differences in the results of preliminary probit and OLS regressions run on the two types of data. Consequently, we rely solely on the micro-aggregated dataset for the final results in this paper.

The cleaned sample of innovative firms used in this study includes 14,931 firms that introduced either a product or process innovation between 1998 and 2000. The firms are located in 15 European countries: Belgium (734 firms), Bulgaria (841), Czech Republic (1074), Estonia (717), Germany (1805), Greece (468), Hungary (258), Iceland (148), Latvia (437), Lithuania (624), Norway (1528), Portugal (799), Romania (1799), Slovakia (439) and Spain (3260).<sup>3</sup>

We classify the innovative firms into four types of innovators: in-house R&D performers, contract R&D performers, non-R&D innovators and technology adopters, using a latent measure of innovative capabilities. In-house R&D performers report intramural R&D activities. Contract R&D performers lack intramural R&D, but report extramural R&D, for instance through

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<sup>3</sup> We exclude cases with negative innovation expenditures.

contracting out R&D to another firm or organization. Non-R&D innovators report neither intramural nor extramural R&D activities, but report one or more of the following activities: acquisition of other external knowledge such as patents, know-how, trademarks or software to use in innovations; training for innovation, market introduction of innovations, design, and other preparations for production/deliveries. Technology adopters report none of the above activities, but acquired advanced machinery or equipment and introduced new or improved products or processes that were mainly developed by other enterprises and institutions. The four categories are mutually exclusive, with each respondent firm to the third CIS assigned to only one of these four categories.

Among the unweighted 14,931 respondent firms, 8,188 (54.8%) are classified as in-house R&D performers, 810 (5.4%) are contract R&D performers, 5,399 (36.2%) are non-R&D performers, and the remaining 534 (3.6%) are technology adopters. After population weighting,<sup>4</sup> 46% of the innovative firms in the 15 countries covered in the micro-aggregated CIS-3 data innovated without performing R&D in-house or contracting out R&D. Figure 1 gives the distribution of the unweighted results by country. Compared to the weighted results, R&D performers are over-sampled. The unweighted share of firms that neither perform in-house R&D nor contract out R&D is much higher in the economic transition countries of Bulgaria, Romania and Estonia than in the economically-developed countries, such as Norway, Belgium and Germany. Figure 2

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<sup>4</sup> Since the CIS is a random survey instead of a census, population weighting scales up the estimates to the known population of firms in each country surveyed by the CIS, using information on the number of firms in each sampling cell (defined by sector, firm size, and country). This provides the best possible estimate of the distribution of each type of innovative firm and corrects for oversampling of R&D performers in many countries. Following standard practice for innovation survey research, the unweighted results are used in the regression analyses.

provides an unweighted breakdown by firm size. As expected, the percentage of firms that do not perform R&D in-house declines with firm size.

(Here insert Figure 1)

(Here Insert Figure 2)

One possible explanation for the high percentage of firms that innovate without drawing on R&D is that the respondents to innovation surveys fail to understand the concept of R&D and are therefore unable to accurately report both R&D and non-R&D activities. An evaluation of research on this issue (Arundel *et al.*, 2008) finds that innovation surveys are more likely to over-report than under-report R&D in comparison to Government R&D surveys, as shown in one study by Kleinknecht (1987) using data for the Netherlands. Roper (1999) reports that 2.4% of German small firms fail to report R&D, but this is a relatively minor degree of under-reporting. The rate of under-reporting is likely to be highest in the service sectors, since the concept of R&D fits more easily with the science and engineering disciplines used in manufacturing (Djellal *et al.*, 2003).

### **3.2 Regression models**

We assume that firm managers choose between each of the four different methods of innovating, using an assessment of their firms' capabilities, the financial advantages and costs of each innovation method, and other relevant information available to them. Under this assumption of a discrete choice, the appropriate model is a multinomial logit, shown in equation 1. This model

determines if the relevant factors identified in each of the five hypotheses influence the firms' decision to choose one of the four methods of innovating.

$$(1) \text{Pr ob}(Y_i = j | x_i) = \frac{e^{\beta_j x_i}}{1 + \sum_{k=1}^J e^{\beta_k x_i}} \text{ for } j=1, 2, \dots, J. \beta_0=0.$$

$$(2) \delta_i = \frac{\partial P_i}{\partial x_i} = P_j \left[ \beta_j - \sum_{k=0}^J P_k \beta_k \right]$$

It is difficult to interpret the coefficients  $\beta_j$  of the multinomial logit model estimated from equation (1) because it does not provide the marginal effects. As shown in equation (2), the

marginal effect  $\delta_j$ , i.e.  $\frac{\partial P_i}{\partial x_i}$ , need not have the same sign as  $\beta_j$  because every  $\beta_j$  enters every

marginal effect  $\delta_j$ . We therefore provide the marginal effects  $\delta_j$  of the multinomial logit model results instead of the coefficients  $\beta_j$ . The marginal effect measures the change in the probability that a firm chooses a specific method of innovating, given a one unit change in the value of a continuous explanatory variable or a one-unit change in a dummy variable (from 0 to 1).<sup>5</sup>

In addition to studying the decisions of firms to choose between one of four methods of innovating, we are also interested in the factors that influence the share of each firm's innovation budget spent on innovation activities that do not involve R&D. We therefore use the non-R&D innovation expenditure share as the dependent variable, which is defined as the ratio of non-R&D innovation expenditures (excluding expenditures on in-house and contract R&D) to the

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<sup>5</sup> See Greene (2003, p. 720) for the estimation of the multinomial logit model and its marginal effects.

firm's total innovation expenditures. Among the 12,766 innovative firms which declared positive innovation expenditures, 11,305 invested in non-R&D innovation activities and 1,461 only reported R&D expenditures.

We use two regression models to examine the effect of a set of independent variables on the non-R&D innovation expenditure share. We observe non-R&D innovation expenditures only for firms that invest in these types of innovation activities. The first model uses Ordinary Least Squares regression (see equation 4) and excludes 1,461 firms that do not report any innovation expenditures outside of R&D.

The second method uses a standard Tobit model and includes the 1461 firms whose non-R&D innovation expenditure share equals zero. This provides a robustness check of the baseline ordinary least square model. In the Tobit model (see equations 3 – 5),  $y_i$  is the observed response and  $y_i^*$  is the value of the latent variable for the non-R&D innovation expenditure share:

$$(3) \quad y_i = 0 \text{ if } y_i^* \leq 0,$$

$$(4) \quad y_i = y_i^* \text{ if } y_i^* > 0,$$

$$(5) \quad y_i^* = x_i \beta + \varepsilon_i.$$

The coefficients of the above model could be biased if there is sample selection bias, for instance if the amount of expenditure on non-R&D innovation activities is influenced by the decision on whether or not to invest in these activities. To examine the issue of sample selection bias, we draw on the following sample selection mechanism:

$$(6) \quad y_i = x_i \beta + u_{1i},$$

where  $y_i$  is observed only when  $z_i = 1$ .

$$(7) \quad z_i = 1 \text{ if } z_i^* = w_i \gamma + u_{2i} > 0 \text{ and } 0 \text{ otherwise.}$$

$$(8) \quad u_{1i} \sim N(0, \sigma_{u_{1i}}^2)$$

$$(9) \quad u_{2i} \sim N(0, 1)$$

$$(10) \quad \text{corr}(u_{1i}, u_{2i}) = \rho.$$

Equation (6) is the outcome equation, which estimates the non-R&D expenditure share of a firm if it chooses to invest in such activities. Equation (7) is the selection equation that estimates whether a firm would invest in non-R&D innovation activities. The selection indicator  $z_i$  is equal to 1 if a firm invests in non-R&D innovation and 0 otherwise. If the disturbance  $u_{2i}$  in equation (7) is correlated with the disturbance  $u_{1i}$  in equation (6), a sample selection model should be adopted. Following Heckman (1979), we estimate the sample selection model through a two-step procedure. We conduct the likelihood-ratio test of the null hypothesis that  $u_{1i}$  and  $u_{2i}$  are independent, i.e.  $\rho = 0$ . If the null hypothesis is not rejected, it means that the selection equation and outcome equation can be estimated separately. In other words, the estimation results of the OLS model are unaffected by sample selection bias.

The results of the OLS model, standard Tobit model, and the Heckman sample selection model are broadly similar.

### 3.3 Independent Variables

With two exceptions, the same set of independent variables is used in the multinomial model of the factors that influence the firm's choice of how to innovate and in the OLS, Tobit and Heckman models of the share of innovation expenditures spent on non-R&D innovation activities. The exceptions include the variables for 'in-house innovation activities' and 'innovation expenditure intensity' which are excluded from the multinomial model.<sup>6</sup>

Four dummy variables are constructed to measure the ability of the firm to develop innovations that require creative effort: two indirect variables (firm size and export status) and two direct variables (in-house innovation activities and human resources). We use two dummy variables for small and large firm size to measure the impact of firm size on the dependent variable. The variable 'small firm' equals 1 if the firm employs 10-49 employees and zero otherwise. The variable 'large firm' equals 1 if the firm employs 250 or more employees and zero otherwise. The reference category includes firms that employ between 50 and 249 employees. The value of 'export' equals 1 if the firm reported exports in 2000 and zero otherwise. The value of 'in-house innovation activities' is equal to 1 if the firm reported introducing a new or significantly improved product or process innovation that was mainly developed by the firm or other members of its enterprise group, without the involvement of other, unaffiliated firms or organizations. The value of 'employee with higher education' equals 1 if one or more employees had a university level education and zero otherwise.

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<sup>6</sup> The value of 'in-house innovation activities' for technology adopters is 0 by definition (seen in the following paragraph) and therefore can not explain the decision to innovate through technology adoption. The variable for the innovation expenditure intensity is not included in the multinomial model for how firms innovate because the value is missing for 25% of technology adopters (versus only 2.6% of in-house R&D performers). This results in a high loss of cases for technology adopters, distorting the results.

The type of innovation is captured by two dummy variables, 'product innovation' and 'process innovation', which equal 1 if the firm reports introducing, respectively, a new or significantly improved product or a new or significantly improved process between 1998 and 2000.

Technological opportunities are explored through variables for the use of different information sources between 1998 and 2000 'for suggesting new innovation projects or contributing to the implementation of existing projects'. The information sources include suppliers, competitors, university and research institutions, and conferences, journals and fairs. The survey provides interval level data, ranging from high (3), medium (2) to low importance (1). The value of each variable equals zero if the firm does not use the information source.

Appropriability is measured by two dummy variables: whether or not the firm has applied for one or more patents and whether or not the firm reports the use of other innovation protection methods between 1998 and 2000. The other methods include the use of design registration, trademarks, copyright, secrecy, complexity of design and lead-time advantages.

We construct a variable, 'economic risk', for the financial riskiness of innovation. The variable equals the highest reported value to one of three factors that could hamper innovation: excessive perceived economic risks, high innovation costs, or a lack of appropriate sources of finance. For instance, the value equals 3 if a firm ranks one of the three economic risk factors as of 'high' importance, 2 if the highest score given to one of these three factors is of medium importance, and 1 if the highest value given to any of the three questions is of 'low importance'. If none of

the three factors are reported as relevant, the value is 0. The variable for risk from a lack of information is obtained from a survey question on the ‘lack of information on technology’ as a hampering factor. A high importance of a lack of information is given a value of 3, a medium level importance a value of 2, and a low level of importance a value of 1 (with a score of zero when the factor is not relevant to the firm).

A variable for obtaining information from customers is also included, with the variable identical to the other information source variables. It is expected to capture a decline in market risk.

### **3.4 Control variables**

As noted earlier, technological opportunities are expected to vary by each firm’s sector of activity, with higher technological opportunities expected for firms active in high-technology sectors than for firms active in low technology sectors. We classify firms into low, medium-low, medium-high and high-technology manufacturing sectors and into knowledge-intensive and less knowledge-intensive services sectors, using the definitions of each type of sector established by the OECD and Eurostat<sup>7,8</sup>, in order to control for differences in technological opportunities by

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<sup>7</sup> High-technology manufacturing includes aerospace (NACE 35.3), pharmaceuticals (24.4), computers and office machinery (30), electronics-communications (32) and scientific instruments (33). Medium-high technology manufacturing includes electrical machinery (31), motor vehicles (34), chemicals, excluding pharmaceuticals (24, excluding 24.4), other transport equipment (35.2, 35.4 and 35.5), and non-electrical machinery (29). Medium-low technology manufacturing includes coke, refined petroleum products and nuclear fuel (23), rubber and plastic products (25), non metallic mineral products (26), shipbuilding (35.1), basic metals (27) and fabricated metal products (28). Low-technology manufacturing includes other manufacturing and recycling (36 and 37), wood, pulp, paper products, printing and publishing (20, 21 and 22), food, beverages and tobacco (15 and 16), and textiles and clothing (17, 18 and 19). The knowledge-intensive service sectors include water transport (61), air transport (62), post and telecommunications (64), financial intermediation (65, 66 and 67), computer and related activities (72), research and development (73), and other business activities (74). The other service sectors include motor trade (51), land transport and transport via pipelines (60) and supporting and auxiliary transport activities and activities of travel agencies (63)(cf. the Concepts and Definition Database (CODED), Eurostat, available at

sector and for other sectoral factors that can influence both how firms innovate and the share of innovation expenditures spent on non-R&D activities. Hansen and Serin (1997) argue that the innovation process in low- and medium-technology sectors are often less formal and more related to adaptation and learning by doing than in high-technology sectors. In low- and medium-technology sectors, the embodied knowledge is transferred from suppliers through marketing, design and process optimization, rather than through formal R&D. Santamaria *et al.* (2009) find that non-R&D activities such as design, the use of advanced machinery and training are crucial to firms in low- and medium-technology industries. Therefore, we expect firms active in low and medium-high technology sectors to spend a higher share of their innovation budgets on non-R&D activities than firms in high-tech sectors. These sectoral differences are verified by the third CIS, as shown in Figure 3. The share of non-R&D innovators is 52% among firms active in low-technology manufacturing sectors but falls to 18% among firms active in high technology manufacturing sectors. A similar pattern exists in the services sectors.

(Here insert Figure 3)

The innovative capabilities of a firm are partly influenced by its decisions on building up internal capacity (for instance through hiring tertiary-educated staff), its stock of previous investments in

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[http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST\\_NOM&StrGroupCode=CONCEPTS&StrLanguageCode=EN](http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM&StrGroupCode=CONCEPTS&StrLanguageCode=EN)). The classification used in this article is to a great extent in line with the OECD and Eurostat's definition, except that aerospace (NACE 35.3), pharmaceuticals (24.4) and shipbuilding (35.1) are classified as medium-high technology manufacturing. The discrepancy is due to the reason that CIS-3 micro-aggregated data are not available at NACE 3-digit level and we are thus not able to separate the three-digit industry sectors within the chemicals (24) and other transport equipment (35) sectors.

<sup>8</sup> The OECD definitions are as follows and are based on the average ratio of business R&D expenditures to production values. The ratio is above 5 percent in high technology sectors, between 3 percent and 5 percent in medium-high technology sectors, between 3 and 1 percent in medium-low technology sectors, and below 1 percent in low-technology sectors (Smith, 2005).

innovative capabilities, and spill-over effects from public research institutes and other firms active in its line of business. All three of these factors can be influenced by the national system of innovation of the country where the firm is located (Nelson, 1993). As an example, national conditions will influence the quality of education and public sector research and the capabilities of other firms that act as suppliers, customers, and competitors. We expect national factors to have a large effect on innovative capabilities because the survey includes both highly innovative countries such as Germany, with a long history of public research institutions that provide assistance to private firms, and economic transition countries such as Romania and Bulgaria with a poorly developed innovation infrastructure. Furthermore, the economically optimal, low risk choice for firms in technologically catching-up countries could be to purchase existing technology from industry leaders in other countries. As firms build up their technological capabilities and approach the technology frontier, they will be impelled to conduct non-R&D creative activities such as production engineering to extract greater cost savings from their technology. The final step would be to use R&D to develop more advanced technology than what can be developed without using R&D.

We assign the 15 European countries in our dataset into four groups according to the 2005 European Innovation Scoreboard (EIS) ranking of national innovative capabilities (European Commission, 2005).<sup>9</sup> The EIS classifies countries into one of four categories based on their innovative performance. The categories are described here as leading, intermediate, catching-up, and lagging innovative countries. Germany is classified in the leading country group; Belgium,

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<sup>9</sup> Although the first EIS was produced in 2001, the 2005 version is used because it provides more complete coverage of all European countries. National performance has remained reasonably consistent over time, suggesting that data for 2005 should approximate conditions during the survey years of 1998 to 2000.

Iceland and Norway are in the intermediate group of countries; the Czech Republic, Greece, Hungary, Latvia, Lithuania, and Portugal are in the group of catching-up countries; and Estonia, Bulgaria, Slovakia, Spain and Romania are in the group of lagging innovative countries. We expect the share of innovation expenditures allocated to non-R&D innovation activities to be highest in the catching-up and lagging innovative countries, intermediate in Belgium, Norway and Iceland, and lowest in Germany.

Finally, we include a variable for innovation expenditure intensity (the logarithm of the ratio between total innovation expenditure in 2000 divided by total revenues in 2000) as a control variable in the OLS, Tobit and Heckman sample selection models of the share of total innovation expenditures spent on non-R&D activities. The innovation expenditure intensity is a measure of the strategic focus given by firm management to innovation. However, whether or not high innovation expenditure intensity increases or decreases the share of spending on non-R&D activities is unknown. The problem can partly be envisioned as how firms choose to spend above average innovation budgets (given the average for similar firms). Will the extra expenditure be spent on R&D or on other innovation activities? The choice is likely to depend on each firm's decision as to which innovation activity is likely to be most profitable, after taking into consideration the firm's innovative capabilities, product or process focus, technological opportunities, and appropriation conditions.

Of note, although we include innovation expenditure intensity as a control variable because we cannot predict the direction of its effect on the share of innovation expenditures spent on non-R&D activities, the outcome is of interest to national policy efforts to increase the innovative

capabilities of firms. For instance, do firms in countries with poorly developed innovation systems tend to spend their ‘additional’ innovation budget on non-R&D innovation activities? Or, as innovation expenditure shares increase, do they shift additional expenditures to R&D?

Neither the firm’s sector nor country is likely to capture all possible confounding factors. In addition, there is considerable policy interest in how innovative capabilities vary by country and by sector. Consequently, we present separate results by sector and country for the innovation expenditure share model.

#### **4. RESULTS**

Table 1 provides the names of all variables except for the country group and industry sector dummies, and the methodology of constructing them. The mean and standard deviation of the variables are listed respectively for the samples analyzed in the multinomial logit model and the OLS, standard Tobit and Heckman sample selection model. The correlation matrix of the variables for the OLS, standard Tobit and Heckman sample selection model is provided in Table 2.<sup>10</sup>

(Here insert Table 1)

(Here insert Table 2)

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<sup>10</sup> The correlation coefficients of the variables for the multinomial logit model are very similar to those for the OLS and Heckman sample selection model. The correlation matrix of the former is available upon request from the authors.

#### **4.1 How firms innovate**

Table 3 provides the marginal effect of the multinomial logit model for how firms choose to innovate. The results are given separately for manufacturing and service sector firms.

(Here insert Table 3)

The results for the three measures of innovative capabilities (firm size, employees with higher education, and export status) support the first hypothesis for how firms innovate. Manufacturing firms with less than 49 employees (small firm), no employees with higher education, and no exports are significantly more likely to be non-R&D innovators. The marginal effect for the variable 'small firm' is statistically significant and positive for non-R&D innovators, which means that if the value of the variable changes from 0 to 1, i.e. a firm becomes a small firm, the probability that it is a non-R&D innovator is increased by .077. Both manufacturing and service sector firms with no exports or no employees with higher education are more likely to innovate through non-R&D activities.

The results only partly support hypothesis 2, which predicts that product innovators are more likely to be R&D innovators while process innovators are more likely to be non-R&D innovators and technology adopters. As expected, both manufacturing and service sector firms engaged in product innovation are more likely to be in-house R&D performers, and manufacturing firms are also less likely to be technology adopters. Conversely, process innovators are not more likely to be non-R&D innovators or technology adopters, and in fact are significantly less likely to be

technology adopters in both the manufacturing and services sectors. The latter suggests that process innovation requires some in-house capabilities, if only to make modifications to adapt purchased equipment to existing processes.

Hypothesis 3 predicts that the type of information sources drawn on by firms will vary by how they innovate, with firms that give a high importance to suppliers being more likely to be non-R&D innovators and firms that attach a high importance to university and research institutions being more likely to perform R&D. As expected, both manufacturing and service firms which regard university and research institutions as important sources of information tend to innovate through in-house R&D activities. In contrast, firms which innovate through non-R&D activities are more likely to give a higher importance to suppliers as a source of information for their innovative activities.

Two other information sources were included for which it was not possible to predict the direction of their effect on the firm's innovation status: competitors and a group of publicly available open sources: conferences, journals, fairs, and exhibitions. Assigning a high importance to competitors increases the probability that both manufacturing and services firms are a non-R&D innovator and decreases the probability that they perform R&D. One explanation for this effect is the use of reverse engineering and production engineering to imitate competitors. For both manufacturing and service sector firms, giving a high importance to publicly available open sources increases the probability of performing in-house R&D and decreases the probability of being a non-R&D innovator or a technology adopter. This could be due to the importance of conferences and journals as a source of leading-edge research results.

The results for the use of both patents and other types of appropriation methods strongly support hypothesis 4. Manufacturing firms that applied for at least one patent or used other innovation protection methods have a higher probability of performing R&D in-house. The effect also holds for service sector firms for the use of other innovation appropriation methods.

Firms that report high economic risks as a factor hampering innovation were *more* likely to be in-house R&D performers and less likely to be non-R&D innovators, contradicting hypothesis 5. Our interpretation is that in-house R&D performers may be more sensitive to the riskiness of the innovation projects than the non-R&D performers because the former engage in risky R&D projects, and have experience about the risk, while the latter lack sufficient experience to correctly evaluate risk. Firms which report a lack of information on technology as an important factor hampering innovation are more likely to engage in R&D, supporting the second half of hypothesis 5. However, this effect could be due to the same interpretation as for high economic risks: the more innovative firms could be more aware of risk factors. A reduction in market uncertainty, as indicated by a high importance attributed to clients as an information source, decreases the probability of being a non-R&D innovator and increases the probability of performing R&D in-house for both manufacturing and service sector firms. This supports the third part of hypothesis 5.

The results for the sector and country control variables are as expected. Compared to the reference category of low technology manufacturing, the probability of performing R&D in-house is ranked in descending order for firms in high-tech, medium-high tech, and medium-low tech manufacturing sectors. Similarly, knowledge-intensive services firms have a higher

probability to carry out R&D activities than other service sector firms. For the four country categories of innovative capabilities, manufacturing firms in countries with leading, intermediate, and catching-up innovative capabilities were more likely to perform in-house R&D than firms based in the lagging countries in terms of innovative capabilities. However, service sector firms in the leading country of Germany were more likely to carry out non-R&D activities than the firms in the reference category of lagging countries. Service sector firms in the intermediate and catching-up countries were less likely to be non-R&D innovators or technology adopters than service sector firms in the lagging countries.

Of interest, the factors that influence how firms innovate vary across all four innovation methods. For example, although ‘non-R&D innovator’ manufacturing firms share many determinants with the ‘technology adopter’ manufacturing firms, including small size, lack of exports, a low importance attributed to clients as an information source, and no patents or reported use of other appropriation methods; there are also notable differences. Firms which assign a high importance to competitors as an information source are more likely to be non-R&D innovators and less likely to be technology adopters. Non-R&D innovators have a lower probability of reporting high economic risks and a lack of information on technology as factors hampering innovation, while neither factor has a significant influence on the probability of being a technology adopter. There are even larger differences between manufacturing firms that perform R&D in-house versus those that contract out R&D. The probability of performing R&D in-house increases for large firms, for product innovation, and the use of ‘other appropriation methods’. Conversely, all of these factors *decrease* the probability that the firm contracts-out R&D. At the same time, many of the factors that determine the probability of a manufacturing

firm contracting out R&D differ from the factors that determine if the firm is a non-R&D innovator. For instance, small firms are less likely to contract out R&D and more likely to be non-R&D innovators, higher education and export activity have no impact on the probability of contracting out R&D but decrease the probability of being a non-R&D performer, and the pattern of use of information sources does not affect the probability that the firm contracts out R&D but information sources have a statistically significant effect on the probability of being a non-R&D innovator. There are also notable differences in the determinants of how service sector firms innovate.

These results show that there is not a simple dichotomy between firms that perform R&D in-house and firms that do not. Instead, the factors that influence how firms choose to innovate is more complex, both among firms that use R&D (performing R&D in-house or through contracting-out R&D) and among firms that do not rely on R&D (non-R&D performers and technology adopters).

#### **4.2 Share of innovation budget spent on non-R&D activities**

Table 4 presents the results of each of three models, for both all manufacturing firms and all service sector firms, for the factors that influence the share of innovation expenditures spent on activities that do not involve R&D (the non-R&D innovation expenditure share). The results include firms that perform in-house R&D and contract-out R&D, as the majority of these firms also report expenditures on innovation activities that do not require R&D.

(Here insert Table 4)

As shown in Table 4, the results of the standard Tobit model are not significantly different from those of the OLS model. To examine whether or not there is sample selection bias in the decision to engage in non-R&D innovation activities and how much is invested in such activities, we also include a Heckman sample selection model. The null hypothesis of no correlation is not rejected in either of the two equations and the coefficients of the outcome equations are not materially different from those of the ordinary least square model. We therefore conclude that the results of the ordinary least square regressions are unaffected by sample selection bias.

The results of each of the three models are consistent with the multinomial logit model for how firms innovate. In almost all regressions, small firms, process innovators, firms that find suppliers or competitors as important information sources, and firms based in catching up countries spend a larger share of their innovation budget on non-R&D activities compared to the respective reference categories. In contrast, large firms, firms with in-house innovation activities, exporters, product innovators, firms that have tertiary-educated staff, firms that assign a high importance to universities and research institutes as an information source, and firms that report using patents or other appropriation methods, spend a lower share of their innovation budget on non-R&D activities compared to the respective reference categories. These results confirm hypotheses 1 to 4.

The results for the riskiness of innovation projects are also similar to that of the multinomial choice model. Economic riskiness decreases the non-R&D innovation expenditure share (contradicting hypothesis 5) while a lack of information on technology forces firms to shift their innovation budget towards R&D (confirming the second half of hypothesis 5). Of note, this effect is only observed for manufacturing firms. A lack of information on technology has no effect on the non-R&D innovation expenditure share for service sector firms. A reduction in market risk through obtaining information from clients also reduces the share of innovation expenditures for non-R&D activities.

The coefficients for the variable 'innovation expenditure share' are always negative and statistically significant. This demonstrates that firms allocate more of their innovation budget to R&D as their innovation expenditures increase as a percentage of total revenues.

Understandably, firms in intermediate and leading innovative countries spend a lower share of their innovation budget on non-R&D innovation activities than their counterparts in the reference group of lagging countries, while manufacturing firms in catching up countries spend more of their innovation expenditures on non-R&D activities. This could be due to the importance of productivity-enhancing improvements to processes, requiring investment in new technology and production engineering to benefit from this technology.

Firms in different industry sectors could allocate their innovation budget differently due to sector specific conditions. For instance, firms in high-tech manufacturing sectors could spend

proportionally more on R&D as their innovation expenditure intensity increases, but firms in low-tech manufacturing sectors could spend proportionally more on non-R&D activities. Table 5 gives the ordinary least square model for the four main manufacturing and two service sectors and shows some differences by sector in the factors influencing the non-R&D innovation share.

(Here insert Table 5)

Generally, determinants that are negative or positive in Table 4 for either all manufacturing or all services (large size, exports, appropriation methods, etc) are consistently negative or positive across the sub-sectors in Table 5, suggesting that most of the determinants in the model are applicable to most sectors. However, there are a few interesting exceptions. For example, the positive effect of small size noted in Table 4 is limited to the medium-low and low technology manufacturing sectors, with small size having no effect in the other four sectors. The lack of an effect in high tech manufacturing could be due to the activity of small, technology intensive firms in fields such as biotechnology, nanotechnology and communications equipment. In the Table 4 results for lack of information on technology, the coefficient is positive but not statistically significant for all service sectors combined. Table 5 shows that this is because this variable has opposite effects in the two main sectors. A lack of information on technology has the expected effect in less knowledge-intensive service sectors (reducing the non-R&D expenditure share), but it increases investments in non-R&D innovation in the knowledge-intensive services.

However, one notable difference is for innovation expenditure intensity, where we could expect differences by sub-sectors, with firms in high-tech and medium-high tech manufacturing sectors allocating proportionally more of their innovation budget to R&D activities, while firms in low-tech manufacturing sectors should spend proportionally more of their additional innovation expenditures on non-R&D innovation activities such as investment in new equipment. The coefficients are statistically significant and negative, as expected for high tech and medium-high tech manufacturing, negative but not significant for medium low tech manufacturing, and statistically significant and positive (as expected) for low tech manufacturing. The coefficients across sectors also follow the expected pattern, with the strongest negative coefficient for high tech manufacturing and the strongest positive effect for low tech manufacturing.

We also expect firms in different countries to allocate their innovation budgets in diverse ways. Particularly, the factors that influence how firms innovate in the leading country of Germany could differ from the factors that influence innovation in the lagging countries of Estonia, Spain, Bulgaria, Slovakia and Romania. Table 6 provides the OLS model for each of the four country groups for manufacturing and services firms. The determinants are generally consistent across the different country groups, with two exceptions.<sup>11</sup> The coefficient for innovation expenditure intensity is positive for manufacturing firms in the catching up countries, indicating that investment in non-R&D activities, possibly new equipment, plays a key role in catching up to the innovative and productivity levels of more advanced European countries. Second, the effect of a lack of information on technology surprisingly increases investment in non-R&D innovation

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<sup>11</sup> In addition, the results of running separate multinomial logit models for the leader country (Germany) and for the intermediate innovative countries (Luxembourg, Belgium and Iceland) are consistent with the results for all countries combined, which means that the results for all countries combined hold for small groups of countries. These results are available upon request from the authors.

activities in the leading country of Germany in both the manufacturing and services sectors, while it is negative in the lagging countries (supporting hypothesis 5), and not significant in the catching up and intermediate countries. The positive coefficient for Germany is difficult to explain and could possibly be due to a national difference in the interpretation of the survey question.

## **5. CONCLUSIONS**

Although R&D is vital for the innovation activities of firms and the competitiveness of an industry and a country, survey research shows that about half of European firms which report product or process innovations do not perform R&D in-house. In the technologically less developed economic transition countries, the share of non-R&D innovators is higher than in the technologically more developed European countries. Non-R&D innovators are more prevalent in low technology manufacturing and services sectors and among small and medium sized firms.

In this article we use firm-level data from the third European Community Innovation Survey (CIS-3) for 15 countries to investigate the determinants of the firms' decision to engage in innovative activities that do not require R&D. We classify innovative firms into in-house R&D performers, contract R&D performers, non-R&D innovators and technology adopters and use a multinomial logit model to identify the determinants of how firms innovate. We also investigate the factors that determine the non-R&D innovation expenditure share (the percentage of all innovation expenditures spent on non-R&D activities).

We find that firms with weak innovative abilities, demonstrated by their small size, lack of in-house innovation activities, exports, or employees with higher education are more likely to innovate through non-R&D activities. Firms engaged in product innovation are more likely to engage in R&D activities than firms that are not product innovators. Firms that find clients and university and research institutions as an important information source for innovation are more likely to be R&D performers, while firms that source information from suppliers and competitors have a higher probability of innovating through non-R&D activities. Firms that apply for patents or use other methods to appropriate their investments from innovation (design registration, trademarks, copyright, secrecy, design complexity or lead-time advantages) are more likely to perform R&D. These results are generally valid not only for manufacturing firms but also for services firms.

However, the three types of firms that innovate without performing R&D do not form a homogeneous group. Firms that contract-out R&D share some similarities with R&D performing firms and other similarities with non-R&D innovators. Technology adopters also differ from other non-R&D innovators.

The multinomial results have several implications for policy. The first is a clear need for good indicators on how firms innovate. It is insufficient to simply provide data on the number of firms that perform R&D or the total number of innovative firms. The group of firms that innovate without performing R&D should also be disaggregated, as there are several important differences between contract R&D performers, non-R&D innovators, and technology adopters. This type of detailed information could assist policy analysts in identifying where weaknesses in innovative

ability occur and support policy to encourage firms to move up the ladder of innovative capabilities.

Second, the results suggest that the concept of a latent scalar variable for innovative capabilities is relevant between in-house R&D performers and non-R&D innovators, with contract R&D performers an intermediate stage between them. The position of technology adopters along this scale is less clear, but this could be due to the small number of observations. Contract R&D performers share some characteristics of R&D performers and some with non-R&D innovators. The coefficients for contract R&D performers are consistently intermediate between the R&D performers and the non-R&D innovators, as shown for export status, employees with higher education, and the importance of universities and research institutions as an information source. This suggests that contracting out R&D is a transitional stage between non-R&D methods of innovating and performing R&D in-house. Consequently, an effective policy option might be to improve the innovative capabilities of firms by subsidizing non-R&D innovators to contract out R&D, for instance to the public research sector. Developing experience with how to define an R&D contract and how to implement the results could be a helpful step towards developing in-house R&D capabilities.

The results also clarify the role of user-producer relationships in innovation by highlighting the distinct differences between firms that source information from suppliers compared to firms that source information from clients. The latter increases the probability of performing R&D, possibly because the information provided by customers reduces market uncertainty. This result points to the possible benefits of policies to reduce uncertainty, for example through

procurement. Conversely, firms that source information from suppliers are more likely to be non-R&D innovators whose innovative activities could involve production engineering and other activities to adapt new technology. These types of activities could be essential for productivity improvements, but firms that source information for innovation from suppliers may find it difficult to benefit from investing in R&D, particularly if their position in a supply chain limits their opportunities for product innovation. There could be few policy options (or need) to encourage these firms to perform or contract out R&D.

The results of the analysis for the share of innovation expenditures spent on non-R&D innovation activities show that many of the same determinants for how firms innovate also influence the distribution of the innovation budget between non-R&D and R&D activities.

An interesting result is the similarity of the determinants of the non-R&D innovation expenditure share across sectors and countries, with two notable exceptions concerning the innovation expenditure intensity, which is a measure of the strategic focus that firms place on innovation. Generally, firms spend more on R&D as their innovation expenditure intensity increases, but firms in low-tech manufacturing sectors and firms based in catching up countries increase the share of their innovation expenditures for non-R&D activities as their innovation intensity increases. Aside from these two exceptions, these results raise doubts over the strongly-held assumption of European policy makers that a 'one size does not fit all' approach to innovation policy is correct. Instead, once firms and countries reach an appropriate level of innovative capacity, the same determinants, such as exposure to export competition, a shift to product innovation, a better educated labor force, a well-developed public research system that provides

useful information for innovation, etc., are positively correlated with a shift towards greater innovative capabilities as shown by the share of investment in R&D. And, these positive determinants are generally consistent across most countries and across most industrial sectors. Of course, the details of innovation support policies are likely to differ across regions or countries to account for local conditions, but the results of this study suggest there are consistent patterns in the factors that influence the share of innovation expenditures for R&D versus other innovation activities.

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Table 1: Definition of variables and summary statistics

Variable Name	Definition and Note	Mean and standard deviation (in parentheses) (14931 firms, included in the multinomial logit model)	Mean and standard deviation (in parentheses) (12766 firms which have innovation expenditure, included in the standard Tobit, OLS and Heckman sample selection model)
Non-R&D innovation expenditure share (dependent variable)	Innovation expenditure excluding intramural and extramural R&D expenditure / Total innovation expenditure	-	.63(.41)
Innovation expenditure intensity	Ln (Total innovation expenditure in 2000/ Turnover in 2000)	-	-4.4(2.5)
Small firm	The value is 1 if the firm employs 10-49 employees. Otherwise, the value is 0.	.34(.48)	.33(.47)
Large firm	The value is 1 if the firm employs 250 or more than 250 employees. Otherwise, the value is 0.	.18(.38)	.19(.39)
In-house innovation activities	The value is 1 if the firm or enterprise group mainly developed new or significantly improved goods, services and processes without external assistance. The value is 0, otherwise.	.67(.47)	.69(.46)
Employee with higher education	The value is 1 if the firm employed staff with higher education. The value is 0, otherwise.	.88(.32)	.88(.32)
Export	The value is 1 if the firm exported in 2000; 0 otherwise.	.64(.48)	.65(.48)
Product innovation <sup>1</sup>	The value is 1 if the firm introduced a new or significantly improved product; 0 otherwise.	.78(.41)	.78(.41)
Process innovation <sup>1</sup>	The value is 1 if the firm introduced new or significantly improved production process; 0 otherwise.	.68(.47)	.68(.47)
Suppliers as source of information for innovation	The value is 3 if a firm ranks the information from suppliers as high importance for its innovation. The value is 2 if information from suppliers is ranked as medium importance, and if low importance, the value is 1. The value is 0, otherwise.	1.6(1.1)	1.6(1.1)
Clients as source of information for innovation	The value is 3 if a firm ranks information from clients as of high importance for its innovation. The value is 2 if information from clients is ranked as medium importance and 1 if ranked as of low importance. The value is 0, otherwise.	1.7(1.1)	1.7(1.1)
Competitors as source of information for innovation	The value is 3 if a firm ranks information from competitors as of high importance for innovation. The value is 2 if information from competitors is ranked as medium importance, and 1 if ranked as low importance. The value	1.3(1.1)	1.3(1.1)

	is 0, otherwise.		
University and research institutions as source of information for innovation	The value is 3 if a firm ranks information from universities or research institutions as of high importance for innovation. The value is 2 if the information from universities or research institutions is ranked as medium importance and 1 ranked as of low importance. The value is 0, otherwise.	.79(1.0)	.79(1.0)
Conferences, journals and fairs as source of information for innovation	The value is 3 if a firm ranks the information from professional conferences, journals and fairs as high importance for its innovation. The value is 2 if the information from professional conferences, journals and fairs is ranked as medium importance, and if low importance, the value is 1. The value is 0, otherwise.	1.7(1.0)	1.7(1.0)
Patent application	The value is 1 if the firm applied for at least one patent; 0 otherwise.	.15(.36)	.15(.36)
Other appropriation methods	The value is 1 if the firm makes use of at least one of the following methods to protect its invention or innovation: registration of design patents, trademarks, copyright, secrecy, complexity of design or lead-time advantage on competitors, etc. The value is 0, otherwise.	.49(.50)	.48(.50)
Economic risks as a factor hampering innovation	The value is 3 if the firm ranks excessive perceived economic risks, high innovation costs, or lack of finance sources as a highly important factor hampering innovation. The value is 2 if the highest ranking for these factors is medium importance and 1 if the highest value is low importance. The value is 0, otherwise.	1.7(1.3)	1.7(1.3)
Lack of information on technology as a factor hampering innovation	The value is 3 if a firm ranks lack of information on technology as a highly important factor hampering its innovation activities. The value is 2 if the factor is ranked as medium importance, and if low importance, the value is 1. The value is 0, otherwise.	.69(.88)	.70(.89)

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Note:

1. By the definition of this study, a firm either introduced product or process innovation or had on-going or abandoned innovation activities is considered as an innovative firm. There are 520 firms in the sample which did not introduce product or process innovation, but had on-going or abandoned innovation activities.

Table 2: Correlation matrix

Variable name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Non-R&D innovation expenditure share of the firm under analysis (dependent variable)																	
2 Innovation expenditure intensity	-0.12																
3 Small firm	0.09	0.04															
4 Large firm	-0.11	-0.06	-0.34														
5 In-house innovation activities	-0.12	0.06	-0.05	0.06													
6 Employee with higher education	-0.13	0.00	-0.20	0.12	0.03												
7 Export	-0.13	0.03	-0.18	0.11	0.07	0.13											
8 Product innovation	-0.15	0.05	-0.08	0.07	0.34	0.07	0.07										
9 Process innovation	0.10	0.07	-0.09	0.11	0.08	-0.02	-0.03	-0.15									
10 Suppliers as source of information for innovation	0.06	0.07	-0.04	0.03	-0.04	0.00	0.00	-0.02	0.15								
11 Clients as source of information for innovation	-0.10	0.08	-0.06	0.05	0.11	0.07	0.11	0.19	-0.02	0.18							
12 Competitors as source of information for innovation	-0.02	0.02	-0.05	0.05	0.05	0.05	0.03	0.09	-0.02	0.21	0.47						
13 University and research institutions as source of information for innovation	-0.22	0.11	-0.15	0.13	0.03	0.12	0.08	0.08	0.04	0.14	0.18	0.18					
14 Conferences, journals and fairs as source of information for innovation	-0.05	0.08	-0.04	0.03	0.06	0.04	0.04	0.08	0.04	0.28	0.26	0.32	0.28				
15 Patent application	-0.23	0.09	-0.10	0.13	0.12	0.07	0.14	0.14	0.01	-0.01	0.10	0.06	0.19	0.09			
16 Other appropriation methods	-0.21	0.08	-0.12	0.10	0.13	0.09	0.18	0.19	0.00	0.04	0.16	0.12	0.15	0.15	0.34		
17 Economic risks of factors hampering innovation	-0.06	0.04	0.07	-0.04	-0.02	-0.02	-0.04	0.01	0.00	0.07	0.08	0.08	0.07	0.12	0.05	0.08	
18 Lack of information on technology as a factor hampering innovation	-0.03	0.00	0.03	-0.02	-0.01	-0.02	0.02	0.01	0.02	0.08	0.08	0.09	0.07	0.07	0.02	0.06	0.43

Table 3: Marginal effect of multinomial logit model on types of innovators

Independent variables	Manufacturing firms				Services firms			
	In-house R&D performers	Contract R&D performers	Non-R&D innovators	Technology Adopters	In-house R&D performers	Contract R&D performers	Non-R&D innovators	Technology Adopters
Small firm	-.067(.013)***	-.0098(.0053)*	.077(.013)***	-.00025(.00077)	-.019(.019)	-.0040(.0079)	.020(.018)	.0026(.0015)*
Large firm	.10(.015)***	-.015(.0056)***	-.084(.014)***	-.0016(.00097)*	.084(.028)***	.0051(.012)	-.087(.026)***	-.0017(.0020)
Employee with higher education	.095(.018)***	.00022(.0077)	-.092(.017)***	-.0031(.0014)**	.17(.031)***	-.042(.016)***	-.12(.030)***	-.0048(.0027)*
Export	.10(.014)***	.0048(.0056)	-.10(.013)***	-.0027(.0011)**	.11(.018)***	-.016(.0076)**	-.097(.017)***	-.0015(.0012)
Product innovation	.16(.015)***	-.021(.0069)**	-.14(.014)***	-.0035(.0013)***	.12(.021)***	-.019(.0097)*	-.095(.021)***	-.0025(.0018)
Process innovation	.032(.013)	-.015(.0056)**	-.015(.012)	-.0021(.00097)**	.035(.018)*	.0048(.0080)	-.029(.018)*	-.010(.0028)***
Suppliers as information source for innovation	-.020(.0056)***	-.00036(.0024)	.021(.0053)***	-.00029(.00032)	-.022(.0082)***	.0076(.0035)**	.016(.0078)**	-.0017(.00061)***
Clients as information source for innovation	.030(.0057)***	-.00042(.0024)	-.029(.0054)***	-.00074(.00035)**	.023(.0088)***	-.0065(.0038)*	-.016(.0084)**	-.00064(.00059)
Competitors as information source for innovation	-.018(.0061)***	-.0011(.0026)	.020(.0059)***	-.00094(.00047)**	-.037(.0094)***	.0026(.0039)	.034(.0090)***	.00042(.00064)
University/research institutions as information source for innovation	.083(.0062)***	.0040(.0024)	-.087(.0060)***	-.00049(.00047)	.084(.0093)***	.00083(.0040)	-.084(.0092)***	-.0016(.00086)*
Conferences, journals and fairs as information sources for innovation	.019(.0061)***	.00095(.0026)	-.018(.0058)***	-.0025(.00056)***	.035(.0093)***	-.0049(.0039)	-.028(.0088)***	-.0020(.00071)***
Patent application <sup>2</sup>	.16(.016)***	-.0040(.0070)	-.15(.015)***	-.0035(.0011)***	-	-	-	-
Other appropriation methods	.17(.012)***	-.012(.0051)**	-.16(.011)***	-.0046(.0013)***	.18(.017)***	-.012(.0077)	-.16(.017)***	-.0077(.0021)***
Economic risks of factors hampering innovation	.011(.0050)**	-.0010(.0021)	-.010(.0048)**	-.00013(.00029)	.029(.0076)***	-.0054(.0033)*	-.024(.0073)***	.00018(.00048)
Lack of information on technology as a factor hampering innovation	.022(.0068)***	-.0011(.0029)	-.021(.0065)***	.0000035 (.00039)	.0041(.012)	.012(.0046)***	-.015(.011)	-.00075(.0008)
Medium-low tech manuf.	.049(.014)***	.0048(.0064)	-.054(.013)***	.00015(.00086)	-	-	-	-
Medium-high tech manuf.	.12(.014)***	.014(.0067)**	-.14(.012)***	.0011(.0010)	-	-	-	-
High-tech manufacturing	.21(.019)***	-.0016(.010)	-.21(.016)***	.00092(.0017)	-	-	-	-
Knowledge intensive services	-	-	-	-	.29(.017)***	-.042(.0085)***	-.24(.017)***	-.0090(.0025)***
Catching-up countries	.082(.013)***	-.0098(.0053)*	-.070(.013)***	-.0018(.00076)**	.12(.022)***	-.0042(.0088)	-.11(.021)***	-.0037(.0013)***
Intermediate countries	.20(.014)***	-.027(.0054)***	-.17(.014)***	-.0018(.00083)**	.069(.024)***	-.018(.0094)*	-.046(.023)**	-.0058(.0016)***
Leading countries	.096(.019)***	-.020(.0065)***	-.074(.018)***	-.0022(.0011)**	-.028(.027)	-.025(.0095)***	.059(.027)**	-.0062(.0016)***
Number of observations			9998				4417	

Note:

1. The data in parentheses refer to standard deviations. \*\*\* denotes a significance level of 1%, \*\* denotes a significance level of 5%, \* denotes a significance level of 10%.
2. None of the technology adopters in the services sectors applied for a patent. To avoid the problem of collinearity, we remove the variable “patent application” from the multinomial logit model for services.

Table 4: Determinants of Non-R&D innovation expenditure share (manufacturing and services firms in general)

Independent variables	Dependent variable: Non-R&D innovation expenditure share					
	Ordinary least square model		Standard Tobit model		Heckman sample selection model (outcome equation) <sup>2</sup>	
	Manufacturing	Services	Manufacturing	Services	Manufacturing	Services
Innovation expenditure intensity	-.0069(.0016)***	-.032(.0021)***	-.010 (.0038)***	-.090(.0054)***	-.0065(.0016)***	-.032(.0022)***
Small firm	.018(.0090)**	.021(.013)*	.097(.020)***	.044(.027)	.016(.0090)*	.019(.013)
Large firm	-.060(.0099)***	-.069(.019)***	-.14(.021)***	-.18(.042)***	-.068(.0099)***	-.080(.019)***
In-house innovation activities	-.048(.0088)***	-.077(.013)***	-.11(.020)***	-.12(.028)***	-.048(.0088)***	-.075(.013)***
Employee with higher education	-.047(.012)***	-.087(.020)***	-.18(.027)***	-.24(.048)***	-.050(.012)***	-.090(.020)***
Export	-.078(.0091)***	-.0014(.012)	-.16(.021)***	-.032(.026)	-.081(.0091)***	-.0026(.012)
Product innovation	-.065(.010)***	-.045(.015)***	-.14(.023)***	-.032(.034)	-.060(.010)***	-.042(.015)***
Process innovation	.046(.0086)***	.022(.013)*	.17(.018)***	.091(.027)***	.055(.0089)***	.026(.013)**
Suppliers as source of information for innovation	.019(.0037)***	.012(.0056)**	.054(.0082)***	.046(.012)***	.022(.0037)***	.015(.0056)***
Clients as source of information for innovation	-.016(.0038)***	-.0045(.0060)	-.038(.0084)***	-.0094(.013)	-.018(.0038)***	-.0043(.0060)
Competitors as source of information for innovation	.013(.0040)***	.023(.0062)***	.030(.0089)***	.051(.014)***	.012(.0040)***	.022(.0063)***
University and research institutions as source of information for innovation	-.057(.0040)***	-.051(.0063)***	-.11(.0085)***	-.10(.013)***	-.058(.0040)***	-.051(.0064)***
Conferences, journals and fairs as source of information for innovation	-.0037(.0041)	-.0059(.0063)	.0068(.0090)	.0087(.014)	-.0037(.0041)	-.0068(.0064)
Patent application	-.13(.011)***	-.12(.020)***	-.17(.023)***	-.13(.041)***	-.14(.011)***	-.12(.020)***
Other appropriation methods	-.092(.0082)***	-.086(.013)***	-.18(.018)***	-.17(.028)***	-.097(.0082)***	-.090(.013)***
Economic risks of factors hampering innovation	-.013(.0033)***	-.025(.0052)***	-.020(.0074)***	-.038(.011)***	-.014(.0033)***	-.026(.0052)***
Lack of information on technology as a factor hampering innovation	-.012(.0044)***	.0055(.0078)	-.029(.0099)***	-.0023(.017)	-.013(.0045)***	.0058(.0078)
Catching-up countries	.041(.0093)***	-.0027(.015)	.050(.021)**	-.060(.033)*	.055(.0091)***	.012(.014)
Intermediate countries	-.16(.015)***	-.12(.020)***	-.35(.031)***	-.22(.043)***	-.16(.015)***	-.11(.020)***
Leading countries	-.070(.012)***	-.054(.017)***	-.028(.026)	.039(.037)	-	-
Observations	7706	3278	8750	3658	8750	3658
Chi-square likelihood-ratio statistic <sup>3</sup>	-	-	-	-	2.7	0.21

Note: 1. Standard deviations are in parentheses. \*\*\* = significance level of 1%, \*\* = significance level of 5%, \* = significance level of 10%.

2. The variables included in the selection equation and in the outcome equation are the same in this analysis, except that the variable of “leading countries” is excluded from the outcome equation, because it is required that at least one variable in the selection equation is excluded in the outcome equation. The result of the selection equation is available upon request from the authors.

3. Test of no correlation between the residuals in the outcome and selection equations ( $\rho=0$ ).

Table 5: Determinants of Non-R&D innovation expenditure share (Ordinary least square model, results for manufacturing and services sub-sectors)

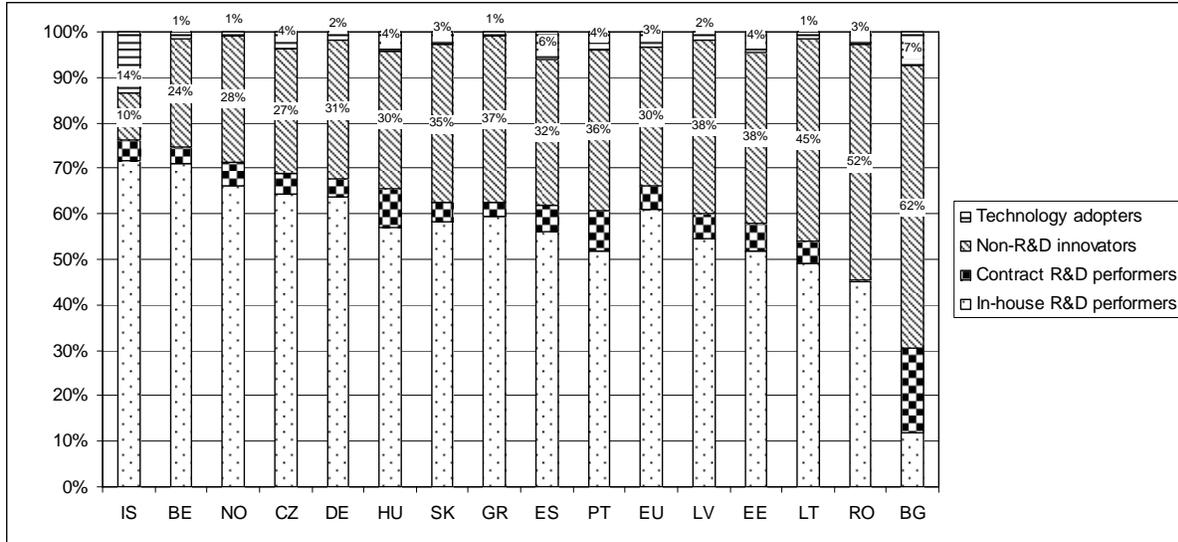
Independent variables	Dependent variable: Non-R&D innovation expenditure share					
	Manufacturing firms			Service firms		
	High-tech manufacturing	Medium-high tech manufacturing	Medium-low tech manufacturing	Low-tech manufacturing	Knowledge-intensive services	Less knowledge-intensive services
Innovation expenditure intensity	-.049(.0085)***	-.020(.0040)***	-.0011(.0032)	.0043(.0021)**	-.038(.0030)***	-.0063(.0028)**
Small firm	-.057(.037)	-.011(.022)	.058(.018)***	.023(.012)**	.0088(.018)	.0013(.016)
Large firm	-.11(.047)**	-.062(.019)***	-.074(.021)***	-.049(.014)***	-.13(.028)***	-.060(.023)**
In-house innovation activities	-.10(.041)**	-.049(.021)**	-.035(.017)**	-.043(.012)***	-.063(.019)***	-.024(.015)
Employee with higher education	-.078(.065)	.022(.032)	-.048(.025)*	-.029(.013)**	-.095(.034)***	-.044(.021)**
Export	-.12(.044)***	-.11(.023)***	-.022(.019)	-.050(.011)***	-.013(.018)	-.037(.015)**
Product innovation	-.14(.052)***	-.092(.026)***	-.060(.019)***	-.038(.013)***	-.075(.024)***	-.020(.017)
Process innovation	.15(.035)***	.021(.018)	.020(.018)	.029(.012)**	.041(.017)**	-.035(.016)**
Suppliers as source of information for innovation	.023(.017)	.014(.0084)*	.010(.0076)	.012(.0050)**	.017(.0079)**	.0070(.0067)
Clients as source of information for innovation	-.022(.018)	-.010(.0088)	-.016(.0074)**	-.0067(.0051)	-.013(.0084)	.0087(.0074)
Competitors as source of information for innovation	-.0054(.018)	.00088(.0090)	.014(.0081)*	.015(.0054)***	.025(.0086)***	.0060(.0079)
University and research institutions as source of information for innovation	-.044(.017)***	-.040(.0084)***	-.041(.0077)***	-.044(.0058)***	-.032(.0085)***	-.032(.0086)***
Conferences, journals and fairs as source of information for innovation	-.0011(.019)	.0052(.0098)	.0043(.0084)	-.012(.0051)**	-.015(.0090)*	-.00092(.0076)
Patent application	-.057(.042)	-.13(.021)***	-.086(.022)***	-.11(.018)***	-.12(.026)***	-.082(.028)***
Other appropriation methods	-.11(.038)***	-.10(.019)***	-.064(.017)***	-.076(.011)***	-.069(.018)***	-.062(.016)***
Economic risks of factors hampering innovation	-.022(.015)	-.0074(.0074)	-.0076(.0069)	-.012(.0044)***	-.040(.0073)***	.0022(.0063)
Lack of information on technology as a factor hampering innovation	.0023(.021)	-.012(.010)	-.024(.0087)***	-.0064(.0059)	.023(.011)**	-.025(.0093)***
Catching-up countries	.11(.045)***	-.020(.022)	.036(.019)*	.050(.012)***	.0097(.022)	-.037(.018)**
Intermediate countries	-.046(.062)	-.17(.029)***	-.16(.030)***	-.17(.024)***	-.14(.028)***	-.072(.026)***
Leading countries	.049(.044)	-.095(.023)***	-.078(.022)***	-.015(.020)	-.0010(.023)	-.11(.021)
Observations	436	1854	1789	3269	1855	1423

Note: 1. Standard deviations are in parentheses. \*\*\* = significance level of 1%, \*\* = significance level of 5%, \* = significance level of 10%.

Table 6: Determinants of Non-R&D innovation expenditure share (Ordinary least square model, results for country groups)

Independent variables	Dependent variable: Non-R&D innovation expenditure share							
	Manufacturing firms				Services firms			
	Lagging countries	Catching up countries	Intermediate countries	Leading countries	Lagging countries	Catching up countries	Intermediate countries	Leading countries
Innovation expenditure intensity	-0.0038(.0024)	.0080(.0027)***	-.022(.0046)***	-.025(.0047)***	-.035(.0035)***	-.0079(.0040)*	-.033(.0054)***	-.027(.0047)***
Small firm	.017(.012)	.045(.017)***	.069(.034)**	.031(.027)	.010(.018)	-.027(.022)	.038(.041)	.032(.032)
Large firm	-.057(.014)***	-.043(.018)**	-.025(.050)	-.054(.025)**	-.084(.026)***	-.044(.054)	-.073(.10)	-.067(.036)*
In-house innovation activities	-.043(.012)***	-.038(.017)**	-.088(.035)**	-.051(.025)**	-.043(.018)**	-.067(.022)***	-.016(.046)	-.082(.032)***
Employee with higher education	-.020(.016)	-.054(.018)***	.018(.057)	-.073(.050)	-.049(.032)	-.10(.028)***	.062(.080)	-.0086(.071)
Export	-.079(.011)***	-.021(.019)	-.064(.046)	-.082(.029)***	-.037(.018)**	-.0097(.022)	-.022(.041)	-.077(.029)***
Product innovation	-.059(.013)***	-.049(.019)***	-.080(.046)*	-.063(.028)**	-.019(.022)	-.012(.025)	-.11(.069)	-.058(.035)*
Process innovation	.0095(.012)	.057(.015)***	.097(.035)***	.088(.022)***	-.011(.019)	.026(.023)	.030(.042)	.037(.029)
Suppliers as source of information for innovation	.020(.0050)***	.012(.0068)*	.015(.015)	.0049(.011)	.0041(.0079)	.0087(.0099)	.016(.018)	.023(.013)*
Clients as source of information for innovation	-.013(.0050)***	-.012(.0071)*	-.0069(.016)	-.0077(.011)	-.011(.0086)	.015(.011)	-.017(.020)	-.019(.014)
Competitors as source of information for innovation	.015(.0053)***	.010(.0073)	.0026(.018)	-.0092(.012)	.020(.0088)**	.010(.011)	.020(.021)	.010(.015)
University and research institutions as source of information for innovation	-.061(.0054)***	-.020(.0070)***	-.084(.017)***	-.050(.011)***	-.056(.0091)***	-.0087(.011)	-.019(.023)	-.034(.016)**
Conferences, journals and fairs as source of information for innovation	-.0033(.0052)	-.011(.0073)	-.0094(.017)	.0074(.013)	-.0039(.0089)	-.031(.011)***	.0043(.022)	.0057(.016)
Patent application	-.14(.015)***	-.066(.022)***	-.032(.039)	-.099(.025)***	-.14(.030)***	-.095(.037)**	-.021(.062)	-.15(.044)***
Other appropriation methods	-.11(.011)***	-.057(.014)***	-.10(.035)***	-.038(.026)	-.051(.019)***	-.050(.022)**	-.13(.046)***	-.10(.031)***
Economic risks as factors hampering innovation	-.010(.0044)**	-.012(.0060)**	.0049(.013)	-.000085(.011)	-.017(.0073)**	-.037(.0088)***	-.020(.019)	.0080(.013)
Lack of information on technology as a factor hampering innovation	-.019(.0057)***	-.013(.0082)	-.021(.023)	.028(.013)**	-.023(.010)**	.021(.015)	.042(.030)	.031(.018)*
Medium-low tech manufacturing firms	-.0046(.012)	-.038(.017)**	-.022(.041)	-.086(.029)***	-	-	-	-
Medium-high tech manufacturing firms	-.079(.013)***	-.21(.017)***	-.13(.038)***	-.20(.030)***	-	-	-	-
High-tech manufacturing firms	-.22(.024)***	-.21(.031)***	-.16(.066)**	-.23(.041)***	-	-	-	-
Knowledge intensive service firms	-	-	-	-	-.21(.019)***	-.17(.022)***	-.24(.044)***	-.11(.028)***
Observations	4282	1863	550	1011	1395	909	356	618

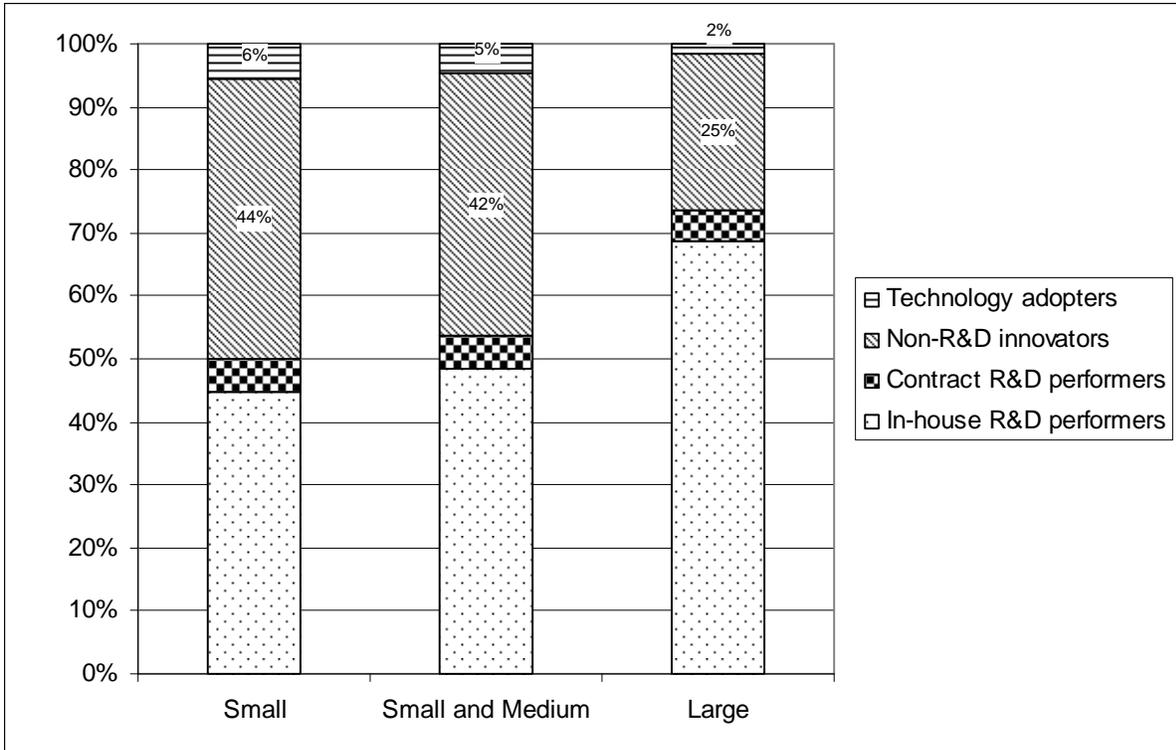
Note: 1. Standard deviations are in parentheses. \*\*\* = significance level of 1%, \*\* = significance level of 5%, \* = significance level of 10%.



Source: CIS-3, Micro-aggregated data.

Notes: 1. IS, BE, NO, CZ, DE, HU, SK, GR, ES, PT, EU, LV, EE, LT, RO, BG represent Iceland, Belgium, Norway, Czech Republic, Germany, Hungary, Slovakia, Greece, Spain, Portugal, the sample average, Latvia, Estonia, Lithuania, Romania, Bulgaria, respectively.

Figure 1: Unweighted Distribution of Innovative Firms by Country

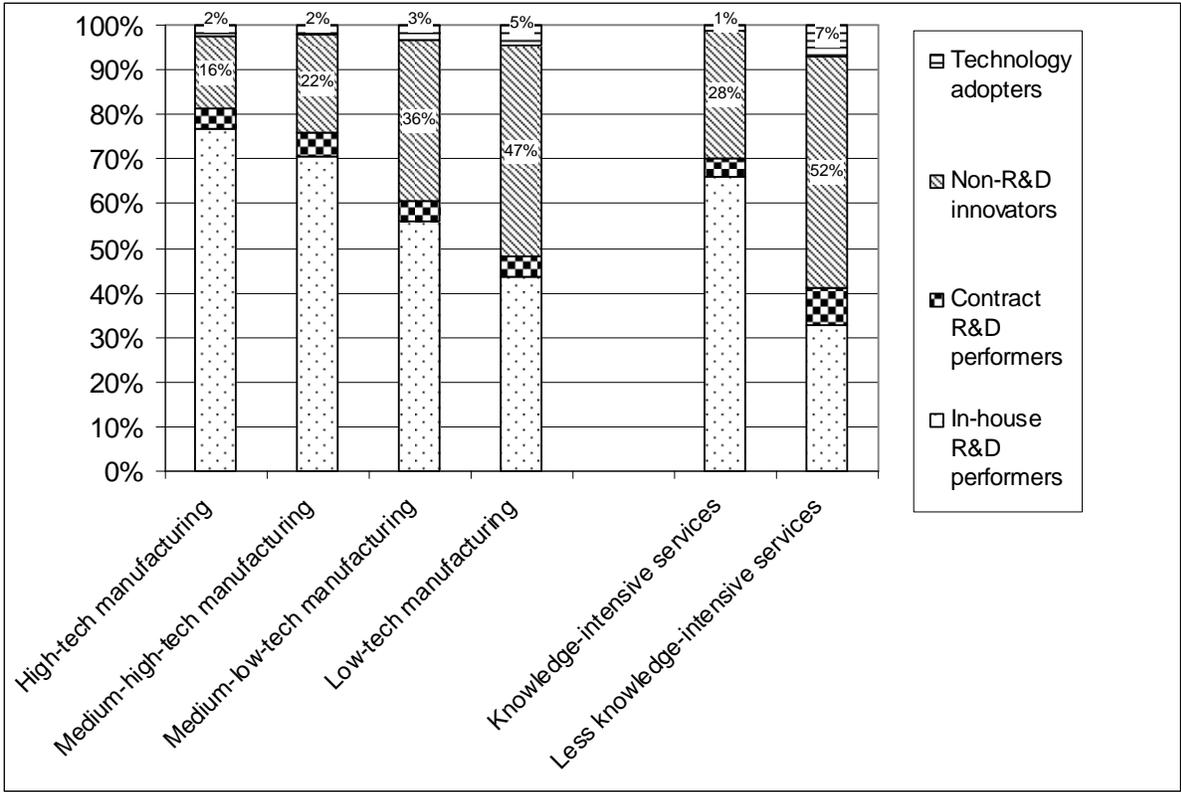


Source: CIS-3, Micro-aggregated data.

Note: 1. Small firms employ 10-49 employees, medium firms employ 50-249 employees, and large firms employ 250 or more employees.

2. Because of anonymisation of the data, the size of a number of small and medium firms can not be identified. We thus group all small and medium firms together to form a category of “small and medium firms”. The “small and medium firms” include all the “small firms”.

Figure 2: Unweighted Distribution of Innovative Firms by Firm Size



Source: CIS-3, Micro-aggregated data.

Note: 1. The correspondence between the two-digit sectors and the high-tech, medium-high-tech, medium-low-tech and low-tech manufacturing and knowledge-intensive and less-knowledge-intensive services can be found in footnote 7.

Figure 3: Unweighted Distribution of Innovative Firms by Sector

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