Non-R&D Innovation of Manufacturing Firms: Theory and Evidence from the Third European Community Innovation Survey

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Abstract:

Non-R&D innovation is a prevalent economic phenomenon, though R&D has been central focus of policy making and scholarly research in the field of innovation. The third European Community Innovation Survey (CIS3) shows that more than half of the European innovative firms did not conduct intramural or extramural R&D. Instead of investing in R&D, they acquire advanced machinery, purchase patents and licenses or carry out training and marketing activities to develop product or process innovation. In this paper, we develop a two-stage non-cooperative game to model the decisions of firms with regard to innovation budget and the allocation of the budget to R&D and non-R&D innovation activities. We demonstrate how the initial productivity of firms, share of their budgets in non-R&D innovation activities, and potential of cost reduction of available technology and R&D project would affect the decisions of firms. Following the theoretical framework and arguments, we examine the CIS 3 data to provide the empirical evidence.

Key Words: Non-R&D innovation, Community innovation survey, CIS

1. Introduction

Until very recently R&D has been synonymous with technology and innovation in many publications on science, technology and innovation. A rough estimate by the authors, based on Trend Chart data, reveals that a minimum of 95 percent of all funding for innovation in the European Union is to support R&D. The Lisbon strategy, which aimed to build Europe by 2010 the most competitive and dynamic knowledge-based economy in the world, incorporated a policy goal that the research and development expenditure in the European economies would reach 3 percent of GDP by 2010. As emphasized in the Lisbon strategy, R&D intensity is extensively used by scholars and policy makers as a benchmark for measuring the innovativeness of a firm, a region and a country.

The importance of R&D is the very reason accounting for the predominant role of R&D in innovation studies and policy making. R&D is the source of many productivity enhancing innovations. It is essential to competitiveness of fast-growing high technology industries such as pharmaceuticals, automobiles, ICT, machinery industries etc. R&D is also critical to absorptive capacity of a firm and an industry (Cohen and Levinthal, 1989) and associated with advantage of terms of trade of a country. In addition, R&D activities create demand and supply for high caliber human resources which would give impetus to the development of education system in a country.

Although R&D is a vital for innovation activities of firms and the competitiveness of an industry and a country, the third European Community Innovation Survey (CIS3) shows that about half of the European firms which report they have product or process innovation do not conduct intramural or extramural R&D (Figure 1). Naturally, in the less developed Eastern European countries, the shares of non-R&D innovators are higher than in the developed Western European countries. Breaking down the data of non-R&D innovators by sector, we find that non-R&D innovators are concentrated in low technology manufacturing and service sectors (Figure 2). The distribution of these non-R&D innovators are skewed toward small and medium firms (Figure 3). Given that a significant number of firms innovate without conducting R&D, non-R&D innovation activities should have drawn considerable attention from academics and policy makers. Actually the Oslo Manual provides a broad definition of innovation in recognition of the facts that diffusion is crucial to realizing the economic benefits of innovation and that R&D only covers a part of all of the different methods that firms use to innovate. However, there is lack of systematic studies on the means other than R&D that firms use to innovate and thorough research that links different types of innovation to performances of firms.

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(Here insert Figure 3)

In this paper, we aim to fill this gap by developing a two-stage non-cooperative game to model the decision of firms with regard to innovation budget and how firms allocate the budget to R&D and non-R&D innovation activities. We demonstrate that how the initial productivities of a firm, share of its budget in non-R&D innovation, potential of cost reduction of existing technology and R&D project, and the strategic interaction between the firm and its competitors would affect the decision of the firm. Through examining the data of the third European Community Innovation Survey (CIS3), we provide empirical evidence to support theoretical arguments.

The remainder of this paper is organized as follows. Section 2 reviews the relevant theoretical contribution to understanding R&D or innovation activities of firms. Section 3 establishes a theoretical framework to analyze the factors influencing the decision of a firm on innovation expenditure. Section 4 presents empirical evidence drawn from the CIS3 data to support the theoretical propositions and discusses policy implication. Section 5 concludes.

2. Review of Theoretical Literature

The models studying R&D activities of firms can be classified into two categories, i.e. tournament and non-tournament models (Beath et al., 1995). In the tournament models, firms engage in competition for technological breakthrough or patent application. The single winner of the competition will take all benefit. In the tournament models of patent race, the firms' probability of making a discovery and obtaining a patent at a point of time, i.e. winning the tournament, depends on the firm's current R&D expenses and accumulated experience in R&D activities.[1] In non-tournament models, firms apply for patents to protect the outcome of their R&D investment, but they could not prevent other firms from achieving the same outcome by investing in R&D. No matter whether the models incorporate tournament or non-tournament elements, they reflect the two basic motives of firms of R&D investment, which are increasing profit in the future by allocating resources to R&D and obtaining strategic advantage over the rivals (Beath et al., 1995).

In an article of studying the determinants of number of firms that engage in R&D and the expected welfare performance of the industry, Quirmbach (1993) argued that a firm must consider the cost of doing research, the probability of succeeding, and the likely degree of competition in the market when making a R&D investment decision. There is a trade-off of risk and pay off in investing in a risky R&D project. A risky R&D project, although less likely to succeed, brings a larger return if it does succeed. The decision of a firm of taking such risk may be justified by its motive of preempting rivals. The idea of trade-off was modeled by Dasgupta and Stiglitz (1980a). However, in their model, only one firm, i.e. a monopolist, makes the decision of R&D investment. In a different paper (Dasgupta and Stiglitz, 1980b), they allow a number of firms to enter the competition, but these firms share the same R&D function, which means that they are symmetric.

Differently from the previous work, Rosen (1991) modeled the R&D activities of two asymmetric competing firms. The asymmetry is reflected by the difference between the costs of production of the two firms. The large firm has lower cost of production than the small one. Both firms have a menu of R&D projects with different riskness to choose. In

[1] A review of patent race models is read in Tirole (1988, Chapter 10).

addition to different R&D projects, they also select the levels of R&D investment. The firms' choices depend on their market position and their levels of technology. In a two stage model setup, both firms choose their R&D investment levels and R&D projects with different riskness in the first stage. They then engage in cournot competition in the second stage. Rosen showed that the large firm invests more in R&D, but in the safer projects bringing in incremental technological innovation. On the contrary, the small firm invests less, but in riskier projects which yield more radical innovation. Payago-Thotoky (1996) demonstrated that the outcome of Rosen's model is sensitive to the adoption of additive or multiplicative cost reduction function.[2]

Our simple model that will be presented in the next section is similar to the previous work in the sense that we incorporate the trade-off of risky and risk-free innovation activities in the model. We differentiate from the literature by arguing asymmetry of firms arises not only because of their size or productivity, but also due to industry characteristics and technological opportunities that are associated with the firms.

3. A Simple Model of Non-R&D Innovation Activity

3.1 Model Set-up

We consider two risk-neutral firms that operate in a homogeneous product market. The decision making process of the two firms is modeled as a two-stage non-cooperative game (with no collusion). In the first stage, they simultaneously engage in two types of cost reduction innovation activities which are purchasing existing technology and R&D (including intramural and extramural R&D).[3] The existing technology is manifested in the forms of computer hardware, patents, non-patented inventions, licenses, know-how, trademarks, software, etc. In addition, in order to acquire the available technology to develop product or process innovation, firms organize training for their personnel, implement marketing strategies, and launch technical preparations, which all occur with

[2] The model setup similar to Rosen's can also be read in Yin and Zuscovitch (1998) and Barros and Nilssen (1999).
[3] Product innovation aiming to improve quality of products can also be considered as cost reduction innovation (Spence, 1984).

expenses of firms. In the second stage, both firms participate in a Cournot competition with the reduced production cost. Firms choose the level of their innovation budget in the first stage and allocate the budget to the R&D and non-R&D innovation activities. Both Firms can obtain the complete information of existing technology which they plan to purchase. They can definitely reduce production cost to a certain degree after purchasing this available technology. In this sense, purchasing existing technology is a risk-free activity. In contrast, firms may fail in their R&D projects which means that their innovation investment on R&D may go in vain. In conducting R&D, firms thus face a trade-off between risk of failure and opportunity of making technological breakthrough which will bring more dramatic cost reduction than what they would obtain through acquiring existing advanced technology.

In addition to the risk of the innovation projects, the decisions of firms are also affected by the technological opportunity in the industry. For the firms in a technologically catching-up industry, buying existing technology from industry leaders in other regions or countries may be an optimal choice given the lower risk of doing so. As these firms build up their technological capability and approach the technology frontier, they will be impelled to conduct R&D to move further up along the technology ladder, simply because they could not buy more advanced technology than what they already possess. Differently, for the firms locating in an advanced industry cluster or a developed region, there is little room for them to innovate only by purchasing existing technology, simply because they are already at the technology frontier. Resources and experience of firms also influence their decisions of R&D. Firms having more financial resources and more experience in R&D would have higher probability to succeed in R&D projects. They are more likely to invest in such projects.

The marginal costs of production of the two firms are $\hat{c}_i$ (i = 1, 2) before they invest in innovation. In the first stage, the two firms simultaneously determine their innovation budget e_i (i = 1, 2). The share of the budget spent on purchasing existing technology is x_i (i = 1, 2), $0 \leq x_i \leq 1$. Accordingly, the ratio of the R&D expenditure to total innovation budget is $1 - x_i$. The share of the budget for buying existing technology is simply assumed to be exogenously given. In this way, the share x_i is a parameter in the model. Our ultimate goal is to derive the relationship between the innovation budget e_i and share of the budget spent on existing technology x_i. As seen later, we will reveal how the equilibrium value of e_i changes as the parameter x_i is altered. The cost reduction effect of existing technology is denoted by α, which means if the firms spend $x_i e_i$ on purchasing existing technology, they reduce the production cost by $\alpha x_i e_i$. Here both firms have the same α, which indicates that firms compete in the same pan-European market and are obliged to meet the same quality standard, so they look for existing technology at the same technological level. The probability of succeeding in R&D projects is $\beta_i (i = 1, 2)$. The cost reduction effect of successful R&D projects is $\gamma_i(\beta_i)$. If firms invest $(1-x_i) e_i$ in R&D projects and succeed, they reduce the production cost by $\gamma_i(\beta_i)(1-x_i) e_i$. Different β_i reflects the diverse technological opportunities in the industry and the dissimilar resources and experience that the two firms possess. α and β_i fall in a set [0, 1]. We assume

(1) $\alpha \neq \gamma_i(\beta_i)$.

A R&D project with a lower probability of success may bring a breakthrough technology which reduces the production cost more than a less risky project. Therefore,

(2) $\gamma_i'(\beta_i) < 0$.

If $\frac{\partial(\beta_i \gamma_i(\beta_i))}{\partial \beta_i} = \gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i) > 0$, then $\frac{\frac{\gamma_i'(\beta_i)}{\gamma_i(\beta_i)}}{\frac{-1}{\beta_i}} < 1$, which means when reducing the probability of success of a R&D project by 1 percent, the effect of cost reduction increases less than 1 percent. Similarly, if $\gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i) < 0$, then $\frac{\frac{\gamma_i'(\beta_i)}{\gamma_i(\beta_i)}}{\frac{-1}{\beta_i}} > 1$, which means that when reducing the probability of success of a R&D project by 1 percent, the effect of cost reduction increases more than 1 percent. Thus the return to the risk of a

R&D project is relatively lower under the condition of $\gamma_i(\beta_i)+\beta_i\gamma_i'(\beta_i)>0$ than under the condition of $\gamma_i(\beta_i)+\beta_i\gamma_i'(\beta_i)<0$.

Both firms' marginal production cost c_i at the end of the first stage is $\hat{c}_i - \alpha x_i e_i - \gamma_i(\beta_i)(1- x_i) e_i$ if the R&D project is successful. Otherwise, the marginal production cost is $\hat{c}_i - \alpha x_i e_i$. In the second stage of the game, the two firms engage in a Cournot competition in which each firm determines its production quantity q_i (i = 1, 2) conditional on e_i. The inverse demand function is modeled as $p = A- Q$, where $Q = q_1 + q_2$. p denote the market clear price. We assume

(3) $\hat{c}_i <$A.

The model is solved using backward induction. In the second stage, the expected profit of firm i is

(4) $\pi_i = (A-Q)q_i - c_i q_i - e_i$, $i = 1, 2$. [4]

Substituting c_i into the expected profit function yields

(5)

$$\pi_i = \beta\{(A-Q)q_i - [\hat{c}_i - \alpha x_i e_i - \gamma_i(\beta_i)(1-x_i)e_i]q_i - e_i\} + (1-\beta)[(A-Q)q_i - (\hat{c}_i - \alpha x_i e_i)q_i - e_i]$$

$$= (A-Q)q_i - [\hat{c}_i - \alpha x_i e_i - \beta_i\gamma_i(\beta_i)(1-x_i)e_i]q_i - e_i, \quad i = 1, 2.$$

Since α and $\gamma_i(\beta_i)$represent the cost reduction effect of existing technology and successful R&D projects, respectively, the relationship between α and $\gamma_i(\beta_i)$ reveals the firm characteristics and the technological opportunity of the industry where the firms operate and. Seen in the equation (5), $\alpha - \beta_i\gamma_i(\beta_i)>0$ signify that purchasing existing technology would be more effective in cost reduction for a firm than conducting R&D. In contrast, for a firm which is characterized by the condition that $\alpha - \beta_i\gamma_i(\beta_i)<0$, conducting R&D would be more effective in terms of reducing production cost.

The Nash-Cournot equilibrium based on the equation (5) is computed as

[4] The fixed cost of production is normalized to zero.

(6) $\pi_i^* = \dfrac{\left(A - 2[\hat{c}_i - \alpha x_i e_i - \beta_i \gamma_i(\beta_i)(1-x_i)e_i] + [\hat{c}_j - \alpha x_j e_j - \beta_j \gamma_j(\beta_j)(1-x_j)e_j]\right)^2}{9} - e_i$,

i, j = 1, 2, j ≠ i.

Since the firms choose the level of e_i in the first stage, the first order conditions for the profit maximization problem of firm *i* are

(7) $\dfrac{\partial \pi_i^*}{\partial e_i} = (A - 2\hat{c}_i + \hat{c}_j) + 2 s_i e_i - s_j e_j - \dfrac{9}{4 s_i} = 0$, where $s_i = \alpha x_i + \beta_i \gamma_i(\beta_i)(1-x_i)$ and $s_j = \alpha x_j + \beta_j \gamma_j(\beta_j)(1-x_j)$, *i, j = 1, 2, j ≠ i.*

We obtain a sub-game perfect equilibrium value of e_i^* as

(8) $e_i^* = \dfrac{3}{2 s_i^2} + \dfrac{3}{4 s_i s_j} + \dfrac{\hat{c}_i - A}{s_i}$, *i, j = 1, 2, j ≠ i.*

In order to have $e_i^* > 0$, we need

(9) $\hat{c}_i > A - \dfrac{3}{2 s_i} - \dfrac{3}{4 s_j}$.

3.2 Comparative Statics

We unfold our analysis of comparative statics by computing the first order derivative of e_i^* with respect to $\hat{c}_i$, x_i, x_j, α, β_i and β_j as follows.

(10) $\dfrac{\partial e_i^*}{\partial \hat{c}_i} = \dfrac{1}{\alpha x_i + \beta_i \gamma_i(\beta_i)(1-x_i)}$,

(11) $\dfrac{\partial e_i^*}{\partial x_i} = -\left(\dfrac{3}{s_i^3} + \dfrac{3}{4 s_i^2 s_j} + \dfrac{\hat{c}_i - A}{s_i^2}\right)(\alpha - \beta_i \gamma_i(\beta_i))$,

(12) $\dfrac{\partial e_i^*}{\partial x_j} = -\dfrac{3}{4 s_i s_j^2}(\alpha - \beta_j \gamma_j(\beta_j))$,

(13) $\dfrac{\partial e_i^*}{\partial \alpha} = -\left[\dfrac{3 x_i}{s_i^3} + \dfrac{3(x_i s_j + x_j s_i)}{4 s_i^2 s_j^2} + \dfrac{(\hat{c}_i - A) x_i}{s_i^2}\right]$,

(14) $\dfrac{\partial e_i^*}{\partial \beta_i} = -(1-x_i)\left(\dfrac{3}{s_i^3} + \dfrac{3}{4 s_i^2 s_j} + \dfrac{\hat{c}_i - A}{s_i^2}\right)(\gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i))$, and

(15) $\frac{\partial e_i^*}{\partial \beta_j} = -\frac{3}{4 s_i s_j^2}(1-x_j)(\gamma_j(\beta_j) + \beta_j \gamma_j{}'(\beta_j))$

Based on the assumption (3) and the equation (9),

(16) $\frac{3}{s_i^3} + \frac{3}{4 s_i^2 s_j} + \frac{\hat{c}_i - A}{s_i^2}$ >0 and

(17) $\frac{3x_i}{s_i^3} + \frac{3(x_i s_j + x_j s_i)}{4 s_i^2 s_j^2} + \frac{(\hat{c}_i - A)x_i}{s_i^2}$ >0.

Therefore the sign of the equations (10) is positive and the sign of equation (13) is negative. The sign of equation (11) depends on the sign of $\alpha - \beta_i \gamma_i(\beta_i)$ and the sign of equation (12) depends on the sign of $\alpha - \beta_j \gamma_j(\beta_j)$. The sign of the equations (14) and (15) are determined by the sigh of $\gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i)$ and $\gamma_j(\beta_j) + \beta_j \gamma_j'(\beta_j)$, respectively. We thus could establish

Proposition 1: A firms with relatively higher initial production cost or lower initial productivity has a larger innovation budget.

Proposition 2: A firm decreases its innovation budget as it invests more in purchasing existing technology if buying existing technology is more effective in terms of cost reduction than conducting R&D ($\alpha - \beta_i \gamma_i(\beta_i)$ >0). A firm increases its innovation budget as it invests more in purchasing existing technology if buying existing technology is less effective in terms of cost reduction than conducting R&D ($\alpha - \beta_i \gamma_i(\beta_i)$ <0).

The explanation of this proposition is straightforward. If acquiring exiting technology is more effective for a firm, when this firm invests more innovation budget to do so, it would only need to maintain a smaller budget to compete in the market. In this sense, choosing appropriate way of innovation would save resources for firms.

Proposition 3: A firm decreases its innovation budget as its competitor increases its share of innovation investment in purchasing existing technology if for such a competitor buying existing technology is more effective in terms of cost reduction than conducting R&D ($\alpha - \beta_j \gamma_j(\beta_j)$ >0). A firm increases its innovation budget as its competitor increases its share of innovation investment in purchasing existing technology if for such a competitor buying existing technology is less effective in terms of cost reduction than conducting R&D ($\alpha - \beta_j \gamma_j(\beta_j)$ <0).

Proposition 4: A firm decreases its innovation budget as the cost reduction effect of purchasing existing technology intensifies.

Proposition 5: If the return to the risk of a R&D project is relatively lower ($\gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i)$ >0), a firm decreases its innovation budget as the probability of succeeding in the R&D project increases. If the return to the risk of a R&D project is relatively higher ($\gamma_i(\beta_i) + \beta_i \gamma_i'(\beta_i)$ <0), a firm increases its innovation budget as the probability of succeeding in the R&D project increases.

This proposition is intuitive in the sense that a firm would increase its investment in a risky R&D project as long as the R&D project renders high return. On the contrary, it is not worthwhile for a firm strengthening its investment in a risky R&D project if the return to risk is low.

Proposition 6: A firm decreases its innovation budget as it competitor attains higher probability of succeeding in in-house R&D if the return to the risk of an in-house R&D project is relatively lower for its competitor ($\gamma_j(\beta_j) + \beta_j \gamma_j'(\beta_j)$ >0). A firm increases its innovation budget as it competitor attains higher probability of succeeding in in-house R&D if the return to the risk of an in-house R&D project is relatively higher for its competitor ($\gamma_j(\beta_j) + \beta_j \gamma_j'(\beta_j)$ <0).

4. Empirical Evidence from the Third European Community Innovation Survey Data

4.1 Data, Dependent and Independent Variables

We explore empirical evidence using a dataset of the third European Community Innovation Survey (CIS3) constructed by Eurostat, the statistic office of the European Union. The Community Innovation Survey data are collected on a four-yearly basis. The CIS1 survey was carried out in 1993, the CIS2 survey was carried out in 1997/1998 and the CIS3 survey was implemented in 2000/2001. As with previous Community Innovation Surveys, CIS3 is based on the Oslo Manual (second edition from 1997) which provides methodological guidelines and defines the innovation concept. The cleaned dataset includes 14430 manufacturing firms located in the 18 European countries, namely Belgium, Germany, Finland, Norway, Island, Italy, Spain, Portugal, Greece, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Romania, Slovakia and Slovenia[5].

To test the propositions we derive in the section 3, we adopt the following general econometric framework in the empirical analysis.

(18) *(Innovation expenditure intensity) = f {(Key explanatory variable), (control variables)},*

We use the innovation expenditure intensity in 2000, i.e., the ratio of total innovation expenditure to turnover, as the dependent variable. To test the proposition 1 which reveals the relationship between innovation budget and initial productivity level, the logarithm of labor productivity in 1998 is chosen as the key explanatory variable. For the proposition 2 which demonstrates the relationship between innovation budget of a firm and its decisions in allocating the budget to R&D and non-R&D innovation activities, we construct non-R&D innovation expenditure share as a key explanatory variable, which is

[5] The original dataset includes manufacturing and service firms which together amount to 71602. We clean the data through deleting 186 observations with negative values of labor productivity, innovation expenditure intensity, or non-R&D innovation expenditure share. We also delete 180 observations with innovation expenditure intensity greater than 1. We then exclude all service firms which in the cleaned dataset amount to 25999. We also exclude the manufacturing firms which have zero innovation expenditure and did not report their innovation expenditure (missing value in the dataset), which amount to 17064 and 13756, respectively. Finally we focus on the rest 14430 manufacturing firms which all have innovation expenditure intensities greater than 0, but less than or equal to 1.

defined as the ratio of innovation expenditure excluding intramural and extramural R&D expenditure to total innovation expenditure.

An important condition which yields different theoretical predictions in the proposition 2 and 3 is whether buying existing technology is more effective in terms of cost reduction than conducting R&D. As suggested in Section 3, firms in a technologically catching-up industry or country would find buying existing technology from technological leaders as an optimal choice because existing technology bears less risk. Arguably, a technological leader is most likely to have highest productivity in an industry or operates in a country where the average productivity of the firms is higher than those of the firms in the other countries. A firm operating in a technologically advanced country is thus more likely to become technological leader than its counterparts operating in a technologically laggard country. For such a firm, buying existing technology is accordingly less effective in terms of cost reduction than conducting R&D, simply because it is already at the technological frontier and it has to rely on R&D to innovate and further reduce cost.

To identify technologically advanced and laggard countries in Europe, we classify the 18 countries according to the average labor productivity of the two-digit sectors of each country. The average labor productivity of each two-digit manufacturing sector in each country is ranked in Table 1. The arithmetic average of the ranks of all sectors of each country is calculated and ranked. By ranking the arithmetic average we obtain the position for each country. The exercise shows a descending order of the European countries in terms of technological level as Italy (the highest level), Belgium, Finland, Norway, Spain, Germany, Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia, Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria (the lowest level). Although the ranking based on labor productivity is by no means perfect, it indeed demonstrates that the Western European countries (EU-15 countries) have higher technological level than their counterparts in the East or the new EU member states, which is consistent with the general perception.

(Here insert Table 1)

Different from the proposition 2, the proposition 3 illustrates how the investment in non-R&D innovation activities of the competitors in the market would affect the level of innovation budget of a firm. To test proposition 3, we construct various variables to measure the average ratios of non-R&D innovation expenditure share of competing firms in market. Competing firms are grouped according to the productivity ranks of the countries. We first divide the 18 European countries into three groups, each of which includes 6 countries. Italy, Belgium, Finland, Norway, Spain, Germany are in the country group with high labor productivity level. The competing firms operating in these countries are named Type A firms. Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia are in the group with medium labor productivity level. Firms in these six countries are Type B firms. Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria are grouped together as they have low labor productivity level. Competitors operating in these countries are called Type C firms. We construct a variable of average non-R&D innovation expenditure share of competing firms in the same country group through dividing the sum of non-R&D expenditure of all firms in the same four-digit sector and the same country group except the one under analysis by the sum of total innovation expenditure of all firms in the same four-digit sector and the same country group except the one under analysis. Also we compute two variables to measure the average non-R&D innovation expenditure share of competing firms in the different country group through dividing the sum of non-R&D expenditure of all firms in the same four-digit sector but in the different country group by the sum of total innovation expenditure of all firms in the same four-digit sector but in the different country group. The methodology of constructing these three variables is seen in Table 2.

(Here insert Table 2)

To conduct a robust test, we re-divide the 18 countries into two groups, each of which includes 9 countries. Italy, Belgium, Finland, Norway, Spain, Germany, Iceland, Greece, Slovenia are regarded as advanced countries with higher labor productivity level. Portugal, Czech Republic, Latvia, Slovakia, Hungry, Estonia, Lithuania, Romania and

Bulgaria are classified as catching-up countries with lower labor productivity level. Similarly to the analysis based on the three-country-group classification, we compute the average non-R&D innovation expenditure share of competing firms in the same country group and different country group.

4.2 Control Variables

The control variables in the econometric framework include firm size which is measured by logarithm of employee number, innovation independence variables, R&D continuity variable and country dummy variables.

Schumpeter (1950) was among the first to hypothesize that large firms in a mature capitalist economy generate a disproportionately large share of society's technological advances. Scholars who support this hypothesis have articulated that larger firms possess larger-scale, internally-generated funds, so they secure more resources with which to conduct risky R&D projects. Scale economies of R&D activity and return to R&D investment given a larger volume of sales also contribute to the advantage of larger firms. However, Cohen et al. (1987) argued that these points were flawed because of inadequate attention to the unit of analysis and to industry effects. They found overall firm size has a very small, statistically insignificant effect on business unit R&D intensity. In a recent study, Lee and Sung (2005) contended that firm size does not directly affect R&D intensity, but it does exert influence by affecting firm-specific technological competence. [6] Although no consensus was reached on the relationship between firm size and R&D or innovation intensity in previous literature, we include the logarithm of the number of employees of a firm as a control variable in our analysis.

Firms which independently develop their product and process innovation may invest more in innovation than those conducting their innovation projects in collaboration with other organizations. We construct the variables of independence of product innovation and independence of process innovation to control the impact of independence of

[6] The empirical studies on the relationship between firm size and innovation are reviewed by Cohen (1995).

innovation on the innovation expenditure intensity. The values of the variables of independence of product or process innovation are 1 if a firm reports that mainly it and its group develop product or process innovation. The values are 0 if a firm reports that it develops product or process innovation in cooperation with other enterprises or institutions or mainly other enterprises or institutions develop the product or process innovation. Firms which conduct R&D projects continuously and have long-term commitment to innovation may spend more in innovation than firms which only occasionally engage in R&D projects. We construct a variable named continuity of R&D to control for the effect of continuous R&D on innovation expenditure intensity. The value is 1 if a firm reports that it engaged in R&D continuously. Otherwise, the value is 0. We are suspect that the causal relationship may run from the innovation expenditure intensity to the variable of independence of product and process innovation and continuity of R&D activity as firms which have more resources can afford to develop product and process innovation by their own or continuously finance R&D projects. However, the central focus of the paper is not on the control variables. We thus do not instrument the control variables in the analysis below.

The firms from each of 18 countries would averagely account for about 5.6 percent of total firms in the sample. However, in our cleaned dataset, the German, Italian, Romanian and Spanish firms account for 7.6 percent, 23.8 percent, 8.8 percent and 17.1 percent, respectively, which indicates that the firms from these four countries are over-represented. To control for the over-representation, we include four country dummy variables in the regressions. The names of all variables and the methodology of constructing them are listed in Table 3.

(Here insert Table 3)

4.3 Econometric Strategy

We only focus on the firms which have positive innovation expenditure intensity. We are not interested in the firms which did not invest in innovation in the survey period, for which the key explanatory and the dependent variables in the test for proposition 2 and 3 are both zero. Given the fact that the values of the dependent variable fall in the range of (0,1], we estimate the regressions by the method of Ordinary Least Square. We control for heteroskadasticity in all the regressions.[7]

4.4 Results

To test proposition 1, we regress the dependent variable of innovation expenditure intensity on the key explanatory variable which is the logarithm of labor productivity of 1998 and control variables. As seen in Table 4, the regression is run for each two-digit sector. For 23 two-digit sectors, all the coefficients of logarithm of labor productivity of 1998 are negative. 15 of them are statistically significant. The insignificance of some coefficients is due to the limited number of observations in certain industry sectors, e.g. tobacco products (NACE 16) and petroleum products (NACE 23). In all two-digit sectors, firms with lower productivity in 1998 would have larger innovation expenditure intensity in 2000, though the results are only statistically significant in 15 sectors. These results conform to proposition 1.

(Here insert Table 4)

Manufacturing firms in different sectors do not rely on R&D to acquire technology or to innovate in the same way. In his paper on innovation in British manufacturing industries, Pavitt (1984) concluded that in scale-intensive sectors such as metal manufacturing and vehicles, firms generally tend to develop their own process technology. In textile firms,

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[7] The variance-covariance matrix is estimated by sandwich estimator of variance (Huber, 1967). The formula for the robust estimator of variance is $v = \hat{V}(\sum_{j=1}^{N} u'_j u_j)\hat{V}$, where $\hat{V} = (-\frac{\partial^2 \ln L}{\partial \beta^2})^{-1}$,

$\ln L = -\frac{n}{2}\ln(2\pi) - \frac{1}{2}\sum_{i=1}^{n}[\ln \sigma_i^2 + \frac{1}{\sigma_i^2}(y - X\beta)'(y - X\beta)]$, and u_j is a row vector, measuring the contribution from the jth observation to $\frac{\partial \ln L}{\partial \beta}$. For the linear regression such as the Ordinary Least Square, $v = (X'X)^{-1}(X'\Omega X)(X'X)^{-1}$, which is White heteroscedasticity consistent estimator (White, 1980).

however, most process innovations come from suppliers. Therefore, R&D intensity does not accurately measure innovation efforts in certain manufacturing sectors, particularly in low-technology sectors (von Tunzelmann and Acha, 2005). In addition to R&D activities, other important contributors to innovation efforts include design, engineering development, testing and prototyping, adoption-related learning activities, and exploration of markets for new products (Smith, 2005). Considering the different extent to which firms rely on non-R&D activities to innovate in different industries, we analyze the firms in high- and medium-tech sectors and low- and medium-tech sectors separately when testing proposition 2 and 3.[8]

Proposition 2 predicts that innovation expenditure intensity of a firm decreases as its non-R&D innovation expenditure share increases if the firm finds purchasing existing technology more effective in terms of cost reduction than conducting R&D. This type of firms which can compete through buying existing technology normally lag behind the technological frontier. Arguably, they are likely to operate in the catching-up countries, instead of advanced countries. Proposition 2 also foresees that innovation expenditure intensities of firms increase with their non-R&D innovation expenditure shares if the firms are at the technological frontier and rely on R&D to innovate. These firms are likely to operate in the advanced countries. Our empirical analysis in Table 5 shows that the coefficients of the variable of non-R&D innovation expenditure share of the firm under analysis are positive and statistically significant in the regressions on the firms in the high-labor-productivity and medium-labor-productivity country groups, which conforms the proposition 2. The theoretical prediction on the firms in medium-labor-productivity country group is not as clear-cut as on those in the high-labor-productivity and low-labor-productivity groups. As a result, it would not be surprising to find negative coefficients in the regression on the firms in the medium-labor-productivity countries.

[8] The high- and medium-tech sectors are the industry sectors of NACE 24, 29, 30, 31, 32, 33, 34 and 35. The low- and medium-tech sectors are the industry sectors of NACE 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 36 and 37. The classification of high-, medium- and low-tech sectors in this paper is fully in line with the standard of Eurostat, which is read in Concepts and Definition Database (CODED), Eurostat. (available at http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM&StrGroupCode=CONCEPTS&StrLanguageCode=EN.)

The coefficient of the variable is negative (-.29) and statistically significant in the regression on the high- and medium-tech firms in the low-labor-productivity country group, which also supports the proposition 2. However, the coefficient of the variable in the regression on the low- and medium-tech firms in the low-labor-productivity country group is positive (.30) and statistically significant, which is not consistent with the theoretical prediction of proposition 2. The different signs of the same variable obtained in different regressions on high- and medium-tech and low- and medium-tech firms justify the estimation on these firms in different sectors separately.

(Here insert Table 5)

Different from proposition 2 which predicts how the decision of a firm in allocating its innovation budget would affect the budget itself, proposition 3 delineates how the innovation budget of a firm would be affected by its competitors' decisions and activities. Shown in Table 5, we use three variables to measure the impact from the competing firms. To understand the results of the three variables of average non-R&D innovation expenditure share of competing firms in the same or different country groups, we recall the methodology of constructing the variables described in Table 2.

The result of the variable of average non-R&D innovation expenditure share of competing firms in the same country group shows that the decisions of competitors operating in the high-labor-productivity countries (Type A competitors) positively impacts the innovation expenditure intensity of the low- and medium-tech firms in the same country group (the coefficient is .025), which supports proposition 3. A negative coefficient (-.021) which is statistically significant at 10 percent is obtained for the competing firms in the medium-labor-productivity countries (Type B competitors) in the regression on the high- and medium-tech firms in the same country group. The negative sign of this variable is not perceived as contradictory evidence to proposition 3 since the theoretical prediction is less clear-cut in terms of whether the sign would be positive or negative for the firms at medium labor productivity level.

The results of the variables of average non-R&D innovation expenditure share of competing firms in the different country groups demonstrate a positive and statistically significant coefficient for Type A competitors which operate in high-labor-productivity countries (the coefficient is .021). Negative and statistically significant coefficients are attained for Type B (the coefficients are -.028 and -.040) and Type C (the coefficients are -.023 and -.021) competitors which operated in medium-labor-productivity and low-labor-productivity countries, respectively. These results are supportive of proposition 3. To summarize, among 13 statistically significant coefficients of the key explanatory variables, 12 are consistent with the prediction of proposition 2 and 3.

In a robust test of the proposition 2 and 3 by re-dividing the 18 countries into two groups, the coefficients (.018 and .040) of the variable of non-R&D innovation expenditure share of the firm under analysis are positive and statistically significant in the regressions on the firms in the advanced countries, which again confirms proposition 2 (Table 6). However, the coefficient (.037) is also positive in the regressions on the firms in the catching-up countries, which contradicts the theoretical prediction. Among the four statistically significant coefficients of the variables as to competing firms, three are supportive of proposition 3. One coefficient of the four (-.023) shows that non-R&D innovation expenditure share of competing firms in advanced countries negatively impacts the innovation expenditure intensity of high- and medium-tech firms in the same country group, which contradicts proposition 3. In summary, among 7 statistically significant coefficients of the key explanatory variables, 5 are supportive of proposition 2 and 3.

(Here insert Table 6)

The coefficients of the variable of firm size are universally negative both in Table 5 and 6, which indicates that larger firms have lower innovation intensity. The degree to which firms independently develop product innovation is negatively associated with the innovation intensity. However, firms which develop process innovation independently and have continuous R&D activities have higher innovation intensity.

5. Conclusion

In this paper, we develop a two-stage non-cooperative game to model the decision of firms with regard to innovation budget and allocation of the budget to R&D and non-R&D innovation activities. We demonstrate how the initial production cost or productivity of a firm, cost reduction effect of existing technology and R&D project, share of non-R&D innovation budget of a firm and its competitor would affect the innovation expenditure of a firm.

Following the theoretical framework and arguments, we examine the data of the third European Community Innovation Survey (CIS3) to provide the empirical evidence. We find that in all the two-digit sectors, the European manufacturing firms with lower productivity in 1998 have larger innovation expenditure intensity in 2000, which conforms to the theoretical proposition that a firm with lower initial productivity has a larger innovation budget.

Through regressing innovation expenditure intensity of the European manufacturing firms on their non-R&D innovation expenditure shares, we demonstrate evidence to support the proposition that as a firm which is away from technological frontier allocates more innovation budget to acquiring existing technology it can maintain competitive edge with a smaller budget. Similarly, a firm which is at technological frontier and spends less in R&D would have a larger innovation budget in order to compete in market. In general, these propositions lead to an argument that choosing appropriate ways of innovation could save resources for firms.

To test the theoretical proposition about how the innovation budget of a firm would be affected by the decision of its competitors in market with regard to innovation budget allocation, we explore the relationship between the innovation expenditure intensity of a firm and the non-R&D innovation shares of its competitors. We obtain the results of empirical analysis which are by and large consistent with the theoretical prediction.

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Table 1: Ranking of Average Labor Productivity of the European Firms in Each Two-Digit Manufacturing Sector and Each Country

Industry Sector (NACE Code)	BE	BG	CZ	DE	EE	ES	FI	GR	HU	IS	IT	LT	LV	NO	PT	RO	SI	SK
15	1	18	12	6	13	5	4	8	11	9	2	17	15	3	7	16	10	14
16	10	6	2	4	No Data	No Data	No Data	No Data	No Data	5	No Data	11	1	9	3	8	7	No Data
17	1	18	11	3	13	5	4	9	12	8	2	16	15	6	10	17	7	14
18	1	17	11	5	15	3	7	6	10	9	2	14	13	4	8	18	12	16
19	1	17	10	6	12	5	4	7	14	15	No Data	13	3	8	16	9	11	2
20	1	18	14	8	12	7	3	2	15	5	6	16	11	4	9	17	10	13
21	2	17	11	6	14	4	1	12	9	15	No Data	10	3	8	16	7	13	5
22	2	18	12	1	14	5	7	6	10	8	3	17	15	4	11	16	9	13
23	10	4	2	12	1	5	11	No Data	No Data	3	No Data	No Data	8	9	7	6	No Data	No Data
24	1	18	12	7	14	6	4	5	11	8	3	16	15	2	9	17	10	13
25	1	18	12	6	15	5	4	10	9	7	2	13	16	3	8	17	11	14
26	1	18	11	7	14	6	4	8	12	2	5	16	13	3	9	17	10	15
27	2	18	13	6	10	5	1	8	15	7	4	16	12	3	9	17	11	14
28	5	17	12	7	11	6	1	8	13	2	4	15	16	3	10	18	9	14
29	1	17	12	5	13	6	2	10	11	7	3	16	15	4	8	18	9	14
30	9	14	10	5	2	4	7	3	12	No Data	No Data	1	11	15	8	13	6	No Data
31	3	16	12	7	13	6	1	9	15	5	4	17	11	2	8	18	10	14
32	1	17	12	2	14	6	4	8	10	11	No Data	16	3	7	15	9	13	5
33	6	18	13	4	12	7	2	10	11	3	5	15	16	1	8	17	9	14
34	1	17	11	4	13	2	5	14	7	10	No Data	15	6	8	16	9	12	3
35	5	18	13	3	14	4	6	9	10	8	2	12	16	1	11	17	7	15
36	3	17	11	6	15	8	5	7	13	2	1	16	14	4	10	18	9	12
37	6	12	14	3	9	5	1	16	No Data	10	No Data	15	13	2	8	11	7	4
Arithmetic Average	3	16	11	5	12	5	4	8	12	7	3	14	11	5	10	14	10	11

Table 2: Methodology of Constructing the Variables of Average Non-R&D Innovation Expenditure Share of Competing Firms in Different Country Groups (Dividing 18 Countries into Three Groups)

The Variables	The Value of the Variables		
	Regressions on firms in Italy, Belgium, Finland, Norway, Spain, Germany (countries with high labor productivity level)	Regressions on firms in Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia (countries with medium labor productivity level)	Regressions on firms in Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria (countries with low labor productivity level)
Average non-R&D innovation expenditure share of competing firms in the same country group (dividing 18 countries into three groups)	A	B	C
Average non-R&D innovation expenditure share of competing firms in a different country group with the higher labor productivity level	B	A	A
Average non-R&D innovation expenditure share of competing firms in a different country group with the lower labor productivity level	C	C	B

Note: 1. A: Average non-R&D innovation expenditure share of competing firms in Italy, Belgium, Finland, Norway, Spain, Germany (countries with high labor productivity level); B: Average non-R&D innovation expenditure share of competing firms in Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia (countries with medium labor productivity level); C: Average non-R&D innovation expenditure share of competing firms in Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria (countries with low labor productivity level).

Table 3: The Variables

Variable Name	Definition and Note
Innovation expenditure intensity (dependent Variable)	Total innovation expenditure in 2000/ Turnover in 2000
Logarithm of labor productivity (1998) (Unit of labor productivity: 1000 Euro per employee)	Ln(Turnover in 1998 / Employee number in 1998)
Non-R&D innovation expenditure share of the firm under analysis	Innovation expenditure excluding intramural and extramural R&D expenditure / Total innovation expenditure
Average non-R&D innovation expenditure share of competing firms in the same country group (dividing 18 countries into three groups)	Sum of non-R&D expenditure of all firms in the same four-digit sector and the same country group except the one under analysis / Sum of total innovation expenditure of all firms in the same four-digit sector and the same country group except the one under analysis
Average non-R&D innovation expenditure share of competing firms in the different country group with the higher labor productivity level (dividing 18 countries into three groups)	See Table 2
Average non-R&D innovation expenditure share of competing firms in the different country group with the lower labor productivity level (dividing 18 countries into three groups)	See Table 2
Average non-R&D innovation expenditure share of competing firms in the same country group (dividing 18 countries into two groups)	Sum of non-R&D expenditure of all firms in the same four-digit sector and the same country group except the one under analysis / Sum of total innovation expenditure of all firms in the same four-digit sector and the same country group except the one under analysis
Average non-R&D innovation expenditure share of competing firms in the different country group (dividing 18 countries into two groups)	Sum of non-R&D expenditure of all firms in the same four-digit sector but in the different country group / Sum of total innovation expenditure of all firms in the same four-digit sector but in the different country group
Firm size	Ln(Employee number)
Independence of product innovation	The value is 1 if a firm reports that mainly it and its group develop product innovation. The value is 0 if a firm reports that it develops product innovation in cooperation with other enterprises or institutions, or mainly other enterprises or institutions develop the product innovation for the firm.
Independence of process innovation	The value is 1 if a firm reports that mainly it and its group develop process innovation. The value is 0 if a firm reports that it develops process innovation in cooperation with other enterprises or institutions, or mainly other enterprises or institutions develop the process innovation for the firm.
Continuity of R&D	The value is 1 if a firm reports that it engaged in R&D continuously. Otherwise, the value is 0.
Dummy variable for the German firms	The value is 1 if a firm is a German firm. Otherwise, the value is 0.
Dummy variable for the Italian firms	The value is 1 if a firm is an Italian firm. Otherwise, the value is 0.
Dummy variable for the Romanian firms	The value is 1 if a firm is a Romanian firm. Otherwise, the value is 0.
Dummy variable for the Spanish firms	The value is 1 if a firm is a Spanish firm. Otherwise, the value is 0.

Table 4: Relationship between Innovation Expenditure Intensity (Dependent Variable) and Initial Production Cost (Logarithm of Labor Productivity of 1998, Key Explanatory Variable)

NACE Classification	Industry	Number of Observations	Key Explanatory Variable (Logarithm of Labor Productivity of 1998)
15	Food products and beverages	1583	-.013(.0032)***
16	Tobacco products	26	-.043(.025)
17	Textiles	661	-.014(.0037)***
18	Wearing apparel	485	-.018(.0034)***
19	Tanning and dressing of leather	252	-.014(.0078)*
20	Wood and wood products	562	-.012(.0048)***
21	Pulp and paper	342	-.011(.010)
22	Publishing and printing	611	-.012(.0043)***
23	Coke, refined petroleum products	70	-.021(.029)
24	Chemicals	1100	-.013(.0036)***
25	Rubber and plastic products	781	-.018(.0043)***
26	Non-metallic mineral products	793	-.0075(.0037)**
27	Basic metals	463	-.012(.0063)*
28	Fabricated metal products	1176	-.017(.0033)***
29	Machinery and equipment	1549	-.012(.0029)***
30	Electrical and optical equipment	122	-.011(.016)
31	Electrical machinery and apparatus	710	-.013(.0052)**
32	Radio, television and communication equipment	439	-.0017(.0057)
33	Medical, precision and optical instruments	545	-.0050(.0064)
34	Motor vehicles	479	-.0075(.0072)
35	Other transport equipment	324	-.0097(.0073)
36	Furniture	832	-.014(.0032)***
37	Recycling	78	-.067(.024)***

Note: 1. The data in parentheses are standard deviations. *** denotes a significance level of 1%, ** denotes a significance level of 5%, * denotes a significance level of 10%.
2. To simplify, the coefficients of the control and dummy variables are not reported.

Table 5: Relationship between Innovation Expenditure Intensity (Dependent Variable) and Non-R&D Innovation Expenditure Share: Dividing 18 Countries into Three Groups

Independent variable	Firms in Italy, Belgium, Finland, Norway, Spain, Germany (countries with high labor productivity level)		Firms in Iceland, Greece, Slovenia, Portugal, Czech Republic, Latvia (countries with medium labor productivity level)		Firms in Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria (countries with low labor productivity level)	
	High- and medium-tech sectors	Low- and medium-tech sectors	High- and medium-tech sectors	Low- and medium-tech sectors	High- and medium-tech sectors	Low- and medium-tech sectors
Non-R&D innovation expenditure share of the firm under analysis	.028(.0055)***	.046(.0033)***	.021(.0088)**	.036(.0060)***	-.029(.014)**	.030(.0070)***
Average non-R&D innovation expenditure share of competing firms in the same country group (dividing 18 countries into three groups)	-.016(.011)	.025(.0076)*** (Type A competitors)	-.021(.012)* (Type B competitors)	.013(.0097)	-.021(.014)	.015(.0096)
Average non-R&D innovation expenditure share of competing firms in the different country group with the higher labor productivity level (dividing 18 countries into three groups)	-.028(.0097)*** (Type B competitors)	.00062(.0058)	-.00032(.018)	.021(.013)* (Type A competitors)	-.019(.019)	-.011(.016)
Average non-R&D innovation expenditure share of competing firms in the different country group with the lower labor productivity level (dividing 18 countries into three groups)	-.023(.0063)*** (Type C competitors)	.00012(.0050)	-.011(.0095)	-.021(.011)** (Type C competitors)	-.040(.019)** (Type B competitors)	.0055(.012)
Firm size (Logarithm of Employee number)	-.0099(.0014)***	-.016(.0012)***	-.0078(.0019)***	-.0074(.0019)***	-.014(.0037)***	-.012(.0020)***
Independence of product	-.0062(.0039)	-.0063(.0027)**	-.0084(.0063)	-.013(.0049)***	-.029(.0091)***	-.0063(.0049)

innovation						
Independence of process innovation	.014(.0038)***	.0097(.0027)***	.016(.0065)**	.022(.0056)***	.0088(.0089)	.015(.0051)***
Continuity of R&D	.037(.0042)***	.028(.0037)***	.022(.0060)***	.012(.0053)	.00095(.010)	.0048(.0062)
Dummy variable for the German firms	-	.044(.0077)***	-	-	-	-
Dummy variable for the Italian firms	-.033(.0054)***	-.0011(.0035)	-	-	-	-
Dummy variable of the Romanian firms	-	-	-	-	.0046(.011)	-.0061(.0054)
Dummy variable for the Spanish firms	-.030(.0055)***	.0019(.0034)	-	-	-	-
Number of observations	3130	4457	685	1192	822	2093
F statistic	F(10, 3119) =15.64***	F(10, 4445)=	F(8, 676)=5.87***	F(8, 1183)=9.31***	F(9, 812)=4.61***	F(9, 2083 =10.58***
Adjusted R-Squared	.063	.088	.053	.066	.071	.040

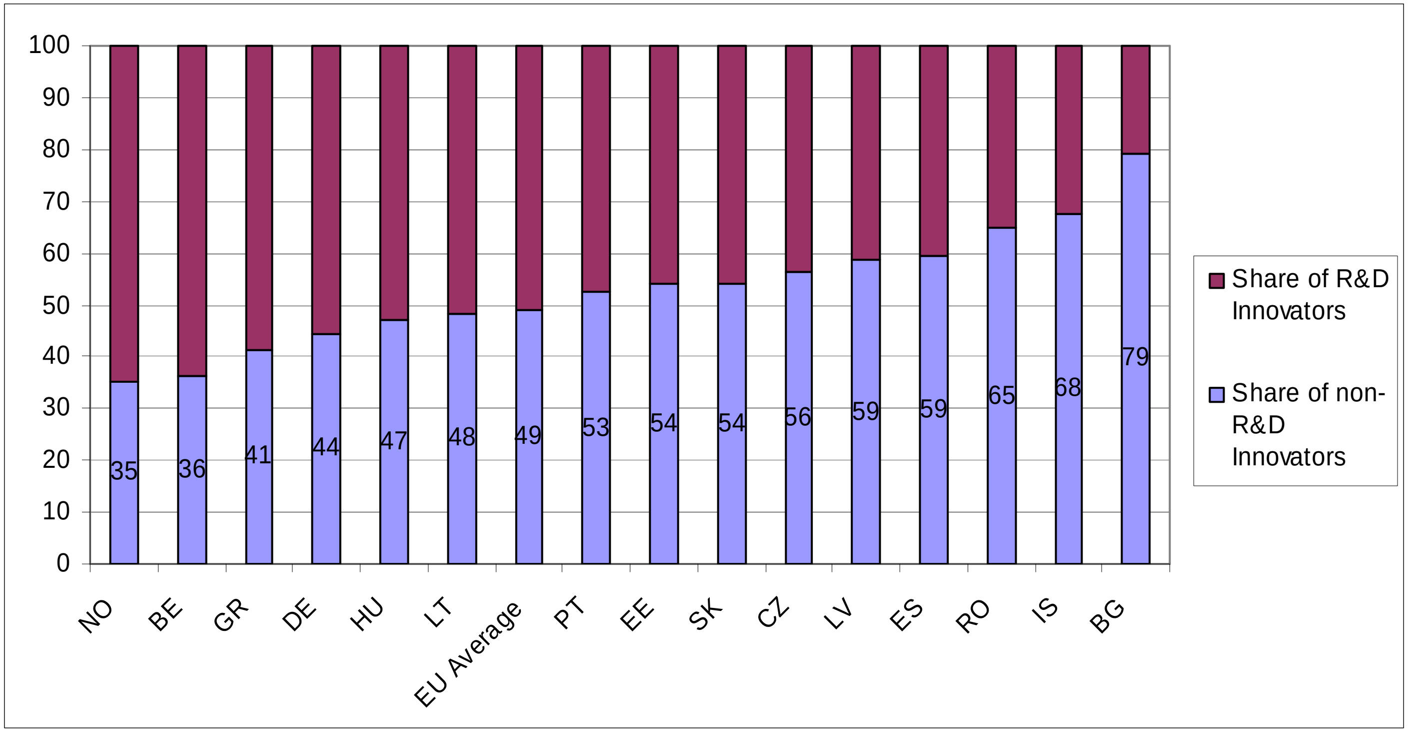
Note: 1. The data in parentheses are standard deviations. *** denotes a significance level of 1%, ** denotes a significance level of 5%, * denotes a significance level of 10%.

Table 6: Relationship between Innovation Expenditure Intensity (Dependent Variable) and Non-R&D Innovation Expenditure Share: Dividing 18 Countries into Two Groups

Independent variable	Firms in the 9 advanced countries (Italy, Belgium, Finland, Norway, Spain, Germany, Iceland, Greece, Slovenia)		Firms in the 9 catching-up countries (Portugal, Czech Republic, Latvia, Slovakia, Hungry, Estonia, Lithuania, Romania and Bulgaria)	
	High- and medium-tech sectors	Low- and medium-tech sectors	High- and medium-tech sectors	Low- and medium-tech sectors
Non-R&D innovation expenditure share of the firm under analysis	.018(.00)***	.040(.0028)***	-.011(.0096)	.037(.0052)***
Average non-R&D innovation expenditure share of competing firms in the same country group (dividing 18 countries into two groups)	-.023(.011)** (Competitors operating in advanced countries)	.011(.0060)* (Competitors operating in advanced countries)	-.046(.015)*** (Competitors operating in catching-up countries)	.012(.010)
Average non-R&D innovation expenditure share of competing firms in the different country group (dividing 18 countries into two groups)	-.025(.0080)*** (Competitors operating in catching-up countries)	.00036(.0050)	-.013(.015)	.0038(.012)
Firm size (Logarithm of Employee number)	-.0099(.0013)***	-.014(.00097)***	-.014(.0025)***	-.013(.0016)***
Independence of product innovation	-.0052(.0035)	-.0070(.0024)***	-.021(.0064)***	-.0087(.0040)**
Independence of process innovation	.015(.0034)***	.012(.0024)***	.0091(.0064)	.014(.0041)***
Continuity of R&D	.034(.0038)***	.023(.0031)***	.0097(.0071)	.0079(.0047)*
Dummy variable for the German firms	.00048(.0076)	.011(.0044)***	-	-
Dummy variable for the Italian firms	-.019(.0043)***	.0092(.0030)***	-	-
Dummy variable of the Romanian firms	-	-	.0029(.0082)	-.0020(.0044)
Dummy variable for the Spanish firms	-.017(.0045)***	.011(.0029)***	-	-
Number of observations	3573	5393	1279	2916
F statistic	F(10,3562)=15.24***	F(10,5382)=52.63***	F(8, 1270)=6.96***	F(8, 2907)=20.40***
Adjusted R-Squared	.050	.082	.058	.050

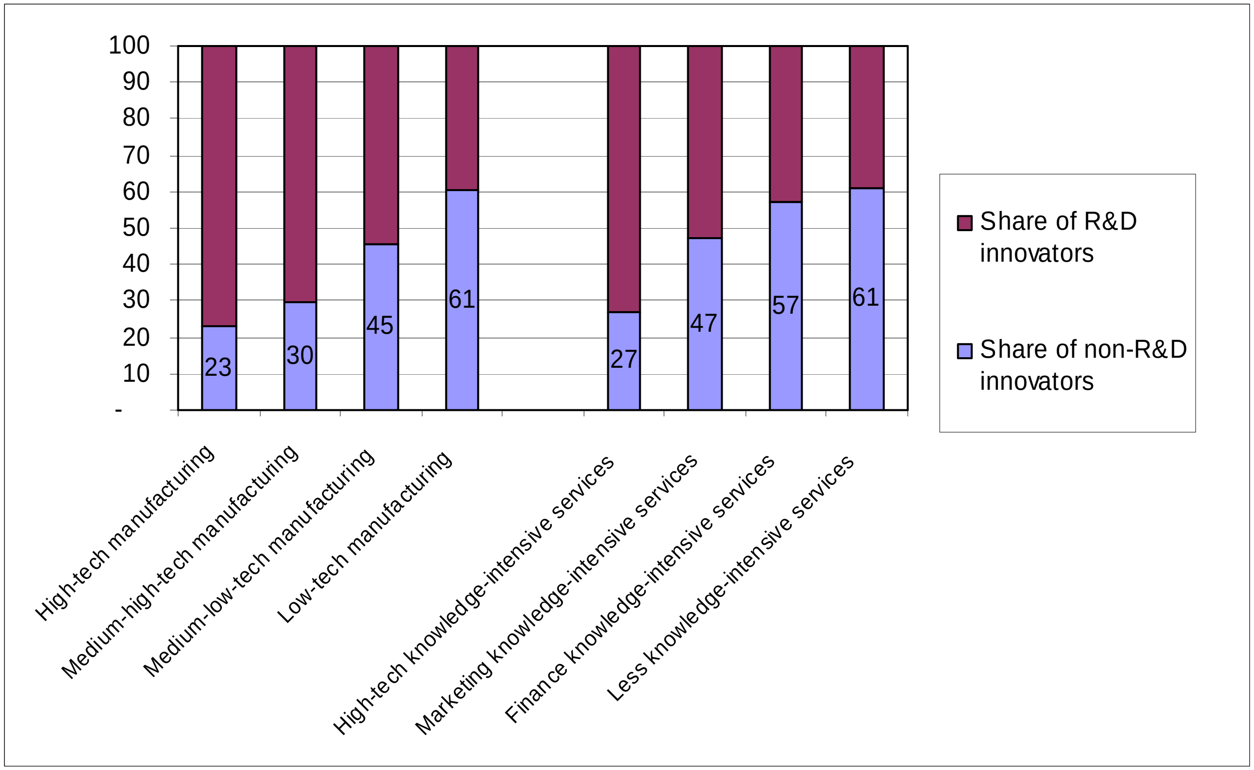
Note: 1. The data in parentheses are standard deviations. *** denotes a significance level of 1%, ** denotes a significance level of 5%, * denotes a significance level of 10%.

Figure 1: R&D and Non-R&D Innovators in 2000: Breakdown by Country (CIS-3, Micro-aggregation data)



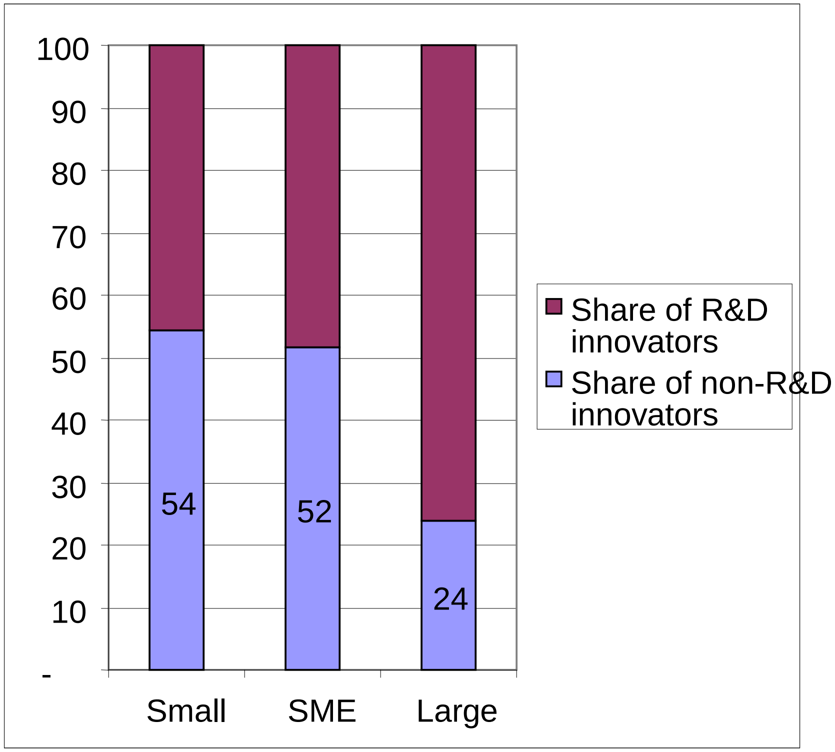
Source: Authors' calculation.
Note: 1. Non-R&D innovators are defined as innovative firms which have product or process innovation, but do not perform intramural and extramural R&D. R&D innovators are defined as innovative firms that perform intramural and extramural R&D.
2. NO, BE, GR, HU, DE, LT, PT, EE, SK, CZ, LV, ES, RO, IS and BG represent Norway, Belgium, Greece, Hungary, Germany, Lithuania, Portugal, Estonia, Slovakia, Czech Republic, Latvia, Spain, Romania, Iceland and Bulgaria, respectively. The country code of the EU member states is found in http://publications.europa.eu/code/pdf/370000en.htm.

Figure 2: R&D and Non-R&D Innovators in 2000: Breakdown by Sector (CIS-3, Micro-aggregation data)



Source: Authors' calculation.
Note: 1. The definition of Non-R&D innovators and R&D innovators is the same as in Figure 1.
2. The definition of the sectors is fully in line with the standard of Eurostat which is available at http://europa.eu.int/estatref/info/sdds/en/htec/htec_base.htm.

Figure 3: R&D and Non-R&D Innovators in 2000: Breakdown by Firm Size (CIS-3, Micro-aggregation data)



Source: Authors' calculation.

Note: 1. The definition of Non-R&D innovators and R&D innovators is the same as in Figure 1.

2. Small firms are the firms hiring 10-49 employees. Medium firms are the ones hiring 50-249 employees. Large firms hire equal or more than 250 employees.