R&D expenditures: Evidence from the Greek Manufacturing sector

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Abstract

This paper examines the factors that determine the variation of R&D activity across a sample of 150 Greek manufacturing firms for the period 1996-2000. Alternative methods (Fixed effects and 2SLS fixed effects) have been applied to test the effects of a number of firm level variables on firm R&D intensity, by taking into consideration the conditions, the initiatives and the status of technological performance in Greece. The results show that when the Greek firms are profitable and fast growing, there is limited motivation to invest in R&D.

Résumé

Cette article examine les facteurs qui déterminent la variation des activités de R&D dans un échantillon de 150 usines pendant les années 1996-2000. Des méthodes alternatives ont été appliquées afin de tester les effets d'un certain nombre de variables sur l'intensité des usines en terme de R&D. Ceci sur la base des conditions, des initiatives et du niveau de performance technologique en Grèce. Les résultats montrent que les usines grecques rentables et à croissance rapide ont moins de motivations en termes d'investissements en R&D.

1. Introduction

The relationship between market structure and industry R&D performance has been studied both intensively and extensively, while a large number of empirical studies focus on both the intensity and the determinants of firm R&D. Total R&D effort has long been viewed in both the popular and academic literature as a key determinant and indicator of the technological progressiveness of firms, industries and even nations.

The goal of this paper is to investigate the relationship between R&D intensity and other firm level variables, such as size, growth, profitability and other financial variables and to provide an explanation for the diverse and often conflicting findings of the literature, taking into consideration the different conditions, initiatives and status of technological performance of a Mediterranean country that is examined: Greece.

This paper is structured as follows: Section 2 briefly presents the science and technology policy in Greece in order to make clear the existing situation of Greek manufacturing firms concerning their technological performance. Section 3 explains a model of firm R&D and draws theoretical predictions about the relation between R&D intensity and other firm level variables. Section 4 describes the data set that is used, while in Section V the method of analysis and paper's empirical results are presented and Section 5 offers some concluding remarks.

2. Science and Technology Policy in Greece

The experience of the last 20 years in the Greek science and technology policy points out the growing concern regarding the technological development and the introduction of new elements in the Greek institutional set-up that may encourage economic actors to improve their technological and organizational capabilities.

The major steps of S&T policy in Greece over the last 20 years show an evolution towards a more European consistent framework of policy tools. Policy makers in this context seem gradually to recognize the importance of linkages and knowledge flows in strengthening the innovative performance of the Greek industrial system. In this respect promotion of R&D collaboration has been introduced recently as a means for developing interaction among different types of organizations (universities, firms, research institutes, etc.) aiming to underpin innovative process. However, although policy initiatives for supporting R&D collaboration show a certain interest in this type of research activities, it does not appear that public and private actors have integrated the involvement in R&D collaborations in their technology strategy. On the contrary, they do not seem to disassociate their R&D activity from public support.

As indicated in Table 1, gross domestic expenditure on R&D as a percentage of GDP in Greece is one of the lowest among EU countries, 0.61 in 2001 while the respective indicator for EU25 is 1.92 and for EU15 1.98 for the same year. The percentage of R&D expenditure financed by business in Greece, as it appears in Table 2, shows the weak level of Greek firms expenditure on R&D compared with other EU countries. Only 29.7% of R&D expenditure is financed by business in 2001, while the respective indicator for EU25 is 55.4% and for EU15 56%. On the contrary, Table 3 shows that 46.6% of Greek R&D intensity is financed by the government, while the respective indicator for EU25 is 34%, and for EU15 is 33.7%.

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Tab. 1. *R&D intensity as a percentage of GDP in Greece and other EU countries (1999-2003)*

Countries	1999	2001	2003
EU25	1.86	1.93	1.92
EU 15	1.90	1.99	1.98
BELGIUM	1.96	2.17	1.89
DENMARK	2.10	2.40	2.64
FINLAND	3.23	3.41	3.48
FRANCE	2.18	2.23	-
GERMANY	2.44	2.46	2.52
GREECE	0.67	0.64	0.61
IRELAND	1.19	1.15	1.17
ITALY	1.04	1.11	-
NETHERLANDS	2.02	1.89	1.76
PORTUGAL	0.75	0.85	0.78
SPAIN	0.88	0.95	1.05
SWEDEN	3.65	4.27	3.98
UNITED KINGDOM	1.85	1.89	1.88

Source: Eurostat Website (2005)

However, low R&D expenditure is not an indicator that alone could evaluate innovative efforts in Greece. As empirical evidence from OECD countries indicates, only 30-50% of all innovation costs relate to R&D expenditure (OECD, 1998). The rest is expenditure on product design, market analysis, outsourcing and expenditures on patents and licenses.

As it is increasingly recognized, innovation relies on interactive processes and knowledge flows. One of the main problems in the Greek S&T system is the limited linkages between economic actors and the weak infrastructure for diffusion of information and knowledge. In the same time infrastructure for scientific and technological services, networks of information and databases are at an early stage of development.

Tab. 2. *Percentage of R&D expenditure financed by business enterprise sector in Greece and other EU countries (1999-2001)*

Countries	**1999**	**2001**
EU25	55.2	55.4
EU 15	55.6	56.0
BELGIUM	66.2	64.3
DENMARK	50.0	61.5
FINLAND	67.0	70.8
FRANCE	54.1	54.2
GERMANY	65.4	65.7
GREECE	24.2	29.7
IRELAND	64.4	.
ITALY	.	.
NETHERLANDS	49.7	51.8
PORTUGAL	21.3	31.5
SPAIN	48.9	47.2
SWEDEN	67.8	71.9
UNITED KINGDOM	48.5	47.3

Source: Eurostat Website (2005)

During the last twenty years a change in the emphasis of S&T policy in Greece occurred mainly in the context of the European Support Framework I and II. The Greek government launched two Programs promoting technological development, Business Program for Research and Technology I and II (EPET I and II). The Programs' objectives were in accordance with those set by the European Support Framework I&II.

Another initiative was STRIDE HELLAS, integrated in the European initiative STRIDE (Science and Technology for Regional Innovation and Development) for the development of the less developed regions of the European Union. The programs PAVE and SYN were launched and funded in the context of the above initiatives. PAVE implicitly promoted R&D cooperation whereas SYN aimed directly to the cooperation of Academic or Research Institutions with firms. It should be mentioned that the above national initiatives (PAVE and SYN) differ from the European Framework Programs supporting cooperative R&D in that they do not set the condition of pre-competitive research. The main interest from a policy perspective was to improve firm's competitiveness through research collaboration that might promote the creation of new products or services and new processes.

Tab. 3. *Percentage of R&D expenditure financed by government in Greece and other EU countries (1999-2001)*

Countries	**1999**	**2001**
EU25	-	34.0
EU 15	-	33.7
BELGIUM	23.5	21.4
DENMARK	31.2	28.2
FINLAND	-	-
FRANCE	36.9	36.9
GERMANY	32.1	31.4
GREECE	48.9	46.6
IRELAND	21.9	25.5
ITALY	-	-
NETHERLANDS	35.7	35.8
PORTUGAL	69.7	61.0
SPAIN	-	39.1
SWEDEN	24.5	21.0
UNITED KINGDOM	-	-

Source: Eurostat Website (2005)

In a bid to promote the information society in a coherent, integrated manner, a separate Information Society Operational Programme has been proposed under the Community Support Framework 2000-2006. It is an innovative horizontal programme, which cuts across government departments and aims to implement the main features of the Greek government's White Paper entitled "Greece in the Information Society" issued in February 1999. It also follows the guidelines set out in the e-Europe initiative and the conclusions of the Lisbon summit in March 2000.

3. Evidence on R&D and Model Specification

The Schumpeter Mark II view (Martin, 2002) is the society ought to be willing to accept static market power for the desirable technological market performance that it brings. Sometimes the argument is that large firms which earn economic profits are better able to finance risky R&D programs. Sometimes, the argument is that firms with market power are more likely to invest in R&D because, having fewer rivals, they are more likely to be able to appropriate the revenue that flows from successful innovation (Martin, 2002).

However, the empirical literature consists of many diverse and often conflicting results, even though the majority of the studies have found a positive correlation between seller concentration and industry R&D intensity. For example, Williamson, (1965), Shrieves (1978), Mukhopadhyay, (1985) and Geroski (1990) found a negative relationship. However the majority of the empirical literature uses industry level data, to analyze mainly the relationship between market power, and R&D intensity.

There is a large number of works that try to investigate the relationship between R&D intensity and size of the firm using USA or German data. Acs and Audretsch (1987) analyze samples of 142 innovative and 42 highly innovative US four-digit industries and their results show that market power and large firm size promote desirable dynamic market performance. They also indicate that rivalry and small firm size sometimes promote desirable dynamic market performance. Kraft (1989) analyzes the relation between market structure, firm structure and innovation for a sample of 57 German metal working firms. According to his results, firm size has no significant impact on the share of new products in total sales. They also confirm that firm characteristics, as well as market characteristics, influence innovative performance. Veugelers and Vanden Houte (1990) examine R&D spending per dollar of sales for a cross-section time series sample describing 47 Belgian firms. Neither firm size nor market concentration has very significant effects on R&D intensity. Lee (2005) uses a data set of Korean manufacturing industries for the year 1983 and proves that the concentration R&D relationship differs depending on the strength of the link or simply the appropriability of R&D in terms of market share: a positive relationship is found in case of low-appropriability industries, where market concentration supplements low R&D appropriability, while a negative or inverted U-shaped relationship for high-appropriability industries.

However, only few works tried to investigate the relationship between firm R&D intensity and other firm level variables such as growth, profitability and also financial status of the firm, using data of a Mediterranean country, such as Greece, in which the technological performance of the industry is limited but growing.

The goal of this paper is to investigate the relationship between R&D intensity and other firm level variables and to provide an explanation for the diverse and often conflicting findings of the literature, taking into consideration the different technological and political situation of the country that is examined.

Following the relevant literature (Nakao,1993; Klette and Griliches, 1997; Lee, 2003 and 2005) the model, which is going to be estimated, is presented below:

RD/S=a1+a2SIZE+a3PR+a4GR+a5LEV+ a6NWTL+a7CASL

where: RD/S is the R&D intensity

SIZE is the size of the firm in terms of total assets

PR is the profitability variable

GR is the growth variable

LEV is the leverage

NWTL is the ratio of net worth over total liabilities

CASL is the ratio of current assets over short-run liabilities

The empirical literature that relates to the issue of the relationship between R&D intensity and size is vast as is clear e.g. from the survey by Cohen and Klepper (1996). Bound et al (1984) concluded that R&D increases proportionally to sales. There were deviations from this pattern among very large and very small firms, which tended to be more R&D intensive than the rest. However as they pointed out, very small firms are likely to be more innovative and do more R&D than the average small firms in US manufacturing. Cohen et al (1987) confirmed this result at the firm level, and also at the line of business level for the sample of R&D performing units. Klette and Griliches (1996) found a similar pattern. Nakao (1993) proves that the relationship between the size of the firm and R&D expenditures has a U form, which seems to suggest that the increase in the firm's resources alone may not increase the firm's investment in R&D. Cohen and Levin (1989) emphasize that the size effects in the R&D intensity, even if they are statistically significant, are "minute both in terms of the variance explained and the magnitude of the coefficients". Similarly, Cohen and Klepper (1996), state that "in most industries it has not been possible to reject the null hypothesis that R&D varies proportionally with size across the entire firm size distribution".

Two studies that empirically examine the relationship between R&D intensity and the profit margin are Geroski, Machin and van Reenen (1993) and Brouwer and Kleinknecht (1994). Both studies find a positive and statistically significant relationship. The study by Geroski et al. emphasizes a causal relationship that runs from changes in R&D to changes in the profit margin, but they also point out that the longitudinal effects are small compared to persistent cross sectional differences in the profit margins. Hula (1988) found no statistical significant effect of profit on R&D.

The variables of leverage, the ratio of net worth over total liabilities and the ratio of current assets over current liabilities are included in the model in order to investigate the

effects of firm's financial status on R&D intensity, which has not been recognized and investigated in previous studies. It has been suggested that innovation must be largely financed internally, for uncertainty is an inherent component of innovation. In addition, borrowing requires disclosure of information, and this might be a risk for the firm, as information on new products can leak out to potential rivals (Kraft, 1989). The possibilities of external financing are taken into account by the variable LEV, which among others shows the efficient use of borrowed capital.

4. Data and measurement of variables

The study is based on financial data collected from Balance Sheet and Income Statement of 150 large manufacturing firms which are present in the Greek Stock Market. The data were obtained from the published database of Athens Stock Market. The financial data set covers the period 1995-2000.

The total number of annual observations would be 750 (150 firms x 5 years). However, financial data for some firms are not available for the whole period and actually the data set is not complete. Given the small number of observations without data and that all these do not refer to the leading firms, the problem is not serious. Further these cases are treated as missing values, by the econometric program, without affecting the quality of the obtained results. The data for 1995 have been used in order to compute the growth variable.

The dependent variable R&D intensity is measured as the logarithm of the ratio of R&D expenditures over sales, while the explanatory variables are measured as follows: PR is the logarithm of the ratio of gross profits over assets, SIZE is measured as the logarithm of total assets, GR Growth is measured as the ratio of firm's sales of year t over sales of year t-1, LEV is measured as total liabilities over equity, CASL is measured as the ratio of current assets over short run liabilities, while NWTL is the ratio of net worth over total liabilities.

The sample has been also divided into seven separate groups according to the industry they belong in order to investigate if the behavior of the firms, in different industries, in terms of R&D intensity, is different. The R&D intensity for the following seven groups is presented in Table 4: Food and beverages, Textiles, Metal products, Chemicals, Mining, Plastics, Wood and furniture. As it is suggested from the theory, industries with higher innovative opportunities, larger willingness to pay for higher quality products and larger demand will have higher R&D intensities. In case of Greek manufacturing, plastic industry and textile industry are the two most R&D intensive sectors for 2000, with R&D intensity equal to 0.34% and 0.24% respectively.

Tab. 4. *Average R&D intensity for each sector (%)*

	no of firms	1995	1996	1997	1998	1999	2000
Textiles	17	0.130	0.020	0.080	0.070	0.120	0.240
Metal	14	0.060	0.020	0.020	0.020	0.050	0.057
Mining	7	0.170	0.012	0.090	0.080	0.088	0.088
Food	25	0.012	0.021	0.079	0.060	0.122	0.086
Plastic	6	0.990	0.440	0.430	0.360	0.380	0.340
Wood	5	0.045	0.048	0.150	0.120	0.160	0.100
Chemical	10	0.245	0.282	0.220	0.252	0.120	0.131

5. Method of Analysis and Results

A number of researchers (Hsiao,1986; Klevmarken, 1989; Solon, 1989) lists some of the main advantages of using time series and cross section data. They claim that only panel data can control for individual heterogeneity, can give more informative data, more variability, less co-linearity, more degrees of freedom and more efficiency. Also they argue that panel data are better able to identify and measure effects that are simply not detectable in pure cross sections or pure time series data and allow us to construct and test more complicated behavioural models than purely cross-section or time-series.

In cases where the data are time series and cross section the fixed effects method is used, which assumes that all industries have identical coefficients except for the intercept. Following Judge et al. (1988), we estimated the relevant statistic (F-test) for the fixed effects model which is used to test for the existence of the model. The estimated value for the F-test is equal to 7.22 which is higher than the theoretical value for 1% level of significance, indicating the existence of the model.

The use of fixed effects model does not take into consideration the possible existence of endogeneity bias between R&D, profitability and size variables. The 2SLS method for the fixed effects model is used here for the estimation of the parameters of the R&D equation as the above variables could be endogenously determined. By using both panel data analysis and method which take into account the endogeneity problem, the results are consistent and unbiased.

Table 5 shows the results of both the fixed effects method (FE) and two stage least square fixed effects (2SLSFE) analysis with firm R&D intensity as dependent variable by using panel data for the 150 firms of the sample over the period 1996-2000.

The results are similar for both estimation procedures. The results show that the size of the firm has a negative and statistically significant effect on R&D intensity, which shows that large firms are willing to invest less in R&D than small firms. It should be mentioned here that Greek manufacturing firms are characterised by a rather small size compared with firms in other countries. However, the impact of size was not found statistically significant in the case of 2SLS method.

Also the relationship between R&D intensity and the profit margin is found negative and statistically significant. Although the majority of the studies prove that firms with

Tab. 5. *Factors affecting R&D intensity in Greek firms, 1996-2000.*

Variables	Fixed effects	2SLS Fixed effects
SIZE	-0.29 (-2.99)*	-0.31 (-1.50)
PR	-0.15 (-2.61)*	-0.32 (-2.09)*
GR	-0.002 (-2.54)*	-0.002 (-2.54)*
LEV	0.002 (2.40)*	0.002 (2.46)*
NWTL	0.008 (0.47)	0.007 (0.39)
CASL	-0.057 (-0.96)	-0.06 (-0.97)
Observations	573	568
R^2	0.85	0.85
Adj. R^2	0.80	0.79
SIZE	-0.29 (-2.99)*	-0.31 (-1.50)

** denotes statistical significance at 5% level of significance*

higher profit margins will attract more R&D investment, theory suggests that in industries where the competition is low, there is limited motivation for firms to invest in R&D. For a long time high level of protectionism ensured high levels of profits to Greek firms preserving their monopolistic position (Vaitsos and Giannitsis, 1987). Policy initiatives included development laws, trade policy for the goals of industrial policy (tariff protectionism), export subsidies, exchange rate, direct intervention for saving ailing firms, government procurements. Most policy tools aiming to improve productive patterns and competitiveness maintained the productive and corporate status quo (Kastelli, 2000). Altogether these results seem to support the hypotheses that when the profits are high and the competition is low, firms have limited motivation for R&D. A negative and statistically significant relationship is also found between firm R&D intensity and firm growth, which means that fast growing firms are willing to spend less in R&D.

The coefficient of leverage is positive and statistically significant, while the other two control variables have no significant effect. This result seems to suggest that most Greek firms that invest on R&D, use borrowed capital, or generally external finance. The latter can be explained in part by the fact that there are many European and national programs that subsidize an R&D project. Taking into consideration also that according to a survey carried out in 80 Greek firms (Kastelli, 2000), Greek firms would not have undertaken the specific R&D projects without public funding and external finance, we conclude that Greek firms use a combination of public funding and external finance to increase their R&D intensity.

6. Conclusions

This study examines the variation and growth of R&D activity across a sample of 150 Greek manufacturing firms, and tries to investigate the relationship between R&D intensity and firm level variables such as size, growth, profitability and other financial variables. This work tries to explain the contradicting results of the literature by taking into consideration the difference in technological performance of each country.

In order to test the effects of a number of variables on firm's R&D intensity, both fixed effects method (FE) and two-stage least square fixed effects (2SLSFE) analysis are applied.

The results show that the size of the firm has a negative and statistically significant effect on R&D intensity, which shows that large firms are willing to invest less in R&D than small firms, while the relationship between R&D intensity and the profit margin is found negative and statistically significant, which proves that profitable firms have a limited initiative to apply R&D programs. A negative and statistically significant relationship is also found between firm R&D intensity and firm growth, which means that fast growing firms are willing to spend less in R&D.

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