

INNOVATION AND ECONOMIC PERFORMANCE: the case of Greek SMEs

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Abstract

The relationship between innovation and economic performance is estimated for Greek SMEs using ICAP 1999 micro data and a CDM four equation model. The empirical analysis shows an unwillingness of the Greek private sector to invest in R&D and the low productivity of innovation.

JEL Classification: O30, O31, O32, O34, O52

Keywords: Greece; CDM-Model; Innovation; Economic performance

1. Introduction

The link between innovation and performance at various levels of aggregation has been the focus of attention in a number of studies in recent decades (Loof and Heshmati, 2006).

Early empirical analysis focused on the relationship between research and development (R&D) activity and productivity growth within a Cobb-Douglas production function framework (e.g. Griliches, 1979; 1984; 1995; 1998). Pakes and Griliches (1984) were the first to develop and estimate a full model of both the knowledge production function and the final output production function. As an indicator of economically valuable knowledge they used patent counts; where, investments in knowledge creation were modeled using R&D expenditures.

Crépon, Duguet and Mairesse (1998) proposed and estimated a structural model for French manufacturing enterprises, which in Löf and Heshmati (2002) is labelled “CDM”. This combines a knowledge-production function (relating R&D activity to patenting or innovative activities) and economic performance (measured by labor productivity). The model states that an increase in innovation input increases innovation output and that firm’s productivity increases along with innovation output. According to Hall and Mairesse (2006), the final contribution of this article on CDM was the development of an explicit modeling framework, in order to use appropriate estimation methods in the presence of sample selectivity (due to the firm’s choice of whether or not to undertake R&D), potential endogeneity of some of the right-hand side variables, and the partially qualitative nature of some of the dependent variables (binary or categorical).

Many researchers adopted, in one way or another, the CDM-model framework to empirically explore the impact of innovation on productivity. Hall and Mairesse (2006) presented a list of five selected papers¹ which apply a model of the R&D, innovation, and productivity interrelations at the firm level, more or less similar to that of CDM, to

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¹ Benavente, 2006; Loof and Heshmati, 2006; Jefferson et al., 2002; Klomp and Leeuwen, 2001; Mohnen et al., 2006

countries as different as Chile, Sweden, China and the Netherlands, and to a comparison of seven European countries.

The CDM model has become popular in many countries among scholars using data from the Community Innovation Survey (CIS). Starting in the 1990s, CIS has provided a basis for research bringing a three-stage, firm oriented dataset by distinguishing between the input, throughput and output stage of the innovation process (Klomp, 2001). In specifying the empirical model, the usual problem is that innovation output is not observable. Standard proxies are patents or the share of innovative sales. The use of data obtained from the CIS has allowed the use of a more direct measure of the innovative output, which is a binary variable indicating whether an innovation has been introduced or not (Duguet, 2006; Parisi et al., 2006; Mairesse and Mohnen, 2005; Griffith et al., 2006; Robin and Mairesse, 2008; Musolesi and Huiban, 2010).

There is an extensive literature that studies how public and private R&D investments influence the productivity of countries (Department of trade and industry-DTI, 2006). The majority of the empirical analyses rely on an extended production-function approach, which includes R&D (or alternative measures of innovation effort) as another input to production. Firm level studies, including Lichtenberg and Siegel (1991) on the US, Hall and Mairesse (1995) and Mairesse and Mohnen (2005) on France, Klette and Johansen (1996) on Norway, Lotti and Santarelli (2001), Parisi et al. (2006) on Italy, Lööf and Heshmati (2002) on Sweden, Bönte (2003) on Germany, van Leeuwen and Klomp (2006) on The Netherlands, Janz et al. (2004) on Germany and Sweden, and Zachariadis (2004) on 10 OECD countries, provided indications of the correlation between R&D and productivity.

Moreover, the econometric results of Griffith et al. (2006) suggested that process innovation is only associated with higher productivity in France; in the other countries there is no such connection. Product innovation was associated with higher productivity in France, Spain, and the UK, but not in Germany. The study of Robin and Mairesse (2008) (re-)investigated the links between R&D, innovation and productivity using French data from CIS3 and CIS4. Findings resulted that product innovation is associated with a higher labour productivity. The effect of process innovation appears to be weak. Bloch (2008) found that the interaction of customer driven innovation and innovation output has a positive significant impact on productivity. The collaboration variable is also not significant in the productivity equations.

Hall, Lotti and Mairesse (2009) investigated the relationship between innovation and productivity specifically with Italian small and medium-sized firms by trying to improve on the CDM original specification. Results showed that firm size and R&D intensity, along with investment in equipment, have a positive impact on firm's productivity, especially process innovation. Musolesi and Huiban (2010) found that innovation is frequent in Knowledge Intensive Business Services and has a strong and positive effect on productivity, using France micro-data.

More recently, Huergo and Moreno (2010) adapted also a variation of the CDM-model for a sample of Spanish manufacturing firms between 1990 and 2005. Findings reflected the existence of true state dependence both in the decision of R&D investment and in the production of innovations. Last but not least, the aim of the research of Vakhitova and

Pavlenko (2010) was to estimate a link between investment in innovations and productivity in Ukrainian manufacturing firms. The findings suggested that only the effective government innovation policy may actual positively contribute to the productivity.

In this study, the CDM-model framework addresses the relationship between innovation and economic performance in Greek firms. To our knowledge, this is the first attempt for estimation, using CDM-model, with firm-level data from Greece.

The paper is organized as follows. Firstly, the CDM-model is presented. Section 3 provides data set description and outlines the econometric model behind the study and the estimation process. Section 4 presents the estimation results. The final section concludes the discussion.

2. The Theoretical Model

The CDM model is a four-equation knowledge production function model which incorporates three relationships: the productivity equation relating innovation output to productivity, the knowledge production function (or innovation equation) relating innovation input to innovation output, and the research investment equation linking innovation input to its determinants. An additional equation concerns investment decisions (Crépon et al., 1998; Lööf and Hesmati, 2002).

The structure of the CDM- model

The investment model:

In order to describe firms' research behavior, we use a model with two equations. In the first equation, firms decide whether to engage in research activities or not (the selectivity equation) and in the second, firms decide how much to invest in research activities conditional that they have already decided to make an investment (the research investment relation). That is:

$$\mathbf{g}_i^* = \mathbf{x}_i^0 \beta_0 + \mathbf{u}_i^0 \quad \text{with} \quad \mathbf{g}_i = 1 \text{ if } \mathbf{g}_i^* > 0, \text{ else } \mathbf{g}_i = 0 \quad (1)$$

$$\mathbf{k}_i^* / \mathbf{g}_i^* > 0 = \mathbf{x}_i^1 \beta_1 + \mathbf{u}_i^1 \quad \text{with} \quad \mathbf{k}_i = \mathbf{k}_i^* \text{ if } \mathbf{k}_i^* > 0, \text{ else} \quad \mathbf{k}_i = 0 \quad (2)$$

where, g_i^* is a dependent variable (decision variable) for the firm i , that is the decision of firm i to engage or not in R&D activities, k_i^* is the capital (capital used in R&D) of firm i used in R&D and x_i is a vector of explanatory variables. Consider that g_i and k_i are the corresponding observable measures. The β_0 and β_1 are vectors of unknown parameters to be estimated reflecting the impact of certain factors on the probability on engagement in investment and the actual level of R&D investment. The u_i^0 and u_i^1 are random error terms with mean zero, constant variances and not correlated with the explanatory variables.

The Innovation Equation:

The Innovation equation, describes the procedure taking place in order to transform innovation input, such as R&D capital and activities, to economic effective innovation output. This is a procedure to create Knowledge and Innovation called, too, “The Knowledge Production Function”, Griliches (1994). This equation is specified below.

$$\mathbf{t}_i = \alpha_k \mathbf{k}_i^* + \mathbf{x}_i^2 \beta_2 + \mathbf{u}_i^2, \quad (3)$$

where $\mathbf{t}_i$ is the innovation output, α_k is the elasticity of innovation output, $\mathbf{x}_i^2$ is the vector of explanatory variables (innovation input) and $\mathbf{u}_i^2$ is the random error term with mean zero, constant variance and not correlated with the explanatory variables.

The Productivity Equation:

The last equation of CDM-model is the firm’s economic efficiency function and describes the relation between innovation output and the firm’s economic performance. This function is an “enriched” Cobb-Douglas production function described as:

$$\mathbf{q}_i = \alpha_t \mathbf{t}_i^* + \mathbf{x}_i^3 \beta_3 + \mathbf{u}_i^3, \quad (4)$$

where $\mathbf{q}_i$ is value added from innovative products of firm i , α_t is the efficiency elasticity of scale with respect to innovation output, $\mathbf{x}_i^3$ is the usual vector of explanatory variables in a common Cobb-Douglas production function and $\mathbf{u}_i^3$ is the error term.

The basic econometric problems that the CDM solves are selectivity and simultaneity biases. When only the innovation sample is used, the firms are not randomly drawn from the larger population, and selection bias may arise. Therefore, it is inappropriate to limit the focus only on innovative firms, and the method suggested by CDM adds a selection equation (Löf and Hesmati, 2002).

3. Methodology***Data and description of variables***

Our sample consists of Greek enterprises that responded in 1999 to the survey “Measurement of R&D activities in enterprises”². The information was collected through the use of a structure standardized questionnaire provided by EUROSTAT. Responsible for the collection of data in the last survey was ICAP SA (ICAP). The sampling procedure was Stratified Random Sampling. The stated objectives of the survey were: a) the collection of reliable data assessing private R&D expenditure b) the measurement of the real participating personnel in R&D activities.

In order to distinguish firms by their innovative nature, we selected a sample of 510 innovative firms.³ Innovative firms, according to our definition, consist of firms with

² This was funded by the General Secretariat of Research and Technology (GSRT) in Greece. The survey had a national coverage and had been conducted irregularly from 1986 to 1999 (six times). The last survey covered the year 1999 and is used in this article.

³ The ICAP dataset includes data of 3841 firms. 1.469 of them had non-negative working cycle and from them the 510 were innovative firms.

positive expenditures for R&D. The key economic variables of our study include total personnel, gross capital, working cycle, investments, total personnel's revenue, net profit (before tax), number of patents requested, private sector's expenditures for R&D, public sector's expenditures for R&D, number of researchers, and total R&D personnel. Total R&D personnel is expressed as the sum of the number of researchers, the number of technicians and the number of other supporting personnel, and public sector's expenditures for R&D as the sum of government's and European Community's expenditures for R&D, respectively.

The abbreviations of the variables are shown in Table 1.

Table 1. Description of Variables

Abbreviation	Measure	Abbreviation	Measure
TP	Total Personnel	PR	Net Profit (Before tax)
K	Gross Capital	BRD	Private Sector's Expenditures for R&D
WC	Working Cycle	GRD	Public Sector's Expenditures for R&D
IN	Investment	SA	Total Personnel's Revenue
APN	Number of Patents Requested	TRP	Total R&D Personnel
RP	Number of researchers		

Descriptive statistics

For joint sample of innovative and non-innovative firms and separately for only innovative firms, simple summary statistics of the data are presented in Tables 2 and 3.

Table 2. Summary statistics of data: Total firms (N=1.469)

Variables	Mean	Std. Dev.	Minimum	Maximum
TP	146.867	1070.06	1.00000	32888.0
K	6080.31	71448.2	.000000	.211379E+07
SA	508.157	7870.64	.000000	292774.
WC	8419.24	46044.5	.103131	.102237E+07
IN	514.800	7334.44	.000000	251896.
PR	1189.45	11801.2	-15609.3	268654.
BRD	30.2064	324.000	.000000	11884.0
GRD	9.88641	62.6426	.000000	1500.00
RP	5.29899	21.6597	.000000	473.000
TRP	4.83186	25.1047	.000000	751.000
APN	.274112	1.79150	.000000	27.0000

Table 3. Summary statistics of data: Innovative firms (N=510)

Variables	Mean	Std. Dev.	Minimum	Maximum
TP	284.588	1790.96	1.00000	32888.0
K	13493.4	119637.	.000000	.211379E+07
SA	1388.62	13298.1	.000000	292774.
WC	15565.9	71782.3	2.26600	.102237E+07
IN	1288.92	12153.5	.000000	251896.
PR	2039.99	14092.1	-11363.0	268654.
BRD	87.0063	545.718	.780000E-01	11884.0
GRD	23.1477	98.7931	.000000	1500.00
RP	5.62157	23.1986	.000000	473.000
TRP	12.5549	40.0647	.000000	751.000
APN	.261297	1.75477	.000000	27.0000

The It is shown that for five variables (TP, K, WC, PR, GRD) the mean values of Greek innovative firms are about twice higher than those of total firms in Greece. Furthermore, for two variables (SA, TRP) the mean values of Greek innovative firms are approximately three times greater than those of total firms, and the average investment of innovative firms is 2.5 times greater than that of total firms. Finally, the average number of patents of innovative firms is almost the same with (slightly smaller than) with that of total firms.

Model Specification

The econometric analysis of this study follows the basic idea of Crépon et al. (1998) article. Our model consists of four equations, two of which are estimated by two step approach, namely tobit estimation in the first step⁴ followed by OLS estimation in the second step, and the last two equations of which are estimated in a simultaneous equation system framework. In estimating the system of equations we have adopted the Seemingly Unrelated Regression (SUR) technique⁵.

Next we present the specifications of the four equations of the CDM.

Selectivity Equation

The explanatory variables $\mathbf{x}^0$ of the selectivity equation consist of number of total personnel and public sector's expenditures in R&D.

Research Investment Relation

The determinants of innovation input labeled as $\mathbf{x}^1$ vector consist of the number of researchers, public sector's expenditures in R&D, and net profits. The research investment equation has private sector's expenditures in R&D as dependent variable.

⁴ The method of Tobit eliminates the problem of selectivity bias we would have if we used a sample with only companies that innovate. Instead we take the estimated values from the selectivity equation to correct the error in the research investment relation and, subsequently, that in innovation equation and productivity equation.

⁵ The last two equations were estimated in a 2SLS simultaneous equation system, as well. However, SUR gave better results, and therefore, these are reported in this article. The 2SLS results are available upon request.

Innovation Equation

The determinants of innovation output, the $\mathbf{x}^2$ vector, consist of the number of researchers, public sector's expenditures in R&D, and private sector's expenditures in R&D.

Productivity Equation

Finally, as independent variables (besides the innovation output) of the productivity equation we use the well known Cobb-Douglas variables, i.e. Capital and Labor. For the factor Capital we use alternatively either Capital or Investments, with the second giving more credible results than the first. For the factor Labor we use alternatively either total personnel or Total Personnel's Revenue with the second giving marginally better results.

The dependent variables include private sector's expenditures in R&D, $\mathbf{k}$, in equation (2); $\mathbf{t}$ is defined in two ways in equation (3), first as the number of patents and secondly as the total R&D personnel⁶; $\mathbf{q}$ in equation (4) is defined as the working cycle, due to the fact that it is more easily measurable and more earnestly declared than the net profit.

The specifications of all different models are given in Table 4.

Table 4. Specification of eight CDM-models; where the dependent variable in the innovation equation is either the number of patents (APN) or the total R&D personnel (TRP)

Models	1	2	3	4	5	6	7	8
<i>Selectivity Equation</i>								
Dep. variable	0 – 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1
Independent variables	TP	TP	TP	TP	TP	TP	TP	TP
	GRD	GRD	GRD	GRD	GRD	GRD	GRD	GRD
<i>Research Investment Relation</i>								
Dep. variable	BRD	BRD	BRD	BRD	BRD	BRD	BRD	BRD
Independent variables	RP	RP	RP	RP	RP	RP	RP	RP
	GRD	GRD	GRD	GRD	GRD	GRD	GRD	GRD
	PR	PR	PR	PR	PR	PR	PR	PR
<i>Innovation Equation</i>								
Dep. variable	APN	APN	APN	APN	TRP	TRP	TRP	TRP
Independent variables	BRD	BRD	BRD	BRD	BRD	BRD	BRD	BRD
	GRD	GRD	GRD	GRD	GRD	GRD	GRD	GRD
	RP	RP	RP	RP	RP	RP	RP	RP
<i>Productivity Equation</i>								
Dep. variable	WC	WC	WC	WC	WC	WC	WC	WC
Independent variables	APN	APN	APN	APN	TRP	TRP	TRP	TRP
	K	K	IN	IN	K	K	IN	IN
	TP	SA	TP	SA	TP	SA	TP	SA

⁶ As an alternative to patents, CDM-models use the information provided by the CIS, in particular, the share of sales of innovative products, to measure innovation output, which is probably more appropriate (Hall and Mairesse, 2006). Unfortunately, this is not provided by the ICAP survey.

4. Estimation results

As it was mentioned above, the CDM-model is estimated twice assuming first, the variable output of innovation to be the number of patents (models 1-4), and secondly the R&D personnel (models 5-8). The estimation process was performed by LIMDEP. The estimation results of productivity equation for the eight models are presented in Table 5.

Table 5. Estimation results of productivity equation function

	Model 1	Model 2	Model 3	Model 4
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
Constant	6966.34	24238.8	5735.18	10524.6
	(0.0006)	(0.0000)	(0.0006)	(0.0000)
Number of patents requested	-112.82	1.547	6.224	-152.63
	(0.0027)	(0.9753)	(0.8677)	(0.0063)
Gross Capital	-2434.35	-28471		
	(0.2437)	(0.0000)		
Investment			-0.5798	0.957
			(0.0079)	(0.9862)
Total Personnel	32.71		35.206	
	(0.0000)		(0.0000)	
Total Personnel's Revenue		1.341		0.017
		(0.0000)		(0.9795)
Durbin-Watson	2.27	2.016	2.237	1.993
R^2	0.720	0.516	0.729	0.383
	Model 5	Model 6	Model 7	Model 8
	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>	<i>Coefficient</i>
Constant	6972.08	33983.27	4912.58	11495.3
	(0.0056)	(0.0000)	(0.0049)	(0.0000)
Total R&D Personnel	3.967	-434.15	66.154	-60.18
	(0.9412)	(0.0000)	(0.1245)	(0.4057)
Gross Capital	-2209.79	-38220.6		
	(0.4031)	(0.0000)		
Investment			-0.664	4.04
			(0.0030)	(0.0000)
Total Personnel	32.89		37.523	
	(0.0000)		(0.0000)	
Total Personnel's Revenue		0.845		-0.275
		(0.0002)		(0.7118)
Durbin-Watson	2.28	1.980	2.229	1.983
R^2	0.726	0.547	0.729	0.394

The estimation of the CDM models using the Tobit method results to a satisfactory prediction⁷, 68,96%. The relevant analysis of the predictions of the binary model are given in Table 6.

Table 6. Analysis of Binary Choice Model Predictions

Prediction Success		Prediction Failure	
Sensitivity = actual 1s correctly predicted	12.549%	False pos. for true neg. = actual 0s predicted as 1s	1.043%
Specificity = actual 0s correctly predicted	98.957%	False neg. for true pos. = actual 1s predicted as 0s	87.451%
Positive predictive value = predicted 1s that were actual 1s	86.486%	False pos. for predicted pos. = predicted 1s actual 0s	13.514%
Negative predictive value = predicted 0s that were actual 0s	68.029%	False neg. for predicted neg. = predicted 0s actual 1s	31.971%
Correct prediction = actual 1s and 0s correctly predicted	68.958%	False predictions = actual 1s and 0s incorrectly predicted	31.042%

The two best models according to the R^2 and the t-statistic significant level are shown in the table below:

WC	Con	APN	K	IN	TP	SA	D-W	R^2
Model 1	6966.3	-112.82	-2434.4		32.71		2.274	0.720
	(0.0006)	(0.0027)	(0.2437)		(0.0000)			
	Con	TRP	K	IN	TP	SA	D-W	R^2
Model 7	4912.58	66.154		-0.664	37.523		2.229	0.729
	(0.0049)	(0.1245)		(0.0030)	(0.0000)			

⁷ That is, the estimated values with the Tobit method, which we used to "fix" the problem of selectivity bias in the system of innovation and productivity equations, are 68,958% correct.

In Table 7 below, we can see the estimated values for the innovation equation for the best two models. Unlike model 1, we can see that Model 7 has a sufficiency R^2 and is significant, based on the t-statistics coefficients. In conclusion, Model 7 is the overall the best one.

Table 7. Estimates of the Innovation Equation

TRP	Con	BRD	GRD	RP	D-W	R^2
Model 1	-1.8581 (0.3588)	-0.0282 (0.3944)	0.0771 (0.3816)	0.1656 (0.4396)	2.994	0.1222
Model 7	3.0854 (0.0000)	-0.0398 (0.0000)	0.1124 (0.0000)	1.8641 (0.0000)	2.063	0.9395

5. Conclusions

This study was aimed at investigating the relationship between innovativeness and firm economic performance in Greece. The data set used contains detailed information on various key characteristics of Greek firms. This includes total personnel, gross capital, working cycle, investments, total personnel's revenue, net profit (before tax), number of patents requested, private sector's expenditures for R&D, public sector's expenditures for R&D, number of researchers, and total R&D personnel. The estimation strategy employed in the study is based on a CDM-model framework with regards to two different variable outputs of innovation; the number of patents and the R&D personnel.

The above analysis shows a negative correlation between investment and turnover and a positive between investment and innovation (which is the result of research and technology). At the same time we know that, while investment grows over time, private spending on R & D does not follow the same path; this exists rather as a prerequisite for attracting public expenditure on research and development. These let us confirm a paradox, namely, that Greek SMEs invest (especially in new technology), but productivity is reduced.

In addition to the above, it is worth mentioning that we find a positive correlation between innovation, public sector's expenditures for R&D and number of researchers. On the contrary, innovation is negatively associated with private sector's expenditures for R&D.

The above analysis identifies a severe problem of the Greek Innovation System, namely, the unwillingness of the private sector to invest in R&D and the low productivity of innovation.

Our empirical findings underline the importance of leveraging private investment in innovation through public investment. There is a need for a new plan and a new target for the Greek innovation system, a new instrument and a new way to build new R&D programs, in order to increase the productivity of innovation. That is what we can call an *Efficient Innovation*, thus an innovation resulting in greater economic performance or greater social productivity.

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