Productivity, Product Differentiation And Profitability In The Greek Chemical Industry: An Empirical Analysis, 1991 And 2001

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ABSTRACT

The purpose of this study is to investigate the relationship between the profitability of the firm and its R&D expenditures. We separate R&D expenditures in two main categories, R&D that focuses on the product differentiation and R&D that concerns improvements in production process. The latter leads to more efficient production, which can be measured by labour productivity. We estimate our model using cross section analysis and test the significance of each one of rhe R&D expenditures in firm's profitability. Our model was applied to the Greek chemical industry, for a data set of 124 enterprises, in two distinct years, 1991 and 2001. Our findings support that the role of productivity is growing within time.

INTRODUCTION

In recent decades, the growing rivalry of firm's forces enterprises to quest new strategies suitable to applied in both production line and product market. These strategies focus on rising their profit by increasing their market share and creating barriers to entry. According to Bain (1956) product differentiation can be used by firms as a mean of creating strong barriers to entry in the market. Bain's view is in accordance to other investigations concerning several sectors of industry (Commanor 1967). Additionally, late researches supports that innovated firms invest in Research and Development a great amount of money in order to produce new products (Cooper, 1994) and increase their profitability.

Furthermore, a series of empirical investigations supports a close relationship between corporate behaviour and R&D (Scott, 1984 and Lunn and Martin, 1985). The question rises next is, are the R&D expenditures related with enterprises' financial results? The answer in the above question is that product differentiation increases its rivalry, compare to the other products of the market sector, and finally increases firm's profits (Gatingnan and Huereb, 1997). It is also known that firms' secure their profits when strong barriers to entry are exists; product differentiation constitutes a strong mean to increase entry barriers in the market. Thus, R&D expenditures help firms to increase entry barriers and are directly related to firms' profitability.

According to economic theory, R&D can affect both product differentiation and production process. We have already analysed how R&D is related to product differentiation. As far as the production process is concern, firms can improve their production process in such a way to increase the quality of the product. Additionally, by evolving their production process firms can also lower the cost of sales in three ways. First, an advance production process can produce less defective products; second, to minimize waste in raw materials and labour (Mata, 1993); and third can increase the daily productivity of the firm. The effectiveness of production process, leads to more efficient production which can be measured by labour productivity.

Our empirical investigation uses cross section analysis and estimates the relationship between the gross profit of the firm and its R&D expenditures, which have been separated in two main categories: R&D concerning the product differentiation and R&D concerning the production process. Our data set is constituted by 124 enterprises from chemical industry. In contrast to previous investigations we did not use sector data but firm level data.

The paper is organized as follows. Section two introduces the theoretical background of our empirical investigation and analyses the main idea of our model. The next section presents the data used and defines the variables of our estimated model. Section four exhibits our empirical findings for both years 1991 and 2001. Finally, section five presents our concluding remarks regarding our empirical investigation.

THEORETICAL BACKGROUND AND MODEL

Companies can increase their profits by raising barriers of entry. R&D is a source of product differentiation, and therefore, a source of competitive advantage in oligopoly industries (Beath, Katsoulakos and Ulph 1987, 1992, Beath and Ulph 1990, Schmalenssee 1976, Reedie and Bhoyrub 1981). Product differentiation can be measured by several proxies such as the percentage of the patent and trademark expenditures in total productions and by R&D density (Gisser 1991, Milgrons and Roberts, 1986).

According to literature (Schmalenssee 1987) and Lerner index of market power of the firm, the degree of monopoly power in terms of effectiveness can be measured by:

$$\frac{P-MC}{P}=\frac{1}{e} \qquad (1)$$

where, P is the price, MC is the marginal cost of the firm and e is the price elasticity of demand. Taking into account constant return to scale (Martin 1994), marginal cost equals to average cost, which is the normal rate of return of investment. Hence, the marginal cost can be written as:

$$MC=AC=wL+\frac{\lambda P^{k}K}{Q} \qquad (2)$$

where, AC is the average cost, wL is the wage bill and $\lambda P^k K$ is the rental cost of capital (λ is the rental cost per euro's worth of capital assets which includes a normal rate of return of investment).

Subtracting equation (2) from (1) and rearranging terms, the following equation can be derived:

$$\frac{PQ-wL}{PQ}=\frac{1}{e}+\lambda\frac{P^{k}K}{PQ}=\frac{1}{e}+\frac{P^{k}K}{PQ} \qquad (3)$$

The left hand side of equation (3) is the rate of returns of scale / the cost of capital, while the second term on the right hand side is the capital sales ratio. According to Martin (1994) market structure can be described by the following equation:

$$Log\left(pg_i\right)=a_0+a_1Log\left(\Pr oductivity\right)_i+a_2Log\left(R\&D\right)_i+u_i \qquad (4)$$

where, pg_i is the gross profit of the i^{th} firm, R&D is the expenditures on research and development and Productivity is the outcome of R&D on production process. As we analyse earlier, R&D can involve production line and improve the performance of the enterprise. Such an improvement can be measured by the labour productivity, i.e. how productive a labourer, who uses the firm's production process, is. Thus, we measure productivity by dividing the production of the firm with its number of workers.

The sing of α_1 coefficient is expected to be positive, a priori ($\alpha_1>0$). The sing of α_2 is expected to be positive since production innovation, a) increases productivity, which usually creates barriers to entry, and b) results in cost deduction by saving both time and raw materials.

DATA AND VARIABLE DEFINITION

In order to analyse the relationship between price cost margin and R&D as presented in section 2, i.e. firm's productivity and product differentiation, firm level data are used. We choose to apply our model in chemical industries. The chemical industry is an intensive sector where each firm in order to operate successfully in the market spends a considerable amount of money in R&D. Our input data were selected from various sources. Gross profit, which represents the price – cost margin, was obtained from ICAP (a company which owns a data source with all published financial statements). Investments in R&D concerning both, product differentiation and production process, were gathered by sending appropriate questionnaires to all firms of the sector.

Our intention is not only to empirically estimate and test our model but also to check for any kind of change in the coefficients of independent variables within time. Thus, our empirical investigation conducted using cross section data for two distinct years 1991 and 2001, and consists of 124 enterprises from the total 200 of the chemical industry in Greece. The number of firms used in our sample is smaller than the population of the chemical industry since our data have to meet two criteria. First, all firms should be act in the chemical industry in both periods and full data should be available for each firm included in our investigation.

The obtained results can be considered as representative since our sample includes the 65 percent of the total firms that were in business in 2001 in the Greek chemical industry.

In order to investigate the impact of product differentiation and production process on profitability, equation (4) has been estimated using cross – section analysis for years 1991 and 2001.

EMPIRICAL RESULTS

Our empirical investigation provides us with very interesting results. We estimate equation (4) using cross section data for both years 1991 and 2001. The 1991 coefficients of equation (4) are presented next in equation (5):

$$\underset{}{Log\left(pg_i\right)} = \underset{(7.292)}{3.331} + \underset{(5.867)}{0.548 Log\left(\Pr oductivity\right)} + \underset{(2.623)}{0.211 Log\left(R\&D\right)} \qquad (5)$$

In order to test the accuracy of the estimated equation (5), for 1991, we find the Durbin Watson coefficient. The figure of DW is 1.732, which is greater than the critical value provided by the tables of DW statistic indicating that there is no evidence of autocorrelation in the residuals of the estimated model.

Our next step is to find if there exists any association between the explanatory variables, multicolinearity problem. Thus, we calculate the correlation coefficient between Productivity and R&D, the figure of the correlation coefficient is 0.0004; the low correlation indicates that we do not face a multicolinearity problem with our data.

The coefficient of multiple determination R^2 computed as 0.254, which means that the 25.4% percent of the variation in firms' profitability can be explained by the variation in both Productivity and R&D. The value of R^2 is satisfactory since we use cross – section data. However, when dealing with multiple regression models, the adjusted R^2 should also be considered since it takes into account both the number of explanatory variables, in the model, and the sample size. The R^2_{adj} is 0.242, i.e. the 24.2% of the variation in profitability can be explained by the above model adjusted for the number of predictors and the sample size.

The reported results indicate a strong positive relationship between firms' productivity and gross profit. R&D proved a good explanatory variable, which affects the gross profit of the firms. The estimated regression indicates that production process and R&D act as barriers to entry in the sector of chemical industry, which strengthen the ologopolistic power of the firm.

Both explanatory variables are statistically significant. In this way both parameters constitute barriers to entry and act as means of ologopolistic rivalry. The profitability of the firm is explained by the two explanatory variables. This seems a very reasonable result because profitability is affected by R&D and also because both variables lead to barriers to entry, which increase profitability. We also observe that the coefficient of productivity is greater than the coefficient of R&D and both are statistically significant at the level of 5%.

To further analyse the contribution of explanatory variables the partial F – test statistic was used. In order to determine the contribution of variable j, assuming that all the other variables are already included, the following equation can be used:

$$\text{SSR}(X_j \backslash \text{all variables except j}) = \text{SSR}(\text{all variables including j}) - \text{SSR}(\text{all variables except j}) \quad (6)$$

The term SSR (X_j) represents the regression sum of squares for the model that includes only variable X_j. The null and the alternative hypothesis should be investigated to test for the contribution of X_j to the model.

H_0: variable X_j does not significantly improve the model after all the other variables have been included.
H_1: variable X_j significantly improve the model after all the other variables have been included.

The partial F – test statistic is defined as follows:

$$F = \frac{\text{SSR}(X_j \backslash \text{all variables except j})}{\text{Mean Square Error}} \quad (7)$$

while the coefficients of partial determination can now be written as:

$$R^2_{Yj,(all\ variables except\ j)} = \frac{\text{SSR}(X_j \backslash \text{all variables except j})}{\text{SST-SSR}(X_j \backslash \text{all variables including j})+\text{SSR}(X_j \backslash \text{all variables except j})} \quad (8)$$

To apply the partial F – test criterion in our study we need to evaluate the contribution of R&D after the productivity has been included in the model and conversely we must also evaluate the contribution of productivity after R&D has been included in the model. The results are presented in table 1:

Table 1
Partial F – Test Criterion

	SSR	MSE	SST	F	R^2_Y
X_1	32.88				
X_2	6.58				
X_1 and X_2	39.45	0.95	154.98		
$X_1 \| X_2$	32.87			34.42	0.22
$X_2 \| X_1$	6.57			6.88	0.05

X_1: Productivity
X_2: R&D
SST: Total sum of squares for Y (profitability)

Table 1 depicts that the introduction of productivity improves the model that already contains R&D. This happens since the partial F – test statistic (F=34.42) is slightly greater than the critical F value (from tables) and hence the decision is to reject H_0. The coefficient of partial determination of profitability with the productivity, keeping the R&D constant, is $R^2_{Y1,2}=0.22$, and means that, given the R&D expenditures, the 22% of the variation in profitability can be explained by the variation in productivity.

In the same way the partial F – test statistic for R&D is F=6.88, which is greater than the critical F value (from tables) and hence the null hypothesis can be rejected. According to our findings the introduction of R&D in our model it is only marginally improve the model which already contains the productivity variable. Since, $R^2_{Y2,1}=0.05$, the 5% of the variation in profitability can be explained by the variation in R&D.

Thus, by testing the contribution of each explanatory variable in the model, we found that, for the year 1991, both explanatory variables are statistically significant and productivity affects profitability more than R&D does.

As far as the year 2001 is concerned, we also estimate equation (4) using cross section data for the year 2001. The 2001 coefficients of equation (4) are presented next in equation (9):

$$\underset{(8.998)}{Log(pg_i) = 2.634} + \underset{(13.325)}{0.876 Log(Productivity)} + \underset{(2.806)}{0.122 Log(R\&D)} \qquad (9)$$

In order to test the accuracy of the estimated equation (9), for 2001, we find the Durbin Watson coefficient. The figure of DW is 1.724, which is greater than the critical value provided by the tables of DW statistic indicating that there is no evidence of autocorrelation in the residuals of the estimated model.

Our next step is to find if there exists any association between the explanatory variables, multicolinearity problem. The correlation coefficient between Productivity and R&D, the figure of the correlation coefficient is 0.0712; the low correlation indicates that we do not face a multicolinearity problem for the year 2001, too.

The coefficient of multiple determination R^2 is 0.613, which means that the 61.3% percent of the variation in firms' profitability can be explained by the variation in both Productivity and R&D; the value of R^2 is satisfactory. The R^2_{adj} is 0.606, i.e. the 60.6% of the variation in profitability can be explained by the above model adjusted for the number of predictors and the sample size.

The reported results are similar to 1991 and indicate a strong positive relationship between firms' productivity and gross profit. The estimated regression indicates that production process and R&D act as barriers to entry in the sector of chemical industry, and strengthen the ologopolistic power of the firm.

Both explanatory variables are statistically significant. In this way both parameters constitute barriers of entry and act as means of ologopolistic rivalry. The profitability of the firm is explained by the two explanatory variables. We also observe that the coefficient of productivity is greater than the coefficient of R&D and both are statistically significant at the level of 5%.

To further analyse the contribution of explanatory variables, for 2001, the partial F – test statistic was used. The results are presented in table 2:

Table 2
Partial F – Test Criterion

	SSR	**MSE**	**SST**	**F**	**R^2_Y**
X_1	55.61				
X_2	4.29				
X_1 and X_2	57.99	0.30	94.58		
$X_1 \| X_2$	53.70			177.57	0.59
$X_2 \| X_1$	2.38			7.87	0.06

X_1: Productivity
X_2: R&D
SST: Total sum of squares for Y (profitability)

Table 2 depicts that the introduction of productivity improves the model that already contains R&D. This happens since the partial F – test statistic (F=177.57) is greater than the critical F value (from tables) and hence the decision is to reject H_0. The coefficient of partial determination of profitability with the productivity, keeping the R&D constant, is $R^2_{Y1,2}$=0.59, and means that, given the R&D expenditures, the 59% of the variation in profitability can be explained by the variation in productivity.

In the same way the partial F – test statistic for R&D is F=7.87, which is slightly greater than the critical F value (from tables) and hence the decision is to reject H_0. According to our findings the introduction of R&D in our model it is only marginally improve the model which already contains the productivity variable. Since, $R^2_{Y2,1}$=0.06, the 6% of the variation in profitability can be explained by the variation in R&D.

CONCLUSIONS

In our investigation we analyse the impact of production process, measured by labour productivity, and R&D expenditures, as an investment for product differentiation, on firms' profitability. Cross section analyses with firm level data were used to examine the relationship between gross profit, labour productivity and R&D as an appropriate strategy, which lead to product differentiation. Our data set contains 124 enterprises, which act in chemical industry, and refers to two distinct years 1991 and 2001.

The estimated results show, for both years, that production process is greatly influences the profitability of the firm. This finding was expected since chemical industry is an intensive sector where each firm, in order to operate successfully in the market, spends a considerable amount to improve both its products and its productivity. The purpose of these expenditures is to establish strong entry barriers and create oligopolistic markets.

To further determine the contribution of production process and product differentiation in our model the partial F – test was used. It is deduced that R&D expenditures for product differentiation is less significant than the production process for years 1991 and 2001.

Our findings provide us with evidences that productivity has a greater affection of firm's profitability than R&D does (the productivity coefficient is greater than the R&D's one). Moreover, according to tables 1 and 2, the explanatory power of productivity is greater than the one of R&D. Finally, we detect a change in corporate behaviour, of chemical industry, since enterprises tend to sustain their profitability by improving their production process, as we found earlier the explanatory of R&D decreased through time.

SUGGESTIONS FOR FURTHER RESEARCH

As we described in section I, the effectiveness of production process improves firm's profitability by minimizing defections, raw materials expenditures and increasing daily productivity. A further analysis should be carried out in order to determine the importance of each parameter in firm's profitability.

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