Research Note

Productivity, Product Differentiation and Profitability: A Comparison between the Chemical and the Textile Industries in Greece

Zoe Ventoura
Athens University of Economics and Business
Ioannis Neokosmidis
National Technical University of Athens
Anastasios Theofilou
Athens University of Economics and Business

Abstract

The purpose of this study is to investigate the relationship between the profitability of the firm and its Research and Development expenditures. We separate Research and Development expenditures in two main categories, Research and Development that focuses on the product differentiation and Research and Development, which concerns improvements in production process. The latter leads to a more efficient production, which can be measured by labour productivity. We estimate our model using cross section analysis and test the impact of the two aforementioned variables upon firm's profitability. Our model was applied to Greek Chemical industry and to Greek Textile industry, for a data set of 124 enterprises of the chemical sector 139 enterprises in the textiles sector in the year 2001. Our findings support the positive influence of productivity on profitability is present in both manufacturing sectors, although not at an equal weight.

Introduction

The business world has entered the last decades in an era of extremely close competition. Enterprises seek for strategies which will allow them not only to increase their profit by increasing their market share but will also create barriers for other enterprises to enter the existing market.

In this paper 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: (a) R&D concerning the production process. and (b) R&D concerning the product differentiation.

According to economic theory, R&D can affect both production process and product differentiation.

Shu-Ching Chan and Wenching Fang (2006) support that in order to gain advantage through competitor differentiation and gain rewards, a manufacturer must lead an outstanding product design. In order to obtain an outstanding product design enterprises invest in Research and Development. A high R&D orientation of a firm leads to a stronger relationship between R&D and business performance results (Mansfield, 1981, Kotabe, 1990b), and to a higher prospect that R&D will affect corporate profitability in the long-term (Hatfield, 2002). The improvement of the product line leads to the reducing of the cost of sales which is caused by the production of defective products, the loss of raw material and labour (Mata, 1993) and a low/slow production. Furthermore the improvement in product process leads to the increase of the quality of the product.

The investment in R&D also leads to the production of new products (Cooper, 1994) and to product differentiation. 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 exist (Bain 1956). R&D expenditures help firms to increase entry barriers and are directly related to firms' profitability.

It is generally known that in technologically intensive industry the amounts invested in R&D are high (Loefsten and Lindeloef 2005). In this paper the authors undertook the challenge to investigate the R&D impact in the Chemical and Textile industry.

Our data set is constituted by 124 enterprises from chemical industry and 139 enterprises from textile 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 in the year 2001. Finally, section five presents our concluding remarks regarding our empirical investigation.

Theoretical Background and Model

Product differentiation and the development of new products raise the cost of entry and therefore the barriers of entry (Eriotis, Frangouli, Vasiliou, Ventura, 2002). By raising the barriers of entry companies can increase their profits. Taking into account that R&D is a source of product differentiation, it is 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). According to Gisser 1991, Milgrons and Roberts, 1986 there are several methods which can be employed in order to measure product differentiation, such as the percentage of the patent and trademark expenditures in total productions and by R&D density.

Given that Lerner index is expressed as $L = (P-MC) / P$ we use it in order to measure market power of the firm. The degree of monopoly power in terms of effectiveness can be measured by:

$$\frac{P - MC}{P} = \frac{1}{e} \tag{1}$$

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:

$$MC = AC = wL + \frac{P^k K}{Q} \tag{2}$$

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:

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

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 of the two selected industries (Chemical & Textile) can be described by the following equations:

$$Log\left(ch_i\right) = \alpha_0 + \alpha_1 Log\left(pch\right)_i + \alpha_2 Log\left(R\&Dch\right)_i + u_i \tag{4}$$

$$Log\left(tex_i\right) = \beta_0 + \beta_1 Log\left(ptex\right)_i + \beta_2 Log\left(R\&Dtex\right)_i + u_i \tag{5}$$

where, for equation (4) ch_i is the gross profit of the i^{th} firm of the chemical industry, pch_i is the outcome of R&D on production process and R&Dch_i is the expenditures on research and development for the chemical industry. For equation (5) tex_i is the gross profit of the i^{th} firm of the textile industry, $ptex_i$ is the outcome of R&D on production process and R&D tex_i is the expenditures on research and development for the textile industry. 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 sign of $\alpha 1$ and b1 coefficients are expected to be positive, a priori ($\alpha 1>0$, $b1>0$). The sign of α_2 and b_2 are 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 and textile industries. The chemical industry, likewise the textile 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 sectors.

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. Thus, our empirical investigation conducted using cross section data for 2001, and consists of 124 enterprises from the total 200 of the chemical industry and 139 from a total 301 of the textile industry in Greece. The number of firms used in our sample is smaller than the population of both industries since the firms included in our investigation should work at least on a break even level. The percentages of each industry which will be used in our research are presented in Table I.

In order to investigate the impact of product differentiation and production process on profitability, equations (4) and (5) have been estimated using cross – section analysis for both industries in the year 2001.

Empirical Results

Our empirical investigation provides us with very interesting results. We estimate equation (4) using cross section data for the year 2001. The 2001 coefficients of equation (4) are presented next in equation (6):

$$\underset{(8.998)}{Log\left(ch_i\right) = 2.634} + \underset{(13.325)}{0.876 Log\left(pch\right)_i} + \underset{(2.806)}{0.122 Log\left(R\&Dch\right)_i} \tag{6}$$

In order to test the accuracy of the estimated equation (6), 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 figure of correlation coefficient between Productivity and R&D is 0.0712; the low correlation indicates that we do not face a multicolinearity problem for the year 2001.

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 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 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:

$$SSR(X_j \backslash \text{all variables except j}) = SSR(\text{all variables including j}) - SSR(\text{all variables except j}) \quad (7)$$

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:

$$F = \frac{SSR(X_j \mid all \cdot variables \cdot ecxept \cdot j)}{Mean \cdot Square \cdot Error} \quad (8)$$

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

$$R^2_{Yj(all \cdot variables \cdot except \cdot j)} = \frac{SSR(X_j \mid all \cdot variables \cdot except \cdot j)}{SST - SSR(X_j \mid all \cdot variables \cdot including \cdot j) + SSR(X_j \mid all \cdot variables \cdot except \cdot j)} \quad (9)$$

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 2:

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 of 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 of R&D.

As far as the textile industry is concerned, we also estimate equation (5) using cross section data for the year 2001. The 2001 coefficients of equation (5) are presented next in equation (10):

$$\underset{(5.66)}{Log(tex_i) = 3.32} + \underset{(4.92)}{0.57\,Log(ptex)_i} + \underset{(2.03)}{0.17\,Log(R \,\&\, Dtex)_i} + u_i \quad (10)$$

In order to test the accuracy of the estimated equation (10), for 2001, we find the Durbin Watson coefficient. The figure of DW is 1.721, 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 0,104; the low correlation indicates that we do not face a multicolinearity problem with our data.

The coefficient of multiple determination R^2 computed as 0.184, which means that the 18.4% 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 0.172, i.e. the 17.2% 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 textile industry, which strengthens 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 for textile industry the partial F – test statistic was used.

The results are presented in Table 3:

Table 3 depicts that the introduction of productivity improves the model that already contains R&D. This happens since the partial F – test statistic (F=24.17) 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 $R^2_{Y1,2}=0.15$, and means that, given the R&D expenditures, the 15% of the variation in profitability can be explained by the variation of productivity.

In the same way the partial F – test statistic for R&D is F=4.13, which is accepted according to 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, $R^2_{Y2,1}$=0.02, the 2% of the variation in profitability can be explained by the variation of R&D.

Thus, by testing the contribution of each explanatory variable in the model, we found that, for the Textile industry for the year 2001, both explanatory variables are statistically significant and productivity affects profitability more than R&D does.

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 of the chemical industry and 139 enterprises of the textile industry, referring to year 2001. There were no signs of multicolinearity nor of autocorrelation.

Taking into account that R^2 is 61,3% for the chemical industry and only 18,4% for the textile industry we deduce that the chosen variables influence more the profitability of the chemical industry than the profitability of the textile industry.

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 both industries.

Finally, our findings provide us with evidences that productivity has a greater affect on firm's profitability than R&D (the productivity coefficient is greater than the R&D's one). It must be remarked that this is rather odd that for the chemical industry. One could have expected R&D to have a greater affect on a firm's profitability than productivity. This is explained when one takes into account that the Greek chemical industry is oriented in producing non differentiated products. Concerning the textile industry, the fact that textile depends mainly from labour intensity and thus the profits of textile firms are determined on labour productivity, explains why productivity has a greater affect of R&D.

References

Bain, J. S., (1956) Barriers to New Competition, Cambridge, MA: Harvard University Press. Beath, J., Katsoulacos, Y., & Ulph, D. (1987). Sequential Product Innovation and Industry Evolution. *Economic Journal (Supplement*), 97, 32 – 43.

Beath, J., Katsoulacos, Y., & Ulph, D. (1992). Sequential Product Innovation with Endogenous Market Structure, in A. Gee and G. Norman, (eds), Market Structure and Market Strategy, London: Wheatseaf, pp. 329 – 350.

Beath, J., & Ulph, D. (1990). The Trade – Off between Static and Dynamic Efficiency in a Non-Tournament Model of Innovation. University of Bristol, Discussion Paper, 90/286.

Comanor, W. S. (1967). Market Structure, Product Differentiation and Industrial Research, *Quarterly Journal of Economics,* 81 (4), 639 – 657.

Cooper, (1994). R&D: Its Relationship to Company Performance. *Journal of Product and Innovation Managemen*t. 191-200.

Eriotis, N., Frangouli, Z., Vasiliou, D., & Ventura, Z. (2002). Tobin's Q And Entry Barriers: An Empirical Relationship. The European Applied Business Research Conference, Rothenburg, Germany 2002

Gatingnan, & Huereb (1997). The R&D – Marketing interface and New Product Entry Strategy. *Marketing Intelligence and Plannin*g. 82 – 85

Loefsten, H., Lindeloef, P. (2005). R&D networks and product innovation patterns— academic and non-academic new technology-based firms on Science Parks. *Technovation, 2*5, 1025–1037

Hatfield, G. R. (2002). R&D in an EVA world. *Research Technology Managemen*t, 45 (2).

Kotabe, M. (1990b). The relationship between offshore sourcing and innovativeness of U.S. multinational firms: An empirical investigation. *Journal of International Business Studie*s, 21 (4), 623 - 638

Lunn, J., & Martin, S. (1986). Market Structure, Firm Structure and Research and Development. *Quarterly Review of Economics and Busines*s, 31 – 44.

Mansfield, E. (1981). Composition of R&D expenditures: Relationship to size of firm, concentration, and innovative output. *Review of Economics and Statistic*s, 63, 610-614

Mata J. (1993). Firm entry and firm growth. *Review of Industrial Organizatio*n, 8, 567-578.

Martin, S. (1994). Industrial Economics: Economic Analysis and Public Policy. Prentice – Hall International.

Milgrons, P., & Roberts, J. (1986). Price and Advertising as Signals of Product Quality. *Journal of Political Econom*y, 94 (4), 796 – 821.

Reekie, D. W. (1981). Profitability and intangible assets: Another Look at Advertising and Entry Barriers. *Applied Economic*s, 13, 99-107.

Schmalensee, R. (1976). Advertising and Profitablility: Further Implications of the Null Hypothesis. *The Journal of Industrial Economic*s, No. XXV, No 1.

Scott, J. T. (1984). Firm versus Industry Variability in R&D Intensity. in Zvi Griliches, ed. R&D, Patents and Productivity, Chicago University Press, 1984, pp. 233 – 52.

Shu-Ching Chan, Wenching Fang (2006). A Study on the Factors of Manufacturer Profitability: The Moderating Effect of Different Industries. *The Journal of American Academy of Business ,* Cambridge, 8 (2).

Table 1: Percentages used in our research

Industry	Total Number	Sample	Percentage	Representative
Chemical	200	124	65%	YES
Textile	301	139	46%	YES

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		
$X_1 \mid X_2$	53.70			177.57	0.59
$X_2 \mid X_1$	2.38			7.87	0.06

X_1: log(*pch*)
X_2: log(*R&Dch*)
SST: Total sum of squares for Y (*log*(*ch*))

Table 3: Partial F – test criterion

	SSR	MSE	SST	F	R^2_Y
X_1	14.05				
X_2	3.46				
X_1 and X_2	16.23	0.528	88.05		
$X_1 \mid X_2$	12.77			24.17	0.15
$X_2 \mid X_1$	2.18			4.13	0.03

X1: log(*ptex*)
X2: log(*R&Dtex*)
SST: Total sum of squares for Y (log(*tex*))