RESEARCH AND DEVELOPMENT IN GREEK FOOD MANUFACTURING INDUSTRIES

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ABSTRACT

This paper examines the factors that determine the variation of R&D activity across a sample of 40 food industries in Greece. Alternative methods (single and simultaneous models) have been applied to test the effects of a number of variables on the industry R&D intensity. Both OLS and 3SLS results show that R&D intensity is high in profitable and rapidly growing industries. However, the results do not show that large firms operating in highly concentrated industries are more able to apply R&D programs, than small firms in low concentrated industries.

RÉSUMÉ

Cet article examine les facteurs qui déterminent la variation de l'activité de Recherche et Développement sur un échantillon de 40 industries alimentaires en Grèce. Des méthodes alternatives (modèles individuels et simultanés) ont été appliquées pour tester les effets d'un nombre de variables sur l'intensité de R&D de l'industrie. Tant les résultats des OLS que des 3SLS montrent que l'intensité de R&D est élevée et en croissance rapide pour les industries rentables. Toutefois, les résultats n'indiquent pas que les grandes entreprises agissant en des industries à forte concentration sont plus capables d'appliquer les programmes R&D que les petites entreprises en des industries à faible concentration.

A large number of empirical studies focuses on both the intensity and the determinants of 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. In recent years, industrialists, policymakers and academics have increasingly appreciated the importance of the composition of that effort as well (Cohen and Klepper, 1996). Since the importance of R&D expenditures are associated with other variables affecting structure and performance of each industry, and the variation of R&D activities across food industries with different profitability and growth rates, is examined.

The work presents R&D activity in Greek food and beverage industry and explains in a more comprehensive way the determinants that affect R&D outlays. Alternative methods (OLS and 3SLS) have been applied to test hypotheses concerning the relationship between the level of industry R&D activity and its determinants.

R&D IN GREEK FOOD AND BEVERAGE INDUSTRY

Food and beverage industries have been recently characterised by a high profitability and fast growth in both the European Union and Greece. The respective profitability indices for Greece are 13.6 and 26.9 percent for the food and beverage industries, respectively, against 11.3 percent for the total manufacturing for 1991 (NSS, 1987-92). The same industries also achieved a faster growth than the rest manufacturing. The respective indices (1980=100) are 103.3 and 101.7 for the manufacturing, as compared to 115.3 and 123.8 for the food industry and to 135.1 and 145.6 for the beverage industry in 1988 and 1991, respectively (NSS, 1987-92). The sector have also experienced high profitability and fast growth in both Greece and the European Union as a whole. The profitability indices for the Greek food and beverage industries, are 13.6 and 26.9 percent, respectively, against 11.3 percent for the total manufacturing for 1991 (NSS 1987-92).

In 1991, R&D expenditures in Greek food industry accounted for 6.2% of the total expenditures in R&D in manufacturing. Although food is not a high technology industry, the food and beverage sectors ranked sixth in terms of contribution to R&D outlays, among all the other sectors in Greek manufacturing; machinery except electrical (30%), electrical machinery (25%), plastic (7%), chemical, (7%) and metal products (6.8%), were ranked first, second, third, fourth and fifth respectively. However, the contribution of food industry in terms of personnel engaged in R&D, accounted 9.5%, of R&D employees in manufacturing and ranked third among all the other sectors in Greek manufacturing (machines and electrical machines were ranked first and second with a contribution of 29 and 15%, respectively).

Table 1 presents R&D expenditures by 4-digit Greek food industry and the growth for the period 1988-91. The most innovative industry in food and beverage sector for 1991 was the manufacturing of oil products (olive oil, seed oil). The amount invested in R&D for oil products was 8195 million drachmas at constant 1970 prices and accounted 31% of the total R&D expenditures in food and beverage industry. The second more innovative industry which spend an important amount of money on R&D, in 1991, was the manufacturing of chocolate and cocoa products, with a contribution of 16% of total food R&D outlays. Also the manufacturing of food preparations had a contribution of 15.5%, the

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Table 1 ***R & D expenditures by 4-digit Greek food industry in thousands drachmas at constant 1970 prices.***

Industries		1988	1991	growth 88-91
2011	Animal slaughtering	0	0	0
2012	Intestine processing	0	0	0
2013	Sausages and other preparedmeats	246.6	199.61	0.81
2014	Meat processing and packing plants	0	0	0
2015	Poultry slaughtering and processing	0	2.28	0
2021	Dry condensed evaporated products	2171.5	775.91	0.35
2022	Cheese natural and processed	0	0	0
2023	Ice cream and frozen deserts	305.0	1774.82	5.81
2031	Fruit juices	122.04	113.48	0.92
2032	Sugary fruits and vegetables	0	878.24	—
2033	Canned fruits and specialities	14.46	109.79	7.59
2034	Olive processing	0	0	0
2035	Dehydrated fruits and vegetables	595.3	0	0
2036	Figs cleaning and sterilised	0	0	0
2037	Currants' cleaning	0	0	0
2038	Preserved sea food	58.56	65.07	1.11
2040	Manufacturing of oil products	5015.8	8195.01	1.63
2051	Flour and other grain mill products	96.2	76.49	0.79
2052	Rice and legume milling	0	45.50	0
2061	Bread production	18.78	434.80	23.15
2062	Cookies and crackers	298.14	1107.06	3.71
2063	Other confection products	0	20.52	0
2071	Sugar production	0	0	0
2081	Chocolate and cocoa products	819.66	4192.83	5.11
2082	Candy products	380.22	691.6	1.81
2083	Delight products	0	0	0
2084	Sweet sesame and honey products	0	0	0
2085	Salted and roasted nuts and seeds	82.02	0	0
2092	Sugar except can and beet	0	0	0
2093	Paste products	0	0	0
2094	Macaroni and spaghetti	90	0	0
2095	Pie production	0	267.86	0
2096	Roast coffee	0	0	0
2097	Prepared feeds	27.78	119.8	4.30
2099	Food preparations	2583.7	4082.62	1.58
2111	Ethyl alcohol & Alcoholic liquors	222.96	0	—
2120	Wine industries	287.82	164.80	0.57
2130	Breweries and manufacturing ofmalt	1317.54	1760.26	1.33
2140	Soft drinks and carbonated waters industries	526.3	1259.58	2.39
20&21	Food and beverage	15280.9	26372.3	1.72

Source: National Statistical Service, 1988-91.

manufacturing of malt 6.6% and ice cream and frozen desserts industry 6.7%.

The increase in aggregate food and beverage R&D expenditures for the period 1988-91, was 1.72%. However, there are sectors showing higher rates of growth. The highest rate of growth is found in bread production with an increase of 23.1%. Above the average rate of growth in R&D, is found also in the cases of canned fruits and specialities (7.5%), ice cream and frozen desserts (5.8%), chocolate and cocoa products (5.1%), prepared feeds (4.3%), cookies and crackers (3.7%) and soft drinks and carbonated waters (2.4%).

R&D intensity which is measured as the ratio of R&D expenditures over sales for each industry, in 1991, is presented in **table 2**. According to these data the most technologically intensive industry for 1991, was pie production (1.2%), while ice cream and frozen desserts (0.36%), food preparations (0.28%), manufacturing of oil products (0.18%), chocolate and cocoa products and fruit juices (0.16%) had an R&D intensity above the average.

Empirical evidence on R&D

Theory suggests that industry concentration will be an important determinant of expenditures on R&D. Scherer (1987) tested the theory for 58 US industry groups in 1960 The dependent variable was the ratio of employment of scientists and engineers to total employment in each sector. Although the overall explanation was good the concentration variable was significant only at the 10% level. Levin et al. (1975) examined the determinants of both R&D intensity and innovation in US industry in the 1970s. Regressing these dependent variables on the four-firm concentration ratio and its square gave significant coefficients implying an inverted U shaped relationship. In Schumpeter's discussion of the effects of market power on innovation, there are two distinct themes. First, Schumeter recognised that firms required the expectation of some form of transient market power to have the incentive to invest in R&D. Second, Schumpeter argued that an ex ante oligopolistic market structure and the possession of ex ante market power also favoured innovation. Economists have offered an array of theoretical arguments yielding am-

Table 2 ***R&D intensity in Greek food industries, 1991.***

Industries		RD/S 1991 (%)
2011	Animal slauthering	0
2012	Intestine processing	0
2013	Sausages and other prepared meats	0.014
2014	Meat processing and packing plants	0
2015	Poultry slauthering and processing	0
2021	Dry condensed evaporatedproducts	0.018
2022	Cheese natural and processed	0
2023	Ice cream and frozen deserts	0.36
2031	Fruit juices	0.160
2032	Sugary fruits and vegetables	0.034
2033	Canned fruits and specialities	0.007
2034	Olive processing	0
2035	Dehydrated fruits and vegetables	0
2036	Figs cleaning and sterilised	0
2037	Currants' cleaning	0
2038	Preserved sea food	0.020
2040	Manufacturing of oil products	0.270
2051	Flour and other grain mill products	0.002
2052	Rice and legume milling	0
2061	Bread production	0.1
2062	Cookies and crackers	0.12
2063	Other confection products	0.014
2071	Sugar production	0
2081	Chocolate and cocoa products	0.16
2082	Candy products	0.12
2083	Delight products	0
2084	Sweet sesame and honey products	0
2085	Salted and roasted nuts and seeds	0
2092	Sugar except can and beet	0
2093	Paste products	0
2094	Macaroni and spaghetti	0
2095	Pie production	1.20
2096	Roast coffee	0
2097	Prepared feeds	0.012
2099	Food preparations	0.280
2111	Ethyl alcohol & Alcoholic liquors	0
2120	Wine industries	0.011
2130	Breweries and manufacturing of malt	0.066
2140	Soft drinks and carbonated waters industries	0.033

Source: National Statistical Service, 1988-91.

biguous predictions about the effects of market structure on innovation. The majority of the studies that examine the relationship between market concentration and R&D have found a positive relationship (Scherer, 1967; Mansfield, 1968). A few have found evidence that concentration has a negative effect on R&D (Mukhopadhyay, 1985).

Recognising the potential simultaneity between innovation and concentration, some investigators (Levin et. al. 1975) have used instrumental variables for concentration in regression studies of the effects of market structure on innovative activity. Others (Farber, 1981; Lunn and Martin, 1986; Lunn, 1986; Levin and Reiss, 1988; Uri, 1988) have used industry-level data to estimate multi-equation models in which concentration and R&D are both treated as endogenous. Connolly and Hirchey (1984), Levin and Reiss (1988) and Levin et al. (1975) all find that Hausman-Wu test reject the hypothesis the concentration variables are orthogonal to the error term (Cohen and Levin, 1989). This result, however, may well arise from misspecification or omitted variables (Cohen and Levin, 1989). In any event, Howe and McFetridge (1976) found that, relative to ordinary least squares, instrumental techniques produced little change in the coefficient of concentration term in R&D equation. Although the majority of the studies found similar results by using either separate or simultaneous models, there is a suggestion that it is worth examining the simultaneity bias and the application of both methods (Hay and Morris, 1991).

Perhaps the most persistent finding concerning the effect of concentration on R&D intensity is that it depends upon other industry level variables. Scott (1984) and Levin et al. (1975) provide strong evidence that results concerning the effect of concentration on innovation are sensitive to industry conditions and therefore factors associated with the industry performance (e.g. profitability) and structure (e.g. growth and industry size), should be included in the relevant equation.

R&D EQUATION

Following the relevant literature (Cohen and Levin, 1989), the proportion of industry revenue spend on R&D is given from the following equation:

$$\frac{R\&D}{S} = \frac{CR}{e_p} \qquad (1)$$

where R&D is the research and development outlays, S is the value of sales, CR is the industry concentration and e_p is the elasticity of demand.

The above condition suggests that R&D intensity is a function of level of concentration in the market, for a given elasticity of demand. Given that e_p cannot be estimated, the relevant empirical studies included factors that affect e_p such as industry size and growth.

Following the theoretical model and the other empirical studies we are going to estimate the model:

$$R\&D = \delta_0 + \delta_1 CR + \delta_2 CR^2 + \delta_3 PR + \delta_4 SI + \delta_5 GR + \delta_6 KS$$

where CR is the concentration index, CR^2 is the square value of concentration index, PR is profitability, SI is the industry size, KS is capital intensity and GR is the rate of growth in demand.

We have already underlined that the relationship between concentration and R&D is ambiguous. On one hand highly concentrated industries are expected to be more interested for R&D and innovative products, on the other hand Scherer and Ross (1980) and other researchers proved that when competition exist, firms invest more on R&D. Scott (1984) concluded that the relationship is not linear. In less concentrated industries R&D expenditures increased, while when the concentration ratio increased more than 65% R&D expenditures decreased.

Following Schumpeter, R&D expenditures expected to be higher in cases where high profits exist. The literature contains two other sort of stories about the relationship between profitability and R&D. The first involves liquidity: because an ongoing R&D program is the kind of intangible asset that is difficult to finance in imperfect capital markets, only firms that are profitable enough to generate a large cash flow can finance sub-

stantial R&D programs. On the other hand, it may be that it is only when conventional price competition is severe that R&D becomes attractive as a product differentiating strategy. In this interpretation, profitability appears not in its own right, nor as a proxy for liquidity, but as an index of the state of rivalry in the market place; the expected impact of profitability on R&D intensity is then negative (Lunn and Martin, 1986) and (δ3><0).
The size variable is included to allow for the fact that research budgets probably vary with the size of the industry. The effect of the industry size could go either way, because there is just no strong theory to predict either a positive or a negative effect (δ4><0).
Industries with high rate of growth are supposed to offer greater opportunities for R&D activities. More rapidly growing industries are both assimilating and promoting new innovations, creating additional R&D undertakings (δ5>0). Capital intensity variable is included in the equation, as a measure of inefficiency. Thus the ratio of fixed assets to the generated output, the higher the cost and the lower the efficiency which can be negatively associated with the R&D intensity (δ6<0).

DATA AND MEASUREMENT OF VARIABLES

The industry sample utilised in the estimation of the models consists of 40 Greek food processing industries defined by the census at the four-digit level of the Standard Industrial classification system (SIC), which is used by the Greek National Statistical Service (NSS). A total of 1327 food manufacturing firms which operated in 1991 are classified into industries and the relevant measures calculated for each industry given that with the exception of R&D expenditures, data for the rest variables are not available by NSS. Data are drawn from the annual reports (ICAP, 1987-92) that provide individual balance sheet data for all food manufacturing firms. Data for industry R&D expenditures, are drawn from the annual reports of National Statistical Service (1988-91).
Following the relevant literature we measure the variables included in the model as follows: Total sales of all firms in each industry is used as industry sales in 1991 (S). In this analysis, concentration index in period t is measured by Herfindahl index, which is calculated as the sum of the squared values of firm's shares in each industry. Growth (GR) is measured as the ratio of industry sales in 1990 minus industry sales in 1988, over industry sales in 1988 (in constant prices). Similarly, the total value of fixed capital of the industry over industry sales in 1991 gives the capital-sales ratio (KS). The size of the industry as measured as the logarithm of industry sales, in 1991 (SI). R&D intensity (R&D) is measured as the ratio of industry research expenditures over industry sales in 1991. Profitability (PR) is measured as the sum of gross profits of each industry in 1991 over the industry sales in the same year. **Table 3**, shows the mean values of the variables used.

Table 3 ***Mean values of the variables.***

Variables	Mean Values
R&D	0.007%
H	32.7%
PR	27.6%
SI	16.20
KS	85.1%
GR	30.3%

RESULTS

The empirical findings from the ordinary least square (OLS) analysis are shown in **Table 3**. The coefficient of profitability is found to be positive and significant supporting the "liquidity" theory of R&D. Thus industries which are profitable enough to generate large cash flow tend to finance R&D programs. The above result is consistent with our data of profitability indices for 1991, where industries with high level of profitability have also high R&D intensity. Ice cream and frozen desserts, food preparation and chocolate products industries, have profits over sales ratio equal to 39%, 45% and 32% respectively, while their respective R&D ratios are 0.36%, 0.28% and 0.16%. It is worth noting that the R&D figures of these industries are well above the average R&D intensity for the whole food sector.
The coefficient of growth variable has a positive and statistically significant sign which suggests that rapidly growing industries (e.g. manufacturing of chocolate products with a rate of growth equal to 44%) offer relatively better opportunities for R&D activities, which also consistent with the rates of growth for the industries with high level of R&D intensity.

Table 4 ***OLS and 3SLS estimates explaining R&D intensity in Greek food manufacturing industries, 1988-91.***

Variables	OLS	3SLS
C	0.009	0.012
	(2.221)	(0.718)
H	−0.003	−0.007
	(−0.587)	(−0.607)
H^2	0.003	0.007
	(0.535)	(0.710)
PR	0.009	0.010
	(2.675)*	(2.528)*
GR	0.001	0.001
	(2.760)*	(2.48)*
SI	−0.0006	−0.0007
	(−2.605)	(−0.836)
KS	−0.001	−0.002
	(−2.061)*	(−1.393)
R^2	0.36	0.35
no of industries	40	40

* denotes statistically significance at 5% level of significancel.

The size of the industry is found to be negatively associated with R&D intensity, which suggests that research activity decreases when the industry size increases. Also the coefficient of capital intensity variable is negative and statistically significant indicating that efficient use of the fixed capital encourages more intensive R&D activity.

The sign of the coefficients of Herfindahl index and the square value of Herfindahl index shows that the relationship is not linear. However both coefficients are in significant.

Since it was suggested that R&D, profitability, concentration and advertising are more properly considered as jointly determined within a system of equations, we estimated a simultaneous equation model with the above four equations using an instrumental variable technique. Following Maddala (1992), the Hausman (1978) and the Lagrangian multiplier tests for the system of equations proved that both endogeneity and contemporaneous correlation problems exist in the system of equations, so the most appropriate joint estimation technique is the three stage least square technique (3SLS), (Maddala, 1992). The results for R&D equation(1) are presented in **Table 3**, and they are similar to the OLS, as in other studies.

CONCLUSIONS

This study examines the variation and the growth of R&D activity across a sample of 40 Greek food and beverage manufacturing industries and the determinants of R&D intensity.

The data show that although the R&D activity in the food industry is relatively smaller than in other manufacturing industries, there is an increasing trend in R&D expenditures for the period 1988-91, with an aggregate rate of growth of 1.72%. However, there is a variation in the application of R&D programs across food industries, and the most technologically intensive industries are pie production, ice cream and frozen desserts, food preparations and manufacturing of malt.

In order to test the effects of a number of variables on industry R&D both OLS and 3SLS methods are applied. The results show that R&D intensity is higher in the cases of highly profitable and rapidly growing food industries. Also the OLS results show a positive association between the efficient utilisation of the capacity (fixed assets) and the R&D intensity. These results show that efficient firms with high profitability, growth and utilisation of the fixed capital are more technologically progressive.

The results do not show that there is a significant effect of concentration on R&D activity. It is found that large firms operating in highly concentrated industries are not more able to apply R&D programs than small firms in low concentrated industries. The above results suggest that the relevant policy should encourage the involvement in R&D activities of both large and small-medium enterprises in the food sector. ●

(1) Since the presentation of the results for the whole simultaneous equations system is beyond the scope of this paper, we present here only the results for research and development equation. The results for the whole system of equations are available by the authors upon request.

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