

DECISION MAKING UNDER RISK AND UNCERTAINTY : CASE OF R&D INVESTMENTS

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ABSTRACT

The paper deals with the empirical testing of the two following hypotheses:

- 1) Large firms spend more on research and development activity than the small and medium size firms.
- 2) Firms in concentrated industries (monopoly, oligopoly) are more innovative than firms in unconcentrated industries (perfect competition). The two hypotheses are attributed to the late american economist (J. Schumpeter, 1950).

Key words:

Innovation, Research and Development, Risk, Size, Technological Opportunity and Market Power.

I- INTRODUCTION

For quite some time now, economists have been concerned with the relationship between technological change and productivity growth . The prosperity of an economy and the well being of people depend heavily on the rate of technical progress. There is little doubt that technological change has resulted in the reduction of the work week and an improvement in the quality of life (Denison ,1962) . Furthermore, it has contributed to the reduction of the mortality rate, has led to the automation of many production processes and an increased use of computers .

Today's industrial society is characterized by large investments in research and development. In 1976 american firms spent 26 billion dollars on research and development. A large proportion of these expenditures come from the federal government, and in particular from the department of defense. The proportion is estimated to be about 40 percent of the total research and development performed by the whole industry (Mansfield 1977). Research and development activities can be broken down into 3 separate categories :

Fundamental research

Basic research

Applied research and development .

Development is a major process at the firm level since it puts research findings into applications. The development stage of the innovation tries to bring to life new types of products and processes. A survey of research and development expenditures conducted by Mansfield in 1975 showed that in most industries 50 percent of research and development responding firms was aimed at improving existing products, 36 percent were targeted to developing new products and only 14 percent went for the development of new processes. From this, we can draw two conclusions. Namely, that about 86 percent of research and development expenditures at the firm level are targeted towards product innovations and 14 percent are aimed at process innovations. Furthermore, the bulk of these expenditures go towards the development of the innovation rather than research (Basic and applied).

All research and development projects involve a great deal of risk and uncertainty. Uncertainty deals with events in which we cannot associate a probability distribution of occurrence of these events. Risk deals with events in which their outcomes can be predicted with a certain probability (Van Horne, 1983). Accordingly, by the time a project reaches the development stage, much of the risk and uncertainty concerning its technical feasibility is eliminated. But there is often considerable uncertainty and risk associated with development costs, development time and the profitability of the innovation itself.

Almost all research and development projects are very risky in nature since they involve a distant future in which the payoffs are uncertain. Research itself involves more uncertainty and often requires more time than development. Although research and development are not the same activities, we tend to group them under heading called research and development expenditures. Furthermore, these three types of activities (basic, applied and development) tend to complement each other. Also, the distinction between research and development is not clear yet. Most of the literature in this area has been concerned primarily with the investigation of the interrelationship of research and development expenditures with firm size and market structure. Most of the empirical studies conducted to date have not dealt with the degree of influence of risk and uncertainty on the research and development investment decision. After all, research and development competes for the same dollars as advertising and other kinds of investments at the firm level. Another variable neglected by some of the previous studies (Scherer, 1970) is referred to in the literature as technological opportunity. In a few words, technological opportunity reflects the availability and the easy access to financial and human resources at the

firm level. It is thought that some industries (electronics for instance) have more technological opportunity than some other industries (textiles and food) .

In conclusion we can say that our research is original because it tries to depict the degree of risk involved in the development of innovations. The study also tries to account for technological differences that exist among manufacturing industries.

II- RISK, MARKET STRUCTURE AND THE OPTIMAL AMOUNT OF R&D

Unlike most situations in the price market economy, the allocation of resources to inventive activity (research and development) is likely to be non-optimal because the incentive to innovate and the rewards are closely related. Given the low or zero cost of transmitting the information content of innovative activity, the incentive to engage in such activities deriving from the creation of a salable property right conflicts fundamentally with the efficiency rule of pricing at marginal cost. As Arrow (1962) points out «In an ideal world the incentive or reward for innovation would be completely divorced from the charging of users for the innovation, e.g., by payment of royalties to successful inventors out of general government revenues. Because even minor changes in the private property market system of resource allocation seems remote; the question naturally arises as to the precise workings of the market system in the allocation of resources to R&D».

1- RISK AND RESEARCH AND DEVELOPMENT

Insurance and financial market instruments such as common stocks that spread risk across numerous individuals are the usual methods whereby the market system attempts to cope with risk. Both methods of sharing risk are, however, subject to moral hazard causing undesirable behavior. For example, the separation of ownership from management reduces the incentive of managers to act efficiently since they now receive only a fraction of the profit. The indivisibility or public good nature of information created by R&D activity is an important reason for market failure. Legal protection such as patents are an attempts to make the information an appropriable commodity, though the inherent inefficiency of restricting access is obvious. The testable hypotheses that emerge are clear-cut, though there will be a greater degree of private R&D for profit innovation the more thoroughly appropriable the information is. Thus as between an innovation that is a simple and pure idea versus a complex

one in a manufacturing process, the former is less appropriable. There is likely to be a greater divergence between social and private efficiency in R&D activity in industries specializing in information technology. Other things being equal, mobility of personnel among firms is just one way to overcome barriers to the flow of information. one would expect that industries where the mechanisms for the flow of information is best developed will create a strong disincentive to innovate. A well established trade information system, e.g., *faits*, journals, trade associations are possible examples. A related problem is that, given the uncertainty surrounding the commercial usefulness of information, a firm must often actually possess the data before it can fully appraise its potential worthiness. This phenomena obviously inhibits the willingness to pay and conflicts with the desire of the producer to maintain a private property right.

It might be thought that in industries where contract research is more significant that appropriability is greater. This increases the incentive to undertake R&D but impedes the socially optimal diffusion. Research and development activities are risky because a stochastic element enters the production function; the output is information but the input of productive resources does not produce a predictable level of output. Insurance is unlikely to arise because it would create undue incentive not to succeed. One way around this dilemma was suggested by Schumpeter (*ibid*) that large firms self-insure by undertaking a number of different projects and therefore engage in risk pooling. A test of this relationship might involve examining the number or average size of R&D projects or patents applications.

2) CUMULATIVENESS AND PRIVATE APPROPRIABILITY

The model of technical change we have outlined in the previous chapter must now be linked to the nature of industrial dynamics and the behavioural mechanisms at work in the company sector of the economy. Let us start from a very obvious but nonetheless important statement that suggests that the company sector in capitalist economies will generally undertake innovative activities if the latter involve some expectation of economic return or if the lack of such activities involves the threat of the loss of some present economic benefits.

Different market structures are supposed to yield different incentives to innovation. The features of technological advances suggested above will help us in relating together three concepts which are sometimes found in

the literature, namely:

a) Cumulativeness of technical progress.

b) Technological opportunity.

c) Private appropriability of the effects of technical change.

We have already hinted at the non randomness of technological advances. In a strong form, this feature of technological progress, together with the concept of «learning-by-doing», might lead to significant cumulative effects at the level of a company and of a country's industry. Of course, different technologies and different industries show different degrees of cumulativeness. A cumulative pattern of technical change implies that time profiles of innovation (or speed of imitation) broadly respect the initial innovation ranking either among companies or among countries. It can be easily seen how this feature relates, in an inverse function, with the possibility of inter-company or international diffusion of technology.

It was suggested that a technical paradigm also determines, together with the «dimensions» which define progress, the scope (the potential) of innovations and improvements and the easiness in the achievement of these improvements and innovations. It is intuitive that the technological opportunity in electronics is much higher than in, say, clothing but this quite obvious fact is generally neglected or ill-treated, as we shall see when dealing with the relationship between industrial structures and innovative activities.

3) TECHNOLOGICAL OPPORTUNITY

The manufacturing sector of the economy in the US reflects what is called technological differences between industries (in terms of degree of innovativeness, availability of human and financial resources...).

Furthermore, firms in the same industry also do exhibit the technological differences that will affect all the performance indicators (i.e profits, growth etc.).

The present study tries to analyse the elements of market structure and performance at the firm level. Accordingly, technological opportunity in our model tries to depict the interindustry variance which is not usually accounted for or explained by firm level data and models. In other words, there is more technological opportunity in the electronics industries than in the food and clothing industries respectively.

Scherer (1970) demonstrated the importance of technological opportunity or technological differences among industries when dealing with R&D-firm size and R&D-concentration relationship. Scherer (ibid) used «technology classes» dummy variables as proxies to technological opportunity. Likewise, Schrieves (1974) emphasized the importance of technological opportunity in explaining the relation between R&D and market structure and performance. To quote Schrieves (1974): «It is not structure per se which influences the allocation of resources to innovation, but Structure combined with product market and technological characteristics. The Schumpeterian and neo-Schumpeterian theories are, in themselves, quite deficient in explaining the relationship between firm size, market structure and innovation».

We can say that no study of technical change and innovation can be carried out without accounting for technological differences that exist among industries. Furthermore, there is a degree of cumulativeness of technical change through time and a «learning by doing» effects that should not be neglected in empirical testing (Arrow 1962).

The technological environment will vary accross industries. Some have been defined as «high-tech» and other labeled «low-tech». In terms of our model, we are alluding to elasticity of demand with respect to R&D. Since advertizing serves the same purpose as new produtes to differentiated products, it is likely that industries where advertizing is an important marketing tactic that they will also find R&D product innovation as an attractive strategy.

III) THE MODEL

$$RD = AS^a R^b TO^c U_i$$

$$RD = B CR^a AP^b R^c U_i$$

Where :

RD : = Research and Development Expenditures in the United States .

R : = Business And Financial Risk.

TO : = Technological Opportunity.

CR : = Four - Firm Concentration Ratio.

S : = Size Of The Firm Measured By Sales.

U_i : = Error Terms.

AP : = Appropriability Factor.

A,B : = Constants

3.1) EMPIRICAL ESTIMATION

We measure the dependent variable in our model as the firm research and development expenditures in the United States (U.S.A.) as it is defined in the data file. In exploring the economic theory, we can suggest the following statements:

- 1) *Higher profit firms will undertake more R&D. This factor can also be thought to include the effect of capital market imperfections. The risk associated with R&D activity may require self-financing by firms. In addition, «leaks» of proprietary information may be lessened by avoiding public capital markets.*
- 2) *The response of sales to new products will affect R&D activity. If firms use product differentiation instead of price competition as a market strategy, R&D will be more attractive.*
- 3) *The ability of high costs firms to overcome this handicap via innovation and any economies of scale will tend to raise R&D expenditures.*

IV) ECONOMETRIC ANALYSIS

1) REGRESSION ESTIMATES OF THE LINEAR MODEL : $RD = F(SIZE, RISK, TO)$

number of Firms = 182

Source = compustat (S & P)

Year = 1988

<i>Variable Name</i>	<i>Estimated Coefficient</i>	<i>Standard Error</i>	<i>T - Ratio *****DF</i>
SALES	0,166	0,127	13,048*
RISK	-118,51	43,72	- 2,7106*
TO	0,154	0,636	2,4181*
INTERCEPT	38,727	24,706	1,5675

* All results significant at 0.05 Level .

2) REGRESSION ESTIMATES OF THE MODEL LOG RD = F(LOG SIZE ,LOG RISK ,LOG TO)

number of Firms = 182

Source = compustat (S & P)

Year = 1988

<i>Variable Name</i>	<i>Estimated Coefficient</i>	<i>Standard Error</i>	<i>T - Ratio *****DF</i>
Log SALES	1,0263	0,5853	17,535*
Log RISK	-0,2766	0,6684	- 4,139*
Log TO	0,5933	0,3171	1,870**
Log INTERCEPT	- 5,2532	0,4722	- 11,124*

*) Significant 0.05 level

**) Significant 0.10 level

3) REGRESSION ESTIMATES OF THE MODEL RD = F(CR, CR²)

number of Firms = 182

Source = compustat (S & P)

Year = 1988

<i>Variable Name</i>	<i>Estimated Coefficient</i>	<i>Standard Error</i>	<i>T - Ratio *****DF</i>
CR	0,16980	0,36209	4,6893*
CR ²	0,25206	0,69011	0,3652
INTERCEPT	12,2751	5,680	0,78286

*Significant at 0,05 percent level

4) REGRESSION ESTIMATES OF THE MODEL $RD = F(\text{LOG CR}, \text{LOG RISK}, \text{LOG AP})$

number of Firms = 182

Source = compustat (S & P)

Year = 1988

<i>Variable Name</i>	<i>Estimated Coefficient</i>	<i>Standard Error</i>	<i>T - Ratio *****DF</i>
Log CR	0,128	0,412	3,11*
Log RISK	- 0,233	0,417	2,27*
Log AP	0,152	0,574	2,65*
Log INTERCEPT	0,947	0,417	2,27

* All results significant at 0.05 Level .

V) CONCLUSION

1) R&D AND FIRM SIZE

We have seen that research and development is done across all manufacturing industries. We have found an elasticity of R&D with respect to sales of close to unity (1.026). The latter means that research and development activity is a linear function of size and large firms do not spend proportionately more than small firms on R&D activity. These results are contrary to the preponderance of previous work on the size-R&D intensity relationship. Comanor (1967) found a weakly decreasing relationship between R&D intensity and firm size. Scherer (1970) found that R&D intensity increased with firm size up to an intermediate level and decreased (except in the chemical and petroleum industries, in which it did increase). This has been interpreted to imply, for most industries, a threshold size necessary before R&D is performed, presumably because of fixed costs in performing R&D (Kamien and Schwartz 1982) .

As noted above, our results suggest that R&D does not increase with size and that small firms do spend proportionately as much as large firms on R&D expenditures .Our results are in accordance with Scherer (1970), Mansfield (1975) and in complete disagreement with the results of Grilliches (1984) which found that R&D do indeed increase with size .

To conclude, we suggest that it is not size per se that determine the level of R&D activity but the combination of several factors (i.e technological opportunity, appropriability and the level of risk involved at every stage of R&D expenditures).

2) *R&D AND MARKET STRUCTURE*

Based on an ad hoc model, we found that R&D activity does not increase with the concentration level of the industry as it is stated in some empirical works. As noted above, our results show that R&D activity level increase with the degree of appropriability of the innovation and the technological opportunity that exist in that industry. Appropriability measures the extent to which an industry can enjoy the benefits of R&D return in the short and long run. The risk factor affects R&D activity in an opposite way. The higher the risk as measured here in this paper, the lower the expenditure on research and development activity.

VI) DATA

1) DEFINITIONS OF THE VARIABLES USED

a) RESEARCH AND DEVELOPMENT

Research and development expenses includes all research costs incurred during the year that relates to the development of new products or services.

b) ASSETS

Total assets represents current assets plus net plant plus other non current assets (including intangible assets and deferred items) .

c) DEBT

This variable includes debt obligations due more than a year from the company's balance sheet data .

d) EQUITY

This variable represents common stock plus retained earnings , capital surplus, self - insurance reserves and capital stock premium .

e) SALES

Sales consist of gross sales reduced by cash discounts , trade discounts , and returned sales allowances for which credit is given to customers .

2) TECHNOLOGICAL FACTORS :

a) APPROPRIABILITY

It is measuring the rewards that are gained from the introduction and application of a new process or a new product.

We are using a table of the number of patent applications provided by Scherer (1970) as a measure of the appropriability factor.

b) THE CONCENTRATION RATIO

The concentration ratio is taken to represent market power and is considered to be an important element of market structure .We are using in this study the four firm concentration ratio as a measure of market power.

c) TECHNOLOGICAL OPPORTUNITY

It measures the differences between industries in terms of the degree of innovativeness ,the availability of human and financial resources. It is measured by the salaries and compensations given to the scientists and engineers working for the firm.

d) THE RISK FACTOR

$RISK = \text{debt} / \text{equity ratio}.$

BIBLIOGRAPHY

Adams, W .J., «Firm size and research activity :France and the United States. “ quaterly journal of Economics, V. 84, 1970 .

Adelman, M.A., “The measurement of industrial concentration “, Review of Economics and statistics 33 (nov.1951): p 269-296 .

Allen, Bruce T. “Concentration and Economic Progress :Note . “American Economic Review, V. 59, 1969 .

Ames, E. “Research, Invention, Development and Innovation . “ American Economic Review V .51 , 1969 .

Angilley, Alan S. “Returns to Scale in Research in The Ethical Pharmaceutical Industry : some further Evidence . journal of industrial Economics . V . 22, 1973 .

Arrow, K., "Economic Welfare And The Allocation of Resources for Inventions . "In R. R. Nelson (ed.) The rate and direction of inventive activity , Princeton, N.J :Princeton University Press, 1962 .

Arrow, K., "The Economic Implication of Learning By Doing " Review of Economic Studies XXXIX, 1980, p.155-73 .

Bailey , D.and S. E. Boyle "The optimal measure of concentration " , journal of the American Statistical association 46, (Dec .1971): p.702-6

Baily , M. N. " Reasearch and Development costs and Returns : The U.S pharmaceutical industry . Journal Of Political Economy , V. 80, 1972 .

Denison, E.F , " The source of economic Growth in the United States and the alternatives before us " CED Supplementary paper n° 131, 1962

Kamien, M. I. and Schwartz, N. L. "Market structure and innovation" Cambridge University Press, 1982.

Mansfield, E. "Technological Change : An Introduction to a vital area of modern economics" New-York, 1975.

Mansfield, E. Rapoport, Romeo, Villani, Wagner, Husic, " The production and application of new industrial technology " W. W. Norton and Co. Inc . New-York 1977.

Van Horne, J. C., "Fundamental of Financial Management", Fifth edition, Prentice-Hall, Inc. , Englewood Cliffs, New-Jersey, 1983.

Scherer, F. M. "Industrial market structure and economic performance " Chicago, Illinois, Rand Mac Nally and Co., 1970

Shrieves, R ."Firm size, market structure and innovation: Further evidence" University of Tennessee, Working paper no. 19, 1974.

Schumpeter, J. A. "Capitalism, Socialism and Democracy" , third edition , New York, Harper Brothers, 1950

Comanor, W, S. "market Structure, Product Differentiation and Industrial Research. "Quaterly Journal of Economics. v. 81, 1967.

Grilliches, Zvi "R and D, Patents and productivity" Harvard University press New-York, 1984.