Industrial R&D Laboratories: Windows on Black Boxes?

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ABSTRACT. This paper provides an overview of the survey-based literature on industrial Research and Development (R&D) laboratories, beginning with the work of Edwin Mansfield. Topics covered include R&D projects, new products, and new processes; the appropriability of intellectual property; the limits of the firm in R&D; and spillovers of knowledge from other firms and universities into the laboratories. I discuss the value of collecting information from industrial R&D managers, who participate in a wide range of R&D decisions and are the natural best source of information on these decisions. I also emphasize gaps in our knowledge concerning R&D from past studies, such as the private and social returns to R&D, the nature of firms' R&D portfolios, and other topics. The paper closes with a discussion of the benefits from building a national database on R&D laboratories that could be shared among researchers and that could take this area of research to a new and higher level of achievement.

Key words: industrial research and development, management of R&D, spillovers, technology transfer, survey data

JEL Classification: L2, L3, O3

1. Introduction

The opportunity to learn firsthand how firms invent and innovate is one that should not be missed. It is surely a unique window on the black box of the firm, one that can be looked through from any angle to study interactions between the firm's innovative establishments, other divisions of the firm, and the rest of the economy. We owe this opportunity to Edwin Mansfield and his students. It is their field work that brought the study of R&D laboratories into economics, opened up research opportunities for the investigators that followed them, and created an economic literature on the subject. In this paper, mindful of this huge contribution, I survey some of the economic research that has illuminated the black box of industrial R&D. Along the way I shall comment on questions raised by this research that in my opinion remain unanswered.

The topic is important for several reasons, all of them based on the inability to substitute other information for data from R&D laboratories. This special attribute of the data rests on the extraordinary skills of their source, the laboratory managers of R&D.[1] An argument can be made that the data are irreplaceable because R&D managers are Renaissance individuals who engage in project selection, negotiate with operating divisions of the company, and work co-operatively with universities, federal laboratories, and other firms (Adams, 2002; Adams 2005, forthcoming; Adams *et al.* 2003; Cohen *et al.* 2002; Mansfield and Brandenburg, 1966). Questions such as the efficient management of industrial R&D, the returns to R&D projects, the nature of co-operative research, and the role of universities, government, and other firms in invention and commercialization are best answered by asking those who know about them. And R&D managers specialize in functions of the kind just described.

Field research in this area has uncovered critical findings on industrial R&D that could not have been obtained using received data.[2] In practice this approach has relied on data collection by many different researchers and this has its advantages as well as disadvantages. The data are heterogeneous and as a result are exceptionally rich. Also, the data are designed from the start to address the relationships of interest rather than designed for an unrelated purpose. The questions posed are limited only

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by the ingenuity of investigators and the patience of respondents. But these same qualities make it hard to compare results, and confidentiality places strong restrictions on data access. However, given sufficient community, field work can have recombinant properties. Learning by one researcher passes to the next, lending a cumulative increasing returns to scale property to the investigations as a whole.

The rest of the paper consists of five sections. The next four sections form the heart of this paper. Each explores a specific topic related to R&D laboratories. I chose these topics because they have attracted attention and I am familiar with them. Section 2 samples the literature of R&D projects, products, and processes. Section 3 reports some of what we have learned about the appropriability of intellectual property from R&D laboratory studies. Section 4 explores what studies of laboratory R&D have taught us about the limits of the firm in R&D. Evidence for spillovers of outside knowledge into the laboratory is examined in Section 5. Section 6 is a summary, discussion, and conclusion.

2. R&D projects, products and processes

R&D projects

During the 1960s and 1970s Edwin Mansfield and his co-workers undertook a series of studies of R&D projects. I begin with Mansfield and Brandenburg (1966). Its subject is the decision-making process that governs projects in the R&D laboratory of a large manufacturer. Its findings are that forecasted profits are a key driver of project expenditures, along with the scientific appeal of projects to researchers and the practical needs of manufacturing divisions. Other findings are that laboratory managers are risk-averse and take on projects that are short-term (less than five years from development) and low on technical risk. As a result, projects are completed rapidly and rarely fail for technical reasons, though the risk of commercial failure remains. The paper raises questions having to do with the portfolio aspects of R&D projects. What is the correlation matrix of returns on the projects? What is the overall level of risk of the portfolio compared with individual projects? Questions like this are of interest to the Real Options approach to investment (Dixit and Pindyck, 1994) given that R&D projects are a collection of real assets subject to uncertainty.

The uncertainty of R&D projects is further highlighted by Mansfield and Beardsley's (1978) study of industrial forecasts of their returns in a large company. One finding is that forecasted profits on new products are poorly explained by actual profits. While this explanatory power of actual for forecasted profits is higher in process-oriented R&D, in both cases forecasted profits are under-predicted. Thus considerable uncertainty and discounting apply to the projects. To my knowledge little if any work has since been done that covers the portfolio of a firm's R&D. Only in this way can the entire landscape of its research can be understood.

A recent study of project-level R&D, though not of the portfolio of a single firm, is by Bizan (2003). He explores the determinants of technical and commercial success of Israeli–American research alliances. He finds that projects are more likely to be a success when one partner is a subsidiary of the other, when the two firms have complementary capabilities, and when project size and duration increase.

New products and processes

Mansfield *et al.* (1977) estimate the private and social returns to industrial innovation. The work is based on a sample of 17 innovations in several industries that consist of new products and processes. The remarkable finding is that the median (pre-tax) *private* rate of return on the projects is 25%. The median *social* return is 56%. The figures seem to justify public subsidies for industrial R&D, and yet the high private rate of return calls for an explanation. Is it the risk characteristics of R&D projects and their hurdle rates that bring about a return of this size? The question harks back to whether the firm's R&D portfolio diversifies risk away, or not. Otherwise, are the private returns upward biased, perhaps because a new product replaces an older one in the same firm? How do these rates of return compare with returns on other industrial investments? Another