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Research and Development

Research and Development (R&D) is the term commonly used to describe the activities undertaken by firms and other entities such as individual entrepreneurs in order to create new or improved products and processes. The broadest meaning of the term covers activities from basic scientific research performed in universities and laboratories all the way to testing and refining products before commercial sale or use. The performance of, incentives for, and the contributions of R&D are topics that are widely studied in management, economics, and other social science disciplines. Total spending on R&D activities is also one of the most widely used indicators of the innovative performance of firms, industries, and countries.

Informal R&D has existed at least since the first person experimented with methods of knapping flint to make stone age tools. In a formalized sense, it became part of the arsenal of the modern corporation beginning with the creation of industrial labs in the late 19th century and today it comprises about 2-3 per cent of the GDP in advanced economies (for a history of the rise of organized R&D in the U.S., see the 1989 book by David Mowery and Nathan Rosenberg). Spending on and outcomes of R&D investments have become important enough to be the subject of a satellite account in the US System of National Income Accounts that was introduced in 2006-2007 and to be under consideration for inclusion in the international standard for systems of national income accounts (United Nations 2006).

The Frascati Manual of the Organization for Economic Cooperation and Development (OECD), first published in 1963, created an international standard for surveys of spending on R&D. This manual defines R&D as "creative work undertaken on a systematic basis in order to

increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." R&D is generally thought to consist of three main activities: basic research, applied research, and development. Basic research is research undertaken primarily to acquire new knowledge without a view as to its application. Applied research is research directed towards a specific objective and development is work drawing on existing research results and directed specifically towards the creation of new and improved products and processes. In general, more than two-thirds of R&D spending by firms or countries is directed toward development rather than research. The 2003 *OECD Science, Technology, and Industry Scoreboard* reports that in developed countries with high R&D intensities, basic research is less than one fifth of total R&D spending.

Economic analysis of R&D

In the theoretical economics literature, the term "R&D" is commonly used to describe the conscious choice of firms and individuals to invest in the invention and commercialization of new products and processes. Although the activity being described is seldom made precise in these models, in practice this kind of investment is assumed to correspond roughly to the spending on R&D that is reported in firm accounts and to various governmental surveys. Important insights into the motives underlying investments in R&D were first developed in seminal papers by Richard Nelson in 1959 and Kenneth Arrow in 1962. These two authors clearly argued the economic policy case for subsidies to R&D investment that arise from the nature of its output.

Briefly stated, the argument is that because most inventions (processes and products) can be imitated once they are made, and at a cost lower than the original cost of making them, the

incentives for undertaking R&D directed toward the creation of such inventions are inevitably weaker than society would like. The performance of R&D therefore generates positive externalities or *spillovers* that benefit others. The paper by Nelson distinguishes between basic research with wide applications (which is most likely to be insufficiently provided) and development expenditures targeted to particular products or processes (which are more easily protected by patenting and other means). Arrow made the case for underinvestment in R&D more broadly, by setting it in the context of the (then) newly invented Arrow-Debreu general equilibrium model. He argued that the allocation of resources for invention (that is, R&D spending) was likely to be non-optimal because the production of information about new products and processes failed all three of the assumptions required for perfect competition to achieve a Pareto optimum: that the good (information) be infinitely divisible, that it be tradable on the market (that is, its returns fully appropriable by the owner), and that there be no associated uncertainty.

All three of these characteristics (indivisibility, inappropriability, and uncertainty) have proved to be important in the case of R&D. Indivisibility implies returns to scale because information about new products and processes can be spread over many units at increasingly lower cost per unit, leading to monopolistic competition in R&D-intensive industries. As Arrow and subsequent economic theorists have shown (see the 1989 survey by Jennifer Reinganum), this can lead to either over or underinvestment in R&D from a social perspective. In contrast, lack of full appropriability suggests that there will be underinvestment in R&D. In a 1992 article, Zvi Griliches surveyed the evidence on the existence of R&D spillovers -- based on the evidence on measured private and social returns to R&D from a wide number of empirical studies, he

concluded that overall R&D spillovers were both "prevalent and important." This result suggests that underinvestment dominates overinvestment, at least in the majority of sectors.

Finally, uncertainty about the nature of the information to be produced by R&D makes it a risky undertaking and sometimes implies that there will be an asymmetric information problem between its producers and those who might finance its production, again leading to potential underinvestment. Empirical evidence for the existence of difficulties in financing R&D investment is surveyed by Bronwyn Hall in an article published in 2002.

R&D as investment

The phrase "R&D" is often followed by the word "investment," which hints at one its most important attributes: research and development undertaken today continues to benefit both those who undertake it and society at large into the uncertain future. Another attribute of R&D that has been emphasized in the modern economic growth literature is its cumulative nature, which can lead to increasing returns, both in the aggregate, and also for individuals and firms. The idea is that the stock of knowledge created by doing R&D makes one more productive in acquiring additional knowledge. In the case of individuals, this is sometimes termed the "Matthew" effect (after the Gospel, XXV, 29). In the case of economies, it has given rise to the modern endogenous growth literature that is discussed in the 1998 book by Philippe Aghion and Peter Howitt.

These attributes create some interesting problems for measurement and analysis. In general, applied researchers have dealt with the intertemporal nature of R&D investment by treating it in the same way as ordinary investment in tangible assets, adding up expenditures to create an R&D stock, using a suitable depreciation rate to capture the fact that older research

may become less useful over time. However, the aforementioned spillover effects make this exercise somewhat more speculative than in the case of ordinary assets, because R&D that has ceased to be useful for the production of private profit may still be useful to others in the production of new knowledge. The process that renders some R&D output obsolescent is the same one that was given the name “creative destruction” long ago by Joseph Schumpeter (1942). For a recent survey of the R&D depreciation problem and its implications for measuring the returns to R&D, see Bronwyn Hall (2006).

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