INDICATORS OF THE IMPACT OF R&D ON THE ECONOMY

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This paper reviews the literature on the economic effects of R&D and then examines the gaps in our knowledge. While most micro-studies show that R&D raises economic growth, existing knowledge of the mechanisms by which R&D affects productivity and output is sparse, and it is unclear whether the micro-studies can be generalized to the national economy. The paper concludes by examining some possible consequences of the reduced R&D effort by the United States.

Introduction

Increases in the stock of useful knowledge due to research and development (R&D) and other scientific activity have two basic effects on the economy.

First and foremost, increases in knowledge contribute to economic growth. In the long run, indeed, growth would cease without additional knowledge of what and how to produce. At any given time, the goods and services in the economy depend on capital, natural resources, the skill and efficiency of workers and management, and knowledge of how to combine these inputs. The addition of more physical capital or discovery of new supplies of natural resources, with no change in technological knowledge, will increase output for some time but ultimately runs into diminishing marginal productivity. Increasing the education and training of workers produces growth until all have received the relevant knowledge and then contributes no further. Only by augmenting the stock of knowledge and applying it to production can growth be sustained.¹ The critical role of advancing knowledge is perhaps best illustrated by considering what output might have been in the Middle Ages if all workers had "best-practice" Middle Ages technology, capital equipment, and natural resources. Output would have been higher than actual historical levels but would surely have fallen far short of modern day possibilities.

*I have benefitted immensely from discussion with Richard Nelson.
Second, R&D induced changes in production have important consequences for factor markets, saving on some inputs and requiring relatively more use of others. The skills of various craftsmen, such as typesetters, have been outmoded by change while new jobs have been created for others, as in computer programming. A recurrent fear about technological change, most recently expressed in the 1960s' automation scare, is that new technologies will obliterate labor skills and produce massive unemployment. While these fears have not been validated by events, there is no law guaranteeing increased skill use nor forestalling serious short run "technological unemployment" due to the labor-saving bias of techniques.2

What is known about the impact of R&D on productivity and growth in a modern economy? On the basis of current knowledge, what are the likely consequences of the post–1969 cutbacks in R&D activity in the U.S.? This paper examines these questions. Because several reviews of the economics of R&D have recently been published (Mansfield 1972; Nelson and Winter 1977; Mansfield 1973; Kamien and Schwartz 1975) no effort is made to survey the extant literature. Instead, I shall rely on the available surveys to provide an overview of results and concentrate first on gaps in current work, then on the anomalous relation between national R&D activity and economic performance, and finally on the additional knowledge needed to assess these questions with greater surety. Because the economic effects of R&D depend, in part, on the extent to which the level, allocation, and factor-saving "bias" of research and innovative activity respond to market incentives, I also consider the reverse link from the economy to R&D and technological change.

R&D and growth: What we (think we) know and what we don't know

A reasonably large number of high calibre studies have analyzed the economic impact and returns to R&D activity.3 One set of studies relates changes in output, with non-R&D inputs held fixed, to various measures of R&D using a neoclassical production function or growth accounting framework.4 Both cross-industry and cross-company data sets have been examined, with the latest work by Griliches (1977) expanding the sample size to nearly 1000 enterprises. These studies provide estimates of the marginal product of R&D and, given various assumptions about the limiting of the returns, of the rate of return. Another set of studies has focused on specific research projects, estimating benefit–cost ratios and rates of return to particular innovations. Much of the early work on innovations dealt with agricultural products like hybrid corn (Griliches, 1958) but Mansfield (1968) and Mansfield and colleagues (1977a,b) have extended the analysis to both major and