Research and Development, Productivity, and Inflation

Edwin Mansfield

Summary. R & D, through its effects on the rate of productivity increase, can significantly restrain the rate of inflation in the medium and long run. High rates of inflation damage the workings of the price system and impair the efficiency of practically all economic activities, including R & D. Findings suggest that the percentage increase between 1969 and 1979, in total real R & D expenditures, has been exaggerated due to the inadequacy of the gross national product deflator as applied to R & D.

Earlier this year, the inflation rate hit 18 percent, and even now, as we seem to be sliding into a substantial recession, the inflation rate has not fallen below 10 percent. Clearly, inflation is one of the central problems in the American economy, but why should it be of central importance in discussions of public and private policy toward R & D? I think that there are two reasons: (i) R & D influences the rate of inflation and (ii) the rate of inflation influences R & D. This article summarizes what I think we know about these relations between R & D and inflation and presents findings of an ongoing study of the rate of inflation in R & D.

Effects of R & D on Productivity Increase

It is essential to recognize that R & D has an important effect on the rate of productivity increase. Economists have used econometric techniques to estimate the relationship between output, on the one hand, and labor, capital, and R & D on the other. Studies (*1*) in the 1960's provided reasonably persuasive evidence that R & D had a significant effect on the rate of productivity increase in the industries that were investigated. A variety of both agricultural and manufacturing industries were included in these early investigations. Without exception, it was found that an industry's or firm's rate of productivity increase was directly related to the amount spent on R & D (*1*).

More recently, Zvi Griliches (*2*) conducted a study for which he used data from almost 900 manufacturing firms. His results, like those of the earlier studies, indicate that a firm's rate of productivity increase is directly related to the amount it has spent on R & D. Nestor Terleckyj (*3*), using data for entire industries, found that an industry's rate of productivity increase is directly related to both the amount of its own R & D and the amount of R & D carried out by industries that supply it with inputs. This is reasonable since one industry's R & D often results in improved machines and inputs for other industries.

There is also some evidence that the composition of an industry's or firm's R & D expenditures, as well as their size, influences the rate of productivity increase. I (*4*) found that there is a direct relation between the amount of basic research carried out by an industry or firm and its rate of productivity increase when its expenditures on applied R & D are held constant. Whether the relevant distinction is between basic and applied research is by no means clear; basic research may be acting to some extent as a proxy for long-term R & D. Holding constant the amount spent on applied R & D and basic research, an industry's rate of productivity increase between 1948 and 1966 seemed to be directly related to the extent to which its R & D was long term (*4*).

The author is professor of economics at the University of Pennsylvania, Philadelphia 19104. This article is adapted from the lecture he delivered at the AAAS Colloquium on R & D policy on 19 June 1980 in Washington, D.C.

Effects of Productivity Increase on Inflation

The rate of productivity increase has an important impact on the rate of inflation. Total cost per unit of output equals total cost per hour of labor divided by output per hour of labor. Thus, the rate of increase of total cost per unit of output equals the rate of increase of total cost per hour of labor minus the rate of increase of labor productivity (defined as output per hour of labor). If the rate of increase of labor productivity is high, the rate of increase of total cost per unit of output will be much lower than the rate of increase of total cost per hour of labor. If the rate of increase of labor productivity is low, the rate of increase of total cost per unit of output will be almost as great as the rate of increase of total cost per hour of labor.

As an illustration, suppose that total cost per hour of labor is increasing at 13 percent per year. If labor productivity is increasing at 3 percent per year, total cost per unit of output will increase at 10 percent per year. On the other hand, if labor productivity is not increasing at all, total cost per unit of output will increase at 13 percent per year. Thus, if prices increase at about the same rate as unit costs, the inflation rate will be 3 percentage points lower if labor productivity is increasing at 3 percent per year than if it is not increasing at all.

This point is widely recognized. Many economists, including the President's Council of Economic Advisers (*5*), have pointed out that, in addition to its adverse effects on our rate of economic growth and on the competitiveness of some of our goods in international markets, the slowing of our rate of productivity growth in recent years has exacerbated the problem of quelling inflation. Of course, factors other than the slowing of our rate of productivity growth have been major culprits responsible for the excessive recent rates of inflation in the United States. This factor, nonetheless, has been an important one.

Considering that R & D affects the rate of productivity increase and that the rate of productivity increase affects the rate of inflation, it follows that R & D, by increasing productivity, exerts a restraining influence on inflation. Petroleum refining provides an example. According to John Enos (*6*), the cost of making enough gasoline for 100 ton-miles of transportation would have been $1.47 in 1955 if the Burton process had still been used. Instead, because of a number of major cracking innovations,

 0036-8075/80/0905-1091$00.75/0

the actual cost was only 26 cents. In the case of ammonia production, the advent of large-scale ammonia plants in the mid-1960's reduced the cost of ammonia by more than 20 percent, according to SRI International. In any R & D-intensive industry, it is relatively easy to find such illustrations.

Effects of Inflation on Productivity Increase

The effects of R & D and productivity increase on the rate of inflation are only part of the story. The rate of inflation affects both productivity increase and R & D in important ways. Inflation that is high on the average tends to be very variable in its rate and, as Milton Friedman (*7*) pointed out in his Nobel lecture, this reduces the efficiency of the price system as a mechanism for coordinating economic activity. A major function of a price system is to transmit the information that economic agents and organizations need in order to decide what to make and how to make it, or how to use owned resources. The relevant information concerns relative prices—the price of one product relative to another, of the services of one input relative to another, of products relative to inputs, or of current prices relative to prices in the future. In practice, the information is transmitted in the form of absolute prices—prices in dollars and cents. As Friedman states (*7*):

> If the price level is on the average stable or changing at a steady rate, it is relatively easy to extract the signal about relative prices from the observed absolute prices. The more volatile the rate of general inflation, the harder it becomes to extract the signal about relative prices from the absolute prices: the broadcast about relative prices is, as it were, being jammed by the noise coming from the inflation broadcast. . . . At the extreme, the system of absolute prices becomes nearly useless, and economic agents resort either to an alternative currency or to barter, with disastrous effects on productivity. . . .

In particular, economists, both liberal and conservative, worry about the effects of high rates of inflation on investment. Thus, Robert Nathan (*8*) recently stated:

> There are many serious consequences of an economic, social, and political nature flowing from high rates of inflation. Perhaps its most clearly identifiable negative impact has to do with investment. High interest rates, difficulties in floating equity securities, the tendency of government policies to fight inflation with recessions, the drop in the value of the dollar, all relate to inflation and all serve to discourage new investment.

Clearly, inflation means that depreciation allowances frequently tend to be too small. As the late Arthur Okun (*9*) put it, "the gap [created by inflation] between actual, historical costs of old plant and equipment and current or predicted costs of new facilities creates agonies in capital budgeting and weakens investment."

Investment tends to increase productivity because it provides workers with more and better tools. In the United States, investment is a relatively small percentage of total output. In manufacturing, whereas Germany has devoted about 16 percent of its output to capital investment and Japan has devoted about 29 percent, we have devoted only about 9 percent of our output to capital investment (*10*). This is one of the reasons for our sluggish rate of productivity increase. Very high rates of inflation are unlikely to be conducive to the increase in investment rates that so many observers regard as desirable.

Effects of Inflation on R & D

Besides affecting the rate of productivity increase, high rates of inflation, through their effects on investment and through other channels, also affect R & D. Alone, R & D frequently is of little value to a firm. Only when combined with plant and equipment and with manufacturing, marketing, and financial capabilities does R & D result in a commercially meaningful new product or process (*11*). To the extent that inflation reduces investment rates it tends to discourage R & D that requires new plant and equipment for its use. To the extent that inflation makes long-run prediction of prices and circumstances increasingly hazardous, it tends to discourage R & D that is long term and relatively ambitious. Indeed, many of the reasons why inflation adversely affects investment in plant and equipment hold equally well for investment in relatively ambitious R & D projects. This does not mean that firms necessarily cut back on R & D expenditures in inflationary times. For example, according to National Science Foundation (NSF) data, firms increased R & D expenditures by more than 10 percent between 1978 and 1979. But it does suggest that firms often are less inclined to fund relatively ambitious R & D projects that would be the case under a regime of relative price stability. In the words of a General Electric executive, "the additional discounting now required to compensate for inflation is leading to even more emphasis on shorter term programs where an adequate return can be projected (*12*)."

In addition to affecting industry-financed R & D, inflation can have a negative impact on government-financed R & D. Faced with excessive inflation, governments may feel compelled to trim R & D budgets as part of an anti-inflationary fiscal policy. To the extent that R & D would promote more rapid productivity increase in the long run, this may have the unintended effect of lowering productivity growth and perhaps worsening inflation.

Inflation also has a pernicious influence on R & D decision-making in both the public and private sectors because of the great difficulties in measuring the rate of inflation in R & D. In view of the inherent difficulties and the strong assumptions underlying the few alternative measures that have been proposed, the official government R & D statistics use the GNP (gross national product) deflator to deflate R & D expenditures. The relevant government agencies are well aware that the GNP deflator is only a rough approximation. For example, the Comptroller General's 1979 report on science indicators (*13*) suggested the use of alternative price indexes for R & D. Little is known, however, about the extent to which price indexes for R & D inputs, if they were constructed in various industries, would differ from the GNP deflator.

The preliminary results of a small-scale NSF-funded study that my students and I are conducting may shed some new light on the extent to which the use of the GNP deflator is misleading. Our basic data were obtained from more than 30 firms in the chemical, electrical equipment, oil, primary metals, fabricated metal products, rubber, textiles, and stone, clay, and glass industries. These industries account for a large share of the privately financed R & D carried out by U.S. industry. The firms in our sample account for about one-ninth of all company-financed R & D in the United States. For each firm and industry, a price index for R & D inputs (including scientists and engineers, support personnel, materials and supplies, the services of R & D plant and equipment, and other inputs) was estimated. This was basically a Laspeyres index with 1969 as the base year and 1979 as the given year. According to the Organization for Economic Cooperation and Development (*14*), this type of index has been preferred in experimental work in other countries.

In practically all the industries, the rate of increase of the price index for R & D inputs exceeded the rate of increase of the GNP deflator between 1969 and 1979. Only in the electrical equipment industry was the former less than the latter. Thus, for these industries as a whole, the official statistics concerning deflated R & D expenditures seem to overestimate the increase during this period in R & D performance, if these R & D price indexes are reasonably accurate. Taking all of these industries together, deflated R & D expenditures increased by about 5 percent, based on the GNP deflator, but only by 1 percent on the basis of our price indexes for R & D inputs. Taken at face value, this seems to indicate that the bulk of the apparent increase in real R & D in these industries was due to the inadequacies of the GNP deflator. Of course, this result should be viewed with considerable caution for a variety of reasons (*15*). But it does illustrate how inflation can distort the basic statistics on which major policy-makers depend.

Conclusion

In summary, I have tried to make five points. (i) R & D, through its effects on the rate of productivity increase, can have a significant restraining effect on the rate of inflation in the medium and long run. (ii) High rates of inflation damage the workings of the price system and impair the efficiency of practically all economic activities, including R & D. (iii) Serious inflation tends to discourage investment, including investment in certain kinds of R & D, because it increases uncertainties concerning relative prices in the future. (iv) Serious inflation can have a significant effect on government-financed R & D if it stimulates an anti-inflationary fiscal policy that affects the size and type of government R & D programs. (v) Inflation can distort the basic R & D statistics on which policy-makers depend. In particular, if price indexes for R & D inputs based on the preliminary and tentative findings of a study of more than 30 major firms are correct, the percentage increase in total, real R & D expenditures during the last decade in the chemical, electrical equipment, oil, primary metals, fabricated metal products, rubber, textiles, and stone, clay, and glass industries has been exaggerated due to the inadequacy of the GNP deflator for this purpose.

References and Notes

1. E. Mansfield, *Science* **175**, 477 (1972).
2. Z. Griliches, in *New Developments in Productivity Measurement and Analysis*, J. Kendrick and B. Vaccara, Eds. (National Bureau of Economic Research, Chicago, 1980), pp. 419–454.
3. N. Terleckyj; *Effects of R and D on the Productivity Growth of Industries: An Exploratory Study* (National Planning Association, Washington, D.C., 1974).
4. E. Mansfield, *Am. Econ. Rev.*, in press.
5. Council of Economic Advisers, *Annual Report* (Government Printing Office, Washington, D.C., 1979), pp. 67–72.
6. J. Enos, *Petroleum Progress and Profits* (MIT Press, Cambridge, Mass., 1962).
7. M. Friedman, *J. Political Econ.* **85**, 466 (1977).
8. R. R. Nathan, in *Stimulating Technological Progress* (Committee for Economic Development, Washington, D.C., 1980), p. 68.
9. A. Okun, address to the Economics Club of Chicago, 6 October 1977.
10. R. R. Nathan, in *Stimulating Technological Progress* (Committee for Economic Development, Washington, D.C., 1980), p. 3.
11. E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, F. Husic, *The Production and Application of New Industrial Technology* (Norton, New York, 1977).
12. L. Steele, testimony before the House Subcommittee on Science, Research, and Technology (U.S. Congress, House Subcommittee on Science, Research, and Technology, *Productivity and Technical Innovation*, 96th Cong., 1st sess., 23 July 1979, vol. 7, pp. 12–13). In my study (*4*), the firms in the sample that cut back on relatively basic, long-term, and risky R & D during 1966–1967 were asked why this occurred. One of the most frequently mentioned reasons was inflation (which, of course, was less severe than now). It was cited by about 40 percent of them. During 1966–1967, there was a general tendency for firms to cut the proportion of R & D expenditures devoted to relatively basic, risky, and ambitious projects. But there was no apparent decrease in the average proportion devoted to relatively long-term projects. According to a number of firms, this was due largely to regulatory and related factors. If we omit the industries (for example, the drug industry) where firms stated that regulatory change resulted in a significant lengthening of projects, there was about a 4 percent decline in the average proportion of R & D expenditures devoted to relatively long-term projects (*4*).
13. General Accounting Office, *Report by the Comptroller General on Science Indicators* (Government Printing Office, Washington, D.C., 1979), pp. 46–47.
14. *Trends in Industrial R and D in Selected OECD Member Countries, 1967–75* (Organization for Economic Cooperation and Development, Paris, 1979).
15. I should emphasize that this project is still under way, and the estimates are preliminary. The data will be refined and, if possible, alternative price indexes will be developed since Laspeyres indexes, although generally preferred for work, have well-known limitations. Because they ignores substitution effects, they may exaggerate price increases. Furthermore, NSF has not yet published data on R & D expenditures in these industries for 1979. To obtain rough estimates, we multiplied 1978 NSF figures by 1.12 since NSF stated that, on the average, firms planned a 12 percent increase in R & D expenditures in 1979 [National Science Foundation, *Science Resources Studies Highlights* (Government Printing Office, Washington, D.C., 1980)]. This is a crude procedure, but it seems unlikely that the general results will be affected.