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R & D AND THE PRODUCTIVITY SLOWDOWN

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ABSTRACT

Can the recent productivity slowdown be explained by the slowdown in the growth of R&D expenditures that has occurred since the mid 60's? The earlier estimated rates of return to R&D together with the observed magnitude of the decline in R&D cannot account for much of the productivity decline. A new econometric study based on recently released BLS data for 39 2- and 3-digit manufacturing industries covering the 1959-1977 time period is used, therefore, to investigate the relationship between productivity, physical capital, and different measures of cumulated past R&D expenditures. It confirms the earlier conclusions and reveals an apparent decline in the effectiveness of R&D expenditures in the latter half (1969-1977) of this period. The interpretation of these results is clouded, however, by problems with the data and doubts about the applicability of standard modes of analysis to disequilibrium situations. Also, many of the effects of the R&D slowdown may still be in the future, while many other important contributions are not reflected at all in the official productivity measures as they are currently defined and constructed.

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R&D and the Productivity Slowdown*

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The question I shall address in this paper is "Can the slowdown in productivity growth be explained, wholly or in part, by the recent slowdown in the growth of real R&D expenditures?". But first we have to review the following questions: (1) What is to be explained? Which productivity and what slowdown? (2) What is the mechanism by which R&D could have contributed to this slowdown? And, (3) What did happen to R&D in the relevant period? Besides traversing this somewhat familiar ground and reviewing some of the recent literature on this topic, I shall also report on some estimates of my own.

The direct answer to the opening question is "Probably not." But how we get there needs documenting and may prove instructive on its own merits.

I

There are several productivity "slowdowns" which may be candidates

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for an explanation. The literature defines two slowdowns in the growth of labor productivity: 1965-73 and 1973-78. The first "slowdown" occurs almost entirely outside of manufacturing. The second is pervasive and steep but seems to be associated with the aftermath of the energy crisis which began in 1974 and the deep recession of 1974-75. If one looks at total factor productivity (as estimated by Frank Gollop and Dale Jorgenson or John Kendrick) the picture is murkier. In Gollop and Jorgenson there is no evidence that total factor productivity grew more slowly in manufacturing in 1966-73 than earlier (1960-66). Among the 20 2-digit industries reported by them 11 had higher (or equal rates of growth in the later period and 9 had lower ones. Kendrick estimates that the rate of growth of total factor productivity in manufacturing in 1966-73 was below that in 1957-66 but comparable to the average rate of growth between 1948 and 1957 (2.1, 3.0 and 2.0 respectively). Looking at 95 BLS growth sectors in manufacturing (most of which are at the 3-digit SIC level) which are the numbers I have been analyzing recently, one cannot discern a clear slowdown in labor productivity before the mid-70's.

In what follows I shall concentrate primarily on manufacturing because this is where one would expect to be able to observe the effects of R&D on productivity best. In most other areas, such as services or government, output is not measured distinctly enough from input to be worth analyzing in any detail. The only other major sectors where measured productivity could be affected by R&D expenditures in the longer run are agriculture, communications, transportation and public utilities. There has been no recent productivity decline to speak of in the first three, while the decline in the utilities sector is largely due to the energy crisis induced reduction in capacity utilization.[1]

II

R&D is an investment flow. What affects output is presumably some cumulated stock of the previous results of such investments. Since such results are not easily measurable, most growth accountants have constructed some stock of R&D capital measure: $K_t = \sum w_i R_{t-i}$, where the "stock" K is a function of past investments R, and the w's reflect the assumed lag and depreciation schemes. Given such a measure, the contribution of K to output growth is measured by γk, where γ is the elasticity of aggregate output with respect to R&D capital and k is its rate of growth. An alternative form is given by $\rho NR/Q$, where ρ is the gross rate of return to R&D investments, NR is the <u>net</u> investment in research capital and Q is total or sectoral output. Thus, we need at least three parameters, facts, or assumptions before we can proceed to an estimate of the effects of R&D on growth: (1) an estimate of γ or ρ ; (2) a measurement of the <u>relevant</u> rate of R&D expenditures; and (3) evidence or assumption about its lag structure and depreciation pattern.[2]

The R&D to GNP ratio peaked at about 2.9% in 1964 and declined slowly to about 2.3 in 1975. Not all of this R&D is contributing to productivity growth as it is currently measured. Much of it is spent on defense and space exploration, on health and environment, and on goods and services (such as computers) where quality improvements brought about by such expenditures are not captured in our national accounts. Since much of the slowdown in R&D occurred in these sectors, the slowdown in R&D that could have had a measurable impact was not as large as the crude figures might indicate. I have previously estimated (1973) that only about half of total R&D as measured is likely to affect measured productivity and that only about half of the remainder represents net additions to the stock of research results. If these ratios have remained constant, the "effective" R&D to GNP ratio may have declined from about 0.72 to .57, or about .25 percentage points. Even assuming a relatively high rate of return of 40 percent would account at most for a .1 percent decline in the rate of growth.

But how about its timing? The fact that R&D investments in constant dollars peaked in the mid-60's does not imply that the associated stock measures peaked at the same time. Figure 1 plots the rates of growth of output per manhour in manufacturing (adjusted for interindustry shifts) and the rates of growth in two measures of the stock of applied research and development capital. The first R&D capital measure is based on a no depreciation assumption while the second assumes a 20 percent per annum decline in the effectiveness of past R&D investments. Since the vertical scale is logarithmic, the slope of the curves is equal to the relevant rates of growth.

Looking at this plot, it is hard to discern a clear decline in the growth rate of labor productivity in manufacturing, though it has been hitting new lows in the 70's. There is, however, a clear decline in the rate of growth of R&D capital, of about 3 to 6 percentage points, depending on the exact comparison period and the particular series chosen for the comparison. The same numbers, averaged for the 1960-65, 1965-73, and 1973-77 periods, are summarized in Table 1.

III

To assess the impact of such a substantial decline in the rate of growth of R&D capital on productivity growth we need an estimate of the elasticity of aggregate or sectoral output with respect to changes in the R&D capital. In previous work (1979) using 1957-65 data on 883 large U.S. corporations, I estimated this elasticity to be about .06 (corresponding to a no depreciation concept of R&D capital). This estimate together with a lowering of the R&D capital rate of growth by about 2.3 percent (see Table 1) imply a contribution of about .14 percent to the productivity slowdown in manufacturing, accounting for about one-tenth of it.

This could be an underestimate for two reasons: (a) my earlier estimates are based on firm data and hence do not capture social returns and the spillover effects of R&D, and, (b) they are based on an earlier period, when everything was growing together. In the more recent period there has been more variance in the R&D variable and perhaps one could get better and also possibly higher estimates if the analysis were extended to the 70's.

I turn, therefore, to an analysis of R&D and productivity at an approximately 3-digit SIC level, using the newly released BLS growth sector output, manhours, and capital stock data (see BLS Bulletins 2018 and 2034), and the NSF data on Applied Research and Development expenditures by product fields. The 95 BLS sectors were aggregated into 39 sectors and the 29 NSF product fields were disaggregated to match. The R&D series were deflated and cumulated using a declining balance depreciation scheme.[3] A capital service flow measure was defined as Depreciation in constant dollars plus .08x Net Stock of Fixed Capital. The BLS numbers are for gross output, not value added, but I shall proceed on the assumption that the two moved proportionately for most of the period in question. Both the numbers and the measures constructed from them are rather crude. The purpose, however, was not to do a detailed industry level total factor productivity analysis but rather to see whether there is some prima facie evidence for R&D being the major culprit in the recent slowdown.

The basic approach is to allow for industrial differences in both the average level of productivity and in the capital elasticity. This is accomplished by estimating everything "within" industries, i.e., after subtracting the mean levels of each variable within each industry, and by multiplying the capital variable in each industry by its estimated share in value added. Table 2 presents the major results of this analysis using the no depreciation version of R&D capital.[4] If one starts with a definition of total factor productivity and allows only R&D to affect it (besides time dummies), the estimated coefficients are high and very significant. If one adds, however, other variables to the equation, such as the average age of capital and total manhours (reflecting the short run phenomenon of increasing returns to scale during the business cycle), the R&D coefficients decline and so does also their statistical significance. If we do not impose the TFP framework and allow the capital variable to have its own coefficient, the results are better both in terms of fit and in the significance of the R&D variables, though the capital variable gets a coefficient of less than half its expected size. When the period is broken into two, 1959-68 and 1969-77, the results for the first period are strengthened, with the estimated coefficient being about the same (.07) as I had found earlier at the micro level, but there is nothing to be found in the second period. The contribution of R&D goes to zero or at least cannot be discerned in these data and in this period.

In part this could be a data problem: price indexes get differentially bad as inflation begins to accelerate, the proportionality between gross output and value added begins to break down in this period, and there are rather large swings in capacity utilization unaccounted for by our theories and by the measures used here. I have a sneaking suspicion, however, that the effect may be real. First, various attempts to improve upon these results by allowing for differential materials and energy intensity of the different industries, adding capacity utilization measures in the 1967-77 period, and by throwing out industries whose price deflators are of dubious quality led to no appreciable improvement. Second, the lack of published results of the contribution of R&D to productivity based on post 1968 data leads me to suspect that this is not an isolated finding or peculiar to the specific data set used here. I know of only three studies whose results are based on data which go past 1968: M.I. Nadiri, R. Brinner, and E.C. Agnew and D.E. Wise. All three studies include parts of the later period in their total sample but only Nadiri examines it separately. He has, however, to resort to ridge regression techniques to get sensible looking results and does not include a separate trend variable, attributing all of TFP growth to R&D. Brinner's estimates are based on total domestic GNP, including many sectors where productivity is either not measured at all (such as residential capital formation) or measured very badly (such as services). His estimates are of similar order of magnitude (.06) but are not very robust to the inclusion of other variables (they fall to .03 when labor is adjusted for quality change). The Agnew-Wise study fits TFP estimates for 11 2-digit U.S. manufacturing industries for the period 1957-75 to various R&D measures and R&D spillover measures and gets essentially nothing. I also have seen a number of unpublished papers where passing remarks are made which imply that the authors tried to extend their study to the more recent period but with little or no success.

If these findings are to be taken at their face value, they imply a larger effect of R&D on the slowdown with the effect coming not so much from the slowdown in R&D as from the collapse in the productivity of R&D. If one assumes that previously R&D capital was growing at a rate of 6 percent per year and the associated R&D output elasticity was .07, then its contribution to the rate of growth of productivity in manufacturing was .42 percent per year in the earlier period. The total disappearance of this contribution could account for more than a quarter of the recent productivity slowdown.

How can one explain this collapse of the R&D coefficient in the 70's? It is possible that a large fraction of recent R&D investments has been diverted to finding ways of complying with various new environmental and other regulatory constraints. But that should not have happened across the board. Not all industries have been subject to the same regulatory pressures. Nor should it depreciate all of the "older" R&D investments down to zero. It is also possible that much of the effect of past R&D is embodied in new equipment and a slowdown in capital growth may induce also a decline (a postponement) in the effect of R&D on productivity. This may be testable and would imply that a pick-up in investment would also induce a recovery in the R&D coefficient. The most likely explanation is one of confusion: the large energy price shocks, the resulting fluctuations in capacity utilization, the substantial increase in uncertainty about future absolute and relative prices may have forced many firms away from their long-run production frontiers. What we see in the data are not movements along the technological frontier and hence they should not and cannot be attributed to a variable whose role is to shift this frontier outward.

The other point to remember as space constraints close in on us, is that even though the measured effects of R&D on measured productivity may be small, its true effects may be quite a bit larger. First, we have yet to learn how to measure the spillover effects of R&D within and across industries.[5] Second, much of past and current R&D is spent on socially valuable activities such as our health and the health of our environment, items that are not valued positively in the national accounts as currently constituted. Finally, R&D is a chancy and fickle process. Even if it has run into a dry spell, this does not imply that current expenditures may not have future returns or that there are no major productivity gains already on the drawing boards. All substantive surveys of new technologies and new technological possibilities seem to contradict the notion that we have exhausted our innovation possibilities. Thus I interpret my lack of findings as reflecting data difficulties and the turmoil of the times rather than a true underlying trend shift. In any case, it is unlikely that the recent productivity slowdown can be blamed primarily on the R&D slowdown. If anything, causality may run in the other direction.

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Footnotes

1. Because of space limitation I am not documenting the various statements made in the text. They are consistent with the facts as reported by Denison, Gollop and Jorgenson, Kendrick, and Norsworthy et al.

2. See Griliches (1979b) for a more detailed exposition. See also Griliches (1973), Mansfield and Terleckyj for earlier applications of this kind of framework.

3. The AR&D data by product field were used rather than the R&D industry figures because (a) they are more compatible with the establishment based productivity series and (b) they provide somewhat more industrial detail. Basic research is not broken down by product field and hence is not included in these stock measures. Since it accounts for only 3 percent of total R&D in industry, its inclusion would not affect the overall picture. Note that one could quarrel with a measure of social R&D capital that may decline just due to the passage of time. But to open this issue here would take us too far afield.

4. Experiments with (geometric) depreciation rates of 10, 20 and 30 percent per year led largely to the same results. The data can hardly distinguish between them, showing a slight preference for 0 or 10 percent. The only noticable difference in the results are negative, though insignificant, R&D coefficients for the 1964-77 period when higher depreciation rates are used.

5. See Griliches (1979b) for more discussion, also Agnew-Wise (1979) and Schankerman (1979) for examples of such attempts. (There has been no convincing showing of spillover effects using post-1968 data.)

Table 1. Average Growth Rates Within Manufacturing Industries
(Percent per Year)

	Output per Man hour	R&D Stock δ = 0	R&D Stock δ = .1	R&D Stock δ = .2
1960-65	3.4	10.3	8.5	7.0
1965-73	2.8	7.9	6.4	5.6
1973-77	1.4	5.6	3.0	1.4
	Deceleration			
60-65 to 65-73	0.6	2.4	2.1	1.4
65-73 to 73-77	1.4	2.3	3.4	4.2

Table 2: R&D Stock Coefficients in Various Specifications: Within 39 U.S. Manufacturing Sectors, N = 741.

Period and Dependent Variable	R&D Stock Coefficient (Standard Errors)	S.E.E.	Other Variables in Equation
1. TFP, 1959-77	.058 (.030)	.124	None
2. TFP, 1959-77	.029 (.027)	.110	Age C, MHRS
3. LPROD, 1959-77	.044 (.026)	.106	(1-LS)·L(SFC/MHRS), Age C, MHRS
4. LPROD, 1959-68	.067 (.029)	.064	(1-LS)·L(SFC/MHRS), Age C, MHRS
5. LPROD, 1969-77	.026 (.046)	.078	(1-LS)·L(SFC/MHRS), Age C, MHRS

TFP = LPROD-(1-LS) [LSFC-MHRS]

LPROD = Log output per manhour

(1-LS)[L(SFC/MHRS)] = (1-Average 71-75 labor share in value added) (Log service flow measure of fixed capital minus log total manhours)

R&D Stock: log (cumulated sum of deflated applied research and development expenditures from 1959 on plus 1958 initial value). 1958 initial value = R_{58}/g, where g is the estimated rate of growth of R in a particular industry during 1959-64.

S.E.E. - standard deviation of residuals.

All equations contain an intercept and year dummies. "Within" means that all variables are measured around their respective industry means.

Fig. 1 Growth rates ($\ln y_t - \ln y_{t-1}$), in percent