THE IMPACT OF APPLIED RESEARCH AND DEVELOPMENT ON PRODUCTIVITY

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I. Introduction

That technological change underlies most of the gains in living standards is now widely accepted. However, the process by which this change occurs and leads to increased output per capita is not yet well understood. The principal reason for this is, apparently, that recorded inputs into the productive process - number of man-hours of labor and dollars of investment capital - fall short of capturing the quantitative and qualitative factors involved.

To remedy this deficiency economists have mainly devised more or less elaborate ways of augmenting measured labor and capital in order to take account of presumed real differences in quality - the so-called embodied productivity schools, which have been summarized by Nelson (10), and need not be reviewed here. The trouble is these procedures tend to be arbitrary, and have to date proved inconclusive. In particular there remains to be specified exactly how new knowledge becomes incorporated into the productive process, and what its contribution is.[1]

The purpose of this paper is to present the results of a study in which is estimated the contribution to labor productivity from new technical knowledge, as measured by formal industrial applied research and development expenditures. This is done, using a production function framework, separately for a cross-section of 24 manufacturing industries accounting for 90 percent of all government plus privately financed industrial R & D, excluding that for atomic energy devices, ordnance, guided missiles, and aircraft.

The direct approach of relating research to technological change has received scant empirical attention. The author is aware of just four previous studies, including

[1]A recent alternative view put forward by Jorgenson and Griliches (7) would indicate that almost the entire so-called productivity residual is to be explained by errors of aggregation and measurement. But their use of output prices for instance, rather than input prices for deflating investment amounts to an embodied productivity adjustment.

Minasian's study (9) of a cross-section of chemical and drug companies; Mansfield's illustrative work (8) with chemical and petroleum firms; Terleckyj's pioneering work (15) using a number of two-digit industries; and the recent important study of Brown-Conrad (1) for groups of durable and non-durable industries. In certain respects the present study bears close resemblance to that of Brown and Conrad, and indeed their treatment of R & D done by supplying industries largely anticipated the approach used here. However, I believe that the study described here constitutes the most explicit, detailed, and comprehensive formulation and testing of R & D as a productive factor, and finds its role substantiated beyond reasonable doubt.

One reason so little research has been done in this area is that the appropriate specification of the time lags involved between research and impact on productivity has seemed to require a longer time series of observations than has generally been available. A basic source of R & D data is compiled by the National Science Foundation (NSF), but is available annually since 1953. We have used the NSF data in this study for applied research and development (excluding basic research), which should substantially reduce the time lag until the impact on productivity is felt.

A second major problem has been that much technological change must be in the form of new and improved products, rather than pure gains in efficiency in producing old products. It is generally believed these new and improved products are not adequately reflected in real output measures.[2] Indeed, Brown and Conrad explicitly limit their model to cost reducing technological improvements. I am inclined to make no such qualification, since at least some of my price deflators pretend to take account of quality improvements. Furthermore, it is not clear that our price deflators have necessarily led to a downward bias, nor, if they have, how quantitatively significant

[2]The most comprehensive discussion of alleged systematic biases in price or output deflator statistics is probably to be found in the Stigler committee report, reference (12).

this has been.[3] Finally, when better price and output measures are developed the framework presented here will be that much more appropriate; until such time we allow for the possibility of a certain amount of bias, in our coefficients of technological change.

II. A Model of Labor Productivity

I assume to begin with that output for industry i in time period t, Y_{it}, is related to the effective stock of technology resulting from the industry's own R & D efforts, T_{it}; to the capital stock adjust for embodied technology, J_{it}; to the total labor input adjusted for quality changes, L^*_{it}; and to the effective stock of technology available from other industries supplying material inputs, M_{it}. This relationship is assumed to take the form of a generalized Cobb-Douglas function as follows:

$$(1) \qquad Y_{it} = A_i e^{\rho t} T_{it}^{\alpha} \; J_{it}^{\beta} \quad L^{*\gamma}_{it} \quad M_{it}^{\delta}$$

where the parameters A_i, α, β, γ, and δ are assumed constant over time, and an external time trend, $e^{\rho t}$ has been included.

Throughout this paper industry output refers to constant dollar value added, where the relevant price deflator should, ideally, be corrected for the influence of quality changes. We proceed to discuss the representation of the four input variables, T, J, L*, and M.

The technology base represented by T and M is assumed strictly a function of applied research and development expenditures. I propose to take account of basic research and other, informal, types of research by assuming their influence is included in the time trend, ρ.

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[3]Gustafson, (4), has speculated on the implications of the timing of the introduction of new products for productivity measures. The work of Triplett (17) indicates that, at least for automobiles, the adjustments for quality changes made in that component of the CPI (similar adjustments are made for the WPI) have over compensated for real or hedonic quality changes during 1960-65.

Most generally T will be a function of current and all previous industry R & D expenditures at a given point in time. If a reasonably stable relation exists between a dollar's investment in R&D and its expected contribution to future output streams, then T can be approximated as a weighted average of current and lagged R&D expenditures as follows:

$$(2) \qquad T_{it} = \sum_{v=0}^{\infty} w_v \; R_{it-v}$$

where R_{it-v} is expenditures for applied R&D in the i^{th} industry for year t-v, and the w_v are assumed constant over time.

We might wish to be agnostic about the relative magnitudes of the w_v's, letting the data determine the shape of the weighting pattern. Since our ability to investigate empirically is severely limited by the relatively short time series available, we will speculate on what can be said a priori about the shape of the weighting pattern.

Applied R&D should have relatively little impact in output concurrently because of the lag involved in putting research findings into operation. Thus the expected impact of R&D on output will increase for a time, eventually reaching a peak, depending on the nature of industry research and the mix of applied research to development expenditures. A survey of manufacturing firms made by McGraw-Hill in 1964 suggests an average lag between R&D expenditures and "large scale production" of about 4.6 years for applied research and 3.5 years for development.[4] It might be argued that once a given R&D expenditure has achieved its full impact on output or productivity this gain is available forever. In terms of equation (2), the weights w_v reach an upper limit and remain there no matter how large v becomes (with the exact increment to output depending on the amounts of other inputs used). There are, however, strong reasons for

[4] Computed from Table XVI, 17th Annual McGraw-Hill Survey Business' Plans for New Plants and Equipment, 1964-67.

believing the w_v will decline after some point. The composition of output will change with changing demands, diminishing the value of prior research aimed at developing or improving products no longer produced. Improved processes that were the result of previous R&D may be rendered obsolete by later innovations. Thus the transistor diminished the contribution of R&D on the tube, and catalytic cracking of gas oil made obsolete earlier R&D on thermal cracking processes.[5] However the contribution of prior research to current output, while diminished and diffused, cannot be assumed to have no value. Specifically I assume that all R&D done prior to t-n contributes to a common pool of technology which increases over time (since R_{t-n-1} is added each year), and augments in multiplicative fashion R&D done in more recent years. Thus equation (2) is rewritten as,

$$(2a) \qquad T_{it} = \sum_{v=0}^{n} w_v R_{it-v} \qquad R_o e^{p1\,(t-n)}.$$

where R_o is an initializing constant.

Turning to the technology contributed by industries supplying current inputs to the i^{th} industry, M_{it}, whether in the form of information or embodied in products, it is assumed that such technology in any given year is a weighted average of applied R&D done by the supplying industries, with the weights determined by the proportion of the supplying industry's total sales that go to the i^{th} industry. Assume this proportion for the j^{th} supplying industry is a_{ji}, and is constant over the time period studied. Then if there are m supplying industries, their effective applied R&D contribution for year t-v is given by $\sum_{j=1}^{m} a_{ji}R_{jt-v}$ (if $a_{ii} > 0$, the i^{th} industry reinforces its own R&D effort through intra-industry sales). Then if M_{it} is assumed to be a function of

[5]Examples and analysis of this process of "creative destruction" can be abundantly found in Nelson, Peck, and Kalachek, reference (11).

current and past "input R&D" given by a stable weighting pattern, as was assumed for T_{it}, we can write

$$(3) \qquad M_{it} = \sum_{v=o}^{\infty} s_v \sum_{j=1}^{m} a_{ji} R_{jt-v}$$

where the weights, s_v, should have properties similar to w_v, but are not assumed to be identical. Specifically, if a line of reasoning analogous to that used in developing (2a) is employed, the contribution to technology from all input R&D done prior to t-n-1 may be assumed captured by a multiplicative time trend as follows:

$$(3a) \qquad M_{it} = \sum_{v=o}^{n} s_v \sum_{j=1}^{m} a_{ji} R_{jt-v} \qquad S_o e^{\rho 2 (t-n)}$$

where S_o is again an initializing constant.

By the capital stock adjusted for embodied productivity, J_{it}, is meant that concept developed by Solow (14), and discussed extensively in the literature, except that I would extend it specifically to include technology that may go along with the capital equipment but is not directly part of it - such as, e.g., the software provided by IBM to customers. With this modification J_{it} would be the capital input equivalent to M_{it}, and if a set of capital coefficients were available I could produce a variable defined similarly to (3) or (3a), and provide what would seem to be an obviously stronger and more appropriate test of the "embodied" effect than has heretofore been done. Unfortunately, a relevant capital coefficients matrix does not seem to exist, and while I have given thought to constructing an approximate one from census data on various categories of power generating machinery owned by each industry, I have neither the time nor resources to pursue this tact at present. Thus a more conventional procedure has been followed. Denote the gross investment made in t-v by I_{t-v}, and that surviving to t by $I_{t,t-v}$, and assume a constant proportion θ of investment in any year is retired in the next. Then the relation between gross investment in year t-v and that surviving in year t is given by

$$I_{t,t-v} = (1-\theta)^{v} I_{t-v}$$

and the total gross capital stock surviving at time t is

$$K_t = \sum_{v=0}^{r} (1-\theta)^{v} I_{t-v}$$

where r is an assumed maximum life of investment.

Following Solow, we assume investment in t embodies an improvement factor of $1+\mu$ over investment in t-1, and hence $(1+\mu)^t$ over investment in year zero. Then embodied capital stock for the i^{th} industry is therefore seen to be

$$(4) \qquad J_{it} = \sum_{v=0}^{r} (1+\mu)^{t-v} (1-\theta)^{v} I_{i,t-v} = (1+\mu)^{t} \sum_{v=0}^{r} \left(\frac{1-\theta}{1+\mu}\right)^{v} I_{i,t-v} \quad .$$

The remaining input variable is the labor supplied to the i^{th} industry, adjusted for quality changes, L^*_{it}. These quality changes come about through the gradual upgrading of educational achievements of the labor force, through changes in the average length of work experience in a given industry, and through changes in the occupational and skill level composition of workers in an industry. With some misgivings, I have principally for lack of sufficient data assumed that the net secular effect of these influences can be represented by a smooth trend increase in the nominal manhours, L_{it}, for the i^{th} industry. Thus

$$(5) \qquad L^*_{it} = L_{it} e^{\rho_3 t}$$

where the trend factor, ρ_3 is allowed to vary among industries, but not over time.

Substituting equations (2a), (3a), (4) and (5) into equation (1), we can express the production function for the i^{th} industry in terms of observable variables as follows:

$$(6) \qquad Y_{it} = B_i e^{(\rho+\alpha\rho_1+\delta\rho_2+\gamma\rho_3+\beta\mu)t} \left(\sum_{v=o}^{n} w_v R_{i,t-v}\right)^{\alpha}$$

$$x \left(\sum_{v=o}^{r} \left(\frac{1-\theta}{1+\mu}\right)^{v} I_{i,t-v}\right)^{\beta} L_{it}^{\gamma} \left(\sum_{v=o}^{n} s_v \sum_{j=1}^{m} a_{ji} R_{j,t-v}\right)^{\delta}$$

where $B_i = A_i R_o S_o e^{-(\rho_1+\rho_2)n}$ and the relation $(1+\mu)^t = e^{\mu t}$ has been used.

Since the principal concern of this paper is the impact of R&D on productivity - specifically labor productivity - rather than output per se, we transform the dependent variable in equation (6) by simply dividing through by L_{it}. In doing so it proves convenient to assume the production function is homogeneous of degree one at a given point in time. Presumably this standard assumption is more justified to the extent that we have carefully enumerated all of the relevant input variables. Thus we use the fact that $\gamma = 1 - \alpha - \beta - \delta$, after dividing through by L_{it}. To put the equation in a linear form appropriate to least squares estimation, we take the natural log and then the first difference - the latter indicated by $\Delta \log x_t = \log x_t - \log x_{t-1}$. The result of these steps is the following relation:

$$(7) \qquad \Delta \log (Y/L)_{it} = \rho+\alpha\rho_1 +\delta\rho_2 +\gamma\rho_3+ \beta\mu$$

$$+ \alpha\Delta \log (\Sigma w_v R_{i,t-v}/L_{it})$$

$$+ \beta\Delta \log\left(\Sigma \left(\frac{1-\theta}{1+\mu}\right)^{v} I_{i,t-v} / L_{it}\right)$$

$$+ \delta\Delta \log (\Sigma s_v \Sigma a_{ji} R_{i,t-v} / L_{it})$$

where the ranges over which the summations take place have been omitted for simplicity.

Equation (7) provides a functional relation explaining trend labor productivity. Estimated values for α, β, and δ show the elasticities of labor productivity to own R&D per manhour, investment per manhour, and input R&D per manhour (The various exponential time trends will be indistinguishable parts of a regression constant). Before equation (7) can be confronted with data, however, account must be taken of cyclical changes in productivity. As numerous studies have shown, most year to year variation in productivity is due to changes in the rates of utilization of capacity and manpower. An explanation in terms of classical short-run costs curves has been given by Eckstein and Wilson (2), and I have offered one in terms of dynamic cost minimization (13). Evidence on the importance of cyclical movements for the 24 industries included in this study is presented later on.

The above references and other work indicate that short-run fluctuations in labor productivity are a positive function of the rate of capacity utilization, as labor is used more efficiently; and, particularly where short time periods are considered, a positive function of the change in the utilization rate, because full and immediate labor supply adjustments are costly or not feasible. (The underlying theory on the latter point was developed by Holt (6) and applied to labor productivity in reference (13)). Denote the capacity utilization rate by U_t and assume, for purposes of exposition only, that trend productivity movements consist simply of an exponential time trend. Then on the above analysis, a model combining both cyclical and secular productivity movements is given by

$$(8) \qquad \left(\frac{Y}{L}\right)_t = a_o e^{a_1 t + u_t} (U_t)^{a_2} \left(\frac{U_t}{U_{t-1}}\right)^{a_3}$$

where u_t is a random error term introduced to account for remaining variations in productivity.

Taking the log of equation (8) and then the first difference, we get

$$(9) \qquad \Delta \log \left(\frac{Y}{L}\right)_t = a_1 + (a_2 + a_3)\ \Delta \log \ddot{u}_t - a_3\ \Delta \log u_{t-1} + \Delta u_t$$

$$= a_1 + (a_2 + a_3)\ \Delta \log Y_t - a_3\ \Delta \log Y_{t-1}$$

$$- (a_2 + a_3)\ \Delta \log C_t + a_3\ \Delta \log C_{t-1} + \Delta u_t$$

where C_t stands for capacity output and we have used the definition $U_t = Y_t / C_t$.

If data were available on capacity of utilization rates for the 24 industries under investigation we could make use of equation (9) directly. Unfortunately information in the detail we require is not available. As a not unreasonable first approximation I have assumed that capacity grows at a steady rate c, differing among industries but constant over time. This means $\Delta \log C_t = \Delta \log C_{t-1} = c$, and equation (9) becomes

$$(9a) \qquad \Delta \log\left(\frac{Y}{L}\right)_t = a_1 - a_2 c + (a_2 + a_3)\ \Delta \log Y_t - a_3\ \Delta \log Y_{t-1} + \Delta u_t$$

Now we can replace the lone trend term in equation (9a), a_1, with all the determinants of productivity trend discussed earlier, i.e., the entire right-hand side of equation (7), to get the final form of the regression model to be estimated:

$$(10) \qquad \Delta \log (Y/L)_{it} = \rho + \alpha\rho_1 + \delta\rho_2 + \gamma\rho_3 + \beta\mu - a_2 c$$

$$+ (a_2 + a_3)\ \Delta \log Y_{it} - a_3\ \Delta \log Y_{it-1}$$

$$+ \alpha\ \Delta \log \left(\sum_v w_v R_{i,t-v} / L_{it}\right)$$

$$+ \beta\ \Delta \log \Sigma\ \frac{1-\theta}{1+\mu}\ I_{\iota'\tau=x} / L_{\iota\tau}$$

$$+ \delta\ \nabla \log \left(\Sigma\ s_v \Sigma a_{ji} R_{j,t-v} / L_{it}\right) + \Delta u_{it}$$

Since the parameters w_v, θ, μ, and s_v are not observed, the next section describes a maximum correlation scheme for obtaining approximate values together with estimates of the coefficients of the variables.

III. Data and Methodology

To estimate equation (10) data are required on applied R&D, value added, investment, total manhours, and various price deflators. What I was finally able to obtain was annual observations for 14 years, 1953-66, for 24 two and three digit SIC industries. These include 5 chemical industries, 6 non-electrical machinery industries, 4 electrical machinery industries primary ferrous and non-ferrour metals, motor vehicles, and 6 two-digit industries. The data are briefly described below. A more detailed description, together with the complete data set, is presented in the Appendix.

The applied research and development data are taken from NSF annual reports (18), and refer to product fields with SIC industry definitions. Comparable data for the 24 manufacturing industries designated in Table A-I of the Appendix are available for 1959-66. Prior to 1959 NSF applied R&D data becomes more aggregative, and less comparable to either SIC definitions or later data. I made every attempt to make the data for the earlier years as nearly comparable as possible, although I could not obtain access to NSF unpublished detailed data.

The data on value added, total manhours, and plant and equipment expenditures are based on Bureau of the Census annual surveys or censuses of manufactures (19). Data for years before 1958 have been made approximately comparable to 1957 SIC revisions. The price deflators for value added are derived primarily from Bureau of Labor Statistics component wholesale price indexes, or BLS industry-sector price indexes where available, supplemented by Census unit value indexes, and, in a few cases, crude indexes I constructed myself from quantity and value of shipments data. I must confess to spending an inordinate amount of time attempting to develop at least ball park price movements, with little assurance in the reliability of the results. It should come as no surprise that the areas in which technology is changing most rapidly are the ones in which price information is most lacking. Plant and equipment in each case was deflated by the GNP deflators for nonresidential structures and producers durable equipment. An overall deflator for R&D was developed based primarily on increases in wages and salaries of scientists and engineers doing R&D.

Turning now to estimation of equation (10), the following procedure was adopted. For each industry the trend variables are designated as follows: "own R&D, defined as $\Delta \log (\Sigma\, w_v R_{i,t-v} / L_{it})$; investment, defined as $\Delta \log \left(\Sigma \left(\frac{1-\theta}{1+\mu}\right)^v I_{i,t-v} / L_{it}\right)$, where for $I_{i,t-v}$ both equipment expenditures and total plant and equipment investment were tried; and "input R&D", defined as $\Delta \log (\Sigma\, s_v \Sigma\, a_{ji} R_{j,t-v} / L_{it})$. The a_{ji} used to compute input R&D are based on the 1958 Input-Output coefficients, reference (3), and are limited to the 24 industries included in this study. Each of these variables was constructed assuming a number of different weighting patterns over time, ranging from a three year period to a five year period. The weights are shown in Table I. For future reference variable numbers are assigned to each different weighting pattern. Regressions were run using each weighting pattern for a trend variable in combination with each weighting pattern for one or both other trend variables. The closest estimate of the true distributed lag structure (including the null structure, where all weights in effect equal zero) was based on best fit adjusted for degrees of freedom, subject to the restriction that the coefficients of all variables have the correct a priori sign.

The values and time spans of the weighting patterns chosen can be justified, if at all, on progmatic grounds, plus some subjective notions I wished to test. For each time span in the case of the R&D variables, three shapes, including uniform weights, an interior peak, and a peak at the beginning of the span, were chosen. The weighting patterns for the two investment variables probably build in more obsolescents than appears to be the case ex post, judging by the overall poor performance of these variables.

Table I Weights for Computing Own R&D, Input R&D and Investment Variables

Applied R&D Variable: Own R&D	Input R&D	Time Period: t	t-1	t-2	t-3	t-4
		Values of w_v and s_v				
X_{31}	X_{61}	.33	.34	.33	-	-
X_{32}	X_{62}	.25	.50	.25	-	-
X_{33}	X_{63}	.10	.30	.60	-	-
X_{34}	X_{64}	.25	.25	.25	.25	-
X_{35}	X_{65}	.10	.30	.40	.20	-
X_{36}	X_{66}	.05	.10	.35	.50	-
X_{37}	X_{67}	.20	.20	.20	.20	.20
X_{38}	X_{68}	.00	.10	.30	.40	.20
X_{39}	X_{69}	.00	.10	.20	.30	.40
Equipment Investment	Total Investment	Values of $\left(\frac{1-\theta}{1+\mu}\right)^v$: θ = .2 equipment, .1 total; μ = .035				
X_{46}		1.00	.77	.59	-	-
	X_{47}	1.00	.87	.75	-	-
X_{48}		1.00	.77	.59	.46	-
	X_{49}	1.00	.87	.75	.65	-
X_{50}		1.00	.77	.59	.46	.35
	X_{51}	1.00	.87	.75	.65	.56

The limitation of the lag structure to at most the change over the current and four previous years was necessitated by the relatively short time series. Starting with 14 observations, the first difference form of equation (10) loses one observation, but is justified as a means of reducing multicollinearity resulting from the common upward time trend in all but the cyclical variables. Then a lag structure extending to t-4 reduces the observations per industry to 9, and, potentially if all variables were included, the degrees of freedom to 3. In fact the degrees of freedom was never allowed to fall below 4. We will return to the question of the adequacy of the lag structure later.

The other side of the coin is the question of whether there are sufficient degrees of freedom to provide meaningful results at all. The problem is compounded by our maximum correlation method of estimating the lag structure. An economist once suggested - I have forgotten who - that economists ought to be penalized 1 degree of freedom for each regression variant of a model they run. If that rule passes I certainly want to sell IBM stock short. Let us say rather that I am attempting to estimate a lag structure characterized by 2 or 3 parameters for which I nominally subtract only 1 degree of freedom. Thus, in my worst case, I am down to an effective 2 degrees of freedom. Countering this to some extent are my a priori restrictions on sign. I also would count consistently good and reasonable results across industries as adding to the weight to be attached to the results.[6] However, there is no avoiding the fact that I am very much in a small sample work. And this fact must qualify the results throughout.

[6] I also conducted a number of runs pooling industry observations using Zellner's seemingly unrelated technique, after incorporating certain restructions on the parameters, in an effort to increase degrees of freedom. These experiments, not successfully completed at present, will be reported on at a later date.

IV. Regression Results

It proves useful to begin discussion of the empirical results by investigating separately the model explaining cyclical fluctuations in productivity, equation (9a). The regression results for all 24 manufacturing industries included in this study (designated by SIC code - descriptive titles are given in the appendix) for the 11 year period 1955-65 are given in Table II. Cyclical fluctuations, as captured by the two proxy variables, current and lagged changes in (the log of) value added (VA), account for more than four-fifths of the total year to year variation in $\Delta\log\,(VA/L)_t$ in 9 of 24 industries, and more than half the variation in 17 industries.

According to equation (9a), the fitted coefficient of $\Delta\log\,(VA)_t$ is an estimate of $a_2 + a_3$, while that of $\Delta\log\,(VA)_{t-1}$ estimates $-a_3$, where both a_2 and a_3 are assumed positive. Thus the coefficients in Table II have the expected positive and negative sign for every industry. In one industry, SIC 333-8, the implied value for a_2 is negative, although not significantly so. Also according to equation (9a), the constant term may be positive or negative, depending on whether a_1 is greater or less than a_2c (where c is the rate of growth of capacity). Since a_1 for this model measures the full impact of all trend influences on productivity, while a_2c appears to be for these industries a fairly small fraction of trend capacity growth (an estimate of a_2 is given by the algebraic sum of the coefficients of the two variables), the predominantly positive constants found in Table II are consistent with a priori expectations. Furthermore, as trend variables are explicitly introduced into the model, we would expect the magnitude of a_1 to be thereby reduced, making the estimated regression constant less positive.

Evidently the model developed to explain cyclical fluctuations is not an unreasonable first approximation for most industries. However, while the coefficient of current output changes was significant at the 5% level in 18 of 24 cases, that of

TABLE II

Regression Results for Model of Cyclical Movements in Labor Productivity
(24 Manufacturing Industries)

dependent variable: $\Delta\log(VA/L)_t$

SIC	R^2	regression constant	Coefficient: $\Delta\log(VA)_t$	$\Delta\log(VA)_{t-1}$
20	.8815	.0093	.6666**	-.1105
281	.9781	.1423	.7489**	-.2095**
282	.9418	.0134	.5793**	-.2700**
283	.6843	-.0007	.9677**	-.6716
284,5,9	.6213	.0137	.5433**	-.1758
287	.8408	.0069	.7266**	-.0628
29	.9546	.0120	.9204**	-.0407
30	.1050	.0164	.0891	-.0729
32	.8249	.0095	.3518**	-.1167
331,2; 3391,9	.6228	.0070	.2421**	-.1429
333-8; 3392	.3031	.0148	.0029	-.3223
34	.4913	.0049	.3441**	-.0462
351	.5665	.0166	.3577**	-.0811
352	.7225	.0047	.4986**	-.1040
353	.4766	.0035	.2762*	-.1520
354	.6789	-.0008	.2375**	-.1090
355,6,8,9	.8333	.0051	.3707**	-.1445**
357	.8236	.0013	.7523**	-.2925*
361	.1690	.0057	.1877	-.0524
362	.6735	.0128	.2727**	-.1028
363,4,9	.3391	.0184	.1973	-.1414
365-7	.0346	.0205	.0759	-.0403
371	.8853	.0163	.2759**	-.0883
38	.6560	.0153	.3272**	-.1859*

* - Significant at 10% level,
** - Significant at 5% level,

Note: all regressions are for 11 years, 1955-65; d.f. = 8.

lagged output changes was significant at the 5% level in only 3 cases, and at the 10% level in only 5 cases.[7] This suggests that, in the interest of conserving degrees of freedom, $\Delta\log\ (VA)_{t-1}$ could be dropped as an explanatory variable without doing extreme violence to the model. Implicit in this is the notion that while the level of utilization is a key variable explaining the level of productivity, the adjustment process resulting from changes in utilization has mostly been averaged out when year over year changes are considered.

In the initial test of the full model, equation (10),data was not available for 1966. Regressions were run for three time periods: 1956-65 using a weighting pattern extending from t to t-2; 1957-65 using a weighting pattern extending from t to t-3; and 1958-65 using the longest weighting pattern for trend variables, extending from t to t-4. A glance back at Table I will indicate which variables were available in each case. Invoking the line of reasoning of the preceding paragraph, $\Delta\log\ (VA)_{t-1}$ was dropped from the 1957-65 and 1958-65 regressions, although the variable was included in the 1956-65 regressions. The results of attempting a large number of weighting pattern combinations indicated that the 1956-65 regressions, incorporating only a three year span for trend variables, consistently proved inferior in terms of explained variation (adjusted for degrees of freedom) and significance of trend coefficients, to regressions allowing for longer distributed lags. Moreover, the variable $\Delta\log\ (VA)_{t-1}$ was even less successful when trend variables were included.

As a consequence of these initial findings, subsequent regressions were limited to those starting with 1957 or 1958, and did not include $\Delta\log\ (VA)_{t-1}$. The various combinations of weighting patterns for trend variables can be summarized succinctly by defining vectors of trend variables, and stating the rule that each variable in a vector

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[7]All significance levels for the t distribution mentioned in this section assume a two-sided test for simplicity.

was tried in conjunction with a variable from either one or both of the other vectors in the set. Thus for the variables defined by Table 1 we have combinations involving the following two sets of vectors:

<u>1957-66 Regressions</u> (obs. = 10)

$$\begin{bmatrix} X_{34} \\ X_{35} \\ X_{36} \end{bmatrix} \quad \begin{bmatrix} X_{48} \\ X_{49} \end{bmatrix} \quad \begin{bmatrix} X_{64} \\ X_{65} \\ X_{66} \end{bmatrix}$$

Total number of regressions per industry equals 18 + 6+ 6 + 9 = 39.

<u>1958-66 Regressions</u> (obs. = 9)

$$\begin{bmatrix} X_{37} \\ X_{38} \\ X_{39} \\ X_{31} \\ X_{32} \\ X_{33} \end{bmatrix} \quad \begin{bmatrix} X_{50} \\ X_{51} \end{bmatrix} \quad \begin{bmatrix} X_{67} \\ X_{68} \\ X_{69} \\ X_{61} \\ X_{62} \\ X_{63} \end{bmatrix}$$

except that X_{51} was never tried with variables from both the own R&D and the input R&D vectors simultaneously, and X_{31}--X_{33} were never tried alone with X_{61}-X_{63}. Total number of regressions per industry equals 36 + 12 + 12 + 9 + 9 + 9 = 87.

To the above regressions one further variant was added. It soon became obvious that in attempting to measure the separate influences of own R&D and input R&D severe problems of multicollinearity were being encountered in a number of industries, as signified by low t values and erratic coefficients when both variables were included simultaneously, compared to high levels of significance when the variables were entered singly. Upon investigation it was found that for a number of these industries, the I-O coefficient for industry sales of current inputs to itself, a_{ii}, was relatively large compared to the other a_{ji}. In these industries, the input R&D variable, by construction, would be strongly dependent on the industry's own R&D. To alleviate this problem of collinearity, an alternative set of input R&D variables was computed, designated by a superscript *, in which the a_{ii} coefficient for each industry was set to zero. The rationale is that since the "input R&D" effect resulting from intra-industry sales evidently cannot be separated from "own R&D" effects for some industries, we assume its effect will be captured by the own R&D variable, and limit the input R&D variable to influences attributable to R&D done outside the industry. I will refer to these new input R&D variables as those with the diagonals of the I-O matrix set to zero, and to the original set as the standard input R&D variables.

A total of 9 regressions for the period 1957-66 and 72 regressions for the period 1958-66 were run for each industry using the new set of input R&D variables together with the relevant equipment investment variable, X_{48} or X_{50}, (which generally had proved more successful than the total investment variables X_{48} and X_{50}), and/or the own R&D variables. The result was a modest reduction in the simple correlation between own and input R&D variables in a number of cases, and some improvement in overall ability to distinguish between own and input R&D effects. However, correlations between own and input R&D variables remained high (for the same weighting pattern) in about half the industries, particularly the machinery industries, SIC 35 and 36.

Results for all 1957-66 and 1958-66 regressions are summarized in Table III, where from one to five regressions have been selected for each industry. The regressions chosen for a given industry are among those with the highest R^2 (really, R^2 adjusted for degrees of freedom, $\overline{R}^2$, although this statistic is not explicitly shown) subject to the restriction announced previously that all coefficients agree with a priori expectations. However, what is shown is not simply a ranking by $\overline{R}^2$. Plural regressions for an industry were selected to emphasize cases where alternative magnitudes of coefficients, and weighting patterns, of trend variables strongly present themselves.

TABLE III

Best and Representative Full Model Regressions Explaining Labor Productivity
(24 Manufacturing Industries)

dependent variable $\Delta\log (VA/L)_t$ (t values shown in parentheses)

SIC	R^2	d.f.	regression constant	Δlog VA coeff.	Own R&D var.	Own R&D coeff.	Investment var.	Investment coeff.	Input R&D var.[2]	Input R&D coeff.
20	.9139**	6[1]	-.0031	.8499 (6.71)	36	.1875 (2.50)	49	.0975 (0.77)	-	
281	.9589	5	-.0093	.9543 (9.65)	37	.0126 (0.05)	-		68	.7541 (2.77)
"	.9835**	5	-.0080	.9615 (15.33)	37	.0387 (0.24)	-		68*	.6973 (5.11)
"	.9833	5	-.0079	.9616 (13.33)	31	.0167 (0.15)	-		68*	.7085 (5.72)
"	.9516	5	-.0259	1.2552 (6.69)	39	.7958 (2.78	-		63*	.5332 (2.54)
282	.9956	5	-.0164	.9874 (33.04)	32	.5342 (3.90)	-		67	.4875 (3.20)
"	.9955	5	-.0172	.9249 (24.08)	38	.7885 (15.02)	50	.0361 (1.18)	-	
"	.9995**	5	-.0165	.9610 (102.99)	32	.8805 (17.57)	-		68*	.0811 (1.55)
"	.9994	5	-.0170	.9640 (74.84)	32	.9331 (25.17)	-		61*	.0270 (0.65)
283	.9944	5	-.0144	.8930 (19.08)	33	.0733 (2.00)	-		67	.9366 (16.34)
"	.9953	4	-.0148	.8919 (18.47)	33	.0720 (1.90)	50	.0225 (0.84)	67	.9439 (15.80)
"	.9945	4	-.0146	.8695 (18.50)	38	.0904 .1.58	50	.0267 (0.92)	67	.9011 (10.29)
"	.9968**	5	-.0089	.8573 (23.81)	33	.1312 (5.15)	-		67*	.8853 (21.70)
"	.9928	5	-.0085	.8180 (16.43)	38	.1525 (2.97	-		67*	.8176 (10.21)
284,5,9	.9955**	4	-.0196	1.1602 (20.46)	32	.3108 (4.89)	50	.1331 (3.27)	68	.9328 (21.32)
"	.9936	4	-.0218	1.0961 (16.65)	32	.2289 (3.08)	50	.1057 (2.21)	68*	.9623 (18.04)
287	.9874	5	-.0120	.9274 (18.92)	33	.0479 (1.24)	-		67	.8688 (8.05)
"	.9850**	5	-.0244	.9820 (16.21)	38	.3771 (3.06)	-		61	.4116 (3.27)

TABLE III (cont'd.)

(t values shown in parentheses)

SIC	R^2	d.f.	constant	Δlog VA coeff.	Own R&D var.	Own R&D coeff.	Investment var.	Investment coeff.	Input R&D var.[2]	Input R&D coeff.
287	.9865	5	-.0153	.9477 (16.46)	38	.1904 (1.29)	-		67*	.6711 (3.62)
"	.9865	5	-.0112	.9222 (18.48)	31	.0980 (1.28)	-		67*	.8421 (7.63)
"	.9801	4	-.0296	1.0186 (11.46)	38	.5096 (3.80)	50	.0070 (0.21)	63	.2313 (2.11)
29	.9927**	6[1]	-.0006	.9615 (25.31)	36	.0334 (0.31)	-		64	.6260 (3.63)
"	.9885	5	.0028	.9660 (20.03)	32	.0592 (0.44)	-		68	.5039 (2.65)
"	.9906	5	.0002	.9627 (21.51)	38	.1093 (0.69)	-		68*	.4822 (2.50)
30	.9858	4	-.0339	1.1863 (9.96)	39	.1109 (2.03)	50	.2436 (3.90)	68	.9008 (12.03)
"	.9749	6[1]	-.0186	.9529 (13.34)	-		49	.0715 (1.93)	65	.8111 (13.82)
"	.9763	5	-.0278	1.1007 (9.10)	-		51	.2208 (3.09)	68	.9391 (11.09)
"	.9962**	4	-.0207	1.0118 (17.82)	39	.0611 (2.17)	50	.0355 (1.25)	62*	.9374 (23.48)
32	.9419	6[1]	-.0169	.8656 (8.23)	-		48	.0043 (0.15)	64	.8398 (5.35)
"	.9471	4	-.0299	1.1789 (6.52)	33	.0420 (0.53)	50	.0243 (0.57)	67	1.1819 (4.00)
"	.9677*	5	-.0251	1.1327 (10.03)	39	.1212 (1.63)	-		67*	1.0936 (7.39)
"	.9601	5	-.0340	1.1962 (8.96)	38	.3474 (4.50)	-		62*	1.0188 (6.13)
331, 2; 3391, 9	.9846	5	-.0232	1.0729 (17.24)	38	.0681 (1.24)	-		62	.8714 (10.92)
"	.9841	5	-.0308	1.1292 (15.60)	32	.7809 (14.11)	50	.0708 (2.52)	-	
"	.9872	4	-.0302	1.1316 (15.55)	32	.6311 (3.86)	50	.0677 (2.39)	67	.2124 (0.98)
"	.9877**	5	-.0195	1.0375 (19.40)	32	.2646 (1.86)	-		67*	.6623 (3.37)

TABLE III (cont'd.)

(t values shown in parentheses)

SIC	R^2	d.f.	constant	Δlog VA coeff.	Own R&D var.	Own R&D coeff.	Investment var.	Investment coeff.	Input R&D[2] var.	Input R&D[2] coeff.
333-8; 3392	.9012	5	-.0103	.8863 (4.97)	32	.0896 (0.75)	-		67	.6722 (2.62)
"	.9784**	5	-.0161	.9868 (11.72)	32	.0584 (1.14)	-		67*	.8778 (7.02)
"	.9795	4	-.0165	.9919 (10.74)	32	.0397 (0.58)	50	.0177 (0.46)	67*	.9030 (6.16)
34	.9766**	5[1]	-.0213	1.0406 (14.34)	35	.1370 (5.25)	48	.1523 (4.08)	65	.9446 (11.80)
34	.9699	4	-.0136	.8402 (9.95)	39	.0891 (4.30)	50	.0987 (2.30)	68	.6981 (7.99)
351	.8840**	5	-.0018	.6656 (5.71)	39	.0030 (0.06)	-		69*	.4250 (3.67)
352	.9553	5	-.0117	.8629 (9.80)	-		50	.0284 (0.32)	67	.6389 (5.96)
"	.9405	5	-.0166	.9319 (8.32)	38	.5494 (5.04)	50	.2719 (2.52)	-	
"	.9596**	5	-.0063	.7297 (10.87	33	.2351 (2.16)	-		61*	.2771 (2.00)
"	.9448	4	-.0166	.9411 (7.53)	38	.5285 (2.06)	50	.2713 (2.10)	69*	.0280 (0.10)
"	.9315	5	-.0206	1.2184 (7.57)	-		50	.0374 (0.36)	67	1.0762 (7.06)
"	.9181**	5	-.0133	1.0014 (6.86)	39	.2122 (1.18)	-		62	.6603 (4.11)
354	.9656	5	-.0123	.8585 (8.26)	37	.0979 (0.68)	-		61	.6581 (2.90)
"	.9795	4	-.0118	.8243 (8.97)	32	.1535 (1.83)	50	.0053 (0.22)	61	.5483 (3.32)
"	.9833**	5	-.0123	.8007 (11.19)	31	.3181 (6.22)	-		61*	.3374 (3.25)
355,6,8, 9	.9559**	5	-.0032	.5741 (9.61)	38	.2028 (3.59)	-		63*	.1144 (3.07)
"	.9485	5	-.0044	.6211 (9.11)	39	.1799 (3.21)	-		63*	.1859 (3.07)
"	.9522	4	-.0061	.6613 (6.42)	39	.2223 (2.29)	50	.0438 (0.56)	63*	.1797 (2.71)

TABLE III (cont'd.)

(t values shown in parentheses)

SIC	R^2	d.f.	regression constant	Δlog VA coeff.	Own R&D var.	Own R&D coeff.	Investment var.	Investment coeff.	Input R&D var.[2]	Input R&D coeff.
357	.9955**	4	-.0494	1.1374 (32.42)	32	.5011 (5.08)	50	.3308 (5.38)	69	.3463 (5.11)
"	.9972	4	-.0463	1.1254 (36.30)	32	.5602 (7.07)	50	.3027 (5.50)	69*	.2678 (5.82)
"	.9925	4	-.0498	1.1151 (22.35)	38	.5920 (4.06)	50	.4550 (5.24)	69*	.0727 (0.63)
361	.8374	5	-.0109	.8173 (4.70	-		50	.4504 (2.63)	69	.4292 (2.95)
"	.8371	5	.0068	.7857 (4.75)	39	.3104 (2.94)	50	.5579 (3.28)	-	
"	.8478**	4	-.0016	.8178 (4.34)	39	.1901 (0.79)	50	.5125 (2.61)	69*	.1880 (0.58)
362	.9906	5	-.0120	1.1773 (15.71)	32	.6571 (8.28)	-		69	.3198 (10.88)
"	.9909**	4	-.0128	1.1862 (13.69)	32	.6469 (6.99)	50	.0140 (0.34)	69	.3351 (6.03)
"	.9786	4	-.0148	.9203 (9.33)	33	.1730 (4.13)	50	.1606 (2.68)	69*	.4786 (6.69)
363,4,9	.9299	5	-.0155	.9028 (7.41)	-		50	.2019 (3.80)	68	.7863 (7.90)
"	.9337	4	-.0157	.9159 (6.77)	31	.0307 (0.48)	50	.1983 (3.40)	68	.7779 (7.09)
"	.9656**	4	-.0259	1.1948 (10.11)	33	.0227 (0.78)	50	.1333 (3.36)	67*	.9979 (9.82)
365-7	.6856	4	-.0419	.9373 (2.70)	33	.2143 (1.31)	50	.8613 (2.67)	68	.4090 (2.01)
"	.9919**	4	-.0387	1.2590 (19.44)	39	.2442 (8.13)	50	.2007 (4.31)	62*	.8028 (18.36)
"	.9540	5	-.0268	1.1252 (9.31)	39	.1493 (3.44)	-		62*	.8646 (9.84)

TABLE III (cont'd.)

(t values shown in parentheses)

SIC	R^2	d.f.	regression constant	Δlog VA coeff.	Own R&D var.	Own R&D coeff.	Investment var.	Investment coeff.	Input R&D var.[2]	Input R&D coeff.
371	.9791	5	-.0137	1.2461 (11.76)	33	.0674 (0.84)	-		67	1.3217 (9.11)
"	.9801	4	-.0148	1.3224 (7.58)	38	.1124 (0.73)	50	.0214 (0.56)	67	1.3728 (6.03)
"	.9928**	4	-.0165	.9360 (13.79)	33	.1533 (2.89)	50	.0663 (2.25)	68*	.7038 (9.63)
"	.9906	4	-.0204	1.1759 (11.09)	38	.3369 (3.39)	50	.1034 (3.18)	67*	.8218 (8.90)
38	.9501	4	-.0106	.6940 (7.01	32	.2966 (4.48)	50	.1059 (1.33)	69	.1679 (1.91)
"	.9003	6[1]	-.0116	.6226 (7.36)	35	.4547 (4.64)	48	.2128 (2.23)	-	
"	.9839**	4	-.0114	.7098 (13.52)	32	.3074 (8.34)	50	.1227 (2.82)	69*	.1534 (3.95)

[1]Regression is for 10 years, 1957-66, other regressions are for 9 years, 1958-66.

[2]Input R&D variables designated by an * superscript are computed with the diagonals of the input-output coefficients matrix set to zero

note: significance levels for t (two-sided test) are as follows:

d.f.	$t_{.10}$	$t_{.05}$	d.f.	$t_{.10}$	$t_{.05}$
4	2.13	2.78	1	6.31	12.71
5	2.02	2.57	2	2.92	4.30
6	1.94	2.45	3	2.35	3.18

Before making some specific comments about individual industries, two overall points can be made. First, by the restrictions imposed, all coefficients shown in Table III have the expected positive sign, and further, at least one of the trend variables is significant at the 10% level in every regression.[8] In each industry there was a varying but substantial number of regressions in which at least one of the coefficients was negative, including in a few cases regressions with the highest overall R^2.

The restrictions simply act to improve the efficiency of the estimating procedure by ruling out results that are spurious on a priori grounds. Second, the persistent negative signs for the constant terms in almost every industry is not inconsistent with, although an apparently strong application of, the analysis of the constant terms in Table II. The coefficients of the trend variables times their average values, which are typically positive, represent positive components that previously were included in the regression constant. Moreover, the coefficient of $\Delta\log(VA)_t$, representing an estimate of a_2 if a_3 is assumed zero, is consistently and substantially greater in Table III than in Table II. The statistical explanation is that there is generally a high negative correlation between $\Delta\log(VA)_t$ and the trend variables, which tends to reduce the coefficient of $\Delta\log(VA)_t$ when the trend variables are excluded from the regression. The ultimate reasons behind a systematic negative relation between cyclical and secular influences on labor productivity, if that in fact is the case, are not clear, but possibly reflect the defensive role of R&D and investment - employed to counter sagging markets and profits - that has been mentioned by Hamberg (5) and others.

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[8]As indicated at the end of Section III, the implication of estimating weighting patterns via multiple trials is to reduce the effective degrees of freedom (d.f.). In this spirit, t values for d.f. = 1,2,3 are shown at the end of Table III, in addition to the nominal d.f. = 4,5,6. Using just a single degree of freedom, at least one trend variable is significant at the 10% level in 16 of 24 industries.

For purposes of evaluating the reliability of the results shown in Table III, I have made a rough judgment for each industry on the success of the model considering the full range of regressions. Based on my own subjective weighting of adverse characteristics such as low R^2's, insignificant coefficients, wrong signs, and other results that seem suspect or erratic, I would rate the following eight industries as weak, with a fair possibility of spurious results: SIC's 20, 281, 29, 333, 351, 352, 353, and 361. I would rank five other industries SIC's 32, 355, 363, 365 and 38 in an intermediate, not weak, not strong, position. The remaining eleven industries on the whole provided consistently good results, and should inspire confidence.

For most of the industries, the best regressions offer a broadly consistent picture with respect to the weighting pattern and magnitudes of the coefficients. There are several exceptions, however, as can be seen in Table III. Industry 282, for instance, shows an important conflict in the magnitude estimated for the coefficient of input R&D, and a corresponding conflict in the coefficient of own R&D, with the regression providing the best R^2 implying a weak influence for input R&D. A similar situation occurs in SIC 287; however, since the first four regressions are all about equally good in terms of explained variation, I tend to favor the weighting pattern in the second regression which makes both trend variables significant. For SIC 331 one might reasonably conclude that all three trend variables are significant, although this was never established in a single regression. Here, the regression with the highest R^2 also provides results as plausible as any. Industry 352 was another case where multicollinearity hindered coefficient estimations. As was true in other cases, dropping the investment variable from the regression permitted plausible and significant estimates of the remaining coefficients. Since I had, a priori, least faith in the investment variable because of the relatively short lag structure available, I have tended to favor such an approach. Thus, I chose for subsequent analysis the third regression for 352, and the second one for 353. High multicollinearity also suggests that the third regression for industry 361 provides the most plausible estimates of the coefficients, despite their low significance.

For the purpose of investigating implications of the empirical results, I have selected a single regression for each industry (as indicated by ** in Table III). Mostly, I have taken the highest $\overline{R}^2$, except in the case of SIC's 287, 353, and 361 discussed in the preceding paragraph, and SIC 357 where a standard input R&D variable was given preference over a faintly superior regression with zero diagonal input R&D variable. Thus by throwing caution to the winds and treating all industries as yielding equally good and unambiguous results, I have made distributions of the weighting patterns and the elasticities for own R&D and input R&D.

Shown in Table IV is the implied distribution of industries by time lag between own R&D or input R&D, and impact on productivity. For purposes of differentiation, own and input R&D variable numbers ending in 1 and 2 are designated as a "relatively short lag" (67--75% of the total weight in the first 2 years); those variable numbers ending in 3, 4, 5, and 7 are designated as an "intermediate lag" (40--50% of the total impact during the first 2 years); and those ending in 6, 8 and 9 are designated as a "relatively long lag" (10-15% of total weight during the first 2 years).

Examination of Table IV does not reveal any obvious grouping by two digit classification, or even by durability of product. Further, the length of lag for own R&D seems if anything, inversely related to the length of lag for input R&D. This could be the spurious result of high intercorrelations among variables with the same weighting pattern.

To investigate the plausibility of these results, I have brought to bear some external data from the 1964 McGraw-Hill survey referred to earlier on how soon companies expect R&D expenditures to result in large-scale production.[9] This survey showed the percent of company responses in a given "industry" (defined as the major product of the company) classified into four time categories: 1-2 years, 3-5 years, 7-9 years; and 10 or more years. Separate distributions were presented, for basic research, applied research, and development. For nine industries comparable to industries or groups of industries in

[9] McGraw-Hill, op. cit., Table XVI.

Table IV

Implied Distribution of Industries by Time Lag Between Applied R & D and Impact on Productivity

SIC's with Relatively Short Lags 1/	SIC's with Intermediate Lags 2/	SIC's with Relatively Long Lags 3/
	(Own R & D)	
282	281	20
294	283	287
331	34	29
333	352	30
354	363	32
357	371	351
362		353
38		355
		361
		365
	(Input R & D)	
287	283	281
30	39	282
352	32	284
353	331	351
354	333	357
365	34	361
	355	362
	363	371
		38

1/ Defined as the weighting patterns of X_{31}, X_{32}; X_{61}, X_{62}.

2/ " " " " " " X_{33}, X_{34}, X_{35}; X_{63}, X_{64}, X_{65}.

3/ " " " " " " X_{36}, X_{38}, X_{39}; X_{66}, X_{68}, X_{69}.

this study, the percent distributions for applied research and development were combined using 1964 NSF R&D data for these industries as weights. The distributions of these nine industries for the first two time periods are compared in Table V with the weighting pattern in my corresponding nine industries, as determined by the "best" (**) regressions in Table III. Where I had to combine three-digit industries to obtain comparability--such as for the chemical (SIC 28) and machinery (SIC 35 & 36) industries--I used 1964 applied R&D as weights.

If we interpret the percent distributions for the McGraw-Hill data as "weights", then the ratio of the weight for the first two years, compared to the next three, is a rough measure of how fast applied R&D leads to increased output and productivity. The comparable ratio for my estimated weighting patterns is shown in the last column of Table V. Comparing the last two sets of ratios, the McGraw-Hill data show a good deal less dispersion. However, the rank correlation between the two sets of ratios for the nine industries is .679--significant at the 5% level. If I drop the two industries that fall entirely within my list of "weak" industries presented earlier, SIC 20 & 29, the rank correlation for the remaining seven industries is .964--significant at the 1% level. Given the problems of differing concept and definition between the two sets of data, this test, devised after the "best" regressions had been selected, offers at least some tentative confirmation of the weighting patterns determined empirically for own R&D.

Using the same set of "best" regressions as previously, the coefficients of the own R&D variable and the input R&D variable, which represent elasticities of labor productivity to the relevant weighted average of own and input R&D per manhour respectively, were divided into five ranges. The resulting distribution of industries (SIC's) by elasticity to own and input R&D is shown in Table VI. I am not sure why the elasticities for own R&D run so much lower than those for input R&D. It is true that six out of the eight industries designated as weak are found in the less than 0.2 range for own R&D, and the remaining two in the 0.2 to 0.4 range. However, there is no particular reason why estimates of own R&D elasticity should be more adversely affected than estimates of

Table V

Comparison of McGraw-Hill Data on Applied R & D Lag Until Full Scale Production with Implied Weighting Pattern for Own R & D

McGraw-Hill Industry	Percent of Companies in Industries Responding (a) 1-2 Years	(b) 3-5 Years	Ratio (a)/ (b)	SIC	Own R & D Variable Proportion of Total Weight for Period (c) t to t-1	(d) t-2 to t-4	Ratio (c) / (d)
Food & Beverage	35.0	43.3	.808	20	.15	.85	.18
Chemicals	30.0	45.5	.659	28	.56	.44	1.27
Petroleum & Coal Products	18.8	75.2	.251	29	.15	.85	.18
Stone, Clay & Glass	26.2	56.2	.466	32	.10	.90	.11
Primary Metals	33.8	40.4	.837	33	.75	.25	3.00
Fabricated Metals & Instruments	38.1	53.7	.709	34, 38	.64	.36	1.78
Nonelectrical Machinery	34.5	57.0	.605	35	.46	.54	.85
Electrical Machinery	34.9	60.2	.590	36	.14	.86	.16
Motor Vehicles	24.2	51.7	.468	371	.40	.60	.67

input R&D elasticity. Moreover, choice of relevant alternative set of regressions would not appreciably change the general picture, as a study of Table III will show.

The conclusion that labor productivity is more responsive to technological developments from supplying industries than it is from own R&D efforts is somewhat surprising, and can only represent a tentative hypothesis. It is possible that by failing to use a double deflation method to calculate output, we have ignored the ability of supplying industries to capture their own R&D efforts through higher prices. As they stand, the empirical findings imply that social rates of return to R&D are substantially greater than internal rates of return.[10]

Contrary to the findings of Brown-Conrad there does not seem to be any systematic difference in the coefficients of R&D between durable and nondurable industries. The simple average for the coefficients of own R&D is .23 for the 16 durable industries compared to .25 for the nondurable group. Similarly the coefficients of input R&D average .56 for durables and .57 for nondurables. In view of the closeness, a more sophisticated test does not seem necessary.

If R&D effort were allocated optimally among industries, marginal returns in terms of output per manhour would tend to be equated, except for technological or institutional barriers. Now the total marginal productivity per dollar of own applied R&D over all relevant time periods for the i^{th} industry is found by taking the partial derivative of equation (6) with respect to $\Sigma w_v R_{it-v}$, after dividing through by L_{it}:

$$\frac{\partial (Y/L)_{it}}{\partial \Sigma w_v R_{it-v}} = \alpha \frac{(Y/L)_{it}}{\Sigma w_v R_{it-v}}$$

---

[10]The argument that our estimates of own R&D coefficients are biased downward because own R&D was not deflated by $(1-a_{ii})$ would deny the distinction between research done by a firm, and that research embodied in a product sold to another firm in the same industry, which distinction we claim should be made. In practice 16 of the 24 best regressions use input R&D variables with $a_{ii}= 0$, so that the issue largely does not arise.

Table VI

Implied Distribution of Industries by Elasticities of Labor Productivity with Respect to Own R & D and Input R & D

Less Than 0.20	0.20 to 0.40	0.40 to 0.60	0.60 to 0.80	More Than 0.80
		(Own R & D)		
20	284	357	362	282
281	287			
283	33k			
29	352			
30	353			
32	354			
333	355			
34	365			
351	38			
361				
363				
371				
		(Input R & D)		
20	352	29	281	283
282	354	351	287	284
355	357		371	30
361	362			32
38				333
				34
				353
				363
				365

If this expression is more or less constant across industries we would expect to find the estimated own R&D coefficients, $\hat{\alpha}_i$, approximately proportional to $\Sigma w_v R_{it-v}$ / $Y/L)_{it}$. In fact the rank correlation between these two quantities for all 24 industries is only .111, not significant at the 5% level. If manhours are held constant then comparable marginal returns to R&D across industries implies a positive correlation between the $\hat{\alpha}_i$ and own R&D per dollar of value added, $\Sigma w_v R_{it-v} / Y_{it}$. The rank correlation for all 24 industries is increased to .284 but is still not significant.

As an alternative, one might expect that industries in which the productivity of R&D was greater would have incentive to undertake a higher level of R&D effort. To investigate this hypothesis I computed the rank correlation between the estimated own R&D coefficients and the level of applied R&D per manhour. The correlation for all 24 industries was .177 for 1957, and .189 for 1964, neither significant at the 5% level. As still a further alternative, it might be assumed that R&D would be increasing faster in industries where the elasticity was greater. The rank correlation of own R&D coefficients with the difference between the 1964 and 1957 applied R&D per manhour rates was slightly improved, being equal to .243, but still not significant.

I suspect that the presence of large amounts of government financed R&D, allocated not on the basis of maximizing overall productivity, tends to reduce the correlations found. However, the applied R&D data by product have not permitted investigation of this hypothesis.

V. The Inter-Industry Structure of R&D Induced Technical Change.

The regression results of the previous section, together with certain additional assumptions, can be used to construct a matrix of inter-industry impacts on labor productivity due to own and input R&D. This I call an applied R&D technical change matrix. We will consider only the interrelations among the 24 manufacturing industries of this study, which, as noted earlier, account for the great bulk of non-defense industrial R&D.

Specifically, we wish to compute the elasticity of labor productivity in the ith industry to applied R&D in the kth industry; i.e., the percent change in value added per manhour in the ith industry due to a one percent change in applied R&D in the kth industry (where k can equal i). Define this elasticity as ε_{ik}. In the notation of Section II we can write ε_{ik} for the t^{th} time period as:

$$(11) \quad \varepsilon_{ikt} = \frac{\partial \log (Y/L)_{it}}{\partial \log R_{kt}} = \frac{\hat{\alpha}_i \; \partial \log \Sigma w_v R_{it-v}}{\partial \log R_{kt}} + \hat{\delta}_i \frac{\partial \log(\Sigma s_v \Sigma a_{ji} R_{jt-v})}{\partial \log R_{kt}}$$

where $\hat{\alpha}_i$ and $\hat{\delta}_i$ represent the estimated coefficients of own and input R&D, α and δ, for the ith industry, and we have assumed that L_i is independent of R_k. Since an increase in productivity can be, and in fact is, associated with both gains and losses in manhours, this seems like a reasonable first approximation.

Now if k=1, the first term on the right hand side of (11) can be evaluated as follows:

$$(12) \quad \frac{\hat{\alpha}_i \; \partial \log \Sigma w_v R_{it-v}}{\partial \log R_{it}} = \hat{\alpha}_i \frac{1}{\Sigma w_v R_{t-v}} \cdot \frac{\partial \Sigma w_v R_{it-v}}{\partial R_{it}} \cdot \frac{d R_{it}}{d \log R_{it}}$$

$$= \hat{\alpha}_i \frac{1}{T_{it}} \cdot w_o \cdot R_{it}$$

where we have defined $T_{it} = \Sigma w_v R_{it-v}$, and used $d R_{it} / d \log R_{it} = R_{it}$.

For the second right-hand term in (11) we get

$$(13) \quad \hat{\delta}_i \frac{\partial \log(\Sigma s_v \Sigma a_{ji} R_{it-v})}{\partial \log R_{kt}}$$

$$= \hat{\delta}_i \frac{1}{\Sigma s_v \Sigma a_{ji} R_{jt-v}} \cdot \frac{\partial \Sigma s_v \Sigma a_{ji} R_{jt-v}}{\partial R_{kt}} \frac{d R_{kt}}{d \log R_{kt}}$$

$$= \hat{\delta}_i . \frac{1}{M_{it}} \cdot s_o a_{ki} \cdot R_{kt}$$

where we define $M_{it} = \Sigma s_v \Sigma a_{ji} R_{jt-v}$.

Equations (12) and (13) may be substituted into (11) to get the elasticity of productivity to R&D in t. However if it is desired to measure the full impact of an increase in current R&D on current and future productivity, then we should sum the elasticities for all relevant time periods. In our case the horizon extends only to t+4. Thus, we repeat the derivations (12) and (13) for t+1 through t+4, substitute each time into (11), and sum to get ε_{ik}.

$$(14) \quad \varepsilon_{ik} = \frac{\partial \log (Y/L)_{it}}{\partial \log R_{kt}} + \ldots \frac{\partial \log (Y/L)_{it+4}}{\partial \log R_{kt}}$$

$$= \hat{\alpha}_i R_{it} \left(\frac{w_o}{T_{it}} + \frac{w_1}{T_{it+1}} + \ldots. + \frac{w_4}{T_{it+4}} \right)$$

$$+ \hat{\delta}_i a_{ki} R_{kt} \left(\frac{s_o}{M_{it}} + \frac{s_1}{M_{it+1}} + \ldots. + \frac{s_4}{M_{it+4}} \right)$$

where the first right-hand team is present only when k = i.

The elasticity defined by equation (14) will vary with R, T, and M, even if the other parameters (including the input-output coefficient a_{ki}) are assumed stable. However, for any specific time period of interest we can substitute appropriate values for R, T, and M. To simplify, I have assumed that the T_i and also the M_i are the same for each time period, enabling them to be factored out of the parentheses in (14), leaving the weights, w_v and s_v, which sum to unity in each case. Further, since $T_i \equiv T_{it} \equiv \ldots \equiv T_{it+4}$ is a weighted average of R_i for periods before and after t, it is reasonable to assume that on the average $R_i = T_i$. Under these assumptions (14) reduces to

$$(15) \quad \varepsilon_{ik} = \hat{\alpha}_i + \hat{\delta}_i \frac{a_{ki} R_{kt}}{M_i}$$

where again α_i is present only for k = i.

Shown in Table VII are the estimated coefficients of technical change, as defined by equation (15), for all 24 industries, using 1966 data for R_{kt} and M_i. The estimated coefficients $\hat{\alpha}_i$ and $\hat{\delta}_i$, as well as the relevant M_i variable, came from the "best" regressions discussed previously. Thus the entry for the k^{th} row and the i^{th} column, is the estimated elasticity of labor productivity in the ith industry to applied R&D in the k^{th} industry. The diagonal elements potentially reflect impacts on productivity from both own and input R&D. However, in two-thirds of the industries the best regression used an input R&D variable with a_{ii} defined as zero, so this second source was not computed for these industries.[11]

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[11]For SIC 20, $\hat{\delta}$ was never successfully estimated, so all column entries except the diagonal have been assumed to be zero.

TABLE VII

An Inter-Industry Applied R & D Technical Change Matrix
(24 Manufacturing Industries)

Note: each column gives for that industry the percent change in labor productivity due to a 1.0% change in applied R & D in the corresponding row industry.

SIC	34	30	32	331	333	282	354	355	363	361	362	281
34	.2524	.0072	.0444	.0908	.0546	.0002	.0048	.0089	.0809	.0050	.0090	.0384
30	.0195	.0611	.0389	.0248	.0084	.0004	0	.0024	.0762	.0012	.0030	.0192
32	.0195	.0062	.1212	.0715	.0168	0	.0008	.0024	.0262	.0006	.0010	.0055
331	.2822	.0010	.0111	.2646	.0042	0	.0048	.0111	.0524	.0043	.0070	.0110
333	.1015	0	.0056	.0468	.0584	0	.0016	.0070	.0405	.0056	.0110	.0137
282	.0209	.8044	.4107	.0110	.4032	.8805	0	.0011	.1238	.0093	.0150	.0493
354	.0500	.0010	.0056	.0468	.0420	.0002	.3181	.0046	.0381	.0025	.0040	.0027
355	.0917	.0052	.0222	.1155	.0546	.0004	.0132	.2028	.0833	.0031	.0050	.0438
363	.0431	.0031	.0500	.0083	.1092	0	.0008	.0105	.0227	.0062	.0120	0
361	.0125	.0005	.0028	.0193	.0042	.0001	.0028	.0097	.0357	.1901	.0150	.0027
362	.0222	.0010	.0056	.0330	.0084	.0002	.0048	.0167	.0619	.0155	.6729	.0055
281	.0292	.0680	.2775	.1018	.0798	.0546	0	.0008	.0190	0	.0030	.0387
287	.0056	.0134	.0555	.0193	.0168	.0108	0	.0001	.0048	0	.0005	.2110
284	.0417	.0216	.1166	.0468	.0378	.0187	0	.0001	.0333	.0012	.0030	.3178
283	.0028	.0021	.0944	.0330	.0084	.0026	0	0	0	0	0	.0137
365	.0556	.0206	0	0	.0840	0	0	.0267	.2356	.1352	.2180	0
38	.0973	.0012	.0222	.0110	.0168	.0015	0	.0113	.1999	.0130	.0250	.0192
29	.0111	.0021	.0389	.0358	.0126	.0004	.0008	.0014	0	0	.0020	.0219
351	.0028	0	0	0	0	0	0	.0019	0	.0012	.0020	0
353	.0125	0	0	.0055	0	0	.0008	.0038	.0024	.0006	.0010	.0027
357	0	0	0	0	0	0	0	.0014	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	.0027
352	0	0	0	0	0	0	0	0	0	0	0	0
371	0	0	0	0	0	0	0	0	0	0	0	0

TABLE VII (Cont'd.)

An Inter-Industry Applied R & D Technical Change Matrix
(24 Manufacturing Industries)

SIC	287	284	283	365	38	29	351	353	357	20	352	371
34	.0062	.0414	.0627	.0666	.0033	.0420	.0258	.0362	.0017	0	.0121	.0780
30	.0062	.0110	.0209	.0444	.0026	.0021	.0129	.0302	.0017	0	.0208	.0718
32	0	.0069	.0139	.0444	.0020	.0063	.0129	.0060	.0006	0	.0017	.0195
331	0	.0028	0	.0222	.0010	0	.0708	.0846	.0012	0	.0311	.0757
333	0	.0014	0	.0555	.0036	0	.0258	.0060	.0017	0	.0017	.0133
282	.0250	.2746	0	.2035	.0023	0	0	0	.0023	0	0	.0172
354	0	0	0	.0222	.0023	.0021	.0322	.0242	.0017	0	.0104	.0296
355	.0125	.0069	0	.0185	.0036	0	.1674	.1601	.0029	0	.0571	.0429
363	0	0	0	.0814	.0023	0	.0580	.0091	.0012	0	.0121	.0803
361	0	.0007	0	.0222	.0026	.0011	.0129	.0211	.0023	0	.0017	.0023
362	0	.0014	0	.0370	.0043	.0021	.0193	.0362	.0041	0	.0035	.0039
281	.2309	.3505	.3485	.0407	.0079	.2100	0	0	0	0	0	.0062
287	.8576	.0690	.0697	.0074	.0017	.0420	0	0	0	0	0	.0016
284	.0998	.4350	.3764	.0185	.0030	.0735	0	.0060	0	0	.0052	.0218
283	0	.1408	.1312	0	0	.0315	0	0	0	0	0	.0055
365	0	0	0	.2442	.1112	0	0	0	.1496	0	0	.2493
38	0	.0152	.0488	.1554	.3074	0	0	0	.0041	0	0	.0523
29	0	.0069	0	0	0	.2686	0	.0060	0	0	.0035	.0039
351	0	0	0	0	0	0	.0030	.1419	0	0	.1142	.0265
353	0	0	0	.0037	0	0	.0580	.3390	0	0	.0087	.0016
357	0	0	0	0	.0142	0	0	0	.7389	0	0	0
20	0	.0028	.0070	0	0	0	0	0	0	.0975	0	0
352	0	0	0	0	0	0	0	.0030	0	0	.2351	0
371	0	0	0	0	0	0	0	0	0	0	.0104	.1533

While most of the off diagonal elasticities are not large (although a few are fairly substantial), the number of strictly zero elements is in the minority. This reflects of course the high degree of inter-dependence in the input-output transactions matrix. The industries have been ordered so as to concentrate relatively more zeros in the lower left hand corner.)

The values shown in Table VII are of course not meant to imply anything like precision, and are shown to five decimal places only to differentiate zeros from potentially greater than zero entries. At most, the numbers are indicative. The potential applications of such a technology matrix, however, seem promising. For instance the impact on productivity in a specific industry, or over-all (to the extent of coverage), of any given pattern of R&D can be evaluated. Also, the total or potential rate of return to all industries from a 1% increase in R&D in a given industry can be estimated. This could be done in Table VII by multiplying each entry in the relevant row by the total manhours of the corresponding column industry, and summing.

Besides the numerous assumptions and qualifications that have already been made, there is one further point that is particularly relevant here. It is not possible of course to take 2 x 24 regression coefficients and produce 24 x 24 technology coefficients without further restrictions. The restrictions made in this paper are that the input R&D coefficients apply with equal force to all input R&D, depending on the transactions matrix. This is stringent, since all we can really say is that the weighted average of input R&D is associated with the input coefficient.

VI. Concluding Remarks.

The theoretical and empirical results presented in this paper argue strongly for the inclusion of R&D as an input factor in production functions. Indeed, in about half of the industries R&D significantly influenced the trend in productivity <u>both</u> as a direct input factor and simultaneously as a factor embedded in material inputs, over and above those influences on productivity explained simply by an autonomous time trend.

While these results should, I believe, be viewed as encouraging to the approach taken, we must reinterate the major limitations of this study. The measures of output used do not adequately capture quality improvements. The effective sample size is extremely small. The R&D variables may be capturing the influence of other, omitted, trend factors such as education and labor skills.[12] The formulation of the capital stock variable, or weighted average of past investment, appears grossly inadequate to the job it has to do, judging by the magnitude and lack of significance of the estimated coefficients. Finally, the fewness of observations forced a rather constricted view of the time lags involved--such that we may have wound up carefully exploring lags of the wrong order of magnitude, estimating in fact echo effects.

Such an array of caveats impells one to devise as many external tests as he can. A couple of these have been discussed above. I have also employed the estimated coefficients to calculate that proportion of the total productivity gain from 1957 to 1965 (years of comparable unemployment rates) attributable to own and input applied R&D for the 24 industries included in this study. Of the aggregate average annual labor productivity gain for these industries of 4.5% per year, 2.4% or 53% was due to the sum of the change in own and input R&D times their respective coefficients. This broke down into a 1.3% per year gain, or 29% of the total, due to own R&D, and a 1.1% a year gain, or 24%, due to R&D embodied in material inputs. While these numbers intuitively are not unreasonable, this would have been true for a wide range of alternative figures.

Finally, I would say that despite current inadequancies, mostly in terms of data, there is a good deal of reach in this approach toward the goal of understanding the fundamental process of economic growth and quantifying its implications. R&D embodied in capital inputs is a logical next step, along with alternative formulations of the inter-industry transfer of technology. Ultimately we should be able to quantify the welfare implications of research dollars, and specify criteria for efficient allocation of research money.

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[12]The restrictiveness implied by a Cobb-Douglas function itself must be counted a limitation, although I do not see it as a major one--possibly because there are so many others.

Appendix - Data and Method

Data on applied R&D, manhours, value added, plant and equipment expenditures, and output price indexes 1953-66 for all industries are given in Table A-1. A discussion of data estimating procedures follows.

Applied Research and Development. NSF publications, reference (18) provided the source material for all R&D data used in this study although I am solely responsible for all adjustments. For 1959-66 inclusive, I used the same industry groupings as published by NSF for applied R&D by product field (SIC), excluding aircraft, atomic energy devices, guided missiles and spacecraft, ordinance, and other miscellaneous product fields. The 1960 Report published figures for these same industry groups for 1958, which I used, although NSF apparently feels the 1958 data lack some comparability with later years. Prior to 1958 at least four problems of data comparability present themselves: the product fields defined in the NSF questionnaire did not always correspond exactly to SIC (new or old) definitions; the product fields are more aggregative for 1956-7, and prior to 1956 only data aggregated by company with all company R&D attributed to its primary industry, is available; the first two surveys, 1953-4 and 1956, were conducted by BLS and lack comparability with later Census surveys due apparently to differences in reporting and methodology; and a significant category -- applied R&D by private firms at government owned AEC facilities on all products -- was not included until 1958. I will outline the procedures used to handle each of these problems.

Based on the questionnaire definitions for early years, SIC codes were assigned as closely as was feasible. The most serious problem of mixture was that a category called "electronics" included, in addition to applied R&D for SIC 365-7, most of that for 357. Based on data for 1958 that 70% of applied R&D for 357 was cross-classified under electronics, applied R&D for 357 was estimated separately by backward extrapulation and 70% of these estimates for 1953-57 were subtracted from electronics to get SIC 365-7. Most of the really heroic assumptions resulted from the necessity to disaggregate the

8 or 9 broad categories (excluding defense oriented R&D) into 24, and for 1953-5, to impute SIC product fields from data based on major industry of a company -- the so called "industry" data. The latter was accomplished by using 1956 data allocating "industry" applied R&D to 8 product categories and assuming the distribution was stable back to 1953. Then various absolute and proportional backward extrapolations were made for the product fields for which there was no detail before 1958, using the most stable relations that could be found. Forcing the disaggregated product fields to sum to the "correct" totals, estimates were made for all 24 industries back to 1953.

The lack of comparability between BLS data for 1953-6 and Census data for later years was handled in effect by applying an over-all correction factor to all product fields based on revised NSF estimates of total industrial R&D back to 1953. The over-all correction was minor; however, NSF indicated in their 1957 Report that significant divergencies would be found for some industries. I was unable to obtain from NSF detailed industry data. At the same time the above correction factor was applied, the data for 1953-7 was adjusted upward to include an estimate of applied R&D done at AEC facilities on all types of products. NSF estimated the total of such R&D done by private firms was $445 million for 1957. The product field atomic energy devices jumped from $195 million in 1957 (excluding AEC facilities) to $567 million in 1958 (including AEC facilities). By extrapolating backward, I estimated atomic energy devices (including AEC facilities) for 1953-7. The estimate for 1957 was $519 million. Thus, $519-$195 = 324 million was the 1957 estimate of R&D done at AEC facilities on atomic energy devices, and $445-$324 = $121 million was the estimated R&D done at AEC facilities on all other products. This figure was assumed distributed proportionately over all other product fields. In practice this correction factor was merged with the one above as follows:

$$\frac{\text{Census total applied R\&D - atomic energy devices (incl. AEC facilities)}}{\text{BLS total applied R\&D - atomic energy devices (excl. AEC facilities)}}$$

The net upward revision was 3% in 1957 and only 0.3% in 1956 (applied also to 1953-5).

Probably the least desirable feature of the data estimates for 1953-7 was the resultant smoothing of individual product fields. The only small consolation is that the early years constitute "start up" values, and effect fewer observations than R&D done in later years.

Total Manhours, Value Added, Plant and Equipment Expenditures. Data for these variables was developed from Census Bureau's annual censuses and surveys of manufacturers, reference (19). For nonproduction worker average weekly hours assumed values, ranging from 40.2 in 1953 to 39.4 in 1966, were used. Industry data prior to 1958 was made approximately comparable to that after by regrouping data published under the old (pre 1957) SIC codes according to the 1958 old and new SIC total employment and value added bridge published in the 1958 Census. Thus, for instance, new SIC 362 was made up of 34% of old SIC 3616, 89% of old 3619, and all of old 3612,4,7 in 1958. These proportions were assumed applicable to total manhours, value added, and investment for the years 1953-57 inclusive. All of the three-digit industry groups in this study were built up in this way. For most of the two-digit industries an over-all adjustment factor based on the 1958 ratio of new to old SIC was applied. Frequently four digit industry detail in earlier years breaking down plant and equipment investment separately was not published, and various assumptions were used to allocate total capital expenditures. A substantial reclassification in the 1963 Census placed about $0.9 bill in value added from SIC 3811 to SIC 3662. Since Census believed the misclassification had occurred over time since 1958, published data for 1959-62 for industries 38, and 365-7 was adjusted assuming a smooth proportional build-up in the misclassification.

Value Added Price Indexes. For most industries, these were taken directly from BLS wholesale price indexes for commodity groups, or estimated by combining wholesale price indexes (reference (20)) for relevant commodity groups and subgroups, according to their relative weights in the overall WPI as of December 1961. Combining indexes was done to approximate more closely SIC definitions. In the few cases, where available, BLS output price indexes by SIC (industry-sector price indexes - reference (21)) were used. Ideally, value added deflators should take account of input prices, but these data were not available. For a number of industries, including SIC's 284,5,9, 287, 30, 351, 357, 363,4,9, 365-7, and 38, BLS price data appeared substantially inadequate. The 1963 Census of Manufacturers published unit value indexes for a number of four digit industries for the three Census years, 1954, 1958, and 1963. These are based on realized price, where quantity data is available for at least 50% of shipments at the five digit product level, and where Census believes there is reasonable comparability of products over time. Thus a unit value index is not available for, e.g., computers. The unit value indexes, which supplemented WPI data in four of the above eight industries, were interpolated smoothly for the intervening years, and combined with WPI data on the basis of 1958 value added. For three other industries, 287, 30, and 351, I computed my own unit value indexes based on available quantity of shipments data (Census data were augmented by (22)). A unit value index was also estimated for computers, as part of SIC 357, under two different assumptions. Since the index for the remainder of 357 fell about midway between the two series, this estimate was used. Unit value indexes were not available for 1964-6.

Price Index for R&D. Since at least a part of the strong upward trend in R&D has been the result of cost increases, it seemed necessary to attempt at least an approximate price adjustment. However, available data appeared to justify only the construction of a single rough index, which was applied to R&D in all industries. For recent years NSF Reports have published the distribution of R&D costs for wages and salaries of scientists and engineers (slightly over 25% of total costs), for those of supporting personnel (slightly under 25%), for materials and supplies (about 20%), and for other R&D related costs, including depreciation, services, and indirect labor (about 30%). From these, weights were estimated consisting of 20% for materials and supplies, 5% for equipment, 5% for combined plant and equipment, and 70% for wages of all types. Based on data for 1957 and 1964 on wages and salaries, and total number of full time equivalent scientists and engineers, an average salary increase of 27.3% or 3.5% per year was estimated from 1957 to 1964. This was assumed to hold for R&D supporting personnel and services, and thus was used for the wage component of 70%. The overall R&D index rises by about 2.3% per year 1957-65, and by an estimated 5%, 1965-6. For 1953-7 the R&D price deflator estimated by Terlecky's (16) was used, which showed an average increase of 5.3% per year.

TABLE A1

BASIC DATA FOR 24 MANUFACTURING INDUSTRIES, 1953-1966

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
SIC 20							
FOOD &	1953	41	12531.9	3012.4	157.0	408.4	0.961
KINDRED	1954	44	14058.6	3403.1	238.3	580.7	0.972
PRODUCTS	1955	50	15103.1	3454.4	216.3	613.2	0.944
	1956	50	16273.9	3522.8	350.5	671.6	0.945
	1957	58	16690.3	3477.7	261.3	697.8	0.979
	1958	66	17532.6	3408.0	311.3	708.9	1.025
	1959	74	18614.4	3469.4	295.4	752.8	0.996
	1960	92	19660.5	3463.9	272.2	769.4	1.003
	1961	92	20194.9	3441.6	253.6	786.2	1.011
	1962	98	20855.6	3393.0	365.9	890.7	1.017
	1963	102	21725.5	3303.7	336.3	912.9	1.018
	1964	119	23053.2	3355.0	391.4	1021.5	1.018
	1965	131	23554.0	3311.0	395.0	1080.6	1.056
	1966	145	24895.9	3312.1	428.9	1263.2	1.118
SIC 281							
INDUSTRIAL	1953	131	3440.2	523.1	102.7	396.0	0.952
INORGANIC	1954	139	3294.0	497.4	102.8	374.5	0.950
& ORGANIC	1955	145	4018.0	502.6	94.7	273.0	0.954
CHEMICALS	1956	178	4351.2	513.6	114.9	376.3	0.981
	1957	171	4423.5	507.6	123.0	509.3	0.999
	1958	199	4259.8	480.0	177.4	505.5	1.000
	1959	191	5018.2	481.7	102.7	386.8	1.002
	1960	207	5101.5	484.5	115.7	553.4	1.004
	1961	225	5238.0	479.8	132.9	609.9	0.984
	1962	230	5673.4	474.6	89.1	562.3	0.963
	1963	242	6171.2	475.5	173.8	639.5	0.947
	1964	304	6791.7	483.3	156.1	833.4	0.941
	1965	313	7297.0	488.7	226.8	999.8	0.949
	1966	333	7702.5	494.9	331.7	1190.0	0.955
SIC 282							
PLASTIC &	1953	162	1482.2	249.0	36.0	155.4	1.109
SYNTHETIC	1954	178	1427.0	220.6	30.0	154.6	1.102
MATERIALS	1955	191	1829.8	233.9	27.1	121.7	1.081
	1956	241	1791.8	247.7	55.4	217.6	1.011
	1957	235	1916.4	254.8	59.8	255.1	1.015
	1958	281	1899.8	243.9	59.8	231.5	1.002
	1959	278	2394.8	258.2	31.0	159.2	0.983
	1960	311	2255.7	259.6	67.7	234.3	0.959
	1961	328	2286.8	256.0	91.6	272.6	0.928
	1962	351	2627.3	273.8	53.3	283.1	0.922
	1963	379	2865.4	292.2	59.2	319.4	0.918
	1964	402	3233.6	307.3	109.1	371.0	0.911
	1965	437	3602.6	330.4	117.3	574.6	0.901
	1966	464	3998.0	357.8	139.8	676.1	0.913
SIC 283							
DRUGS &	1953	61	1328.3	188.1	31.0	37.9	0.994
MEDICINES	1954	71	1360.8	185.7	18.9	36.8	1.004
	1955	81	1525.9	182.0	18.9	34.4	0.993
	1956	107	1767.1	185.2	29.8	42.2	0.985
	1957	111	1969.5	190.0	28.1	51.5	0.998

INDUSTRY	YEAR	APPLIED R&D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
DRUGS &	1958	128	2096.3	192.4	42.8	69.9	1.005
MEDICINES	1959	145	2274.5	198.9	50.1	63.0	0.997
(cont.)	1960	174	2349.1	201.6	58.1	57.6	1.002
	1961	191	2445.9	201.7	49.4	57.6	0.983
	1962	211	2636.0	208.0	35.1	59.9	0.960
	1963	227	2807.3	196.9	54.2	59.2	0.951
	1964	234	2943.3	202.5	47.4	70.8	0.950
	1965	274	3364.2	208.3	59.9	78.3	0.944
	1966	312	3674.8	218.0	60.9	101.5	0.945
SIC 284,5,9							
CLEANING,	1953	134	2618.3	427.4	35.0	86.0	0.882
PAINTING,	1954	140	2805.3	426.8	45.2	78.3	0.923
& MISCELL.	1955	143	3066.9	432.5	33.8	81.0	0.929
CHEMICALS	1956	171	3299.0	432.0	41.6	111.7	0.951
	1957	158	3411.3	429.0	43.5	122.6	0.982
	1958	163	3599.8	408.0	43.1	93.4	1.005
	1959	196	4033.6	419.4	42.5	91.1	1.012
	1960	168	4143.8	415.1	41.2	97.9	1.018
	1961	189	4300.0	412.7	46.8	128.1	1.019
	1962	174	4591.0	418.4	53.1	136.6	1.014
	1963	196	5114.0	429.9	48.2	125.8	1.001
	1964	195	5483.9	433.8	43.4	119.8	1.008
	1965	207	5891.2	452.5	83.7	141.8	1.011
	1966	219	6523.9	490.1	90.9	178.1	1.021
SIC 287							
AGRICULTURAL	1953	11	420.1	88.7	12.3	17.1	1.042
CHEMICALS	1954	13	366.7	83.0	17.0	36.0	1.037
	1955	15	373.2	81.1	21.5	35.8	1.030
	1956	20	350.9	80.1	23.5	44.2	1.010
	1957	21	391.3	79.5	13.1	43.5	1.006
	1958	23	414.8	77.2	12.2	32.5	1.001
	1959	35	494.9	84.1	10.8	32.0	0.992
	1960	27	528.5	86.4	13.5	43.8	1.021
	1961	38	501.3	85.1	20.1	90.5	1.053
	1962	42	532.9	84.7	17.1	57.7	1.058
	1963	45	628.3	87.6	19.5	47.0	1.054
	1964	48	713.3	89.4	54.7	56.5	1.056
	1965	61	800.6	90.0	45.6	146.9	1.081
	1966	65	912.6	95.9	24.1	105.8	1.092
SIC 29							
PETROLEUM	1953	123	2975.5	458.1	507.0	326.4	0.945
& COAL	1954	135	2240.9	364.7	426.7	247.2	0.921
PRODUCTS	1955	136	2793.1	365.8	366.5	178.9	0.939
	1956	165	3317.8	367.0	523.1	177.6	0.992
	1957	151	3249.3	369.6	624.6	274.9	1.063
	1958	156	2518.4	352.9	529.0	158.6	0.971
	1959	147	2894.2	339.9	285.1	147.8	0.968
	1960	178	3201.3	338.2	354.5	130.2	0.975
	1961	166	3438.1	325.7	368.2	126.8	0.993
	1962	178	3439.0	308.5	297.7	181.7	0.982
	1963	181	3713.2	303.4	283.8	129.9	0.971
	1964	190	3780.4	298.2	266.8	145.8	0.929
	1965	206	4168.3	284.5	423.6	179.9	0.960
	1966	205	4636.9	278.5	414.6	254.1	0.994

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
SIC 30							
RUBBER &	1953	24	2683.3	712.3	25.4	132.0	0.903
MISCELL.	1954	28	2575.8	669.4	30.4	144.9	0.912
PLASTICS	1955	34	3102.0	748.8	31.9	143.6	0.983
PRODUCTS	1956	39	3188.8	742.5	37.7	183.9	1.005
	1957	52	3289.4	737.1	31.9	171.6	1.007
	1958	44	3276.6	686.0	43.3	153.8	1.009
	1959	58	3792.9	758.1	37.9	182.1	0.984
	1960	69	3772.6	753.7	53.4	245.3	0.977
	1961	63	3929.0	745.1	48.8	233.8	0.959
	1962	77	4316.1	802.9	55.0	299.0	0.934
	1963	87	4654.0	828.2	58.6	284.9	0.937
	1964	102	4990.9	872.0	78.6	320.8	0.924
	1965	112	5681.4	937.0	91.0	425.0	0.930
	1966	127	6277.1	1002.4	112.2	487.7	0.954
SIC 32							
STONE,	1953	21	4363.8	1153.0	93.6	238.5	0.851
CLAY, &	1954	23	4395.9	1110.8	103.0	254.8	0.874
GLASS	1955	25	5272.5	1198.2	151.2	397.2	0.899
PRODUCTS	1956	33	5725.4	1219.3	284.9	577.6	0.940
	1957	40	5662.8	1177.6	213.3	566.7	0.981
	1958	42	5529.0	1100.7	141.1	348.0	1.003
	1959	48	6479.8	1200.2	152.3	400.6	1.016
	1960	59	6348.0	1187.5	150.6	390.8	1.020
	1961	60	6335.6	1147.5	136.4	417.9	1.020
	1962	66	6604.7	1157.5	130.6	418.5	1.022
	1963	74	7044.0	1161.6	156.4	451.2	1.017
	1964	85	7492.7	1190.2	127.2	500.1	1.019
	1965	92	7995.9	1227.2	180.5	592.7	1.019
	1966	104	8494.6	1248.3	206.4	733.1	1.032
SIC 331,2;							
3391,9	1953	25	8495.0	2001.1	280.7	606.1	0.755
PRIMARY	1954	27	7331.3	1677.7	228.8	498.5	0.785
FERROUS	1955	29	9692.4	1973.3	235.1	540.0	0.819
METALS	1956	37	10350.3	1983.6	401.4	878.6	0.890
	1957	53	10244.1	1893.6	563.9	1062.8	0.972
	1958	51	8585.9	1516.2	422.9	685.0	1.005
	1959	60	9990.1	1590.2	252.4	561.1	1.023
	1960	69	9766.4	1642.8	419.7	944.0	1.023
	1961	78	9273.4	1530.0	294.1	683.1	1.020
	1962	82	9862.4	1572.6	212.5	683.3	1.018
	1963	90	10971.7	1613.0	313.4	800.9	1.023
	1964	97	12324.2	1755.8	353.4	1186.8	1.032
	1965	106	13928.6	1861.6	419.8	1307.3	1.038
	1966	118	14572.4	1887.9	445.3	1613.7	1.053
SIC 333-8;							
3392	1953	28	3158.2	691.2	109.8	188.3	0.929
PRIMARY	1954	31	2633.7	607.7	48.8	148.2	0.918
NON-FERROUS	1955	33	3523.8	673.7	60.5	156.5	1.038
METALS	1956	41	3811.4	698.8	102.3	304.7	1.143
	1957	63	3368.8	660.5	146.5	406.8	1.025
	1958	58	3085.4	581.3	162.3	275.4	0.959
	1959	49	3645.0	642.4	72.6	207.1	1.017

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
SIC 333-8;							
3392	1960	52	3547.7	636.6	58.3	191.5	1.042
PRIMARY	1961	53	3560.8	618.7	63.9	184.0	1.004
NON-FERROUS	1962	59	3882.1	649.4	58.3	209.0	0.994
METALS	1963	62	4096.3	628.6	73.6	258.4	0.990
(cont.)	1964	68	4368.2	646.6	71.0	274.8	1.049
	1965	72	4995.8	686.3	114.0	415.9	1.130
	1966	80	6335.5	758.6	150.1	558.6	1.172
SIC 34							
FABRICATED	1953	107	8690.0	2347.8	138.7	297.8	0.836
METAL	1954	117	7906.0	2102.1	112.6	333.3	0.847
PRODUCTS	1955	131	9064.4	2260.9	126.6	345.4	0.872
	1956	76	9548.9	2273.3	141.0	372.3	0.933
	1957	90	9858.7	2274.4	133.3	410.6	0.992
	1958	96	9412.2	2095.5	148.3	318.0	1.003
	1959	123	10444.6	2206.8	128.0	357.4	1.003
	1960	121	10284.7	2197.5	122.7	360.4	1.005
	1961	122	10282.7	2120.7	102.2	314.3	1.010
	1962	129	11118.7	2211.5	139.8	390.2	1.013
	1963	135	11796.5	2191.6	137.7	432.3	1.018
	1964	150	12692.9	2280.3	177.4	549.4	1.036
	1965	153	14164.0	2409.9	193.7	611.5	1.049
	1966	165	15791.9	2605.3	226.9	708.2	1.075
SIC 351							
ENGINES &	1953	51	772.8	201.2	13.7	30.5	0.897
TURBINES	1954	55	650.9	164.8	10.3	29.8	0.904
	1955	64	751.3	165.6	6.8	29.7	0.913
	1956	88	834.3	175.4	6.9	36.4	0.947
	1957	96	959.4	181.0	19.1	59.5	1.001
	1958	146	1068.0	188.9	18.3	50.5	1.013
	1959	87	1125.6	186.3	14.2	38.2	0.986
	1960	98	999.6	164.2	12.5	28.3	0.959
	1961	100	895.5	152.1	10.8	38.4	0.934
	1962	121	998.5	163.5	6.7	38.4	0.905
	1963	124	1113.5	173.1	7.9	46.2	0.869
	1964	126	1281.7	181.1	8.6	51.4	0.869
	1965	137	1389.9	187.6	17.3	70.7	0.869
	1966	153	1579.4	204.5	24.5	81.1	0.880
SIC 352							
FARM	1953	30	947.2	253.6	12.8	45.0	0.882
MACHINERY	1954	33	785.9	216.0	9.9	40.3	0.881
& EQUIPMENT	1955	38	922.9	233.8	9.7	40.7	0.889
	1956	51	956.3	229.3	8.4	38.0	0.920
	1957	56	957.6	225.8	7.9	36.1	0.963
	1958	58	1087.8	211.4	14.3	40.3	1.003
	1959	67	1172.2	224.4	9.6	36.0	1.034
	1960	75	941.0	197.5	10.9	44.7	1.054
	1961	65	1061.3	200.9	10.9	35.0	1.074
	1962	70	1205.9	209.0	9.6	33.4	1.095
	1963	76	1328.4	224.0	17.1	47.4	1.111
	1964	79	1526.1	237.8	25.0	58.6	1.129
	1965	95	1682.3	248.4	17.1	69.6	1.151
	1966	106	2057.1	277.0	38.9	70.0	1.185

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
SIC 353							
CONSTRUCTION	1953	27	2013.1	482.5	27.9	79.5	0.778
MINING, &	1954	28	1672.8	397.6	23.5	66.3	0.799
MATERIALS	1955	32	2101.7	444.6	25.3	67.0	0.832
HANDLING	1956	41	2574.0	499.5	27.5	68.4	0.903
EQUIPMENT	1957	45	2495.4	485.5	41.4	88.7	0.971
	1958	47	2054.8	389.5	23.2	64.9	1.001
	1959	53	2405.4	444.4	18.2	85.5	1.027
	1960	57	2162.5	440.3	22.2	89.7	1.044
	1961	50	2165.4	393.4	23.4	54.8	1.060
	1962	53	2439.1	407.4	23.6	68.4	1.068
	1963	58	2732.3	426.0	19.3	73.9	1.078
	1964	60	3229.4	468.6	40.0	93.0	1.100
	1965	69	3556.0	506.5	39.8	136.4	1.121
	1966	77	3964.8	540.9	74.2	148.6	1.154
SIC 354							
METALWORKING	1953	14	2769.5	660.5	39.2	93.7	0.769
MACHINERY	1954	16	2380.9	586.8	40.3	106.4	0.781
& EQUIPMENT	1955	19	2440.4	592.0	38.3	96.7	0.836
	1956	27	3074.2	666.0	46.1	123.0	0.917
	1957	32	2871.4	633.2	44.2	125.6	0.979
	1958	39	2058.0	462.2	23.6	82.1	0.998
	1959	39	2489.9	500.4	18.8	70.7	1.023
	1960	42	2687.6	529.8	29.0	83.1	1.055
	1961	46	2492.7	500.1	21.1	73.9	1.070
	1962	52	3042.8	557.6	33.8	88.1	1.093
	1963	58	3037.7	544.4	26.4	110.3	1.098
	1964	66	3525.6	585.0	38.4	137.1	1.126
	1965	62	4037.0	650.1	45.1	179.5	1.169
	1966	69	4899.1	720.8	87.0	251.8	1.223
SIC 355,6,							
8,9	1953	73	4747.3	1282.4	59.3	152.7	0.841
SPECIAL	1954	79	4329.2	1165.3	61.2	179.6	0.853
GENERAL,	1955	92	4900.7	1234.8	50.6	189.4	0.870
SERVICE,	1956	123	5591.5	1312.1	99.9	252.2	0.923
& MISCELL.	1957	135	5503.7	1273.9	103.5	224.2	0.986
INDUSTRY	1958	139	5152.0	1163.0	102.4	191.0	0.998
MACHINERY	1959	148	6198.9	1249.4	79.4	189.4	1.015
	1960	172	6292.1	1261.0	84.4	206.1	1.027
	1961	184	6146.4	1221.3	74.7	203.6	1.026
	1962	171	6843.5	1295.5	90.5	216.8	1.032
	1963	185	7465.1	1326.1	78.7	236.3	1.046
	1964	182	8384.1	1413.6	94.1	283.1	1.062
	1965	207	9330.8	1506.9	121.2	362.7	1.083
	1966	231	10885.7	1651.1	226.8	456.8	1.119
SIC 357							
OFFICE,	1953	101	708.7	188.5	9.5	31.4	0.871
COMPUTING	1954	114	725.7	185.7	7.9	31.4	0.884
& ACCOUNTING	1955	131	786.1	196.8	8.4	35.2	0.908
MACHINES	1956	184	1012.8	226.2	33.3	51.6	0.941
	1957	222	1112.9	249.0	71.7	75.7	0.985
	1958	245	970.5	237.9	29.1	55.5	1.002
	1959	289	1152.3	234.5	14.4	50.5	1.013
	1960	311	1294.8	271.1	23.2	66.4	1.019

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
OFFICE,	1961	356	1386.5	277.0	24.8	84.7	1.020
COMPUTING	1962	362	1538.3	282.7	15.9	90.9	1.019
& ACCOUNTING	1963	412	1633.7	273.5	21.6	98.1	1.028
MACHINES	1964	458	2355.7	288.0	20.0	90.0	1.028
	1965	543	2765.9	317.8	27.4	141.4	1.032
	1966	607	3655.8	375.4	49.6	149.0	1.041
SIC 361							
ELECTRICAL	1953	49	1245.3	295.4	15.8	37.8	0.783
TRANSMISSION	1954	52	1103.2	255.3	23.2	37.1	0.813
& DISTRIBUTION	1955	54	1133.3	261.2	14.6	35.0	0.827
EQUIPMENT	1956	68	1430.1	301.2	12.4	50.0	0.899
	1957	78	1531.5	308.0	20.2	40.8	0.975
	1958	58	1338.7	269.5	18.6	34.4	1.003
	1959	62	1584.9	287.6	22.0	42.5	1.023
	1960	65	1580.1	293.1	21.5	42.4	1.011
	1961	63	1565.5	296.9	27.9	51.0	0.997
	1962	45	1644.2	308.2	14.7	47.1	0.993
	1963	47	1534.7	263.0	12.6	38.0	0.977
	1964	46	1670.2	275.8	10.0	41.5	0.993
	1965	49	1894.0	293.9	18.7	52.6	0.998
	1966	57	2276.6	326.9	34.9	70.8	1.015
SIC 362							
ELECTRICAL	1953	43	1569.0	384.8	19.9	47.5	0.847
INDUSTRIAL	1954	47	1300.6	336.2	12.7	51.4	0.852
APPARATUS	1955	53	1418.0	349.3	14.6	39.7	0.852
	1956	70	1761.1	390.3	14.1	57.1	0.925
	1957	86	1767.3	376.8	31.7	64.0	0.983
	1958	69	1447.8	309.8	15.9	44.0	1.010
	1959	79	1746.5	336.7	15.4	40.1	1.006
	1960	79	1752.8	338.8	24.0	51.3	0.997
	1961	77	1722.2	329.0	21.7	45.7	0.943
	1962	85	1812.6	333.3	19.0	54.5	0.911
	1963	77	1889.2	323.1	14.9	57.1	0.909
	1964	84	2080.1	337.1	21.5	63.8	0.892
	1965	85	2322.7	372.7	23.0	100.0	0.877
	1966	98	2736.0	421.6	40.9	119.9	0.897
SIC 363,4,9							
APPLIANCES,	1953	82	3131.9	798.7	45.8	109.2	0.945
LIGHTING &	1954	90	2891.0	715.6	43.5	122.1	0.958
WIRING,	1955	99	3416.1	770.5	33.0	116.9	0.958
BATTERIES &	1956	131	3567.8	785.9	42.6	139.2	0.960
MISCELL.	1957	160	3538.8	745.6	37.7	109.3	0.995
ELECTRICAL	1958	112	3449.6	678.5	21.0	85.8	0.994
PRODUCTS	1959	185	4065.7	750.8	30.7	95.2	1.011
	1960	127	4014.3	746.2	30.5	111.6	1.015
	1961	162	4010.3	720.5	26.5	102.0	1.003
	1962	133	4515.8	750.2	26.3	116.5	0.987
	1963	152	4699.9	719.0	37.8	132.6	0.971
	1964	175	4997.6	727.7	44.9	148.2	0.973
	1965	185	5630.5	793.4	66.3	219.3	0.974
	1966	216	6130.8	860.8	66.5	228.1	0.993

INDUSTRY	YEAR	APPLIED R & D ($Mill.)	VALUE ADDED ($Mill.)	TOTAL MANHOURS (Mill.)	PLANT EXPEND ($Mill.)	EQUIPT EXPEND ($Mill.)	VALUE ADDED DEFLATOR (1957-9=1.0)
SIC 365-7							
RADIO & TV,	1953	662	3664.3	1059.3	49.8	112.9	1.000
COMMUNICATION	1954	729	3262.1	887.1	40.8	96.1	0.987
EQUIPMENT,	1955	806	3494.5	942.5	37.7	115.6	0.970
& ELECTRONIC	1956	1114	3818.3	993.4	86.5	143.3	0.980
COMPONENTS	1957	1318	4175.2	1007.3	105.9	173.7	0.998
	1958	1386	4394.7	1000.0	101.5	149.0	1.006
	1959	1756	5486.1	1183.5	87.8	205.3	0.996
	1960	2184	6179.1	1388.8	95.7	256.1	0.976
	1961	2209	7048.4	1481.3	125.2	239.2	0.956
	1962	2101	8398.9	1677.9	106.7	277.2	0.936
	1963	2150	8886.9	1696.4	110.7	298.3	0.916
	1964	2148	9017.5	1623.7	116.7	314.8	0.902
	1965	2258	10409.2	1776.4	127.3	439.6	0.886
	1966	2497	12400.5	2014.8	226.4	594.5	0.897
SIC 371							
MOTOR	1953	440	7577.3	1740.2	61.3	405.9	0.854
VEHICLES &	1954	456	6218.4	1425.6	109.9	622.3	0.856
EQUIPMENT	1955	470	9815.6	1759.7	99.4	508.7	0.882
	1956	487	8059.6	1497.4	185.2	863.5	0.932
	1957	502	8691.9	1496.2	98.9	586.8	0.972
	1958	470	6750.7	1143.8	73.0	271.0	1.003
	1959	569	9229.5	1354.2	61.4	310.5	1.025
	1960	530	10119.1	1433.5	102.8	371.0	1.010
	1961	493	8967.6	1229.5	104.0	319.4	1.008
	1962	558	11604.2	1406.8	138.2	364.4	1.008
	1963	623	12780.6	1506.3	145.0	510.4	1.000
	1964	651	13545.8	1557.2	191.2	712.0	1.005
	1965	687	16450.0	1790.1	360.6	889.9	1.007
	1966	750	16086.4	1868.7	283.2	893.9	1.008
SIC 38							
PROFESSIONAL	1953	99	2180.0	573.1	35.0	65.7	0.890
& SCIENTIFIC	1954	110	2061.3	538.5	29.7	75.2	0.902
INSTRUMENTS	1955	109	2288.7	559.8	40.6	78.1	0.914
	1956	147	2601.7	589.9	58.8	103.1	0.944
	1957	179	2777.5	610.3	60.4	102.2	0.984
	1958	204	2781.0	566.7	36.9	77.7	1.006
	1959	191	3410.1	624.7	37.7	107.3	1.012
	1960	231	3641.1	651.7	50.3	112.0	1.021
	1961	227	3574.0	629.7	70.9	107.7	1.030
	1962	272	3690.0	616.8	57.2	120.4	1.039
	1963	298	3992.1	607.7	52.3	139.5	1.047
	1964	346	4314.3	615.5	39.2	120.9	1.055
	1965	372	5002.2	661.5	68.3	163.9	1.064
	1966	443	5845.0	714.9	112.4	194.7	1.069

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