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R&D AND PRODUCTIVITY GROWTH: COMPARING JAPANESE AND U.S. MANUFACTURING FIRMS

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ABSTRACT

We compute rates of growth in labor productivity during the 1973-80 period for samples of individual manufacturing firms, in both Japan and the U.S., and relate them to differences in the rates of growth in their capital-labor ratios and in their intensities of R&D effort. Japanese firms spent about as much of their own money on R&D, relative to sales, as did similar U.S. firms. An econometric analysis of R&D performing firms leads to the acceptance of the hypothesis that the contribution of such expenditures to productivity growth was about the same in both countries. Hence, the rather large differences on the observed rates of productivity growth between the two countries cannot be accounted for by differences in either the intensity or fecundity of such expenditures. We do find two important differences between the two countries which help to explain a significant fraction of the observed differences in productivity but require, in turn, an explanation of their own: 1) Japanese firms reduced their employment levels significantly during this period while U.S. firms were increasing theirs. This, by itself, accounts for the twice as fast growth in capital-labor ratio in Japanese manufacturing. 2) The estimated effect of the growth in the capital-labor ratio on firm productivity is approximately twice as large in Japan than in the U.S. The two factors together can account for about half of the observed differences in the average rates of productivity growth between the two countries.

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R&D AND PRODUCTIVITY GROWTH: COMPARING JAPANESE AND U.S. MANUFACTURING FIRMS*

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I. INTRODUCTION

In economic terms Japan is a large country with a large internal market in addition to its export potential. In an area that is one twenty-fifth of the U.S., it has a population slightly over a half and a total GNP above one-third of the U.S. Its manufacturing sector is somewhat larger relatively, total employment in manufacturing being around 42 percent of that in the U.S. One of the most important differences between the two countries has been in their rates of productivity growth. Although the oil crises of 1973 and 1979 affected both economies severely and output and productivity growth slowed down in both of them, the productivity of labor in manufacturing continued to increase much faster in Japan than in the U.S. during the 1970s. (Economic Report of the President, 1984, Table 3.3). These events elicited many comments and studies but mostly at the at the aggregate-macro level. Also, while there has been much discussion of the possible involvement of R&D policies in the two countries in these events, there has been little quantitative examination of the R&D-productivity growth relationship and what there has been has focused largely on aggregate data and single country analysis.(1) It is our intention to look at these issues using Japanese and U. S. company data in attempt to assess the contribution of R&D to productivity in both countries.

This paper can be viewed as a continuation of our previous work on R&D and productivity growth at the firm level in the U.S. and in France. In analyzing the data for French and U.S. manufacturing we found that one cannot account for much of the observed difference in the average rate of productivity growth or in the distribution of these differences across industrial sectors or firms by differences in their respective R&D efforts. (See Griliches and Mairesse, 1983 and 1984; and Cuneo and Mairesse, 1984.) The availability of similar data for Japan led us to extend these comparisons also to Japan and the U.S., where the contrasts are even larger.

Our work differs from much of the productivity comparisons literature by taking the individual firm data as its primary focus. Firm data have the virtue of providing us with much more variance in the relevant variables and a more appropriate level of analysis, the level at which most of our theories are specified. By working with micro data we escape many of the aggregation problems that plague macro economics. On the other hand, these benefits do not come without cost. Our data bases rarely contain enough variables relevant to the specific circumstances of a particular firm, and the available variables themselves are subject to much higher relative error rates, errors which are largely averaged out in aggregate data.

The basic approach we follow in this paper is to compute simple productivity growth measures for individual manufacturing firms both in Japan and the U.S. for the relatively recent 1973-1980 period and relate them to the differences in the intensity of R&D effort. We start by describing our data sources and the overall pattern of R&D spending in manufacturing in both countries and by reviewing the major trends in productivity growth across different industrial sectors. We then turn to the discussion of a regression results which attempt to account for the differences in labor productivity growth by the differences in the growth of the capital-labor ratio and in the intensity of R&D effort across different firms for total manufacturing as a whole and also separately within specific industrial sectors.

Since, as we shall point out in some detail later on, the Japanese R&D data at the firm level turn out to be especially incomplete, we cannot provide a definitive solution to the original puzzle of differential growth rates, but we still have some interesting facts and several new puzzles to report.

II. COMPARING R&D EXPENDITURES

Before we look at our R&D data at the firm level, it is useful to compare the industrial distribution of R&D expenditures in both countries. In Tables 1A and 1B we present comparative statistics on the magnitude and industrial distribution of R&D expenditures for manufacturing in both countries, focusing on the role of "large" firms, firms with more than a 1000 employees.(2) We look primarily at the large firms both because they account for most of the R&D done in either country and because our micro data concern them mainly.

Comparing the two tables we can see that large firms are more numerous in the U.S. and that on average they are also larger (about 10 thousand employees versus 3.5 thousand in Japan). Large firms account for 70 percent of total sales and 65 percent of total employment in manufacturing in the U.S. versus 52 and 41 percent respectively in Japan. Similarly, large firms do almost all of the R&D in U.S., 94 percent, but only about three quarters in Japan.(3)

Allowing for differences in the size of the countries and the size distribution of firms, there is very little difference either in the intensity or the sectoral distribution of company financed R&D expenditures in the two countries. There is a big difference, however, in the involvement of government in the financing of R&D performed in manufacturing. In the U.S. over a third of total R&D has been federally financed while in Japan the state accounts for less than 2 percent of the total.(4) Because our micro data pertain only to company financed R&D we shall also restrict our discussion to it.

While in absolute terms large Japanese manufacturing companies spend only about a third of the amount that U.S. companies do on R&D, the ratios of these expenditures to their sales are remarkably similar, about two percent in both countries. So is also their sectoral distribution.(5) The distributions of total company R&D by industry and of the intensity of R&D effort are also very similar in the two countries. Most of the R&D is done in three sectors: electrical equipment, transportation equipment, and chemical industries. The highest R&D to sales ratios are to be found in the drug, electrial equipment, and instrument industries, the only noticeable difference being the somewhat higher relative expenditure in the instruments industry in the U.S.

We turn now to the consideration of our firm-level data sources. In both countries the responses to the official R&D surveys are confidential and not publicly available. What is available are reports on the R&D expenditures made by individual firms as part of their public annual reports or filings with the respective securities markets regulatory authorities (10 K statements in the U.S.). In Japan such data are collected and organized by the Nihon Keizai Shimbun Corporation and are known as the NEEDS data base. In the U.S. the equivalent is the Compustat data base created by the Standard and Poors Corporation. We have worked previously with the Compustat data and have created a consistent panel data set based on it.(6) This is our first experience with the NEEDS data, however, and we had to invest heavily in cleaning them up and in trying to understand their construction and provenance. Except for the R&D numbers, as we shall see below, these data seem of comparable quality to those of the U.S.

The general characteristics of the parallel firm samples that we have constructed are depicted in Table 2. If we insist on continuous data from 1972 through 1980 with no major mergers or major jumps in the series and require also consistent reporting of R&D expenditures throughout this period we have complete data for about 400 R&D firms in Japan and slightly over 500 R&D firms in the US.(7) The U.S. firms are significantly larger, by a factor of four on average. They also seem to be doing much more R&D, even relatively. Here we stumble on our major difficulty with the NEEDS data. The R&D data appear to be badly underreported in this source. If we compare the numbers in Table 1A with those in Table 1B, we observe that the overall company financed R&D to Sales ratio is roughly similar in both countries and only slightly lower in Japan (1.9 vs. 2.3 percent in the U.S. for large R&D performing firms) while the numbers in Table 2 imply that the U.S. firms are twice as R&D intensive.

It does not take very long to convince oneself that indeed the NEEDS data are heavily deficient in their R&D coverage. Table 3 reports coverage ratios for 1981 of the NEEDS R&D numbers relative to the official Japanese R&D Survey. While the large firms in the NEEDS sample account for close to 80 percent of the relevant employment and sales totals, the coverage of R&D expenditures is only slightly above a third.(8) Looking at the distribution by industrial sector we see that coverage is good to reasonable for the chemical, drugs and instruments industries, but that it is abysmal for motor vehicles and transportation equipment and poor for the rest of manufacturing. The magnitude of the problem can be appreciated when it is realized that neither Toyota, Hitachi, Nissan or Honda report positive R&D expenditures in the NEEDS data base.

Using information published by the OECD (1984) on the 20 largest R&D performers in Japan in 1979 we find that of the 18 firms that should be within our definition of manufacturing and are indeed in the NEEDS file, 10 report no R&D whatsoever, three report about the same amount of R&D in both sources, and, what may be even more worrisome, five companies report significantly less R&D in the NEEDS data base than is reported by the OECD. For example, the reported R&D expenditures of the Sony Corporation differ by a factor of two in these different sources. If the OECD information is added to the NEEDS data set, total R&D expenditures come close to doubling and the coverage ratio rises to a respectable 73 percent. Thus the problem we face is not only that R&D is missing for some firms, that we could either ignore or adjust for in some way, but that the reported figures themselves appear to be inaccurate. They reflect not only real differences in this variable but also differences in reporting practices. Since there was nothing else that we could do at this point we complemented or adjusted the R&D figures for the 18 very large R&D firms for which we had OECD information and proceeded to analyze these data as if they actually mean what they say. The best we can hope for is that the reported R&D numbers are still acceptable proxies for the true figures (9). We will come back, however, to this issue in interpreting the results of our analyses.

A few words should be said also at this point about the U.S. R&D data. They seem indeed better. Even though they are not exactly conceptually equivalent, the 10K based reports and the NSF collected numbers are not very far apart, especially as far as industry totals are concerned. A recent analysis by the NSF (1985) of data for the 200 largest R&D performers finds the totals in 1981 remarkably close, within 3 percent, though this covers up significant individual variability. Forty-seven percent of the firms reported totals within 10 percent in both sources, 22 percent were within 10 to 25 percent and only 13 percent were off by more than 25 percent. Eighteen percent were not included in the Compustat based data base, primarily because they were either privately or foreign owned. Using 1976 totals and adjusting for differences in definition and coverage, we ourselves estimated that the Compustat based universe contained about 85 percent of total R&D reported to the NSF, the major discrepancy arising from the above mentioned absence of privately and foreign owned firms in these data.(10) At the same time, our selection of "continuous R&D" firms preserves about 80 percent of the total R&D reported in the 1976 large Compustat cross-section. Thus, roughly speaking, the firms contained in our U.S. sample account for about 70 percent of the total company financed R&D as reported to the National Science Foundation.

III. COMPARING TRENDS IN PRODUCTIVITY GROWTH

Bearing in mind the limitations of the R&D data, we look now at the productivity record of the firms in our samples for both countries during the 1970s. Table 4 lists the sample sizes, averages, and standard deviations for some of our major variables by industrial sector and for manufacturing as a whole. The construction of the major variables is similar for both countries except that in the U.S. we were able to use 3-digit SIC level deflators and business segment information to construct individual firm sales deflators while for Japan we had to use general 2-digit level deflators.(11) In both countries the gross plant figures were converted from historical to constant prices using the information contained in the net versus gross plant distinction.(12) In neither data set do we have information on hours worked, and materials purchases are only available for Japan.(13)

There are a number of interesting observations to be made on the basis of Tables 4A and B, some less obvious than others. The major contrast between the two countries is in the employment story and the associated productivity movements. In Japan total employment declined on the average in 8 out of the 9 industrial groupings. In the U.S. it rose in all sectors. In fact, real output per firm as measured by deflated sales grew at about the same rate in the U.S. as in Japan, 3.5 percent per year on average, the big difference in the productivity numbers coming essentially from the behavior of the employment series. The same thing is also true for the growth in the capital-labor ratio, which grew twice as fast in Japan than in the U.S., while the capital stock was growing at roughly similar rates in both countries during this same period. What is also interesting in both countries is that the growth of the capital-labor ratio was very similar for the different industrial groupings, varying much less than the growth in the output-labor ratio. This is consistent with the hypothesis that the real wage-capital user cost ratio moved differently in the two countries but essentially similarly for the different industries within these countries.

If one looks at the estimate of total factor productivity growth that one gets by assuming a common capital input weight of .25 for all firms in both countries one finds several commonalities and also some contrasts. In both countries the high R&D industries split in their productivity experience: electric equipment and instruments have the highest productivity growth rates while chemicals are among the lowest ones. The major contrasts occur in the machinery, transportation equipment and drugs industries where there was significant productivity growth in Japan but not in the U.S.(14) Only in the food industry did the U.S. do significantly better than Japan as far as total factor productivity growth is concerned.

One cannot compare these numbers directly to similar macro estimates, both because the numbers we report are unweighted firm averages and because in both countries many of the firms are multi-nationals with neither their employment nor productivity restricted entirely to the country of origin. Nevertheless, the fragmentary macro evidence that we have examined to date is not inconsistent with these findings. For example, Jorgenson and Fraumeni (1985) find that the TFP growth between 1973 and 1979 was among the highest in the electrical equipment industry in the U.S. and among the lowest in the chemical industry as is also true for the Japanese data examined by Jorgenson, Kuroda, and Nishimizu (1985).

IV. R&D INTENSITY AND PRODUCTIVITY GROWTH AT THE FIRM LEVEL

The model we consider can be thought of as a modified version of the Cobb-Douglas production function in its growth rate form, with labor productivity being a function of the physical capital-labor ratio and research capital. Because we have only a very short history of research expenditures for most of these firms it is difficult to construct a reliable research capital measure. We use, therefore, the R&D intensity version of this model instead, substituting the beginning period R&D to sales ratio for the unavailable R&D capital variable.(15)

Let the true equation be

$$(q-\ell) = \lambda + \alpha(c-\ell) + \gamma k + u$$

where small lettered variables stand for rates of growth of logarithmic changes; q, ℓ, and c represent output, employment, and physical capital respectively;, k is a measure of accumulated research capital; α , β , γ are the elasticies of output with respect to physical capital, labor and research capital. $\mu = 1 - \alpha - \beta$, λ is a constant which reflects among other things disembodied technical change, and u is a, hopefully, random disturbance standing in for all other unspecified effects affecting measured productivity growth. The research capital elasticity γ is equal by definition to (dQ/dK)*(K/Q) and k is dK/K. We can then simplify the $\gamma*k$ term to r*(R/Q), where r=dQ/dK is the marginal product of research capital and R is the level of R&D expenditures.

Two points need to be made about this type of simplification: Firstly, it is assumed that R is a good proxy for net investment in R&D capital. This can be only true if there is no or little depreciation of research capital or if we are in the beginning phases of accumulation and the initial stocks of K are small. Secondly, it is assumed that r rather than γ is constant across firms, that is, the elasticity γ is variable but that the rate of return r is the parameter that is more or less equalized across firms.(16)

The equations that we estimate are then of the form

$$(q-\ell) = \lambda + (c-\ell) + \mu\ell + r(R/Q) + u$$

where the rates of growth of $(y-\ell)$, $(c-\ell)$, ℓ are generally computed for the seven year period 1973-80. Several alternative measures of R/Q were tried with largely similar results. The final variable chosen AR/S relates the average amount of deflated R&D during 1972-1974 to the mean (geometric) levels of deflated sales for the period as a whole (average of 1973 and 1980 sales). The numerator of this ratio relates to the beginning of the period and allows, implicitly, for an approximate three year lag in the effects of R&D.(17) The denominator is positioned in the middle of the period to reduce the spuriousness which may arise when a growth rate is related to a ratio whose denominator is in fact the initial level from which the growth rate is measured.(18) Instead of a unique trend term we include, usually, separate industry dummy variables which allow for differential industrial trends of disembodied technical change, and also for deflator errors and industry wide changes in capacity utilization. Such equations were also estimated separately for each industrial grouping.

Table 5 summarizes our main econometric results. The estimated R&D coefficients in the productivity growth equations are of similar magnitude in both countries. The major difference is that once separate industry trends are allowed for, this coefficient for Japan is not statistically significant at conventional significance levels. In both countries, the coefficient of the R&D variable falls substantially when industry dummies (trends) are allowed for, implying, possibly, the presence of significant inter-firm R&D spillovers. On the other hand, the contribution of the R&D variable to the explanation of the variance in productivity growth across firms is rather small, the fit barely improving in the second decimal place. Nor can R&D account for the mean difference in growth rates between the two countries. Both the average R&D intensities and the estimated coefficients are quite close to each other. Nevertheless, if these coefficients are taken at face value, they imply that R&D contributed on the average between 0.4 and 0.6 percent per year to productivity growth in both countries. Not a small matter after all.

What is most striking in our results is the lower estimated contribution of physical capital to output growth in the U.S. It is about half of what is estimated for Japan. In fact, if we apply the coefficients in Table 5 (regression 3) to the first row of Table 4, we can account for about half of the Japan-U.S. difference in productivity growth by the twice as fast rate of growth of the capital-labor ratio in Japan and its twice as large effect on productivity there. The reasons for both of these remain to be elucidated.(19) On the other hand, the Japanese data seem also to imply a much sharper rate of diminishing returns. This last estimate (the -.24 coefficient in regression 5) seems rather difficult to believe; it could be due to errors in the Japanese labor variable or to our inability to take properly the problem of varying capacity utilization and hours of work properly into account. In any case, since the Japanese firms reduced their average employment during this period such "diminishing returns" could not serve as a brake on their productivity growth.

Table 6 summarizes our attempts to look at the same issues for the individual industries. Given the high error rates in the data at the firm level and the relatively small sample sizes there is little to be seen there. Consistent with our earlier finding of an overall not statistically significant R&D coefficient in Japan, the individual industry estimates are about half positive and half negative and only three of them have both the right sign and exceed their estimated standard error. In the U.S. data matters are only slightly better: seven out of the nine industries have positive R&D coefficients and four of them are larger than their estimated standard errors. There is little relationship, however, in the relative size of these coefficients across the the same industry groupings in the two countries (see Panel B of Table 6).

We made several efforts to improve matters by redefining variables and changing the time periods somewhat but to litte effect. The results are quite robust to the use of net rather than gross physical capital measures or to changes in the averaging procedures for the R&D data. Changing time periods, however, makes more of a difference. Using the slightly shorter 1974-79 period improves matters somewhat in Japan but deteriorates them in the U.S. This leads us to a disappointing finding: the instability of the productivity-R&D relationship and its sensitivity to the business cycle and macro supply shocks.

Table 7 presents annual estimates of the R&D coefficients using approximate TFP growth as the dependent variable. We use TFP here to avoid adding another source of variation which would come from allowing also the physical capital elasticity to vary from year to year.(20) What is striking is that in both countries the oil shock induced sharp recession of 1974-5 hit the R&D intensive firms disportionately hard, though the exact timing was a bit different in the two countries. It is not clear, however, whether what we see in this table represents a real phenomenon or is just another reflection of the thinness of our data and our inability to estimate such effects precisely.

V. TENTATIVE CONCLUSIONS

Japanese manufacturing firms spent about as much of their own money on R&D, relative to their sales, as did similar U.S. firms; about 1.9 versus 2.3 percent respectively in 1976. On the basis of the econometric analysis of our sample of R&D firms we cannot reject the hypothesis that the contribution of these expenditures to productivity growth was about the same in both countries. Hence there is no indication that differences in either the intensity or the fecundity of R&D expenditures can account for the rather large difference in the observed rates of growth of productivity between the two countries.(21) The reasons for this difference must be looked for elsewhere.

We do find two important differences between Japan and the U.S. which help to account for some of this difference but require an explanation of their own:

1. In spite of their success in growing and exporting, Japanese firms reduced their employment levels significantly during this period while U.S. firms were increasing theirs. This alone is enough to account for the twice as fast growth in the capital-labor ratio in Japanese manufacturing since the capital stock itself has been growing at roughly similar rates in both countries.

2. For not well understood reasons, the estimated effect of growth in the capital-labor ratio on firm productivity in manufacturing appears to be twice as large in Japan than in the U.S. An exploration of the reasons for this difference awaits better data, another occasion, and perhaps a different approach to the problem.

There are a number of other puzzling findings which we hope to return to in the future: Why did the chemical industry perform so badly during this period in both countries? Why did the drug industry do so badly in the U.S. during these same years? Is this a real fact or an artifact of poor deflators? While the oil-price shocks provide some explanation for the poor performance of the chemical firms along lines outlined by Bruno and Sachs (1985) it is doubtful that they can also explain the experience of the pharmaceutical firms in the U.S. Why does the effect of R&D intensity on productivity growth vary so much over the cycle? Is it because it should only be observable at or near full capacity? How can such consideration be incorporated into a more complete analysis of our data?

An improved analysis of the role of R&D expenditures in the growth of Japanese firms will require better data than is currently available to us. The Japanese Statistics Office has collected much more extensive and presumably more reliable data on R&D expenditures of firms for many years but as far as we know these data have not been accessible, nor have they been used in their detailed micro form. In the U.S. similarly collected data by NSF-Census have been matched for different surveys and brought together in a usable data file. The confidentiality problem was solved by performing all of the major data assembly and cleaning operations within the Census and by releasing only variance-covariance matrices for the major variables across firms and years without disclosing any individual firm information.(22) It would be certainly interesting to launch a similar effort in Japan. Another way of dealing with the confidentiality requirement is to carry out the econometric analysis within the National Statistical Office itself, as was the case for our studies for France.(23)

We cannot expect, however, that having better and more reliable data will solve all the problems. What we are looking for are effects which are at best variable, uncertain and more or less long term in nature, and which are also relatively small in magnitude. This does not mean, of course, that these effects are unimportant or that we should not devote more effort in trying to analyze them. But we cannot expect to account for much of the observed growth in productivity by focusing only on the firm's own R&D investments. The role of research spillovers between firms, sectors and countries and the impact of other, less formal, ways of generating technical progress, are both likely to be quite large and remain still to be measured.

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1. One exception at the macro level is Mohnen, Nadiri and Prucha, 1984. After this paper was written we became aware also of the work of Odagiri, 1983, and Odagiri and Iwata, 1985, who use the same Japanese data base to construct value-added based TFP growth measures and relate them to firm R&D intensities. Their results for Japan are similar to ours but they do not make cross country comparisons, however.

2. These numbers come from the national R&D surveys conducted by the Statistics Bureau in the Prime Ministers Office in Japan and the National Science Foundation in the United States.

3. Some of this contrast may be an artifact of different reporting conventions in the two countries. A perusal of the individual firm data seems to indicate that there is less consolidation in Japan, with more units which in the U.S. would be treated as subsidiaries appearing as independent firms in the Japanese sources.

4. See Peck, 1985, for more discussion of this difference.

5. Because we try to have reasonably sized samples in the various "industries," we have aggregated some of the more

detailed available statistics into nine industrial "sectors." Thus, sector 2 includes chemical and rubber firms, but not pharmaceutical ones, sector 6 includes computers, electrical machinery, and electrical and communication equipment, while sector 9 brings together the textile, paper, wood, glass, and miscellaneous manufacturing industries. Petroleum refining is excluded from our definition of "manufacturing."

6. See Bound et al, 1984 and Cummins at al, 1984 for a discussion of the construction and description of this data set which includes also a match to the Patent Office data on the number of patents granted to these firms.

7. Because of the significant and intermittent non-reporting of R&D one cannot assume that the other firms, the not included ones, are truly "zero-R&D" firms. Thus one cannot separate our samples clearly into R&D doing and non-R&D firms and compare the results. This has only been possible in a study for France, because it was conducted within the National Institute of Statistics and we had access to the individual data of the French R&D survey (see Mairesse and Cuneo, 1985).

8. The coverage ratios in Table 3 are for the most recent year that we had data on in both the NEEDS and R&D surveys (1981) but they are not much different in the earlier years. There has been little improvement in R&D reporting in the NEEDS data base. The coverage ratio for the large firms were 30 and 35 percent in 1976 and 1981 respectively. Firms that do report their R&D in the NEEDS data base do so continuously and apparently on a consistent basis.

9. Even if the total R&D levels are about right (after correction) and comparable in the two countries, if the individual observations are subject to much error and differences in reporting practices (especially for the smaller R&D performers), our subsequent regression based estimates of the "importance" of R&D may be significantly biased downward as the result of such errors.

10. See Bound et al, 1984, for more detail.

11. In previous work, we were able to verify that using 2-digit deflators in the case of the U.S. had very little effect on the regression estimates.

12. See the appendix of Griliches and Mairesse (1984) for more detail on the adjustment of the gross plant numbers for inflation. Using alternative measures for physical capital had little effect on our results.

13. For Japan we were able to experiment using a value added instead of a sales based output measure. Although deflated value added has grown much faster than deflated sales over the seven years of our study period, our R&D related regressions results did not change much.

14. Using a more appropriate price deflator for the drug companies in Japan results in a significant rise in their estimated productivity growth relative to the earlier version of this paper but has no effect on regression results which allow for separate industry constants.

15. A number of issues are ignored in this formulation, not because they are unimportant, but primarily because there is little that we can do about them in this context. Much of the

Japanese progress may be based on imported technology. We have no data on this. To the extent that R&D expenditures are required to absorb borrowed or imported technology, this may still be captured, in part, by our measures. We can also do little about the role of government R&D support (there are no data on this at the firm level in either data base) or spillovers in this context. (See Griliches, 1979, for a discussion of these and other caveats.)

16. See Griliches 1979, and Griliches and Lichtenberg 1984 for a related discussion of such models.

17. We tried also shorter lags, i.e., defining the R&D measure as of 1976, the middle of our period, with significantly worse results in both Japan and the U.S. We could not really try for longer lags within the framework of these data bases.

18. Using sales in 1973 or an average of 1972 and 1974 sales as a base does indeed make our results look significantly better. Using the R/S73 (est.) ratio [i.e., 2R73/(S72 + S74)] in equation 5 of Table 5, for example, we get for its coefficient .36 with a t-ratio 3 in Japan and .42 with a t-ratio of 6 in the U.S. These are significantly higher than the comparable numbers in Table 5. Since the R&D numerator is the same in both measures, this does imply that our worries about potential spuriousness may not be groundless.

19. The higher capital elasticity estimate in Japan is consistent with the higher capital share in output reported by Jorgenson, Kuroda and Nishimizu (1985).

20. The estimated physical capital elasticity also varies from

year to year. But since the physical capital growth ratio and R&D intensity variables are nearly uncorrelated, the R&D coefficients are almost unaffected by the constraining of the capital coefficient implicit in the TFP equations.

21. Given the high standard errors associated with the Japanese estimates, they are also consistent with the possibility that such differences are indeed present and important.

22. See Griliches 1982 and 1984 and Griliches and Hall 1982 for more detail on these data and their construction and for results of analyses using them.

23. Since this was first written we have been informed that such efforts are indeed underway by researchers associated with the Economic Planning Agency in Japan.

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TABLE 1A
R&D Firms in Manufacturing: Japan, 1976
The Relative Importance of Large Firms (1000 or More Employees)
and Their Industrial Distribution

	Number of Employees in Millions and Percent of Total	Sales in 100 Billion Yens and Percent	Company R&D Expenditures 100 Billion Yens and Percent	Number of Firms	R&D Sales Ratio[1]
All Firms	8.8	1,244	15.14	85,650	.012
R&D firms	59	69	100	11,950	.018
Large firms	41	52	78	1,120	.018
Large R&D firms	39	50	78	1,030	.019
Large R&D doing firms					
Total	3.5	623	11.82	1,030	.019
Distribution by industry:	100	100	100		
1. Food & kindred	5.1	9.0	2.2	60	.005
2. Chemicals & rubber	11.0	14.2	16.6	98	.022
3. Drugs	2.3	2.1	5.8	29	.051
4. Primary & fabricated metals	13.7	16.8	9.8	104	.012
5. Machinery	8.0	6.5	6.2	91	.018
6. Electrical equip.	19.1	14.0	30.4	123	.041
7. Transportation equip.	23.7	22.0	20.5	329	.018
8. Instruments	2.1	1.4	2.1	29	.028
9. Other	15.0	14.0	6.4	167	.009

Notes:

Source: Report on the Survey of Research and Development - 1976, Japan.

"Manufacturing" excludes petroleum refining.

[1] Total R&D/Total sales (not average of firm ratios).

TABLE 1B

R&D Firms in Manufacturing: U.S.

The Relative Importance of Large Firms (1000 or More Employees) and Their Industrial Distribution

	Number of Employees in Millions and Percent of Total	Sales in Billions of $'s and Percent of Total	Company R&D Expenditures Billions of $'s and Percent	Number of Firms	R/D Sales Ratio[1] Total	R/D Sales Ratio[1] Company Financed
1977 All firms	21.5	1,275	18.00	295,000	.022	.014
R&D doing firms	62	63	100	2835	.035	.022
Large firms	65	70	94	1910	.030	.019
Large R&D firms	56	61	94	1140	.035	.022
1976 Large R&D firms						
Total	11.7	672	15.30	1137	.036	.023
Distribution by industry: (in percent)	100	100	100			
1. Food & kindred	7.6	12.7	2.0	102	.004	.004
2. Chemicals & rubber	9.7	11.4	13.2	112	.030	.026
3. Drugs	2.3	3.5	6.8	29	.063	.062
4. Primary & fabricated metals	13.1	13.0	4.8	165	.009	.008
5. Machinery	6.7	6.1	5.9	135	.023	.022
6. Electrical equip.	20.0	14.8	30.9	159	.077	.047
7. Transportation equip.	18.3	20.6	25.2	90	.065	.028
8. Instruments	3.5	2.6	6.6	55	.066	.057
9. Other	18.8	16.3	4.7	290	.008	.007

Notes:

Sources: Information for all firms in manufacturing from 1977 Enterprise Statistics: General Report on Industrial Organization, U.S. Bureau of the Census, ES77-1; R&D related numbers from NSF, Research and Development in Industry: Technical Notes and Detailed Statistical Tables, 1976 and 1977 issues.

"Manufacturing" excludes petroleum refining.

[1] Total R&D/Total sales (not average of firm ratios).

TABLE 2

Japan and the U.S.: 1976 Characteristics of the 1972-1980 Continuous Samples

Variable	Japan[1] Total	Japan[1] R&D Reporting Original[2]	Japan[1] R&D Reporting Corrected[3]	US Total	US R&D Reporting[4]
N	1032	394	406	968	525
Average Employment thousands	2.7	3.4	4.5	13	17
Average Sales million dollars	215	242	345	655	872
Average Plant, million dollars	116	118	187	330	434
Average R&D, million dollars		3.1	6.9	-	22.7
Average R&D/Sales Ratio		.012	.013	-	.024

Notes:

1. From the NEEDS (Nihon Keizai Shimbun) database. Converted to dollars at $1=300 yen.

2. In addition to the 394 continuously R&D reporting firms, in the Japanese sample, there are also 338 firms which reported nonzero RD expenditures in one or more years in the 1972-1980 period.

3. The data on largest R&D performing firms in Japan reported in OECD (1984) were used to fill in some missing values and adjust others for apparent underreporting.

4. In addition to the 525 continuously R&D reporting firms in the U.S. sample with no major jumps, there are also 129 firms which reported nonzero R&D expenditures in one or more years in the 1972-80 period.

5. Average of individual firm R&D to sales ratios.

TABLE 3
Japan: NEEDS81 Relative to R&D Survey 81
Coverage in Percent of R&D Survey Totals

	Firms	Employees	Sales	R&D Expenditures
All	1.2	30	46	29
R&D reporting	4.2	35	38	29
Large firms (1000^+ employees)	58	79	78	35
Large R&D reporting firms: total	45	51	49	35
By Sector:				
1. Food & kindred	27	30	45	26
2. Chemicals & rubber	65	70	80	92
3. Drugs	71	92	95	98
4. Metals or products	60	55	70	42
5. Machinery	46	45	54	27
6. Electrical equip.	51	60	69	26
7. Transportation equip.	38	44	38	14
8. Instruments	42	58	73	75
9. Other	42	48	53	29

TABLE 4
Continuous R&D Reporting Firms Subsample
1973-80 Growth Rates (per year) and 1973 Levels
Firm Means (and Standard Deviations) for Major Variables

A. Japan

				Growth rates 1973-80			
Industry	N	Empl. 76 in thousands	R/S 73 (est)[1]	Empl.	Defl. sales per Employee	Adj. Gross Plant per Employee	Approximate TFP
Total	406	4.5 (9.4)	.011 (.013)	-.021 (.038)	.058 (.046)	.085 (.034)	.036 (.045)
1. Food, etc.	22	2.3 (2.3)	.004 (.006)	-.012 (.028)	.029 (.030)	.090 (.032)	.007 (.026)
2. Chemicals & rubber	82	3.0 (3.8)	.011 (.010)	-.023 (.035)	.026 (.027)	.079 (.037)	.006 (.027)
3. Drugs	31	2.4 (2.4)	.037 (.022)	.006 (.030)	.072 (.037)	.082 (.029)	.051 (.036)
4. Metals	41	5.5 (12.9)	.006 (.006)	-.029 (.031)	.035 (.044)	.078 (.029)	.016 (.042)
5. Machinery	48	1.8 (2.5)	.008 (.008)	-.030 (.035)	.067 (.039)	.081 (.032)	.046 (.037)
6. Electrical equip.	67	7.2 (14.4)	.016[1] (.013)	-.017 (.035)	.105 (.035)	.087 (.037)	.084 (.034)
7. Transport equip.	33	12.3 (17.5)	.009[1] (.005)	-.006 (.033)	.066 (.034)	.084 (.030)	.044 (.031)
8. Instruments	17	2.3 (2.0)	.015 (.017)	-.015 (.055)	.106 (.040)	.101 (.037)	.081 (.035)
9. Other	65	3.0 (3.5)	.004 (.004)	-.039 (.043)	.041 (.042)	.094 (.028)	.017 (.040)

Notes: Average Empl. 76 - Arithmetic average.

R/S 73 (est.) - 1972 through 1974 average deflated R&D divided by the average of deflated sales in 1972 and 1974.

Approximate TFP (Total Factor Productivity) = growth in deflated sales per employee - .25 x growth in gross plant per employee.

[1]OECD data (for 1979) based corrections raise this number from .011 to .016 and from .004 to .009 for electrical and transportation equipment industries respectively. For the total sample, however, these corrections raise R/S only by .001.

TABLE 4 (Continued)
Continuous R&D Reporting Firms Subsample
1973-80 Growth Rates (per year) and 1973 Levels
Firm Means (and Standard Deviations) for Major Variables

B. US

Industry	N	Empl. 76 in thousands	R/S 73 (est)	Growth rates 1973-80: Empl.	Defl. sales per Employee	Adj. Gross Plant per Employee	Approximate TFP
Total	525	16.9 (48.9)	.025 (.023)	.019 (.067)	.016 (.038)	.044 (.051)	.005 (.038)
1. Food, etc.	22	17.0 (17.7)	.006 (.005)	.012 (.042)	.022 (.044)	.042 (.036)	.012 (.041)
2. Chemicals & rubber	71	18.3 (32.5)	.026 (.013)	.014 (.052)	.007 (.034)	.048 (.036)	-.005 (.033)
3. Drugs	44	14.6 (15.1)	.038 (.027)	.040 (.066)	.004 (.033)	.044 (.043)	-.006 (.032)
4. Metals	50	9.5 (18.0)	.012 (.010)	.002 (.053)	.001 (.031)	.045 (.042)	-.010 (.032)
5. Machinery	82	7.8 (12.9)	.024 (.021)	.027 (.074)	.002 (.031)	.046 (.054)	-.009 (.030)
6. Electrical equip.	106	19.4 (51.9)	.035 (.024)	.024 (.080)	.044 (.045)	.046 (.068)	.032 (.047)
7. Transport equip.	34	66.0 (147.8)	.018 (.013)	.004 (.065)	.003 (.032)	.040 (.049)	-.007 (.028)
8. Instruments	39	10.1 (23.6)	.050 (.032)	.047 (.072)	.030 (.025)	.020 (.040)	.024 (.025)
9. Other	77	9.9 (14.0)	.010 (.007)	.001 (.058)	.012 (.027)	.048 (.048)	-.000 (.026)

Notes: Average Empl. 76 - Arithmetic average.

R/S 73 (est.) - 1972 through 1974 average deflated R&D divided by the average of deflated sales in 1972 and 1974,

Approximate TFP (Total Factor Productivity) = growth in deflated sales per employee - .25 x growth in gross plant per employee.

TABLE 5

Productivity (deflated sales per employee) growth in manufacturing at the firm level as a function of growth in the capital-labor ratio and R&D intensity: Japan-US Comparisons, 1973-80

N = Japan-406, U.S.-525

Regression	Coefficients and standard errors of						R^2 MSE	
	Japan			U.S.				
	C/L	L	AR/S	C/L	L	AR/S	Japan	US
1.	.372 (.067)			.132 (.032)			.072 .00198	.031 .00141
2.	.397 (.066)		.562 (.229)	.146 (.032)		.410 (.093)	.085 .00196	.066 .00136
3.	.298 (.051)			.152 (.030)				.220 .00116
4.	.311 (.051)		.302 (.214)	.155 (.029)		.267 (.096)	.502 .00110	.251 .00112
5.	.236 (.052)	-.240 (.049)	.203 (.209)	.107 (.033)	-.080 (.026)	.248 (.096)	.531 .00104	.265 .00110

Equations 3 through 5 contain an additional 13 industry dummy variables and include also the average 1972-74 employment level as a control variable for initial size. Its coefficient is small, positive and significant for the U.S. and essentially zero for Japan.

C/L - growth rate of gross-plant in constant prices per employee.
L - growth rate of employment.

AR/S - average R&D to sales ratio. R&D averaged for the years 1972-4, sales at mid-point of the period: geometric average of beginning (1973) and end period (1980) sales. Both variables are deflated.

MSE - Mean square error of regression residuals.

TABLE 6
Distribution of the R/S
Coefficients by Industry (Regression 4)

	Coefficients			
	< 0	0-.5	>.5	Total
A. <u>t-ratios</u>				
<u>Japan</u>				
< 1	3	2		5
> 1	1		3	4
Total	4	2	3	9
<u>U.S.</u>				
< 1	1	3	1	5
> 1	1	1	2	4
Total	2	4	3	9
B. <u>Coefficients</u>				
<u>U.S.</u>		<u>Japan</u>		
< 0	1		1	2
0-.5	1	1	2	4
> .5	2	1		3
Total	4	2	3	9

Table 7

Coefficients of R&D Intensity in TFP Growth Regressions, by Year

Japan and U.S., 1974-1980

Year	Japan	U.S.
1973-1974	-.73	1.50
	(.91)	(.38)
1974-1975	-.73	-1.48
	(.91)	(.42)
1975-1976	.51	-.58
	(.81)	(.33)
1976-1977	.85	.65
	(.70)	(.34)
1977-1978	1.01	.35
	(.67)	(.27)
1978-1979	.60	1.28
	(.64)	(.29)
1979-1980	.55	.38
	(.58)	(.32)

Approximate TFP growth: (percent growth in deflated sales per employee) - .25 (percent growth in gross plant per employee).

All equations contain an additional set of industry dummies and a base year (1973) size variable.

The AR/S variable is the average of 1972-1974 R&D divided by the average (geometric) 1973 and 1980 sales (both deflated). It is the same for all years.