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Research Activity, Output Growth, and Productivity Increase in Japanese Manufacturing Industries: A Simultaneous-Equations Approach

by

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ABSTRACT

The contribution of R & D expenditures on productivity increase in Japanese manufacturing industries is investigated. With a popular single-equation approach, this contribution was found significant in all of the three periods, 1960-66, 1966-73 and 1973-77. However, when a simultaneous-equations approach was used to allow for an interaction between learning effect (output growth enhancing productivity increase through the accumulation of experiences) and price effect (productivity increase stimulating output growth through a declining price), in 1966-73 we observed not only these two effects strong but also the contriburion of R & D to reduce its value and significance, strongly suggesting that without the simultaneous-equations approach the contribution of R & D would be overemphasized. Also observed was that, unlike in the United States, research intensity increased and its contribution remained undecreased in the seventies in Japan resulting in some increase in the rate of growth of total factor productivity.

1. INTRODUCTION

Since the last half of the sixties, the United States has been suffering from a lower increase in productivity than both in the preceding years and in other economies in the world. This productivity slowdown has stimulated many researchers to investigate its causes: See, for instance, the Papers and Proceedings of the Annual Meetings of the American Economic Association in the last few years. Many of these researchers found the rate of productivity increase significantly affected by the intensity of research activity. Thus argued is that the recent productivity slowdown is at least partly and probably to a large extent due to the slowdown in growth of the aggregate stock of R and D (Nadiri, 1980a and 1980b, and Griliches, 1980), the collapse in the productivity of R and D (Griliches, 1980), and the reduction in the proportion of industrial R and D expenditures going for basic and long-term projects (Mansfield, 1980, and Link, 1981).

In contrast, little efforts have been made to investigate research intensity as a determinant of the rate of productivity change in other countries. For example, Japan has not experienced such productivity slowdown, creating a gap in productivity between Japan and the United States. Has this resulted because Japan maintained the intensity in research whereas the United States did not? To answer this interesting question, we need at first to evaluate the contribution of R and D to productivity increase in Japan.[1] This is the primary aim of this paper.

We undertake this investigation using the industrial data in Japan. The data are taken for the years 1960 to 1977, which are divided into three periods, 1960-66, 1966-73, and 1973-77. The first two periods correspond to, respectively, the first and second halves of the period in which Japan enjoyed such a high rate of economic growth that surprised other countries, whereas the third corresponds to the period of disequilibrium following the oil crisis. The annual rate of the increase of real gross national product was approximately ten percent in the first two periods and three percent in the third. With this variance in economic performance across the three periods, the factors of productivity change likely vary as well. A comparison of estimation results will be made to consider if the results in fact differ among the periods.

Another novelty is incorporated in this analysis which we consider is most important -- the use of a simultaneous-equations model to take into account the simultaneous interaction between productivity increase and output growth. That is, on the one hand, when the productivity of an industry increases we expect a decrease in the average production cost and hence the price, causing an increase in the quantity to be demanded and produced. On the other hand, when the output of a good increases, experience accumulates in the production and the productivity very likely increases. This latter effect is what is usually sugested by the learning curve or the experience curve to the effect that the labor productivity increases and the unit production cost decreases as the cumulative volume of output increases.[2] This relation is usually found to be exponential, implying that the rate of productivity increase is proportional to the rate of increase in cumulative output which of course is determined by the rate of output growth.

Because it has been found that the learning curve fits very well to the time pattern of the amount of required labor inputs or of the unit production cost in many industries, we strongly believe that the study of the causes of productivity change should take into consideration the probable positive effect of output growth on productivity. However, as discussed above, productivity increase in turn stimulates output growth through cost reduction. Thus applying the ordinary least-squares method is bound to yield biases and the use of a simultaneous-equations method such as the two-stage least-squares is called for. This approach is taken in this paper, showing that at least in one of the periods, the predicted interactive relation is quite strongly observed.

Section 2 explains the models and variables. Section 3 gives a general view on the three periods studied. Section 4 presents and discusses the estimation results, and Section 5 summarizes the results and compares them with the results in the United States.

2. MODELS AND VARIABLES

The study is cross-sectional across fifteen manufacturing industries in Japan for each of the three periods, 1960-66, 1966-73, and 1973-77.[3] The list of industries is given in Appendix B together with the data on three major variables. Appendix A gives the data source.

Two alternative measures of the rate of growth of productivity are defined:

GTFP: the rate of increase in total factor productivity net of the effects of qualitative changes in inputs, computed by Kuroda (1981) in the manner developed by Gollop and Jorgenson (1980).

GRVE: the rate of increase in real value added per employee.

In this analysis any variable with G at the top denotes the rate of increase measured as the ratio of the relevant value in the closing year (1966, 1973 or 1977) to that in the starting year (1960, 1966 or 1973, respectively). Note that GTFP is the rate of total factor productivity increase whereas GRVE is the rate of labor productivity increase, and that GTFP is net of the effects of compositional changes (such as in age and sex) of labor and capital whereas GRVE is not.

We define the rate of output growth by

GIND: the rate of increase of the index of industrial production.

Learning is expected to take place through the accumulation of the physical volume of output. This is why GIND is used here as the output growth variable, for it is calculated as the weighted average of indexes each of which measures the change in the physical quantity of a product and is not affected by the choice of deflators unlike, say, the growth rate of real amount of sales or of real value added.[4]

The extent of research activity is usually measured by the expenditures on research and development or the number of scientists and engineers. Following the earlier studies, the first is used here after normalized by the amount of sales.

RD: research and development expenditures made by an industry as a percentage to its sales.

Terleckyj (1980) showed that R & D embodied in purchased goods from other industries positively affects productivity increase in the United States. This data he calculated by summing the R & D of the conducting industies, redistributed in proportion to their sales as given in input-output tables. To see if this indirect effect of research is also present in Japan, we used a similar variable:

XRD: research and development expenditures embodied in an industry's purchased goods from other manufacturing industries, as a percentage to its sales.

That is, if R & D expenditures of j-th industry are X_j and the proportion of its sales to i-th industry is a_{ij}, then $XRD_i = 100 \Sigma_{j \neq i} a_{ij} X_j / Sales_i$, where the summation goes over all the manufacturing industries but not non-manufacturing industries (thus, $\Sigma_i a_{ij}$ is less than one). The industry in question (i.e., i-th industry in this notation) was excluded in calculating XRD_i because a_{ii} turned out to be disproportionally large for most industries and consequently RD and XRD correlate highly if XRD_i were calculated with $a_{ii}X_i$ included.

Basically, we are going to regress GTFP or GRVE on RD and XRD with GIND included or not as another independent variable. In addition, two explanatory variables are defined. First of them concerns the extent of unionization.

UNI: the percentage of an industry's employees that are union members.

Terleckyj (1980), Mansfield (1980), and Link (1981) all found this variable affecting productivity increase adversely; that is, in the United States, an industry with a larger proportion of workers organized _ceteris paribus_ tends to suffer from slower productivity growth. None of these authors discussed why; however, a possible explanation may be that in a well-organized industry effective labor management is hindered, or the adoption of a new and labor-saving production process is delayed due to the organized resistance of workers.

If this is the case, it is interesting to ask whether the same tendency is present in Japan where supposedly labor-management relation is more cooperative and workers are more concerned with the long-run performance of the firm. If this difference in worker attitudes really exists, unionization will not hurt productivity increase in Japan and even a positive effect may be observed suggesting that unions contribute to an efficient labor management and the accumulation of human capital.

I have already explained that two alternative measures of productivity growth, GTFP and GRVE, are used in this analysis and that GTFP measures the growth of total factor productivity while GRVE, that of labor productivity. Obviously, then, an increase in the amount of capital per each worker should increase GRVE, insofar as the marginal productivity of capital is positive, but not GTFP. Thus in the equation with GRVE as the dependent variable, we add the following variable as another explanatory variable:

GKE: the rate of increase of capital stock per employee.

We now consider the following model (suppressing the error terms):

(1) $GTFP = \beta_0 + \beta_1 RD + \beta_2 XRD + \beta_3 UNI$

or

(2) $GTFP = \beta_0 + \beta_1 GIND + \beta_2 RD + \beta_3 XRD + \beta_4 UNI$

If GRVE is to be used as the dependent variable, then the right-hand side should include a term for GKE in addition to those in (1) or (2).

Basically, (1) is the model used by Terleckyj (1980). Similar models have been adopted by many researchers with some modifications; for example, without XRD, with different definitions used to measure productivity increase and/or research intensity, with other variables such as output variation (Terleckyj, 1980), unilization rate (Nadiri, 1980a and 1980b), and market concentration (Caves and Uekusa, 1976), and the division of the R & D variables into privately financed portion and publicly financed portion and/or into basic research, and applied research and development (Mansfield, 1980, and Link, 1981).[5]

As we have argued in the introductory section, however, this single-equation approach fails to account for an important fact, namely, that learning takes place as experiences accumulate in production and this results in interaction between productivity increase and output growth. To remedy this shortcoming, a simultaneous-equations model is proposed here:

$$(3)\quad \begin{cases} GTFP = \alpha_0 + \alpha_1 GIND + \alpha_2 RD + \alpha_3 XRD + \alpha_4 UNI \\ GIND = \beta_0 + \beta_1 GTFP + \beta_2 ADV \end{cases}$$

where the new variable,

ADV: the percentage of advertising expenditures to sales

is expected to stimulate sales growth and hence GIND. Alternatively, in (3), GRVE may replace GTFP with a term on GKE added in the right-hand side of the first equation.

The first equation in (3) implies that the rate of productivity increase in an industry is determined by the rate of its output growth through learning effect, the intensity of research activity in the industry, and so forth. The second equation implies that the faster the productivity increases the faster the output grows. Essentially, this last effect occurs because productivity increase relatively lowers the unit production cost and output price, which stimulates sales and consequently output. To make this price effect more explicit, we consider the following model:

$$(4)\quad \begin{cases} GTFP = \alpha_0 + \alpha_1 GIND + \alpha_2 RD + \alpha_3 XRD + \alpha_4 UNI \\ GIND = \beta_0 + \beta_1 GWPI + \beta_2 ADV \\ GWPI = \gamma_0 + \gamma_1 GTFP + \gamma_2 XRD + \gamma_3 BIG \end{cases}$$

where

GWPI: the rate of increase in wholesale price index

BIG: the share (in percentage) in shipment of the firms with a thousand employees or more.

Again, GRVE may replace GTFP in (4) with a term on GKE added in the right-hand side of the first equation.

Consider the last equation first. We expect γ_1 to be negative because faster productivity increase will cause the wholesale price to decline relatively. Two exogenous variables, XRD and BIG, are added here. If XRD is large, this means that intense research efforts are made in those industries from which the industry in question buys. Our supposition is that these research efforts result in cheaper prices and better qualities of their products lowering the costs of purchased inputs to the industry in question; hence, XRD is expected to have a negative effect on GWPI.

The effect of BIG on GWPI cannot be determined a priori. A concentration of output to big companies may contribute to price stability because of their inclination to avoid price wars, or to inflation because of their power to shift cost increases to the customers. Hence, γ_3 may be negative or positive. At any rate some effect of the concentration on the rate of price increase may occur and we want to know which direction.

The first two equation in (4) are identical to (3) except that GWPI replaces GTFP in the second equation. The effect of GWPI on GIND is expected negative as indicated above. Other coefficients in these two equations are expected positive except for α_4 which, if the Japanese labor unions behave similarly to the American ones, should be negative.

3. AN OVERVIEW OF THE THREE PERIODS

It may be helpful to explain the general characteristics of the three periods, 1960-66, 1966-73, and 1973-77, before proceeding to the discussion of the estimation results.

1960 is the year when Prime Minister Ikeda took his office and started the "Income Doubling Plan." The plan recognized the growth potential of Japan's economy and her real national income actually doubled in seven years. This era of fast growth (with of course some ups and downs) lasted until the impact of oil embargo and price hike in crude oil struck Japan at the end of 1973.

Let us look at some macro figures. In 1960-66, her real GNP rose by 10.0 percent annually, while in 1966-73, by 10.6 percent. More impressively, the index of industrial production in manufacturing rose by 12.1 percent in 1960-66 and by 12.9 percent in 1966-73. On the other hand, the wholesale price index (in all industries) rose only by 0.76 percent in 1960-66 indicating surprising stability in wholesale prices. Inflationary pressure was heavier in the latter half of the era; still, in 1966-73, the annual growth rate of wholesale price index remained at 3.34 percent.

The oil crisis in 1973 changed the whole scene. The terms of trade worsened by 25 percent and the wholesale price index rose by 31 percent in just one year (1973 to 1974). Demand dumped and pessimism spread around businesses. Economic growth rate never returned to a two-digit level since then: In 1973-77, real GNP only increased by 3.17 percent annually. Even worse, in the manufacturing industry the production index recorded a negative growth rate, -0.28 percent. Averaged through this four-year period, the whole sale price index rose by 9.69 percent annually. Thus the period, 1973-77, is basically that of stagflation -- inflation with little economic growth.

The mean values over fifteen manufacturing industries of the variables used in this analysis are given in Table 1. The general tendency across the three periods agrees to the description of the Japanese macroeconomy above. The rate of output growth on average exceeded 10 percent in 1960-66 and 1966-73 but was almost zero in 1973-77, while the rate of increase of wholesale price more than tripled after the oil crisis.

Two measures of productivity growth display a contrasting move. Labor productivity increase, GRVE, equaled or exceeded 10 percent in 1960-66 and 1966-73 but dropped to a mere 1.76 percent in 1973-77 -- a time pattern similar to that of output growth. On the contrary, the growth rate of total factor productivity, GTFP, increased from 1960-66 to 1966-73 and, interestingly, further increased in 1973-77. In view of the definition of the two variables, the most likely reason for this difference is that capital input decreased in 1973-77. Kuroda (1981, p. 69) argues this, showing that particularly in 1975-77 the rate of increase in capital input was negative in most industries. However, our data disagrees with this Kuroda's finding. As shown in Table 1, the rate of increase of capital per employee (GKE) in 1973-77 was somewhat lower than in the previous periods but still in excess of 10 percent. Roughly speaking, I found that in 1973-77 capital increased by 8 percent annually and the number of employees decreased by 3 percent, resulting in the 11 percent increase in the capital-employee ratio. This difference between Kuroda's and ours probably resulted because data sources differ (his is basically from the National Income Account, whereas ours is from the Census of Manufacturers), and because Kuroda controlled for the changes in the purpose of capital assets (land, durable production equipments, dwellings, etc.) and in the users (corporations, non-corporate enterprises, or households), whereas ours did not.

We have argued that 1973-77 was a period of slow economic growth and rapid price increase. It also was a period of disequilibrium and adjustment following external disturbances, particularly the steep price increase in crude oil. Since the effects of these disturbances were not even across industries, shifts in industrial performances took place, resulting in a weaker correlation across industries between 1966-73 and 1973-77 than between 1960-66 and 1966-73. For instance, the coefficients of correlation between 1960-66 and 1966-73, and between 1966-73 and 1973-77, respectively, were 0.27 and -0.19 with respect to GIND, 0.18 and -0.25 with respect to GRVE, and 0.62 and 0.10 for GWPI. Again, however, GTFP yielded a contrasting result -- the correlation coefficients were 0.22 and 0.38, showing a stronger correlation between the latter two periods than between the first two.

In spite of this unique behavior of GTFP, we note that it is well correlated with the other productivity variable, GRVE, in all the three periods -- the correlation coefficients were 0.76, 0.52 and 0.51, in the order of the three periods, all statistically significant at 5 percent level. That is, an industry tends to be of high productivity increase in terms of either total factor productivity or labor productivity. This is a convenient fact for our purpose because we can expect the estimation results not much different whichever productivity variable is used.

Let me close this section with a brief description of other variables which are treated as exogenous in the models. An upward trend is seen in RD and UNI and a downward trend, in ADV and BIG from Table 1. We thus note that the Japanese industries are intensifying their research efforts despite poorer economic performances, such as lower profit rates, after the oil crisis.[6]

The correlation coefficients among these variables were computed, showing a consistently strong correlation between BIG and UNI (the coefficients of correlation were 0.732, 0.850 and 0.580 in the chronological order, significant at 1 percent level in the first two and at 5 percent level in the last), and that RD and ADV correlated strongly in 1960-66 but then declined (0.733, 0.659 and 0.617). An interpretation may be that R & D at first aimed mainly at product innovation, necessitating advertising for innovated new products, but its aim then shifted to product innovation. With the lack of any more detailed information, however, this remains a conjecture. Positive correlation between RD and BIG existed (0.540, 0.352 and 0.551), somewhat supporting the so-called Schumpeterian hypothesis that big businesses tend to make more research efforts.

4. ESTIMATION RESULTS

We have four models, three periods, and two productivity increase variables.[7] Since we found no occation in which the two-equation model (3) fitted much better than the three-equation model (4), and since we consider (4) to be logically more comprehensive, we will not reproduce the estimation results of (3) to save space. We are thus left with three models paired with two alternative variables for each of the periods. Their estimation results are given in Tables 2, 3 and 4.

We first look at the results in the period 1960-66, given in Table 2. The fit is not impressive, for R^2 (adjusted for degrees of freedom) given only to the equations estimated with the ordinary least-squares method (OLSQ) is at most 0.23. We note, however, that the variable of our concern, RD, has a positive effect as expected, though only that on GTFP is significant. The role of GIND, on the other hand, is doubtful. It has insignificant and, contrary to our prediction, negative coefficients, suggesting that learning effect was nonexistent or unimportant in this period. In addition, the fact that an inclusion of GIND does not decrease the coefficient of RD suggests that the effect of RD is not overstated even when learning effect is not separated.

Now consider the simultaneous-equations model estimated by the two-stage least-squares method (TSLS). The effect of GTFP or GRVE on GWPI is negative as expected but only that of GRVE is weakly significant. GWPI in turn affects GIND negatively as expected though only insignificantly. Thus, the hypothesized effect of productivity increase on output growth through price reduction is found but not statistically confirmed. The effect in reverse direction, namely, output growth stimulating productivity increase through learning, was as shown above doubtful. Thus, we may roughly estimate that in 1960-66, productivity, particularly total factor productivity, increased owing to research activity but not learning.

In 1966-73, the coefficients of RD are again positive and significant in the OLSQ models (see Table 3). Unlike in 1960-66, however, the effects of GIND are now all positive as expected and, to GTFP, significant. Moreover, the coefficient of RD and its t-value we find to decrease as GIND is added as another explanatory variable. This strongly suggests that not only learning took place but also the effect of RD would be overevaluated unless learning effect is properly separated. In fact, when learning effect was taken into consideration by means of a simultaneous-equations model, the effect of RD became insignificantly small and, to GRVE, even negative.

In this period, we find that a productivity increase significantly lowers the rate of price increase and this lower price increase in turn significantly increases output growth. This increase in output growth further accelerates productivity increase, again a significant relation (for GTFP). Thus our hypothesis is confirmed that the relation between productivity increase and output growth is bi-directional through learning effect and price effect, one accelerating the other, and that only a simultaneous-equations model can properly capture this fact. That this holds irrespective of the choices on productivity growth variable and on output growth variable (see Appendix C) further supports the hypothesis.

The result in period 1973-77, shown in Table 4, is more like that in period 1960-66 than in 1966-73. The effect of RD is positive and significant to whichever productivity variable. The effect of output growth on productivity increase hardly exists or is negative. It appears therefore that productivity increase was enhanced by research efforts but not through learning. The effect of productivity increase on GWPI was negative as expected, with only that of GRVE being significant. The effect of GWPI on GIND is negative as expected though insignificant. Therefore, in terms of the signs of coefficients, the result suggests price effect (productivity increase lowering the price which stimulates output growth) but not learning effect (output growth enhancing productivity increase).

To sum up the findings so far: Looking at the OLSQ models, the effects of RD on productivity increase were positive as predicted and significant in all the periods (except for the effect on GRVE in 1960-66). The interactive effect of output growth was confirmed for 1966-73. In this period, the effect of RD becomes weaker as the effect of output growth is taken into consideration. These suggest not only that learning effect took place in this period but also that the failure of recognizing this effect would lead one to overevaluate the contribution of research activity. Furthermore, the reverse causality that productivity increase stimulates output growth through price reduction was also confirmed in this period; hence, the two effects -- learning effect and price effect -- are multiplicative implying the importance of a simultaneous-equations approach. In other periods, the learning effect was not confirmed. Hence, it is estimated that in these periods, research activity is more conducive to productivity increase than learning.

It is worth noting that this conclusion generally holds with respect to either the increase in total factor productivity, GTFP, or the increase in labor productivity, GRVE. Of course, there are some differences. For instance, in 1960-66, the effect of RD is significant to GTFP but not to GRVE; yet, it is positive to both as predicted. In 1966-73, the effect of RD turns negative to GRVE in the TSLS model but not to GTFP; yet, to either variable, learning was found effective and the effect of RD was found to decrease significantly as learning effect was introduced. In 1973-77, the effect of output growth in the TSLS model was positive to GTFP but negative to GRVE; yet, both coefficients had negligibly small t-values suggesting the absence of learning effect. Therefore, in terms of both total factor productivity and labor productivity, we can conclude that learning effect was important in 1966-73 in which period the effect of research would be overevaluated if a simple OLSQ model is to be adopted, and that in the other two periods research contributed to productivity increase but not the accumulation of the volume of output.

We turn now to the effects of exogenous variables other than RD. The general impression is that hardly any is significant and many have erratic signs. First, consider XRD, the intensity of research embodied in purchased goods, which Terleckyj (1980) showed to have a positive and significant effect in the United States. In 1960-66, the sign is positive but the t-values are negligibly small. In 1966-73, the sign is consistently negative against our prediction. In 1973-77, its effect is negative to GTFP and positive to GRVE but insignificant anyway. Therefore, we cannot support the hypothesis that research embodied in purchased goods enhanced productivity growth.

The effect of unionization on productivity growth, found negative in the United States, is not clear. In 1960-66, UNI has mostly positive coefficients but insignificantly. In 1966-73, the effect is negative to GTFP but positive to GRVE, both being insignificant. In 1973-77, the effect is consistently negative and, to GRVE, it is weakly significant in the OLSQ models. Hence, the effect of unionization is ambiguous. If any, it appears that the effect of unionization was rather favorable to productivity increase in the early period but later turned somewhat unfavorable, suggesting that Japanese unions may be changing to behave more like American ones. However, the evidence is too weak.

Third, consider the effect of advertising on output growth. In 1960-66 and 1966-73, the effect is negative and insignificant. After the oil crisis, it turns positive and significant as hypothesized. Hence it may be that advertising became a more important and effective means of sales promotion after the oil crisis. The evidence again is not strong enough to assert this, however.

Fourth, the effect of XRD on GWPI is negative in four of six as expected; none of the coefficients is significant, however.

Fifth, the effect of BIG is mostly negative though insignificant except one, giving a weak impression that big corporations rather helped stabilizing prices. Again, the evidence is too meager to assert this.

Finally, the effect of GKE on GRVE is positive as expected (with one being significant) in 1966-73 but negative in other periods. Thus, an increase in capital intensity seems to have contributed to labor productivity increase in 1966-73 but not in other periods.

5. SUMMARY AND COMPARISON WITH THE AMERICAN RESULTS

We have considered three periods in Japan: 1960-66, the first half of the era of fast economic growth; 1966-73, the second half; and 1973-77, the period of slow growth, inflation, and disequilibrium following the oil crisis. Both a single-equation model, which has been previously adopted by many researchers, and a simultaneous-equations model, which take into consideration the interactive influences between productivity increase and output growth through learning effect (output growth enhancing productivity increase) and price effect (productivity increase stimulating output growth through declining prices), were estimated using the data on fifteen manufacturing industries. The number of observations is admittedly small; however, it was the maximum obtainable because of the diversity in industrial classification among data sources.

Notable differences were found among the three periods. Most importantly, learning effect was found to be important and repercussive to output growth through price effect in 1966-73 but not in other periods. On the contrary, the contribution of research efforts on productivity increase was found in all periods; in 1966-73, however, this contribution was found to lose its significance once the learning effect was taken into account.

The effects of other exogenous variables also displayed interesting time patterns though hardly any is statistically significant. It was weakly inferred that unionization was favorable to productivity increase at first but turned somewhat unfavorable later, advertising was effective to output growth only after the oil crisis, big corporations rather helped to stabilize prices, and an increase in capital intensity contributed to labor productivity increase in 1966-73 but not in other periods. Again warned, however, is that hardly any of these are statistically significant.

Let us conclude this analysis with a comparison of our result with the results obtained in the United States. We have already shown that the effects on productivity increase of research embodied in purchased goods, our XRD, and of the percentage of union members, our UNI, were significantly positive and negative, respectively, in Terleckyj (1980) and Mansfield (1980) but were insignificant with unstable signs in our study. That unionization hurts productivity increase in the United States but not in Japan perhaps comes from the difference in attitudes of the unions between these two countries. As I have argued elsewhere (Odagiri, 1982), because of lifetime employment, internal promotion, and more firm-specific than job-specific skills workers accumulate through experiencing a wider variety of jobs within the firm, Japanese employees and unions tend to identify their interests with those of their companies, seek corporate growth as well as higher wages today, and be more cooperative in introducing new production processes, say robots, even if this necessitates transfers of jobs within the company. This should explain why unionization in Japan was not adverse to productivity increase and at times even favorable. The unconfirmed inference from the estimation results that the effect of uninization on productivity increase is lately turning negative, if true, may well imply a grave consequence to the future performance of Japan's industries.

Finally, an attempt is made to compare the contribution of R & D. In Terleckyj, the estimated coefficient of privately financed R & D (as a ratio to value added) to the annual rate of change in total factor productivity (estimated by Gollop and Jorgenson, 1980) was 0.20.[8] His model (estimated with OLSQ) includes R & D embodied in purchases from other industries (our XRD) and the percentage of union members (our UNI) but not the rate of output growth (our GIND); hence, our model (1) is comparable to his. Because he used the annual rate as the dependent variable whereas we have used the ratio of the value in the closing year to that in the starting year, in order to facilitate comparison, we generated the annual rate of increase of total factor productivity out of GTFP, which is comparable to Terleckyj's dependent variable because Kuroda (1981) from which we obtained GTFP closely followed the methodology of Gollop and Jorgenson. We then reestimated the model (1) using this annual rate as the dependent variable, to find the coefficients of RD being 0.02262, 0.02856, and 0.02437 in the order of the three periods, all significant at 5 percent level just as was the case with GFTP. Noting that the ratio of sales to value added will not exceed four, we can estimate that the coefficient of RD, if measured as the ratio of research and development expenditures to value added, is at most 0.1 in Japan. This suggests that the marginal contribution of research activity to total factor productivity was greater (at least in 1948-66, the period of study in Terleckyj's) in the United States than in Japan.

We need to note, however, that the estimated figures show no decline in the coefficient in 1973-77. This is in contrast to Griliches' (1980, p.346) finding that the contribution of R & D stock to labor productivity in the United States decreased to less than half in 1969-77 in comparison to that in the preceding decade.[9] It is therefore well expected that the divergence between the two countries in the contribution of research to productivity increase as estimated from Terleckyj's study for 1948-66 and ours for 1960-66, has narrowed to some extent in the seventies. Whether the United States still maintains the lead at this moment is an interesting question.

This decline in the contribution of research in the United States, but not in Japan, combined with the decrease in research intensity in the United States -- 2.66 in 1966-73 to 2.28 in 1973-77 in terms of the R & D expenditures (both private and public) as a percentage to GNP -- as opposed to the increase in Japan -- similarly, 1.50 to 1.72 -- should at least partly explain why productivity slowdown took place in the United States but not in Japan.[10]

NOTES

1. The only other study I know of that inquired into the effect of research intensity on productivity is the cross-sectional study of 99 Japanese manufacturing industries by Caves and Uekusa (1976, p.136) for the period 1958-67. They regressed the rate of increase in value added per employee on the percentage of R & D expenditures to sales as well as the measures of concentration, plant size, technological imports, and so forth, to find that the R & D variable has a significant but, contradicting the prediction, negative coefficient. When the number of patents was used in place of the R & D expenditure-sales ratio, the coefficient turned to be positive but only weakly significant.

2. Yelle (1979) gives a comprehensive survey on the learning curve. For a theoretical effort to inquire into the consequences of the learning curve on competition, see Spence (1981).

3. The three periods were defined in this manner basically because of the data availability on one of the variables. See the explanation of GTFP in Appendix A.

4. The growth rate of real value added, however, has an advantage in that we can use the same data source as that of GRVE, eliminating disturbances due to differences in data base. For this reason, we made all the estimation using GRVA, the rate of growth of value added deflated by whole sale price index, as an alternative meaure of output growth. Appendix C gives the result.

5. In Japan, government subsidy to research conducted in the private sector is negligibly small -- less than two percent of the research conducted by the businesses. This reflects the fact that Japan does not much engage in research in defense and space.

6. The ratio of operating profits to total assets of manufacturing companies, on average, dropped from nine percent before the oil crisis (1960-73) to six percent after the crisis (1973-77). Source: The Corporation Enterprise Survey. Ministry of Finance.

7. Besides these, I have estimated models with different combinations of exogenous variables and with weights; using BIG to explain GTFP and UNI to explain GWPI, using average wage rate to explain GTFP, adding RD to explain GIND to account for its effect through new products, and several others. None of them consistently outperformed the model in the text (but not all of them were consistently outperformed by the model in the text, either). In view of the logical consistency and imterpretability, and of the comparability with the American results, I have settled with the model in the text.

8. Not statistically significant. His estimated coefficient when the dependent variable was Kendrick's data of total factor productivity (unadjusted for quality or compositional changes in inputs) was 0.27 and significant at one percent level.

9. Nadiri (1980b) presents a somewhat conflicting evidence that in a Cobb-Douglas production function the estimated elasticity of output with respect to the stock of R & D was unchanged between 1958-65 and 1966-75.

10. Source: Kagaku Gijutsu Hakusho, 1981 [White Paper on Science and Technology]. Science and Technology Agency.

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TABLE 1. MEAN VALUES OF THE DATA

Variables	Period 1960-66	1966-73	1973-77
GTFP	.0425 (.70)	.142 (1.92)	.118 (2.83)
GRVE	1.767 (9.96)	2.351 (12.99)	1.072 (1.76)
GIND	2.018 (12.41)	2.324 (12.80)	1.003 (.07)
GWPI	1.038 (.63)	1.238 (3.09)	1.502 (10.71)
RD	.782	.953	1.317
XRD	.090	.168	.138
UNI	39.3	47.3	48.0
ADV	1.234	1.091	.830
BIG	32.2	31.8	25.6
GKE	2.073 (12.91)	2.417 (13.44)	1.523 (11.09)

Note: In parentheses are the annual rates of growth (in percentages).

TABLE 2. ESTIMATION RESULTS --1960-66

MODEL	METHOD	GTFP/GRVE	GIND	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
1	OLSQ	dep			.1394[b]	.1402	-.0009017				.1850
					2.2929	.3546	.4793				
2	OLSQ	dep	-.1085		.1469[b]	.1485	.0001591				.2295
			1.2789		2.4726	.3862	.0792				
4	TSLS	dep	-.3100		.1608[c]	.1639	.002129				
			1.0865		2.1017	.3406	.5901				
			dep	-2.7549				-.1200			
				1.0886				.7642			
		-.8500		dep		.04915			-.002039		
		1.6210				.0805			.9774		
1'	OLSQ	dep			.1503	.1421	.001126			-.1116	-.0974
					.9212	.1598	.2212			.4621	
2'	OLSQ	dep	-.1066		.1713	.1627	.001735			-.07490	-.1858
			.5041		.9809	.1759	.3196			.2865	
4'	TSLS	dep	-.9376		.3349	.3235	.006477			.2113	
			.8424		.9432	.2104	.6005			.3746	
			dep	-1.6265				-.06570			
				.9299				.5692			
		-.4355[c]		dep		-.02021			-.002463		
		1.9952				.0425			1.4829		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 1, 2 or 4, and is GRVE in Model 1', 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.

TABLE 3. ESTIMATION RESULTS -- 1966-73

MODEL	METHOD	GTFP/GRVE	GIND	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
1	OLSQ	dep			.2292[a]	-.5123[c]	-.001063				.5818
					4.4086	2.0538	.6808				
2	OLSQ	dep	.09808[b]		.1683[a]	-.4327[c]	-.001211				.7006
			2.3164		3.2834	2.0236	.9150				
4	TSLS	dep	.1741[c]		.1211	-.3711	-.001325				
			1.9366		1.6070	1.4642	.8684				
			dep	-3.0135[b]				-.1991			
				2.9193				1.2369			
		-.8508[b]		dep		-.08491			-.003680[c]		
		2.9972				.2665			1.8570		
1'	OLSQ	dep			.4467[b]	-.6352	.003348			.7765[b]	.6148
					2.8133	1.0776	.7685			2.7339	
2'	OLSQ	dep	.1400		.2714	-.6129	.005202			.5332	.6026
			.8329		1.0241	1.0226	1.0501			1.2986	
4'	TSLS	dep	.3872		-.03780	-.5735	.008474			.1037	
			1.5179		.1032	.8586	1.4184			.1894	
			dep	-3.4748[a]				-.2339			
				3.4387				1.4049			
		-.5073[a]		dep		-.4381			.0004414		
		3.4008				1.3697			.1777		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 1, 2 or 4, and is GRVE in Model 1', 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.

TABLE 4. ESTIMATION RESULTS -- 1973-77

		Variables									
MODEL	METHOD	GTFP/GRVE	GIND	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
1	OLSQ	dep			.1106[b]	-.1124	-.0001926				.3317
					2.9897	.3977	.1220				
2	OLSQ	dep	.1053		.1010[b]	-.08609	-.0002110				.2891
					2.4342	.2919	.1295				
4	TSLS	dep	.004252		.1102[c]	-.1113	-.0001933				
			.0091		1.9189	.3499	.1168				
			dep	-.0008540				.1226[c]			
				.0060				2.0616			
		-1.4210		dep		-1.0496			-.001764		
		.9219				.8289			.2073		
1'	OLSQ	dep			.1642[a]	.4598	-.003933[c]			-.6482	.6768
					4.0340	1.4785	2.0198			1.5311	
2'	OLSQ	dep	.2131		.1466[a]	.5256	-.004269[c]			-.5081	.6818
			1.0745		3.3609	1.6705	2.1810			1.1549	
4'	TSLS	dep	-.2512		.1850[c]	.3823	-.003536			-.8134	
			.3175		2.2244	.8286	1.2855			1.0922	
			dep	-.01807				.1208[c]			
				.1287				2.0329			
		-1.5751[a]		dep		.1803			-.002237		
		3.6096				.2257			.5001		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 1, 2 or 4, and is GRVE in Model 1', 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.

APPENDIX A. DATA SOURCES

Details on the variables and the data sources follow:

GTFP: Source: Kuroda (1981, Table 1). Since Kuroda divided periods more finely -- 1960-66, 1966-69, 1969-73, and yearly during 1973 and 1977 -- aggregation had to be made; for instance, GTFP in 1973-77 was calculated by (1 + rate of productivity increase in 1973) × (1 + rate in 1974) × ... × (1 + rate in 1977). Two industries, textile and transportation equipments, are subdivided by Kuroda into textile and apparel, and motor vehicles and other transportation equipments, respectively. The weighted averages were obtained for our GTFP by using the value added in the beginning year of each period as the weights.

GRVE: The rate of increase in value added per person engaged in establishments with ten or more persons engaged (Source: Census of Manufactures, Ministry of International Trade and Industry) deflated by wholesale price index (Source: Price Indexes Annual, the Bank of Japan) except for printing and publishing in which the consumer price index for newspaper (Source: Annual Report on the Consumer Price Index, Statistics Bureau, Prime Minister's Office) was used as the deflator.

GIND: For printing and publishing, the rate of increase in the value of shipments (Source: Census of Manufactures) deflated by the consumer price index for newspaper (Source: Annual Report on the Consumer Price Index). For any other industry, the rate of increase in the index of industrial production (Source: Annual Report on the Indexes of Industrial Production, Ministry of International Trade and Industry).

GWPI: For printing and publishing, the rate of increase in the consumer price index for newspaper; for others, the rate of increase in wholesale price index. Sources: As listed for GRVE.

RD: Intramural expenditure by companies on R & D as a percentage to sales, averaged over the first two years of each period. Source: Report on the Survey of Research and Development in Japan, Statistics Bureau, Prime Minister's Office.

XRD: Sources: Report on the Survey of Research and Development in Japan, and Input-Output Table, Administrative Management Agency. The input-output tables of 1960, 1970 and 1975 were used to calculate XRD in 1960-66, 1966-73 and 1973-77, respectively.

UNI: The number of membership in labour unions (Source: The Survey of Labour Unions and Federations, Ministry of Labour) as a percentage to the number of persons engaged (Source: Census of Manufactures).

ADV: The percentage of advertising expenditures to sales of listed companies with a paid-in capital of a billion yen or more. Source: The Financial Statements of Principal Enterprises, the Bank of Japan.

BIG: Source: Census of Manufactures.

GKE: The rate of increase in total value of tangible fixed assets at the end of year divided by the number of persons engaged. Source: Census of Manufactures.

APPENDIX B. INDUSTRIAL CLASSIFICATION AND DATA ON THREE VARIABLES

	1960-66			1966-73			1973-77		
Industry	GTFP	GIND	RD	GTFP	GIND	RD	GTFP	GIND	RD
Food	-.0789	1.834	.335	-.0013	1.406	.395	.1474	1.028	.470
Textile & Apparel	.0600	1.594	.590	-.1839	1.574	.580	.1776	.888	.730
Paper	.1149	1.858	.355	.0707	1.938	.465	-.0263	.952	.565
Printing & Publishing	-.0906	1.884	.235	.0377	1.592	.215	-.1322	.976	.395
Chemical	.1658	2.026	1.565	.3182	2.463	1.830	.0731	1.052	2.235
Petroleum & Coal	-.1190	2.524	.255	.0901	2.736	.205	.1755	.960	.215
Rubber Products	.1802	1.570	.970	-.0190	2.155	1.135	.0358	1.004	1.650
Stone, Clay & Glass	.0691	1.738	.695	.1913	2.036	.870	.0314	.908	1.015
Iron & Steel	.0533	2.104	.485	.1018	2.582	.600	.0959	.888	.935
Nonferrous Metal	-.1271	1.840	.675	.1536	2.575	.990	-.0438	.952	.895
Metal Products	.0941	1.966	.505	.2608	2.799	.745	.0535	.932	.920
Machinery	-.0196	1.918	.770	.2281	3.163	1.040	.1983	.872	1.665
Electrical Equipment	.1104	2.278	1.915	.4540	3.863	2.415	.3946	.936	3.530
Transportation Equipment	-.0091	2.926	1.095	.2331	1.924	1.310	.2367	1.004	1.935
Precision Equipment	.2335	2.206	1.280	.1960	2.057	1.495	.3513	1.692	2.595

APPENDIX C. ESTIMATION RESULTS WITH THE ALTERNATIVE OUTPUT GROWTH VARIABLE

Estimated results of the models with the rate of growth of real value added, GRVA, as the output growth variable in place of GIND are in Tables 5, 6 and 7 (see footnote 4). These findings are comparable with the results in the text as follows:

In 1960-66, the effect of RD is now insignificant and in some cases with a wrong sign. On the contrary, the coefficient of GRVA is positive and in some cases significant, somewhat suggesting learning effect. However, the coefficient of GWPI on GRVA is positive in disagreement with the hypothesized price effect, denying the multiplicative interaction of learning effect and price effect.

In 1966-73, both learning effect and price effect are significant with expected signs as was the case in the text, implying the importance and robustness of these two effects and the interaction between them during this period. Different from the result in the text is the effect of RD on labor productivity increase, which is now positive and significant even after learning effect is controlled in the TSLS model; as in the text, however, both coefficient of RD and its t-value decrease as the simultaneity of learning effect and price effect are taken into consideration.

In 1973-77, the effect of RD is still positive but now insignificant. As if to compensate this, significant learning effect and price effect are found with respect to labor productivity increase. It is thus speculated that as the volume of real value added accumulates, labor productivity increases, which in turn relatively decreases the price and enhance the increase in real value added. Why this effect took place in this period only with respect to GRVE and GRVA is not known.

In sum, when output growth is measured by the rate of increase in real value added in place of that in the index of production, (i) learning effect and price effect, and their multiplicative interaction are still significant in the period 1966-73, (ii) learning effect is now of some importance in the other two periods as well, but (iii) the effect of research intensity is now less obvious in 1960-66 and 1973-77.

TABLE 5. ESTIMATION RESULTS -- 1960-66

		Variables									
MODEL	METHOD	GTFP/GRVE	GRVA	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
2	OLSQ	dep	.1787[c] 1.9240		.07168 1.1053	.1188 .3352	.0003611 .1996				.3457
4	TSLS	dep	.3731 1.4484		-.001984 .0169	.09547 .2242	.001735 .6377				
			dep	.3912 .2477				.1643 1.6760			
		-.8500 1.6210		dep		.04915 .0805			-.002039 .9774		
2'	OLSQ	dep	.6483[a] 5.0714		-.1514 1.4307	.01322 .0277	.007488[b] 2.4911			-.2623[c] 1.9722	.6839
4'	TSLS	dep	.8258[b] 3.0643		-.2340 1.4791	-.02205 .0417	.009229[b] 2.3035			-.3036[c] 1.9462	
			dep	1.0585 .6191				.1964 1.7409			
		-.4355[c] 1.9952		dep		-.02021 .04252			-.002463 1.4829		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 2 or 4, and is GRVE in Model 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.

TABLE 6. ESTIMATION RESULTS -- 1966-73

MODEL	METHOD	GTFP/GRVE	GRVA	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
		Variables									
2	OLSQ	dep	.1002[b]		.1730[a]	-.4216[c]	-.001936				.6979
			2.2864		3,4217	1.9543	1.4012				
4	TSLS	dep	.1365[c]		.1527[b]	-.3887	-.002251				
			2.2133		2.6656	1.7188	1.5277				
			dep	-3.8033[a]				-.2627[a]			
				7.3222				3,2428			
		-.8508[b]		dep		-.08491			-.003680[c]		
		2.9972				.2665			1.8570		
2'	OLSQ	dep	.3107[b]		.1506	-.4800	.003496			.4403[c]	.7995
			3.1962		1.0221	1.1214	1.1122			1.9117	
4'	TSLS	dep	.2759[b]		.1837	-.4974	.003480			.4780[c]	
			2.3601		1.1459	1.1507	1.0991			1.9749	
			dep	-3.8726[a]				-.2679[a]			
				7.9067				3.3205			
		-.5073[a]		dep		-.4381			.0004414		
		3.4008				1.3697			.1777		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 2 or 4, and is GRVE in Model 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.

TABLE 7. ESTIMATION RESULTS -- 1973-77

		Variables									
MODEL	METHOD	GTFP/GRVE	GRVA	GWPI	RD	XRD	UNI	ADV	BIG	GKE	R^2
2	OLSQ	dep	.2029		.08016	-.1893	.0006655				.3098
			.8066		1.5062	.6256	.3457				
4	TSLS	dep	-.2060		.1414	-.03429	-.001064				
			.3570		1.4694	.0879	.3505				
			dep	-.4268[a]				.06176			
				3.4469				1.2019			
		-1.4210		dep		-1.0496			-.001764		
		.9219				.8289			.2073		
2'	OLSQ	dep	.8128[a]		.04806	.1935	-.001499			-.1779	.9213
			5.6644		1.6743	1.2061	1.4244			.7917	
4'	TSLS	dep	.8250[a]		.04631	.1895	-.001462			-.1709	
			3.9509		1.2874	1.1280	1.2755			.7080	
			dep	-.4503[a]				.05935			
				3.5898				1.1178			
		-1.5751[a]		dep		.1803			-.002237		
		3.6096				.2257			.5001		

Notes: In the upper row are the estimated coefficients and in the lower row, the t-values. a indicates significance at 1 percent level, b, at 5 percent level, and c, at 10 percent level. The productivity growth variable is GTFP in Model 2 or 4, and is GRVE in Model 2' or 4'. dep indicates the dependent variable. R squared has been adjusted for degrees of freedom.