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**ABSTRACT**

The study focuses on the influence of labor, capital, R&D, technological knowledge, and other factors influencing labor productivity in different manufacturing industries. The study also examines the competitiveness of these manufacturing industries in the Japanese market.

The results indicate that labor productivity is high relative to capital productivity in most of the Japanese manufacturing industries. Our results show that the quality of capital (e.g. advanced technology) is generally more important to increasing productivity than the quantity of capital. These findings would imply that workers in Japanese manufacturing industries are using capital of high quality, not of large quantity. Along these lines Japanese firms seem therefore to be trying to assess how to make production more efficient and how to improve the quality of products.

The results of this study also show that R&D in Japan is significantly important for aiming not only at the improvement of product technology in the food, spinning, textile, paper products, electrical machinery and equipment, and communication equipment industries, but also at that of process technology in the chemicals, drugs and medicines, petroleum products, machinery, motor vehicles, and transportation equipment industries. The study finds that, while the high turnover rate of technology unfavorably affects electrical machinery, electrical equipment, communications equipment, chemicals, drugs and medicines, and petroleum products industries, the rest of the manufacturing industries enjoy a productive stock of technological knowledge. Despite the fact that Japanese manufacturing industries face stiff competition in domestic product markets, the industries may not be as price competitive in the world market as considered.

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## I. Introduction

Japan has become the United States' principal competitor in many different industries. Its remarkable record of labor productivity growth is often attributed in large part to the high quality of its labor and also to the effects of stock of capital and R&D on labor productivity. The average annual growth rate of output per man-hour in manufacturing during the periof of 1950-1973 was about ten percent in Japan, while the rate was about three percent or less in the United States. In the years after the first oil crisis to 1987, growth rates were about 5.5 percent in Japan and 3 percent or less in the U.S.[1] Japanese productivity in the 1980s did not recover to the level attained in pre-oil crisis. Yet the productivity in Japan was nearly two times higher than that in U.S. How is Japan able to maintain its high labor productivity? What is behind it?

There are a number of studies addressing the facts of the recent productivity slowdown in the United States. Baily (1981) observes the slow rate of technological change and obsolescence of existing capital stock. The study by Griliches (1986) on U.S. manufacturing firms during the 1970s shows that privately financed

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[1]These figures are obtained from Table 1 in Griliches (1988), p. 10. The similar results are also obtained from Table 50 in Monthly Labor Review, Vol. 13, No. 4, April 1990, p. 98. The average annual growth rates of output per man-hour in manufacturing from 1973 to 1988 (or 1987) are as follows: United States (2.6 percent), Canada (2.1 percent), Japan (5.5 percent), Belgium (5.1 percent), Denmark (2.2 percent), France (3.6 percent), Germany (3.2 percent), Italy (4.6 percent), Netherlands (4.2 percent), Norway (2.2 percent), Sweden (2.8 percent), and United Kingdom (3.2 percent).

research and development (R&D) expenditures have significantly larger effect on productivity than federally financed one. Bernstein and Nadiri (1988) find the complementarity of R&D and physical capital that affects productivity growth. The result of Monsfield (1988) shows the importance of process technology in R&D which has been neglected in the United States. On the other hand, Olson (1988) and Jorgenson (1988b) stress that a decline in sectoral productivity growth has its source in the rise in energy prices, i.e., higher oil prices.

In comparison, we cam refer to a few of the many studies which seek to accunt for Japanese labor productivity. Norsworthy and Malmquist (1983) focus on the contribution of labor, capital, energy and materials to the productivity of manufacturing industries in the U.S.and Japan, and find that productivity growth in Japan is attributed to the growth of capital stock. Jorgenson (1988a) compares the impact of external shocks, namely the oil crisis, on technological change and productivity growth in U.S. industries with similar impact on Japanese industries, and finds direct linkage between energy prices and the slowdown in the rate of technological change in 1970s. Odagiri and Iwata (1986) find the effects of research effort and of learning on productivity. Mansfield (1988) states that Japanese firms have the advantage of adaptation and improvement of existing technology through R&D while Japanese firms neglect basic research. Goto and Suzuki (1989) find the significant effects of the stock of technological knowledge to be around 40 percent (i.e., the rate of return on net R&D investment) in Japanese manufacturing industries. A large number of these studies mainly focus on the aggregated manufacturing industries. In this paper we explicitly explore sources of productivity in different manufacturing industries, since we consider that factors enhancing productivity have differential influences in specific manufacturing industries.

In the face of expected circumstances during the next decade, such as an aging labor force and declining labor force growth due to slow population growth in Japan, it is obviously important from both the firm's and the government's viewpoints to seek new and better ways to improve labor productivity, e.g., making more efficient use of workers and introducing labor-saving innovations. Thus, for further insight into sources of improved productivity, we address the following issues in this paper: (1) What are the factors influencing labor productivity in different manufacturing industries? (2) What degree of competition faces foreign producers who seek to enter Japanese markets? (3) What are the policies necessary to maintain high productivity growth?

In answering the above issues, our study differs from previous studies. First, we specifically focus on "labor" productivity rather than on total factor productivity. Second, we use an optimization procedure to derive our structural model. Third, by going through the optimization procedure, we explicitly incorporate the price of products in our structural model, which enables us to observe the market competitiveness of each manufacturing industry. Finally, by following Goto and Suzuki (1989), our model takes into account the influence of the stock of technological knowledge possessed by a given industry and the spillover effects through goods bought from other industries.

The next section of this paper presents an analytical framework. Section III discusses the empirical results and our findings. In section IV, we summarize our findings and discuss some of their implications for government policies. Then we conclude our paper in section V.

## II. Analytical Framework

Let us assume that profit $\pi$ per period of time is defined to be the difference between the total revenue, TR, a firm receives and the total costs, TC, (labor cost, capital cost, and intermediate input cost) that it incurs during the period:

$$\pi = TR - TC = TR - (wL + rK + IC) , \ldots\ldots (1)$$

where w and L denote wage rate and number of working hours, respectively; r and K represent rental cost of per unit of capital and quantity of capital stock, respectively; and IC is intermediate input cost. Equation (1) is also written as:

$$\pi = VA - (wL + rK) , \ldots\ldots (2)$$

where VA (=TR - IC) is value added per period of time. Maximizing profit with respect to labor input will give:

$$\frac{\partial \pi}{\partial L} = \frac{\partial VA}{\partial L} - W = 0 \ldots\ldots (3)$$

The above equation indicates that the profit maximizing condition requires the marginal value added of labor to equal the wage rate.

Let us assume the production function for the firm takes an extended Cobb-Douglas form[2]:

$$Q=AL^{\alpha 1}K^{\alpha 2}RD^{\alpha 3}X^{\alpha 4}, \ldots\ldots (4)$$

where Q is the output per period of time; A and $\alpha$'s are constant; RD is research and development (R&D); and X is a vector of other factors of production. By differentiating Q with respect to labor and multiplying the marginal product of labor by a unit price of the product, P, we substitute the value of marginal product of labor for W in equation (3) and have the following:

$$\frac{\partial VA}{\partial L}=A\alpha_1 L^{\alpha 1-1}K^{\alpha 2}RD^{\alpha 3}X^{\alpha 4}P, \ldots\ldots (5)$$

where $\partial VA/\partial L$ is the marginal value added of labor.[3] To make the above result operational for our study, we use instead an average value added, V, i.e., value added per man hour which we call a labor-productivity equation, for the marginal value. The modified equation is as follows:

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[2]A translog production function will be also useful for our productivity study. Our data limitation, however, does not allow us to estimate the effects of various factors, as included in our Cobb-Douglas production function, on productivity by using a translog production function.

[3] The marginal value added of labor will correctly measure the marginal productivity of the primary factor (here, labor input) if each intermediate input satisfies one of three conditions: (1) intermediate inputs are used in fixed proportions to output, Q; or (2) the relative prices of intermediate inputs are constant; or (3) the original output production function is functionally separable into the intermediate inputs and all primary inputs (See Bruno 1978, p. 10).

$$V=A^{*}L^{\beta_1}K^{\beta_2}RD^{\beta_3}X^{\beta_4}P, \ldots\ldots (6)$$

where $A^* = A\alpha_1$ and $\beta_1 = \alpha_1 - 1$.

We assume the above labor-productivity relation also to hold in a given digit manufacturing-industry level to which the firm belongs and we treat P as it varies across different manufacturing industries within the given digit industry. Finally, our industry model is in a logarithmic form (for brevity, the industry and time subscripts are deleted):

$$\ln V=\ln A^{*}+\gamma_1\ln L+\gamma_2\ln K+\gamma_3\ln RD+\gamma 4\ln X+\gamma_4\ln P+u, \ldots\ldots (7)$$

where $\gamma_1 < 0$ if the law of diminishing marginal productivity prevails; and u is a random residual term.[4] Aside from the conventional productivity studies starting directly with a structural model through an application of an extended Cobb-Douglas

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[4] There are three kinds of variations in the residual term, u, in equation (7): cross-section and time variations in addition to a purely random normal disturbance. We adopt two different specifications that allow for heteroscedasticity and autocorrelation in our model. The first specification is a variance component model. The basic assumption is that the regression disturbance is composed of three independent components--one component associated with time, another associated with the cross-sectional units, and the third varying in both dimensions. To handle this problem, we use the method proposed by Fuller and Battese (1974). The second specification is the cross-sectionally correlated and time-wise autoregressive model which assumes mutually correlated cross-sectional units. Here we use the method proposed by Parks (1967). The advantages and disadvantages are comprehensively discussed by Kmenta (1986).

function,[5] our study has some basic noteworthy points. The first is that a value added approach is a natural vehicle for aggregation across industries. For the second point, we specifically focus the effects on labor productivity rather than total factor productivity of various factors of production. The third point is that, like Schankerman and Nadiri (1984) and Chavas and Cox (1990), we use an optimization procedure to get a structural model which is theoretically plausible. Finally by going through the optimization procedure, we explicitly include a variable on the price of product in our structural model. This enables us to observe the market competitiveness in each Japanese manufacturing industry. The rationale for including most of the variable in our model is found in the literature of productivity studies. Along with the conventional factors such as labor, capital and R&D, our model includes variables on technological knowledge, intermediate/R&D, investment/R&D, price of product, and quality of capital.[6] Goto and Suzuki (1989) also demonstrate the significant impact of spillover effects on the total factor productivity of a given industry, of embodied R&D in the intermediate and investment

[5]See Nortworthy and Malmquist (1983), Griliches and Mairesse (1984 and 1985), Griliches (1986), Jaffe (1988), Mansfield (1980 and 1988), and Goto and Suzuki (1989) for applications of Cobb-Douglas production function.

[6]Baily (1981) argues that stocks of technology affect productivity differently from flows of technology. Technological knowledge, a stock concept, reflects the know-how and accumulation of skill and knowledge possessed by a firm (or an industry) at a certain time. The knowledge depreciates and becomes obsolete due to developments in better technologies as well as new products and so on. Our variable on technological knowledge is the same as the definition on the stock of technological knowledge in Goto and Suzuki (1989).

goods purchased from other industries.[7] To examine the competitiveness of product markets, price of product, P, in each manufacturing industry is included in our labor productivity equation. We use a price index of capital, $P_k$, as a proxy measure for quality of capital, consider it to reflect a vintage of capital to some degree and expect its positive effect on labor productivity.[8] Unexpected external shocks affect manufacturing productivity and lead to changes in the use of factor inputs: the oil crisis affected the evolution of technology,thus leading to changes in the share of energy and resource inputs in total inputs. A dummy variable, D, is used to proxy external shocks, i.e. the oil price hikes, affecting the behavior of manufacturing industries, and consequently to identify biased technological changes in manufacturing behavior as mentioned by Jorgenson (1988a).

The data used in this study pool cross-sectional and annual time-series three digit manufacturing industry data for the period

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[7] Our variables on the intermediate/R&D and investment/R&D slightly differ from that of the intermediate R&D and investment R&D in Goto and Suzuki (1989). They define the intermediate R&D and investment R&D as the inflow of the total embodied (i.e., intermediate and investment together) R&D of supplying industries relative to the value added of the using industry. We separate the intermediate and investment R&Ds, each of which is relative to the R&D expenditure of the using industry. The main reason for not duplicating their variable is that, while accepting their results, we try to identify which manufacturing industry can be dependent for its technology on suppliers' R&D embodied in intermediate or investment goods.

[8]It may be true that an increase in demand for capital in a short run possibly affect the demand curve upward along the supply curve. However this demand-pull effect on the price of capital will be offset by sifting the supply curve toward right with producing more capital. Thus,this type of demand-pull effect will be less severe in the long run to observe the relationship between per man hour productivity and the price of capital as a proxy measure for quality of capital.

of 1975 through 1982. We perform the analysis separately for seven different manufacturing industry aggregates, as well as one for all the seven industry aggregates together (see Table 4 for the composition of the industry aggregate).[9]

[9]Data on R&D, technological knowledge, intermediate R&D, and investment R&D are kindly provided with permission to use by Akira Goto of Hitotsubashi University and Kenji Umetani of the Economic Planning Agency (EPA) of the Japanese Government. The Data are also published in Keizai Bunseki (in Japanese), Vol. 103, (September 1986), published by the EPA.

## III. Empirical Results

The regression estimates for equation (7) are reported in Tables 1 through 3. All variables are in natural logarithms. As an overview, the two estimation procedures, i.e., the Fuller and Battese (F & B) method, and the Parks method, show qualitatively and quantitatively similar results. Their estimated coefficients are theoretically consistent except for a few results.

First, let us see the estimated coefficients of the labor variable in each industry (Tables 1 - 3). The coefficients are negative as expected as a result of the diminishing marginal productivity of labor. A 1 percent increase in labor (increase per man hour) creates about a 0.5 percent increase in per man value added in industry D (machinery products), or more for most of the other industries: about a 0.7 percent increase for industry A (food, spinning, textile, paper and pulp products) and industry B (chemicals, oil and fat, drugs and medicines, and petroleum products) and industry E (electrical machinery, electrical equipment and communications equipment products); and about a 0.9 percent increase for industry G (precision instrument products).[10] The smallest value which remains statistically significant is about a 0.1 percent increase in the value added in industry C (iron and steel, and metal products). In terms of the relative share of labor, labor's contribution is the most prominent for industry G

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[10]To retrieve the value added elasticity of labor, $\partial \ln V/\partial \ln L = \partial \ln[(TR - IC)/L]/\partial \ln L = \partial \ln(TR - IC)/\partial \ln L - 1 = \gamma_1$, where $\gamma_1$ is an estimated coefficient on the labor variable. Hence, $\partial \ln(TR - IC)/\partial \ln L = \gamma_1 + 1$. Also, the obtained values may be considered as the relative share of total product accruing to labor in each respective industry (see equation 4).

and the least for industry C among the seven industries.

Looking at the effects of stock of capital on labor productivity, i.e., per man hour value added, a 1 percent increase in capital increases the value added by nearly 4 percent in industries C (iron, steel, et al.) and E (electrical machinery, et al.), and by about 2 percent or less in industries A (food, spinning, et al.), D (machinery) and G (precision instrument, et al.).[11] In terms of the relative share of total product accruing to capital in comparison with that of labor, although Jorgenson (1988a) emphasizes the importance of capital to Japanese productivity, our results of this study are not necessarily congruent with his finding. That is, the relative share of labor in various Japanese manufacturing industries is substantially higher than that of capital except in industry C.[12] Accordingly we are inclined to believe that labor in Japanese manufacturing industries is highly efficient, i.e., an indication of the high quality of workers.

Next, we consider the implications of the results in the allocation of Research and Development (R&D) resources between projects, aiming to establish whether Japanese R&D is product-technology- or process-technology-oriented. The estimated coefficients on the R&D variable are statistically significant for

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[11]A puzzling result is the negative value on the capital variable in industry F (motor vehicles, ship building and transportation equipment), for which we do not have an adequate explanation.

[12]The relative labor share for industry C is $\gamma_1 + 1 = -.857$ (or $-.843$) $+ 1 = .143$ (or .157), while the capital share is $\gamma_2 = .424$ (or .399).

industries A, B, D, E, F and all manufacturing industries together.[13] Our empirical results are not necessarily clear as to whether Japanese R&D is product-technology- or process-technology-oriented. Among the industries with the statistically significant coefficients, industries A and E may be classified as a group of product-technology-oriented industries, whereas industries B, D and F may be grouped as process-technology-oriented industries. As for the marginal effect, an increase in R&D by one thousand yen raises per man value added by about one thousand yen in industry A, one thousand and five hundreds in industry B, one thousand and six hundreds in industry D, five hundreds in industry E, and one thousand and four hundreds in industry F.[14] The impact of R&D on per man value added is therefore highly efficient in industries B, D and F.

The estimated coefficients of technological knowledge indicate another side of technology used by firms in manufacturing industries. The stock of knowledge is constantly replaced by new technological knowledge and quickly becomes obsolete as a result of the diffusion of knowledge to other firms or industries. The statistically significant negative coefficients of technological knowledge in industry B (chemicals, drugs and medicines, and petroleum products) and industry E (electrical machinery, electrical equipment, and communications equipment) seem to be indicative of a high turnover rate of technology. On the other hand, industries A, C, D, F and G enjoy productive stocks of

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[13]Mansfield (1988) shows that Japanese R&D is process-technology-oriented.

[14]The marginal effects are evaluated at the sample means.

knowledge. A 1 percent increase in the stock of technological knowledge creates about a 0.13 percent increase in per man value added in the food, spinning, textile and paper industries (industry A); a 0.37 (or 0.44) percent gain in the iron, steel and metal industries (industry C); a 0.26 percent increase in the machinery industry (industry D); a 0.25 percent gain in motor vehicles, ship building and transportation equipment industries (industry F); and a 0.04 (or 0.05) percent increase in the precision-instruments industry (industry G). The results show that the stock of technological knowledge more favorably affects heavy industries (C, D and F) than it does the light industries (A and G).

Turning our attention to the spillover effects of the distribution of R&D among manufacturing industries (i.e., the intermediate/R&D and investment/R&D variables in Tables 1 through 3), a negative coefficient on the intermediate/R&D variable implies that the industry can not be dependent on the R&D (embodied in intermediate goods) of supplying industries and need explorative opportunities for technological advance by their own R&D effort. A 1 percent increase in the R&D ratio lowers the value added by a 0.13 (or 0.14) percent in industry A and by a 0.21 (or 0.31) percent in industry B. The negative effect of the ratio on the value added in industry F (motor vehicles, ship building and transportation equipment) is about 0.43 percent, which is twice as large as the values in industries A and B.

As for the positive coefficient on the intermediate/R&D variable, industries E (electrical machinery, electrical equipment, and communications equipment products) and G (precision instrument products) appreciate the benefits. These two industries can be dependent for their technologies on the R&D supplying industries, since the necessary technology for their own industries can be diffused through the intermediate goods. The supplying industries are comparatively advantageous in producing the technology.

Another type of spillover effect is examined by the investment/R&D variable. Rapid technological progress and intense competition tends to encourage firms to hold on to their technological innovations. However, if the technology is diffused through the investment goods to using industries, there would be little incentive to engage in exploring new technology by their own. The negative coefficients indicate that the technology transferred from the supplying industries through investment goods is not highly substitutable for the using industries (firms). To improve their labor productivity, industries E and G, according to our results, need relatively more their own investment-oriented R&D. On the other hand, the positive coefficients on the investment/R&D variable in industries A (food, spinning, textile, and et al), B (chemical, oil and fat, and et al.), and F (motor vehicles, ship building, and et al.) are observable as the positive spillover effects of technology.

Our overall results of the intermediate/R&D and investment/R&D variables in seven classified industries suggest that, when the variables are treated separately, these factors do not necessarily have a positive spillover effect on labor productivity of the input-using industry. Although our results do not negate one found by Goto and Suzuki (1989), their observed result of the intermediate and investment R&D combined together masks to some extent the characteristics of the input-using manufacturing industry.

In examining the market condition of each manufacturing industry, we focus on the elasticity of per man hour value added with respect to its product price (see the estimated coefficients on variable P in Tables 1 though 3). This method of measurement would reveal the level of competitiveness in Japanese markets and the degree of difficulty facing foreign producers trying to enter the markets. The negative coefficients indirectly show rather an elastic demand curve in the market.[15] Put differently, the firms in the industry are facing a relatively price-competitive product market in Japan. By cautiously interpreting the values of the estimated coefficients, industry E (electrical machinery, electrical equipment, and communications equipment) and industry F (motor vehicles, ship building, and transportation equipment) can be viewed in fiercely price-competitive markets. On the other hand, the least price-competitive markets seem to be food,

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[15] By knowing an inverse relationship between the total revenue and its product price if the demand for product is elastic in a particular industry, we are inclined to expect a negative coefficient on the product price variable, P, if the demand curve in a particular industry is elastic. However, in a strict sense, $\partial V/\partial P = \partial[(TR-IC)/L]/\partial P = \{L[y+P(\partial y/\partial P) - \partial IC/\partial P] - (\partial L/\partial y)(\partial y/\partial P)[TR-IC]\}/L^2$, where V, TR, IC and Y are per man value added, total revenue, intermediate cost and output respectively. Whether $\partial V/\partial P$ is either negative or positive is not so obvious, even if $y+P(\partial y/\partial P) = y(1 - e) < 0$ where e, i.e., a price elasticity of demand for product, is greater than one in absolute value. Operationally we can consider the following two cases: (1) under a rather stringent restriction such as $\partial IC/\partial P = \partial L/\partial P = 0$, $\partial \ln V/\partial \ln P = (1 - e)/(1 - R) = \gamma_4$, which is the coefficient on the P variable, where R = IC/TR. $\partial V/\partial P < 0$ as $e > 1$; and (2) under a mild restriction of $\partial IC/\partial P = 0$, $\partial \ln V/\partial \ln P = [(1 - e)/(1 - R)] - (e/\alpha_1) = \gamma_4$, where $\alpha_1$ is the partial elasticity of output with respect of labor input. While being aware that the size of e does not solely determine the value of $\gamma_4$, our discussion in the text is made according to case (1) and additionally R is treated the same across the seven industries.

spinning, textile, paper, iron, steel and metal products industries such as industries A and C in Table 1. We notice that recently these industries (A and C) are not in a strong position in the international market and that Japan seems to have trade and non-trade barriers for these industries, as the U.S. government often points out to the Japanese government. It is not surprising that our results are consistent with the rather negative stance of Japanese manufacturing toward an entry by foreign manufacturing products into the Japanese markets.

Next we consider the effect of the quality of capital, $P_k$, on labor productivity. The statistically significant positive coefficients show a better quality of capital to be considered a significantly important factor to the improvement of productivity in industries A, C, E, F and G. Especially in electrical machinery, electrical equipment, and communications equipment industries (industry E), motor vehicle and transportation equipment industries (industry F) and precision instrument products industries (industry G), installing new vintages (better quality) of capital has much stronger impacts on their per man value added than having more capital in quantity (compare with the coefficients on the variable of "capital" in Tables 1 through 3). These results accordingly reveal that the quality of capital is generally more important to increasing productivity than the quantity of capital in Japanese manufacturing industries.

Finally, we consider how an external shock influences the labor productivity behavior of manufacturing industries. Using a dummy variable, D, we differentiate the period during and after the oil crisis, i.e. 1979 - 1982, from the period before. We observe statistically significant positive coefficients for industries A, B, E and G, with a negative one for industry F. Jorgenson (1988a) characterizes the behavior of Japanese industries as energy users and points out the reduction in the rate of technical change during the oil crisis. Our empirical study however does not strongly support his hypothesis. During the period of 1979-1982, labor productivity is higher in industries A, B, E, and G. The impact of the oil shock through technological changes on labor productivity in industry B (chemicals, drugs and medicines, and petroleum products) is the largest, while the positive influence is the smallest in industry A (food, spinning, textile and paper products). Only the result for industry F (motor vehicles, ship building and transportation equipment) is consistent with Jorgenson's hypothesis. We consequently consider the technical changes during the period of the oil crisis to be rather labor-stimulant and probably energy-saving.

## IV. Summary and Policy Implications

In this study we shed light on the influence of various factors on labor productivity, namely per man value added, in various manufacturing industries in Japan. We have attempted to examine the behavior of manufacturing industries and their product market conditions by using pooled cross-sectional and annual time-series three digit manufacturing industry data for the period from 1975 to 1982.

Our empirical results are as follows. Labor productivity is the highest in precision products industries (grouped as industry G), while labor is less productive in food, spinning, textile, paper and pulp products industries (grouped as industry A), chemicals, oil and fat, drugs and medicines, and petroleum products industries (grouped as industry B), and electrical machinery, electrical equipment and communications equipment (grouped as industry E).

Capital is highly efficient in iron and steel, metals, and wire and cable products industries (grouped as industry C) and industry E. The electric machinery, electric equipment, and communications equipment industries are both capital and labor equally efficient. Machinery products industries (engine and turbine, construction and mining, metalworking: grouped as industry D), industries A and B are more labor efficient than capital efficient.

Among the industries studied, the quality of capital is generally more important to increasing productivity than the quantity of capital. The quality of capital is more important in electrical machinery, electrical equipment, communications equipment, motor vehicles, transportation equipment and precision products industries than other manufacturing industries in Japan. Our findings imply that workers in Japanese manufacturing industries are using capital of high quality, not of large quantity. Japanese firms seem therefore to be trying to assess how to make production more efficient and how to improve the quality of products.

In order for workers in the manufacturing industries to work with the high quality of capital, one would emphasize the importance of the quality of the workers, as indicated by human capital developed through education and on-the-job training. The government should encourage more productive use of workers by adopting an industrial policy that would seek not only to save on the use of labor, but also to upgrade the quality of workers. An improvement in the quality of workers, namely improvement in human capital through education and skill training, would be an important way to cope with a declining labor force in an aging society.

We observe that Japanese manufacturing industries generally increase labor productivity by research and development (R&D) as well. The allocation of R&D resources aims at improvement of product technology in food, spinning, textile and paper products industries (industry A), and electrical machinery, electrical equipment, and communications equipment industries (industry E). Chemicals, drugs and medicines, and petroleum products industries (industry B), machinery products industries (industry D), and motor vehicles and transportation equipment industries (industry F) focus instead on improving process technology. The stock of technological knowledge depreciates, and quickly becomes obsolete in some industries. The high turnover rate of technology unfavorably affects chemicals, drugs and medicines, and petroleum products industries (industry B) and electrical machinery, electrical equipment, and communications equipment industries (industry E). The rest of the manufacturing industries are enjoying a productive stock of technological knowledge.

The spillover effects through intermediate and investment goods from supplying manufacturing industries depend on characteristics of the using manufacturing industries. Electrical machinery, electrical equipment, and communications equipment products industries (industry E) and precision products industries (industry G) receive positive spillover effects from R&D embodied in intermediate goods, while food, spinning, textile, and paper products industries (industry A), chemicals, drugs and medicines, and petroleum products industries (industry B), and motor vehicles, and ship building and transportation equipment industries (industry F) enjoy positive externality from supplying industries' R&D embodied in investment goods.

We find most of Japanese manufacturing product markets to be highly competitive. From our estimated coefficients on the product price variable, Japanese manufacturing industries can be categorized into three groups in terms of competition in the domestic market and the competitiveness of manufacturing industries in the world market. In the first group, the most competitive markets are in electrical machinery, electrical equipment, and communications equipment industries (industry E) and motor vehicles, ship building, and transportation equipment industries (industry F). These industries face fiercely competitive product markets. As we noted, these industries are relatively aggressive in the world market and have penetrated deeply into the U.S. market.

As for as the second group, the less competitive markets are chemicals, drugs and medicines, and petroleum products (industry B) and precision products (industry G), although these industries have relatively elastic product demand curves in Japan. We remark on the possible price discrimination or quasi-dumping of precision products between Japan and the U.S. markets. Japanese drugs and medicines industries are not yet highly developed in terms of quality of products. It is well known that non-trade barriers exist for drugs and medicines in Japan. Concerning the third group, the moderately elastic demand curves for the domestic product market are for food, spinning, textile, and paper and pulp products (industry A) and iron, steel, and metal products (industry C). We recognize that these industries are not strong in the world market. The food, paper and pulp products, and textile products industries, especially, possess explicit trade barriers in Japan. The iron, steel, metal, and textile industries are confronting the competition of the developing countries' market penetration into the Japanese market. We note that Japanese industries which produce iron, steel and metal products have recently tended to develop high value-added quality products and to diversify their products.

With a few exceptions, Japanese manufacturing industries may not be as price competitive in the world market is conventionally believed, while the industries face stiff competition and elastic demand in domestic product markets. Trade and non-trade barriers supported by the Japanese government reflect the manufacturing industries' position and their efficiency level in the world market. With trade and non-trade barriers being cleared away, if U.S. and European manufacturers raised their efficiency and lowered their costs by increasing labor productivity, the resulting further improvement in their competitive position in the world market would facilitate penetration into the Japanese market.

## V. Conclusion

In Japanese manufacturing industries capital is highly efficient. The efficiency stems mainly from the quality of capital rather than the quantity. R&D enhances labor productivity and the contribution is characterized by two types: product-oriented technology and proces-oriented technology. Three distinct groups with different degrees of competitiveness are found among Japanese manufacturing industries in the domestic market. The most fiercely competitive markets are represented by electrical machinery and equipment industries and the motor vehicles industry. The second group with less competitiveness consists of petroleum, drugs and medicines industries. The least competitive markets are food, paper, and pulp products. The varying degrees of competitiveness suggest the existence of room for foreign manufacturing producers to penetrate into the Japanese market.

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Table 1

Regression Results of the Labor Productivity of Manufacturing Industries

| Independent Variable | Industry A F & B Method | Industry A Parks Method | Industry B F & B Method | Industry B Parks Method | Industry C F & B Method | Industry C Parks Method |
|---|---|---|---|---|---|---|
| Labor | -.254[a] (-4.12) | -.229[a] (-16.12) | -.368 (-1.28) | -.333[a] (-5.79) | -.857[a] (-21.00) | -.843[a] (-46.04) |
| Capital | .095[c] (1.79) | .060[a] (4.65) | .042 (.21) | .053 (1.43) | .424[a] (3.54) | .399[a] (9.93) |
| R & D | .039 (1.13) | .050[a] (11.70) | .015 (.10) | .206[a] (7.80) | -.067 (-.53) | -.028 (-.73) |
| Technological Knowledge | .130[a] (3.19) | .131[a] (14.09) | .107 (.92) | -.164[a] (-4.08) | .370[c] (1.75) | .443[a] (9.17) |
| Intermediate /R & D | -.131[a] (-3.74) | -.141[a] (-19.48) | -.316[c] (-1.71) | -.214[a] (-12.89) | -.044 (-.38) | -.005 (-.09) |
| Investment /R & D | .228[a] (6.36) | .260[a] (31.64) | .372[c] (1.95) | .266[a] (14.38) | .030 (.20) | -.034 (-.39) |
| P | -.410[b] (-2.52) | -.320[a] (-15.05) | -.698[a] (-4.41) | -.631[a] (-10.73) | -.481[c] (-1.93) | -.472[a] (-3.57) |
| $P_k$ | .140[c] (1.95) | .160[a] (9.80) | -.125 (-.42) | -.031 (-.59) | .259 (1.16) | .328[a] (3.09) |
| D | .074[c] (1.96) | .047[a] (11.35) | .230[a] (2.73) | .210[a] (9.86) | .017 (.29) | -.003 (-.13) |
| Intercept | 4.323[a] (4.95) | 3.975[a] (35.87) | 9.492[a] (2.68) | 9.444[a] (26.28) | 3.353 (1.56) | 1.755 (1.20) |
| $\rho_c$ | .0012 | | .0439 | | .0835 | |
| $\rho_t$ | .0007 | | .0000 | | .0000 | |
| $\rho_e$ | .0018 | | .0119 | | .0076 | |
| M.S.E. | .0017 | 1.0400 | .0135 | .7312 | .0068 | 1.1420 |

Note: t-statistics are in parentheses below the estimated coefficients.
[a]Indicates statistical significance at the 1% level.
[b]Indicates statistical significance at the 5% level.
[c]Indicates statistical significance at the 10% level.
$\rho_c$ is the variance component for cross-sections.
$\rho_t$ is the variance component for time series.
$\rho_e$ is the variance component for error.
M.S.E. is the transformed regression's mean squared error.

Table 2

Regression Results of the Labor Productivity of Manufacturing Industries

| Independent Variable | Industry D | | Industry E | | Industry F | |
|---|---|---|---|---|---|---|
| | F & B Method | Parks Method | F & B Method | Parks Method | F & B Method | Parks Method |
| Labor | -.332 | -.491[a] | -.366[a] | -.307[a] | .493 | .162 |
| | (-1.53) | (-4.73) | (-2.27) | (-6.29) | (1.37) | (1.69) |
| Capital | .080 | .154[c] | .432[a] | .349[a] | -.313 | -.584[a] |
| | (.53) | (1.85) | (3.96) | (4.04) | (-1.20) | (-5.22) |
| R & D | .148[c] | .290[a] | -.023 | .098[c] | .059 | .149[b] |
| | (1.77) | (5.71) | (-.33) | (1.98) | (.48) | (2.68) |
| Technological Knowledge | .163 | .266[c] | -.013 | -.168[a] | -.247 | .257[b] |
| | (1.35) | (1.93) | (-.12) | (-3.09) | (-.93) | (2.69) |
| Intermediate /R & D | -.144 | -.148 | .023 | .097[a] | -.103 | -.439[a] |
| | (-.69) | (-1.40) | (.35) | (2.73) | (-.24) | (-5.16) |
| Investment /R & D | .166 | .057 | -.046 | -.156[a] | -.298 | .223[a] |
| | (.75) | (.38) | (-.69) | (-4.47) | (-.77) | (5.92) |
| P | -.178 | -.213 | -1.014[a] | -.470[a] | -1.027 | -3.132[a] |
| | (-.31) | (-.39) | (-6.82) | (-3.82) | (-1.20) | (-8.61) |
| $P_k$ | .286 | .101 | .704[a] | .549[a] | .578 | .923[a] |
| | (.86) | (.75) | (3.75) | (6.87) | (1.50) | (6.34) |
| D | .017 | .024 | .128[a] | .124[a] | -.013 | -.158[a] |
| | (.18) | (.85) | (2.99) | (7.81) | (-.14) | (-4.83) |
| Intercept | 1.811 | .492 | 3.153[b] | 2.056[a] | 5.795 | 14.841[a] |
| | (.71) | (.24) | (2.57) | (2.92) | (1.44) | (9.83) |
| $\rho_c$ | .1796 | | .0702 | | 1.5511 | |
| $\rho_t$ | .0016 | | .0005 | | .0000 | |
| $\rho_e$ | .0087 | | .0017 | | .0084 | |
| M.S.E. | .0101 | .6214 | .0018 | .6428 | .0072 | 1.1430 |

Note: t-statistics are in parentheses below the estimated coefficients.
[a]Indicates statistical significance at the 1% level.
[b]Indicates statistical significance at the 5% level.
[c]Indicates statistical significance at the 10% level.
$\rho_c$ is the variance component for cross-sections.
$\rho_t$ is the variance component for time series.
$\rho_e$ is the variance component for error.
M.S.E. is the transformed regression's mean squared error.

Table 3

Regression Results of the Labor Productivity of Manufacturing Industries

| Independent Variable | Industry G: F & B Method | Industry G: Parks Method | ALL Manufacturing Industries: F & B Method | ALL Manufacturing Industries: Parks Method |
|---|---|---|---|---|
| Labor | .036 (.17) | -.123[a] (-3.62) | -.725[a] (-19.13) | -.474[a] (-9.33) |
| Capital | .105 (.87) | .244[a] (5.12) | .440[a] (11.40) | .314[a] (8.26) |
| R & D | -.081 (-1.07) | -.071 (-1.20) | .124[a] (3.94) | .163[a] (6.11) |
| Technological Knowledge | .051[c] (2.08) | .043[a] (3.82) | .037 (1.08) | -.012 (-.37) |
| Intermediate /R & D | .239[b] (2.45) | .193[a] (3.04) | -.025 (-.68) | -.079[a] (-4.19) |
| Investment /R & D | -.124[b] (-2.60) | -.096[a] (-3.98) | -.005 (-.14) | .064[a] (2.16) |
| P | -.579[a] (-3.07) | -.703[a] (-6.31) | -.657[a] (-8.29) | -.371[a] (-5.12) |
| $P_k$ | .870[a] (3.49) | .851[a] (9.99) | .378[a] (5.40) | .302[a] (9.16) |
| D | .186[a] (3.24) | .130[a] (8.64) | .056[a] (2.67) | .036[a] (2.96) |
| Intercept | .948 (.48) | 1.423[c] (2.01) | 4.080[a] (6.78) | 2.734[a] (5.30) |
| $\rho_c$ | .0597 | | .0603 | |
| $\rho_t$ | .0009 | | .0000 | |
| $\rho_e$ | .0015 | | .0088 | |
| M.S.E. | .0016 | 1.5331 | .0094 | .0688 |

Note: t-statistics are in parentheses below the estimated coefficients.
[a]Indicates statistical significance at the 1% level.
[b]Indicates statistical significance at the 5% level.
[c]Indicates statistical significance at the 10% level.
$\rho_c$ is the variance component for cross-sections.
$\rho_t$ is the variance component for time series.
$\rho_e$ is the variance component for error.
M.S.E. is the transformed regression's mean squared error.

Table 4

Definition of Variables*

| Variable Name | Definition |
|---|---|
| Industry A | Food, spinning, textile, paper and pulp products industry, 48 observations. |
| Industry B | Chemicals, oil and fat, drugs and medicines, and petroleum products industry, 64 observations. |
| Industry C | Iron and steel, metals, and wire and cable products industry, 48 observations. |
| Industry D | Machinery products (engine and turbine, construction and mining, metalworking, textile, office, and general) industry, 72 observations. |
| Industry E | Electrical machinery, electrical equipment and communications equipment products industry, 64 observations. |
| Industry F | Motor vehicles, ship building and transportation equipment industry, 32 observations. |
| Industry G | Precision instrument products (measuring and analytical, physical, optical and lenses, and watches) industry, 32 observations. |
| V | Real value-added per man hour, in million yen (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| Labor | Labor input in thousand man hours (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| Capital | Stock of capital input, in million yen (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| R & D | Real research and development, in million yen (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| Technological Knowledge | Stock of technological knowledge, in million yen (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |

Table T-4 (continued)

| Variable Name | Definition |
|---|---|
| Intermediate /R & D | The ratio of outside industries' R&D in input intermediate materials to own R&D by a particular industry, in million yen (each categorical industry A, B, C, D, E, F or G has own means and standard deviation). |
| Investment /R & D | The ratio of outside industries' R&D in investment materials to own R&D by a particular industry, in million yen (each categorical industry A, B, C, D, E, F or G has own means and standard deviation). |
| $P_k$ | Index of capital price (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| P | Index of output price (each categorical industry A, B, C, D, E, F or G has own mean and standard deviation). |
| D | D=1 is used for observations from 1979 to 1982 and zero otherwise, to differentiate the period of the oil crisis from the rest of period. |

* The statistics are available on request.