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Comments welcome

TECHNICAL PROGRESS AND RETURNS TO SCALE IN JAPANESE MANUFACTURING INDUSTRIES BEFORE AND AFTER THE BURST OF THE 1990 FINANCIAL BUBBLE

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1. Introduction

Japanese economic growth has been minimal since the 1990 burst of a financial bubble.[1] No other developed economy has had such a long spell of non-growth. It is important to empirically explore this no-growth phenomenon and the driving forces for Japan's economy prior to and since the bubble burst.

In the post World War II boom years for Japan, the Japanese economy appeared to be a model worth emulating, and there was considerable interest in special institutional features of firm and government policy for encouraging technical progress (TP) and for helping firms to capture returns to scale (RS). As explained, for example, in Diewert and Nakamura (2002a, 2002b), total factor productivity growth is driven by RS as well as TP (except, of course, when the returns to scale are presumed to be 1 as is customary in many growth and accounting and other studies of total factor productivity that intentionally focus on just technical progress).

We develop measures and empirical estimates for technical progress (TP) and returns to scale (RS) at both the plant (establishment) and firm levels for all of the main Japanese manufacturing industries from the late 1980s through the mid 1990s. This study builds on and makes use of some empirical results for 1964 through the mid 1980s from Nakajima, Nakamura and Yoshioka (1993, 1998) as well as from Yoshioka, Nakajima and Nakamura (1994). As explained in section 2, we also make extensive use of theoretical results in Caves, Christensen and Diewert (1982a, 1982b) as well as other results of Diewert and of Yoshioka referenced in the text). This is work in progress that will allow us to consider a number of hypotheses about the behavior of the Japanese economy as related to TP and RS in the pre and post bubble periods including the impacts of R&D on the different industries.

An underlying hypothesis for this research is that firms make excessive investments in a bubble environment because their choices are guided by bubble-inflated expected returns that fail to be realized, leading to stagnant or declining values of TP. Without technical progress that would warrant growth for the economy as a whole, bubble driven excessive investment will eventually come to an end and the bubble must burst.

We are particularly interested in the behavior of TP for some of Japan's key manufacturing industries such as precision, electrical machinery, transportation (auto) machinery and general machinery observed for the 1980s through the 1990s. These industries drove Japanese economic growth through the late 1980s with what many regard as impressive technological advances and achieved large global market shares for their products. Did these industries perform better than other less globally competitive industries in terms of increases in technical progress? Were returns to scale an important part of these Japanese successes? To

[1] A financial bubble is characterized by significant positive deviations of the expected returns of certain real and financial assets from their fundamental values. The causes of bubbles are not well understood (e.g. Blanchard and Watson 1982; Tirole 1985; and Abel, Mankiew, Summers and Zeckhouser 1989). However, most economists agree there *was* a bubble in the Japanese economy in the late 1980s and that this bubble burst late in 1990 throwing Japan's economy into a no-growth state that has persisted since then.

investigate questions of this sort empirically, we first need estimates of technical progress and returns to scale. We present estimates at both the plant and firm levels for roughly two dozen Japanese manufacturing industries and a succession of 2-year time periods.

At the firm level, TP is affected not only by plant level factors but also by improvements brought about by firm-wide investments in things such as IT, the education of managerial personnel, and the rationalization of the firms' overall workforce. Our hope is that studying TP and RS behavior at both the plant and firm levels will help shed light on the functioning of the Japanese economy in its current no-growth state. The public and firm policies aimed at enhancing technical progress versus returns to scale differ.

According to our estimates, TP for Japanese manufacturing industries declined significantly during the few years prior to the burst of the bubble, a result that is consistent with the postulated effects of bubble driven investment.

Having obtained the estimates presented in this paper for TP and RS at the plant and at the firm levels, we will now proceed to investigate a series of hypotheses about the determinants of TP and RS. We are especially interested in measuring the impact of R&D on TP. This portion of our study is motivated by hypotheses put forward by Griliches (1979)[2] and by results in subsequent studies building on Griliches' 1979 paper including the studies of Griliches and Mairesse (1990) and Odagiri and Iwata (1986) and will incorporate institutional aspects of the treatment of R&D in business accounting that are documented in Nakamura, Tiessen and Diewert (2002).

The organization of the rest of the paper is as follows. In sections 2 and 3, we develop the combined index number-econometric methodology used in this study for estimating technical progress and returns to scale. TP and RS are difficult to separate out by econometric methods alone because firm output and input quantities all tend to grow over time and to be larger for larger firms even in the cross section. The resulting multicollinearity problems become especially vexing when the appropriate choice for the production function is some sort of a flexible functional form, as in this study. In section 4 we present our plant and firm level estimation results. Preliminary implications for policy and further directions for this research are outlined in section 4. Section 5 concludes.

2 Methodology for Estimating Technical Progress and Returns to Scale

We need a methodology that can accommodate a broad range of underlying production structures but that does not require the estimation of large numbers of parameters for variables that tend to be highly collinear in both the cross section and over time.

We begin by considering the concept of returns to scale in the cross section, and then go on to allow for disembodied technical change over successive 2-year time periods. Although the forms of returns to scale and technical progress that we allow for are simplistic, in the empirical

[2] The roles Griliches postulated for R&D underlie theories of endogenous growth theory proposed later in the literature (see, for example, Romer (1990)).

application of our methodology, the estimation is carried out separately at both the plant and firm levels for roughly two dozen industries and for success pairs of years over the 1980s and 1990s. This renders less serious the limitations of the methodology.

2.1 Returns to Scale (RS)

Our methodology presumes that panel data are available for one or more samples of production units (PUs, indexed for each sample by $i = 1,\ldots,I$) of some sort -- plants and also firms in each of about two dozen industries in this study, and that the PUs have approximately the same production structure for successive pairs of years over some period of time $t = 1,\ldots,T$ where T is at least 2. In this study, output for each PU is measured as real sales (denoted by the scalar, y_1^{it}). On the input side, data are needed for the quantities for N inputs for each PU in each year (the column vectors $x^{i,t} = (x_1^{i,t},\ldots,x_N^{i,t}))$, and we need unit prices for the inputs (the column vectors $w^{i,t} = (w_1^{i,t},\ldots,w_N^{i,t})$). Our plant and firm level data are described more fully in section 3.

For now we ignore the time dimension (and omit the time superscript) so as to focus on the measure of returns to scale.

We assume that the structure of production can be described by a homogeneous of degree k production function f where the constant term and the returns to scale and technical progress parameters are allowed to vary over industries and from one 2-year time internal to the next.

Thus, for the plants or firms in each of our industry, 2-year data samples, we assume that the structure of production can be described in each year by a homogeneous of degree k production function denoted by

(2-1) $$y^i = f(x^i).$$

It follows from the homogeneity assumption for the production function that if the input vector for the j^{th} PU equals λ times the input vector for PU i, then the level of output for the j^{th} PU is given by λ to the k^{th} power times the output quantity for PU i; i.e.,

(2-2) $$\begin{aligned} y^j &= f(x^j) \\ &= f(\lambda x^i) \\ &= \lambda^k f(x^i) \\ &= \lambda^k y^i. \end{aligned}$$

Taking natural logarithms (denoted by ln), from (2-2) we have

(2-3) $$\ln y^j - \ln y^i = k \ln \lambda .$$

Expression (2-3) can be solved for k, yielding

(2-4) $$k = (\ln y^j - \ln y^i)/\ln \lambda .$$

This is the elasticity of returns to scale with respect to output for the degree k homogenous production function f.

For a pair of PUs i and j that have the production structure described by (2-2), λ is the factor by which the input quantities for PU i must be inflated in order to move from the PU i to the PU j production surface. This is the definition of a Malmquist input quantity index for comparing the inputs of PU i with those of PU j using the technology of PU i. We denote this Malmquist input quantity index by $Q^{*i,j}_{M|i}$ where the superscripts indicate which PUs are being compared, the subscript M denotes that this is a Malmquist index (the notation M(t) will be used instead when we also wish to note the time period for the index) and the subscript i denotes that the comparison is based on the technology of PU i. Similarly, $(1/\lambda)$ is the factor by which the input quantities for PU j must be reduced in order to move from the PU j to the PU i production surface. This is the definition of a Malmquist input quantity index for comparing the inputs of PU j with those of PU i using the technology of PU j. We denote this Malmquist input quantity index by $Q^{*j,i}_{M|j}$. There is no obvious reason for preferring either $Q^{*i,j}_{M|i}$ or $Q^{*j,i}_{M|j}$. Thus, Caves, Christensen and Diewert (1982a) define the geometric average of these two Malmquist input indexes to be *the* Malmquist index for comparing the inputs of firms i and j, with this Malmquist input index denoted equivalently by $Q^{*i,j}_{M}$ or $Q^{*j,i}_{M}$. Thus, what we will refer to as the Malmquist input index is given by

(2-5) $$\begin{aligned} Q^{*i,j}_{M} &= (Q^{*i,j}_{M|i} Q^{*j,i}_{M|j})^{(1/2)} \\ &= Q^{*j,i}_{M}. \end{aligned}$$

In general, Malmquist indexes are theoretical constructs that cannot be evaluated using observable price data. However, Caves, Christensen and Diewert (1982a) provide theory results showing conditions under which the Malmquist input index equals the Törnqvist input quantity index denoted by $Q^{*i,j}_{T} (= Q^{*j,i}_{T})$.[3] One of the conditions under which this wil be true is when the PUs have the same translog distance function. Also, Yoshioka, Nakajima and Nakamura (1994) and Nakajima, Nakamura and Yoshioka (1998) show a proof of (2-5) for the case when the PUs share the same tanslog production function, which is the case assumed in this study. Thus, we have

[3] Caves, Christensen and Diewert (1982a) also establish this result for the case where the two PUs have translog distance functions with different first order coefficients provided that the returns to scale are constant or decreasing (that is, provided that k=1 or k<1), but we cannot exclude the increasing returns to scale case of k>1 in this present study.

(2-6) $$\lambda = Q_M^{*i,j} = Q_T^{*i,j}$$

where

(2-7) $$\ln Q_T^{*i,j} = (1/2)(s^i + s^j)'(\ln x^j - \ln x^i).$$

Under the additional assumption that the PUs minimize costs, then $s^i = (s_1^i, \ldots, s_N^i)$ and $s^j = (s_1^j, \ldots, s_N^j)$ are the cost share vectors for the n input factors for the two PUs. The input price vectors for the PUs i and j are denoted by $w^i = (w_1^i, \ldots, w_N^i)$ and $w^j = (w_1^j, \ldots, w_N^j)$, and the elements of the cost share vectors are given by

(2-8) $$s_n^i = (w_n^i x_n^i)/(w^{i\prime} x^i) \quad \text{and} \quad s_n^j = (w_n^j x_n^j)/(w^{j\prime} x^j)$$

where a prime denotes a transpose.[4]

The Törnqvist input quantity index defined in (2-7) can be evaluated from the data available to us for plants and for firms.

In this study, the production function that is assumed to hold for 2 years at a stretch for the PUs in each of our estimation samples is a homogeneous translog function

(2-9) $$k^{-1} \ln f(x^i) = \beta_0 + \beta_1' \ln x^i + (1/2) \ln x^{i\prime} R \ln x^i.$$

The unknown parameters in (2-9) are β_0, a scalar, and β_1, a column vector of coefficients with column sum 1. R is a non-positive definite matrix with column sums equal to 0. The dimensions of β_1 and R conform to that of x^i. (See Christensen, Jorgenson and Lau, 1973).

For a given time period, if the technology of the PUs i and j can be represented by the translog production function given in (2-9), then under the assumptions that have been made and using (2-6), the returns to scale in the cross-section can be represented as

(2-10) $$\begin{aligned} k &= (\ln y^j - \ln y^i)/\ln Q_T^{*i,j} \\ &= [\ln f(x^j) - \ln f(x^i)]/\ln Q_T^{*i,j} \end{aligned}$$

with $\ln Q_T^{*i,j}$ is given by (2-7).

[4] Note that the PU specific price vectors are treated as being given exogenously and are assumed not to depend on the level of production for a PU, though they can very over the PUs.

2.2 Disembodied Technical Progress (TP)

In this study, we do not allow for within-industry cross section differences in the rate of technical progress (TP). In the time dimension, we allow for technical progress from one year to the next for the plants or firms in an industry, but do not allow for returns to scale over time. More specifically, when modeling the production activities of PUs in the same industry over multiple time periods, we assume a production function that incorporates time as a separable variable:

(2-11) $$y^{i,t} = f(x^{i,t}, t) = \lambda^{-k} f(\lambda x^{i,t}, t) .$$

In this equation, $y^{i,t}$ and $x^{i,t}$ are, respectively, the scalar output quantity and the production input vector for the i^{th} PU in period t, and where λ is a positive constant as before.

We assume that for one time period forward at a time, the technical progress of the PUs can be described, as a first order approximation, by

(2-12) $$\partial \ln y^{i,t} / \partial t = \partial \ln f(x^{i,t}, t) / \partial t = r$$

where r is a constant. With this assumption, (2-11) can be expressed as

(2-13) $$y^{i,t} = f(x^{i,t}) e^{rt} ,$$

so that we have

(2-14) $$k^{-1} \ln y^{i,t} = k^{-1} \ln f(x^{i,t}) + (k^{-1}) rt .$$

In (2-11), $k^{-1} \ln f(x^{i,t})$ is assumed to obey the translog function given in (2-9).

3 Our Empirical Approach

3.1 A Basic Estimating Equation

Suppose that the production for the PUs in an industry is described by

(3-1) $$\ln y^{i,t} = \ln f(x^{i,t}) + rt ,$$

as follows from (2-13). For some reference PU in some given time period s ($1 \le s \le T-1$), say A, from (3-1) we have

(3-2) $$\ln y^{A,s} = \ln f(x^{A,s}) + rs .$$

Now, consider any other PU in time period s, say i. From (3-1) we have

(3-3) $$\ln y^{i,s} = \ln f(x^{i,s}) + rs .$$

Subtracting (3-3) from (3-2) we have

(3-4) $$\ln y^{A,s} - \ln y^{i,s} = \ln f(x^{A,s}) - \ln f(x^{i,s}) .$$

Using (2-10), we have the result that

(3-5) $$\ln f(x^{A,s}) - \ln f(x^{i,s}) = k \ln Q^{*A,i}_{T(s)}$$

where the Törnqvist index on the right compares the inputs for the plant or firm i with those for the reference plant or firm in period s.

For period s+1, the appropriate reference PU for our purposes is A in period s+1, but with the same input vector as in period s; that is, we use

(3-6) $$\begin{aligned}\ln y^{A,s+1} &= \ln f(x^{A,s}) + r(s+1) \\ &= \ln y^{A,s} + r.\end{aligned}$$

Thus for any given period s ($1 \le s \le T-1$), from (3-4) and (3-5) we see that the period s output for the i^{th} PU is related to the period s output of the reference PU by

(3-7) $$\ln y^{i,s} = \ln y^{A,s} + k \ln Q^{*A,i}_{T(s)} .$$

And for period s+1 we have

(3-8) $$\begin{aligned}\ln y^{i,s+1} &= \ln y^{A,s+1} + k \ln Q^{*A,i}_{T(s+1)} \\ &= \ln y^{A,s} + r + k \ln Q^{*A,i}_{T(s+1)}\end{aligned}$$

where $\ln y^{A,s+1}$ is the hypothetical expected output of the reference PU in period s+1 given by (3-6).

Our basic estimating equation is obtained by combining (3-7) and (3-8) as

(3-9) $$\ln y^{i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 \ln Q^{*i,A}_{T(t)} + u^{i,t} ,$$

where $\beta_0 = \ln f(x^{A,s}), \beta_1 = r, \beta_2 = k$ and where the time dummy is defined by

(3-10) $$\begin{aligned} D^{i,t} &= 1 \quad \text{if} \quad t = s+1 \\ &= 0 \quad \text{if} \quad t = s. \end{aligned}$$

The error term u has been added in (3-9) because it is assumed that the derived estimating equation holds with error for the observed data. In estimation, we treat the error term $u^{i,t}$ as randomly distributed in the annual cross sections with zero mean and constant variance σ_u^2 and over time (for t=s, s+1) as autocorrelated with ρ as the first order autocorrelation for the PUs in each of our industry and 2-year subsamples of data for plants and for firms.

To estimate (3-9), a reference PU must be selected or created, and then the values must be calculated for the Törnqvist index for comparing the input quantities of each of the estimation sample PUs with the input quantities for the reference PU.

To estimate (3-9), a reference production unit must be selected or created, and then the values must be calculated for the Törnqvist index for comparing the input quantities of each of the estimation sample production units with the input quantities for the reference production unit.

In the case of our plant data, for each of our industry- 2 year panel data samples, the smallest plant size group for the first of the two years is used as the reference production unit. We then computed Törnqvist indexes comparing the output of each of the other plants to the reference production unit.

For our firm data, we have followed the method proposed by Cave, Christensen and Diewert in their 1982 Economic Journal paper to compute Törnqvist-type input index values.

4. Our Data and Estimation Results

4.1 Plant Data

Each year, the Japanese Ministry of International Trade and Industry (MITI) conducts the Census of Manufacturing by Industry for samples of plants (referred to as establishments) in different size categories classified by the number of employees. Typical size groups (the numbers of employees) used are: (1) 30-49, (2) 50-99, (3) 100-199, (4) 200-299, (5) 300-499, (6) 500-999 and (7) 1000 and more. (The number of these groups and hence the definitions of size groups have varied somewhat over time.) Henceforth "size" refers to plant size measured in terms of the number of employees. MITI publishes only average figures for each of the size groups by industry, and these are what we use in our plant level empirical work (in contrast to the firm level where we have the actual firm data).

The production inputs included are in the plant portion of our study are: the number of workers as labor, the fixed assets at the beginning of each year as capital (with the new investment in fixed assets being deflated using the investment goods deflator by industry published by the Economic Planning Agency), raw material, and the intermediate goods (with these value figures being deflated by the Bank of Japan input price deflator), all measured per establishment.[5] Capital is adjusted by the industry-specific capital utilization rate reported by the Japanese Ministry of International Trade and Industry.

The corresponding input prices used are the average annual cash earnings per worker for labor, the depreciation rate for fixed assets plus the average interest rate for one-year term-deposit for capital. The intermediate goods price is assumed to be one since it is common for all observations for each industry and for each year.

Output is measured as net sales plus net increases in the inventories of final products. The Bank of Japan output price index by industry is used to deflate our output variable (sales).[6]

4.2 Firm data

The firm data are from the company financial statements filed with the Ministry of Finance and compiled by the Japan Development Bank. At the firm level, we use the following four production inputs: the number of workers for the quantity of labor, the fixed assets at the beginning of each year as capital (with the new investment in fixed assets being deflated using the investment goods deflator published by the Economic Planning Agency), raw material, and

[5] It is possible that the costs of capital that plants or firms face differ depending on size. If so, this would show up as part of the measured returns to scale in this study.

[6] Because of the lack of correct industry-specific deflators, not all manufacturing industries have been included in our empirical analysis for all time periods.

other input goods,[7] all measured per firm. Capital is adjusted by the industry-specific capital utilization rate reported by the Japanese Ministry of International Trade and Industry.

What we have used as the input price series are the average annual cash earnings per worker for labor; the depreciation rate for fixed assets plus the average interest rate for one-year term-deposit for capital, with the input price of capital adjusted by the investment goods deflator; the Bank of Japan's input price index for the raw materials; and the GDP deflator for other inputs.

The output quantity measure in this paper is net sales and the Bank of Japan's industry output price index is used as the deflator for the net sales figures (1988=100).

4.3 Preliminary Analysis of Technical Progress Results

The estimated technical progress rates are given in Table 1 for plants, and are displayed as well in Figure 1.

The decline in TP immediately prior to and following the burst of the financial bubble is clearly evident for most industries. The 1989-90 TP figures are lower than the 1998-89 ones for all but 4 of the 22 industries, and lower than the 1964-88 averages for all but the food, apparel, and rubber products industry groups. And the 1990-91 figures are lower even than the 1989-90 ones for 12 of the 22 industries. As can be seen from Figure 1, it was not until 1992 that the TP rates began to recover for several key industries including precision equipment, transportation machinery, and electrical machinery. [8]

The burst of the financial bubble is associated with declines in the firm level TP figures, shown in Table 3. For instance, in 1998-89, there was positive technical progress for all but five of the industry groups, whereas in 1990-91 the TP figures are positive for only seven industries.

4.3 Preliminary Analysis of Returns to Scale Results

Our estimates for the elasticity of scale for plants are reported in Table 3.[9] These elasticity of scale estimates are almost all greater than 1 with the exception of the non-ferrous

[7] This is measured on a cost basis and includes all expenses other than the expenses for labor, raw materials, and depreciation.

[8] It should be borne in mind, of course, that we are only measuring year to year TP effects. Using aggregate time series data for the period of 1961-1980, Tsurumi, Wago and Ilmakunnas (1986) report results that the interpret as showing that Japanese manufacturers take relatively long periods of time (up to ten years) to adjust their production methods to incorporate new technological requirements. Their findings are consistent with ours.

[9] The plant data are adjusted for idle capital stock for the 1988-98 period, but this is not the case for the earlier 1964-88 period. The effects of this are unclear. During business downturns in Japan, small establishments typically suffer from excess capacity more than large establishments, possibly resulting in an overestimation of scale elasticity. However, during the 1970s and the 1980s when depressed industries were restructured, many of the small establishments in these depressed industries dropped out of our data sample. When a data sample has a relatively large number of large establishments with idle capacity, the scale elasticity would presumably be underestimated. From our reported results, it would appear that the massive downsizing of Japanese manufacturing establishments in the 1990s could be one of the factors that caused some of our scale elasticity estimates to be negative.

metals industry. (Although the t-test results are not reported in Table 2, the values in excess of 1 are also almost all significantly greater with a .05 level two tailed critical region for the t test.)

Our firm level returns to scale results are shown in table 4. Now it is only for the petroleum and coal products industry, rubber products, and for non-ferrous metals that the elasticity of scale estimates are mostly greater than 1 (with these results usually being significant with at the .05 level). Indeed, for some industries such as furniture and fixtures the elasticity of scale estimates are often significantly less than 1, while for most, the hypothesis of constant returns to scale is accepted. These firm level results support the standard practice in macro econometric modelling of assuming constant returns to scale (e.g. Solow, 1957, and Jorgenson, Gollop and Fraumeni, 1987) in specifying the aggregate production function to be homogeneous of degree one.[10]

4.4 Technical Progress: Dynamics and R&D

An important research topic of interest is the contribution of investment in R&D to total factor productivity growth and technical progress (TP). Griliches (1979) made a pioneering contribution to our understanding of economic growth by pointing out that accumulation of firms' investments in R&D and the creation of knowledge can create technical progress.[11] Japanese firms' R&D behavior attracted considerable attention in the literature through the 1970s and 1980s but has been little studied relatively since then. In this section we focus on the behavior of technical progress as related to R&D since our primary research interest lies in the relationship between technical progress and R&D. We explore empirical relationships that may exist between TP and R&D investments for our sample period for Japan.

Significant relationships between total factor productivity or technical progress and R&D variables have yet to be discovered for the Japanese economy.[12] The prevalent use of TFPG as the dependent variable in previous studies of the effects of R&D, with the TFPG figures perhaps encompassing scale economy effects could be part of the reason for the findings of no significant relationship in those studies. We will be able to investigate this and other possibilities.

The Japanese government has been implementing various new policy measures in its science and technology policy in the last few years, which aim, for example, to promote more effective university-industry collaborations in R&D. These new efforts in R&D may have additional impacts on the rates of technical progress for Japanese manufacturing industries.

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[10] Other researchers have also found little empirical evidence suggesting that the long-run behavior of Japanese manufacturing industries deviates from that of the standard perfect competition model with constant returns to scale (e.g. Nishimura and Shirai (2000)).

[11] Griliches was the leading figure in advancing our empirical efforts in this direction. See, for example, Griliches (1986, 1994, 1998, 2000), Griliches and Lichtengberg (1984), Griliches and Mairesse (1984, 1990), and Clark and Griliches (1984).

[12] Studies on this topic for Japan include Griliches and Mairesse (1990) and Odagiri and Iwata (1986)

5. Concluding remarks

In this paper we develop measures and estimates for technical progress and the elasticity of scale for Japanese manufacturing industries at both the plant and firm levels, focusing on the period of 1988-95. In our preliminary analyses of these estimates, we have paid particular attention to observed effects immediately prior to and following the burst of the financial bubble in 1990. We argued that a large decline in technical progress can be observed in the final year of when the bubble was being formed and when it burst. This is consistent with the interpretation that massive investments in inputs were made by Japanese manufacturers in the late 1980s to increase their output, but that the expansion of output was not accompanied by technical progress and instead resulted in the excess capacity and the burst of the bubble.[13]

Despite the negative post-bubble circumstances and the lack of effective government policies to move Japan's economy out of the long-lasting recession, many parts of the Japanese manufacturing sector did not collapse in the 1990s and some parts have continued to maintain a certain level of global competitiveness. Indeed, our results and those of other suggest that many Japanese manufacturing industries continue to exhibit technical progress, with this being evident at both the plant and firm levels. Japanese R&D policies may be part of the explanation for this TP. Or planned extensions of this project will focus on exploring that possibility.

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[13] Excessive investment in other sectors such as real estate and property development during the bubble period is another factor which has damaged the Japanese economy.

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Table 1. Technical Progress: plants, 1964-96

	1964-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Food	-0.0001	-0.01261	-0.02455	0.00409	0.01854	-0.00201	-0.01004	-0.02194	-0.01696
Beverage	---	0.05356	0.01650	-0.04870	0.01893	-0.02938	-0.01071	0.00344	0.03875
Textile	0.0164	-0.01715	0.01504	-0.02292	-0.00551	-0.00863	0.08571	0.02401	0.02531
Apparel	0.004	0.03412	-0.02512	-0.02383	0.00032	-0.04348	-0.02609	0.01336	-0.00229
Lumber/wood products	0.0056	0.00922	0.00168	-0.01165	0.00870	-0.00685	0.03211	0.00048	0.00523
Furniture/fixture	0.009	0.00505	-0.03942	-0.00962	-0.02582	-0.02833	-0.01346	-0.00130	0.00423
Pulp	0.0118	0.01687	-0.01835	-0.03489	-0.00124	0.00171	0.01653	0.04608	-0.00311
Printing	---	-0.01572	-0.00005	-0.01078	-0.02001	0.00013	0.00745	0.01197	0.00837
Chemicals	0.0206	0.02367	-0.00022	0.01324	0.00391	0.00422	0.00658	0.02460	0.01140
Petroleum/coal products	0.0088	0.00424	-0.01268	-0.06331	0.03658	-0.11127	-0.00443	0.01206	0.12001
Plastic products	---	0.00667	0.00514	-0.01301	0.01080	0.00712	0.00816	0.00266	0.01461
Rubber products	0.0124	-0.00960	0.02450	0.01896	0.00518	-0.00187	0.01870	0.01036	0.00087
Leather products	0.0065	0.02148	-0.02158	-0.03037	-0.02117	-0.02944	-0.00009	0.03738	-0.00419
Pottery	0.0135	-0.00111	-0.01755	-0.01489	-0.00876	0.00837	0.02868	-0.00492	0.00990
Steel	0.0036	0.02088	-0.00478	-0.00441	-0.00810	-0.02386	-0.00030	0.02251	0.01901
Non-ferrous metals	-0.0014	0.00160	-0.01451	-0.05190	-0.02767	-0.05813	0.05500	0.04826	-0.00550
Metal products	0.0147	-0.02076	-0.01738	-0.02678	-0.01605	0.04600	0.01704	0.02693	0.01318
General machinery	0.0187	0.00028	0.00427	0.00924	-0.01512	-0.01136	-0.00337	0.02121	-0.00087
Elec machachinery	0.026	0.03162	0.01616	0.04255	0.00849	0.03177	0.02724	0.04791	0.00624
Transportation machinery	0.0245	-0.00200	0.01208	0.01192	-0.00058	0.01695	0.00168	0.02554	-0.02123
Precision	0.0316	0.03585	-0.02602	0.00303	-0.01730	0.01518	0.00390	0.03171	0.02036
Other	---	0.03172	0.00175	0.01732	-0.01063	-0.00513	0.00103	-0.03942	0.01092

Table 2. Elasticity of Scale: plants, 1964-96

	1964-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Food	1.08	1.06982	1.06262	1.06995	1.05887	1.06283	1.06853	1.06831	1.07060
Beverage	---	1.33516	1.33793	1.31929	1.30722	1.35810	1.35841	1.34039	1.35212
Textile	1.004	1.04798	1.03750	1.03306	0.97204	1.03148	1.01670	1.00453	1.01079
Apparel	1.019	1.02652	1.03132	0.98135	0.98347	1.06419	1.06003	1.06182	1.03019
Lumber/wood products	1.018	1.05196	1.04312	1.00642	1.02381	1.04622	1.03194	1.05668	1.04945
Furniture/fixture	1.047	1.08568	1.06086	1.02987	1.04889	1.04385	1.05714	1.05681	1.04690
Pulp	1.008	1.02540	1.02310	0.99819	1.00325	0.99710	1.00819	1.03183	1.04738
Printing	---	1.07470	1.06203	1.06563	1.06850	1.06998	1.06611	1.07028	1.07208
Chemicals	1.046	1.07939	1.08801	1.06036	1.06715	1.07600	1.08629	1.08431	1.09208
Petroleum/coal products	1.012	1.04735	1.03125	1.00996	1.01594	1.03009	1.05432	1.08752	1.02425
Plastic products	---	1.02994	1.03658	1.02392	1.02835	1.03197	1.03295	1.03325	1.05593
Rubber products	1.047	1.06486	1.06148	1.06088	1.07659	1.07276	1.06829	1.07746	1.07546
Leather products	1.016	0.93356	1.07730	1.04220	1.04082	1.11505	1.06056	1.02828	1.05862
Pottery	1.073	1.06187	1.05923	1.04884	1.04550	1.04959	1.06309	1.04960	1.04640
Steel	1.012	1.04877	1.05320	1.03234	1.04298	1.04339	1.04495	1.04098	1.06018
Non-ferrous metals	1.008	1.01203	0.99192	0.99318	0.99205	0.98874	0.99187	0.98905	0.99893
Metal products	1.03	1.03160	1.02409	1.03757	1.02734	1.05635	1.04029	1.02939	1.06318
General machinery	1.019	1.01699	1.01435	1.01677	1.01122	1.01301	1.01375	1.02269	1.02309
Electrical machinery	1.044	1.05228	1.05913	1.04383	1.03989	1.03771	1.03547	1.03921	1.04148
Transportation machinery	1.016	1.01545	1.01403	1.00431	1.00414	1.00428	1.00673	1.00720	1.01217
Precision	1.021	1.01596	1.00685	1.00559	1.00207	1.00328	1.00568	0.99855	0.99801
Other	---	1.02603	1.04588	1.02749	1.03113	1.02760	1.03397	1.03814	1.00425

Table 3. Technical Progress: firms, 1988-96

	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Food	-0.00548	-0.00074	-0.00507	0.02468	0.00749	-0.00199	-0.00878	0.01164
Beverage	0.00719	0.02275	-0.00035	-0.03325	0.03879	-0.01541	0.01187	0.02279
Textile	0.00198	0.04033	-0.00236	0.00323	0.06817	0.01330	0.01698	0.00431
Apparel	0.01124	-0.00385	0.03357	-0.06958	-0.03935	-0.00380	0.00067	0.02852
Lumber/wood products	0.01186	0.02320	-0.02885	0.08116	-0.01132	0.06646	0.00311	0.04673
Furniture/fixture	0.07382	-0.01128	-0.04540	-0.02760	-0.00784	-0.01951	0.01050	0.00090
Pulp	-0.03957	0.01519	-0.00713	0.01161	0.01222	0.01413	0.01972	0.01684
Printing	-0.03671	0.00008	0.00958	-0.03096	0.00850	0.00592	-0.01649	0.00453
Chemicals	-0.00690	0.01087	0.00945	-0.00121	0.01011	0.02520	-0.00247	0.03531
Petroleum/coal products	0.01143	-0.03513	-0.06905	-0.01689	-0.04005	-0.05864	0.00337	0.01176
Plastic products	0.02040	0.01532	-0.00134	0.01892	0.00655	0.04144	0.01502	0.02932
Rubber products	0.01245	0.01890	0.05711	-0.00744	0.00600	0.01961	0.03629	-0.00128
Leather prod	---	---	---	---	---	---	---	---
Pottery	0.00245	0.01192	-0.03840	-0.00031	0.00085	0.01970	0.01642	0.01204
Steel	-0.01031	0.00573	-0.02869	0.00154	-0.02047	0.03224	0.01080	0.02750
Non-ferrous metals	-0.00891	0.00795	-0.02856	-0.03895	0.00030	0.01137	0.01848	0.00322
Metal products	-0.04059	-0.01727	-0.02119	0.00022	0.03644	0.03338	0.00913	0.00515
General machinery (a) [a]	0.01044	0.00112	-0.03357	-0.04553	-0.01536	0.02050	0.05006	0.04608
General machinery (b) [b]	0.01183	-0.00063	-0.00843	-0.00287	0.00602	0.00700	0.01073	-0.00453
Electrical machinery (a) [c]	0.04069	0.02826	0.03277	0.02983	0.04232	0.05433	0.06548	0.03313
Electrical machinery (b) [d]	0.04702	0.02147	0.02788	0.07056	0.05842	0.02907	0.05883	0.02262
Transporation machinery	0.01045	0.00778	0.00897	0.00445	0.00665	0.01416	0.00842	-0.00923
Precision	0.02524	0.00324	-0.02372	-0.01379	0.02419	0.01997	0.03620	0.03937
Other	-0.00628	0.00515	-0.01192	-0.01233	0.00959	0.01078	0.00466	0.01520

[a] This category includes boilers, engines, metal processing machinery and general machinery parts.
[b] This category include general machinery which is not included in General Machinery (a).
[c] This category includes industrial electrical equipment, industrial electronic applications equipment and other electrical machinery.
[d] This category includes industrial communication equipment and civilian communication equipment.

Table 4. Elasticity of Scale: firms, 1988-96

	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Food	0.98125	0.90878	0.94929	0.93355	0.92121	0.95072	1.02652	1.01574
Beverage	1.06408	0.87361	0.85435	0.85621	0.98449	1.03380	0.92995	0.57194
Textile	0.98379	0.79502	0.78922	0.85541	0.88940	0.82229	0.89550	0.99571
Apparel	0.84947	0.70535	0.75901	0.96069	0.69177	0.54847	0.49008	0.88152
Lumber/wood products	0.11151	0.46006	0.15918	0.55542	0.65496	0.70836	0.46883	0.59559
Furniture/fixture	0.47492	0.48821	0.83154	0.78528	0.72741	0.76937	0.68692	1.04469
Pulp	0.95787	0.96427	0.92514	0.94416	0.95656	0.91160	0.93000	0.91600
Printing	0.98171	0.95966	0.96164	0.94994	0.96777	0.97534	0.94583	0.93676
Chemicals	0.80751	0.83098	0.80140	0.86277	0.77768	0.79898	0.84615	0.75241
Petroleum/coal products	1.02815	1.11544	1.11334	1.08620	1.02647	1.11768	1.09969	0.94645
Plastic products	0.76476	0.87751	0.77854	0.70200	0.74685	0.07097	0.87242	0.82986
Rubber products	1.00258	1.05441	1.05189	1.03171	1.03937	0.94942	0.97180	0.91887
Leather prod	---	---	---	---	---	---	---	---
Pottery	0.94785	0.89304	0.90877	0.92552	0.96471	0.92597	0.94987	0.95527
Steel	0.95948	0.95728	0.95295	0.94435	0.94555	0.95010	0.93972	0.96294
Non-ferrous metals	1.05416	1.05561	1.05988	1.05144	1.04301	1.04416	1.03373	1.04255
Metal products	0.78661	0.91540	0.92652	0.96763	0.94975	0.96277	0.87071	0.85709
General machinery (a) [a]	0.85218	0.90954	0.95869	0.98662	0.98625	0.96185	0.99944	0.93416
General machinery (b) [b]	0.90037	0.87241	0.92045	0.96023	0.94054	0.89714	0.90427	0.95301
Electrical machinery (a) [c]	0.89664	0.88580	0.92319	0.89870	0.89521	0.90101	0.84999	0.84630
Electrical machinery (b) [d]	0.93265	0.90476	0.85248	0.90157	0.88510	0.67964	0.71220	0.83768
Transportation machinery	0.97057	0.96844	0.96252	0.96720	0.96108	0.95413	0.96780	0.97734
Precision	0.90331	0.88836	0.89296	0.91209	0.91268	0.90401	0.91946	0.84538
Other	0.97507	0.97904	1.04192	0.99194	0.96013	0.89626	0.88345	0.82862

[a] This category includes boilers, engines, metal processing machinery and general machinery parts.
[b] This category include general machinery which is not included in General Machinery (a).
[c] This category includes industrial electrical equipment, industrial electronic applications equipment and other electrical machinery.
[d] This category includes industrial communication equipment and civilian communication equipment.

Figure 10. Technical Progress for Plants, 1986-95