

Technological Progress by Small and Medium Enterprises in Japan

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ABSTRACT. This paper examines various aspects of total factor productivity across different firm sizes in Japan. It shows that larger firms have higher total factor productivity levels and growth than smaller firms. There are, however, some exceptions to this pattern especially in the electric machinery sector where small firms tend to have the edge. The paper also finds that two distinctive characteristics of small and medium firms, the practice of subcontracting and the use of external patents, are positively related to total factor productivity growth while the availability of subsidized public loans is not.

1. Introduction

Technological progress contributed significantly to the remarkable economic growth of the Japanese economy in the post-WW II period. According to an estimate by Nishimizu and Hulten (1978), as much as 30 percent of Japan's economic growth in the 1955–1971 period was attributable to technological progress (as measured by growth in total factor productivity, TFP). While the rate of economic growth declined substantially in the early 1970s, technological progress continued to contribute significantly to economic growth. Indeed, the contribution of technological progress increased after the mid-1970s, accounting for more than 50 percent of economic growth from 1975 to 1985 (Kawai, 1999). However, in the 1990s, during which economic growth stagnated, the rate of technological progress has been

negative. Because of demographic and economic maturity, there is a small likelihood of rapid expansion of capital and labor inputs in the Japanese economy in the future. Accordingly, the importance of technological progress for achieving economic growth will be greater.

One special characteristic of the Japanese economy is a large and important position held by small and medium enterprises (SMEs). In 1957, 99.7 percent of establishments in the nonprimary sector were SMEs, and 82.8 percent of workers were employed by SMEs. Although the shares of SMEs on these indicators declined over time to register 98.8 and 77.6 percent in 1996, respectively, SMEs still hold a dominant and important position in the Japanese economy. These numbers alone point to the importance of SMEs in the Japanese economy, but their importance would be increased if one considers their close relationships with large enterprises through various channels such as subcontracting relationships.

In light of these observations, this paper examines technological progress achieved by SMEs in the manufacturing sector. Specifically, we first estimate the rate of technological progress, here measured by growth of TFP, of establishments of different sizes for the 1966–1996 period. The analysis covers the final part of the rapid economic growth period (1966–1972), the lower but steady growth period (1972–1991) including a sub-period affected by two oil crises (1972–1981) and a sub-period characterized as a bubble economy (1985–1991), and the period of prolonged recession (1991–1996). We then examine differences in the levels of TFP among establishments of different sizes. We also analyze the determinants of technological progress and technological levels. In addition to statistical analysis, we examine technological progress by SMEs by utilizing information obtained from various surveys.

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The structure of the paper is as follows. Section 2 briefly describes the methodology for estimating TFP. Section 3 examines technological progress by SMEs from the mid-1960s to the mid-1990s, and Section 4 analyzes the determinants of technological progress by considering technological capability, interfirm relationships, and government policy. Finally, in Section 5 some concluding remarks and policy implications are presented.

2. Methodology¹

The methodology of estimating technological progress in this paper is based on the standard model of production.² The production function for each sector is assumed to give output (O) as a function of labor (L), capital (K), intermediate inputs (M) and the level of technology (T).

$$O = f(L, K, M, T) \quad (1)$$

Production technology is described as exponential function of the logarithms of inputs, or translog production function. Production is assumed to follow constant returns to scale. Furthermore, necessary conditions for producer equilibrium are assumed to be satisfied.

With these assumptions, one can derive the average rate of technological change (v_T) between time periods t and $t - 1$, which is unobservable, as the difference between successive logarithms of output and a weighted average of the differences between successive logarithms of inputs where the weights are the corresponding average value shares (equation (2)).

$$v_T = [\ln O(t) - \ln O(t-1)] - v_L[\ln L(t) - \ln L(t-1)] - v_K[\ln K(t) - \ln K(t-1)] - v_M[\ln M(t) - \ln M(t-1)] \quad (2)$$

where

$$v_L = [v_L(t) + v_L(t-1)]/2$$

$$v_K = [v_K(t) + v_K(t-1)]/2$$

$$v_M = [v_M(t) + v_M(t-1)]/2$$

$$v_L + v_K + v_M = 1$$

v_L : share of compensation to labor in the value of output

v_K : share of compensation to capital in the value of output

v_M : share of payments to intermediate inputs in the value of output

Since equation (2) measures the difference in output between two periods less the corresponding difference in combined inputs, the resulting measure is called the change in TFP.

Some comments on the meaning of technological progress, which is estimated by equation (2), are in order.³ First, the results of the estimation by using equation (2) are usually interpreted as efficiency gains caused by adoption of new technology. Such an interpretation is appropriate if the firms can achieve maximum amount of output given the level of inputs and technology in both time $t - 1$ and t , for which the estimation is performed. In other words, one may attribute the results of the estimation to technological change in the framework of long run equilibrium. However, in the short to medium run, firms are generally constrained by immobility of inputs, so that they may not achieve most efficient allocation of inputs. As a consequence, under-utilization of inputs occurs. Because of this problem, estimation of equation (2) does not necessarily indicate technological progress, but it is influenced by changes in utilization of inputs.

Second, somewhat related to the problem discussed above, firms may not be able to obtain maximum amount of output because of inefficient management or inappropriate incentive systems. If such a situation arises, our TFP estimates not only reflect the change in technological level but also the change in management style or other elements affecting production. In broad terms, an improvement in management skills or production environment is also characterized as technological progress.

Finally, there is a possible problem related to the characteristics of production function. Although the methodology described above is derived with an assumption of constant returns to scale, true production technology may be subject to increasing returns to scale. Under such circumstances, our estimates would include the effect arising from scale economies.

3. Technological progress by small and medium enterprises

This section provides the results of estimation of TFP for the manufacturing establishments of different sizes. Before examining TFP estimates in

the next section, this section will briefly examine the changing patterns of economic growth in Japan by referring to the changes in output, capital, labor, and intermediate inputs over time, to set the stage for the analysis of TFP.⁴

Changing patterns of economic growth from the mid-1960s through the 1990s

The 1966–1996 period, for which the analysis is undertaken, encompasses different phases of economic growth and performance for the Japanese economy. The 1966–1972 period captures the final part of rapid economic growth in the post-WW II period in Japan. The rate of economic growth declined significantly in the following periods. Two oil shocks, one in 1973 and the other in 1979, resulted in serious economic recession in Japan, which depended on foreign sources for almost 100 percent of its oil supply. Emergence of several structural problems also contributed to slowing of Japanese economic growth. Shortage of labor, as a result of rapid economic growth, made it difficult for the Japanese economy to realize economic growth based on expansion of labor inputs. The situation was particularly serious for SMEs, which were in a disadvantageous position vis-à-vis large firms for attracting workers. Narrowing of the technological gap between Japan and the Western economies, as a result of successful catching up by Japan, also contributed to the decline in economic growth rate, because it reduced the scope for economic growth based on technological progress.

Despite the unfavorable effect of the two oil shocks, the Japanese economy performed rather well through the 1980s when compared with other developed economies. In particular, the Japanese economy recorded a remarkably high growth rate in the latter half of the 1980s, resulting mainly from expansionary fiscal and monetary policies, which were adopted to deal with recessionary impact of the steep yen appreciation in the mid-1980s. Indeed, during this period, a “bubble” economy, characterized by sharply increased asset prices, emerged as a result of active investment based on optimistic future projections. The bubble economy contributed to rapid economic growth, but it did not last long.

The bubble burst in the early 1990s. Since a large part of investment in land and other assets was financed by bank loans, the collapse of the bubble resulted in a huge number of bad loans. Faced with unfavorable balance sheet problems owing to bad loans, the banks reduced their lending, especially to SMEs. Coupled with other problems such as an unfavorable demographic situation and a delay in required structural reforms, the Japanese economy experienced a prolonged period of stagnation during the 1990s, a period that will be looked back upon as Japan’s lost decade.

The preceding discussions present a cursory overview of Japan’s overall economic performance from the mid-1960s through the current period. In the remaining part of this section, we examine the changes in outputs and inputs in the manufacturing sector by focusing on the differences for the establishments of different sizes.

After recording a very high average annual growth rate of 12.2 percent for the 1966–1972 period, the average annual rate of output growth for the manufacturing sector declined to 3.5 percent in 1972–1981, mainly because of the two oil shocks and several structural factors discussed earlier (Table I). The average annual growth rate recovered somewhat to 4.6 percent for the 1981–1991 period, but it declined significantly to 0.9 percent in the following 1991–1996 period.

An examination of the growth rates of output for the establishments of different sizes reveals that the establishments with 30–49 employees, the smallest cohort in the sample, recorded the lowest growth rate for the four periods under study. For the 1991–1996 period, the smallest establishments experienced the average annual growth rate of –0.5 percent. By contrast to relatively unfavorable output performance of small establishments, large establishments performed better in output growth. In particular, the largest establishments with 300 or more employed registered the highest output growth in the 1966–1972 and 1991–1996 periods. For the 1972–1981 period the establishments with 50–99 employees recorded the highest growth rate, while for the 1981–1991 those with 100–199 employees recorded the highest growth rate.

As a result of the differences in the rate of output changes for the establishments of different

TABLE I
Changes in output, inputs, and TFP in the Japanese economy

(Average annual growth rate: %)						
	Size of establishments in terms of employees					
	Total	30–49	50–99	100–199	200–299	300–
Output						
1966–1996	5.2	4.2	5.0	5.2	5.1	5.4
1966–1972	12.2	11.2	12.0	11.2	12.3	12.6
1972–1981	3.5	3.2	4.2	3.8	3.3	3.4
1981–1991	4.6	3.2	4.0	5.0	4.5	4.9
1991–1996	0.9	–0.5	0.4	0.7	1.1	1.2
Labor inputs						
1966–1996	0.0	–0.3	0.3	0.4	0.3	–0.4
1966–1972	2.1	1.0	2.0	2.1	2.6	2.4
1972–1981	–1.4	–1.0	–0.3	–0.7	–1.2	–2.2
1981–1991	0.8	0.4	1.0	1.5	1.2	0.5
1991–1996	–2.0	–2.2	–2.1	–1.6	–1.7	–2.2
Capital inputs						
1966–1996	5.3	6.4	6.7	6.3	6.0	4.6
1966–1972	12.2	13.2	13.8	12.4	12.2	11.8
1972–1981	0.6	2.3	2.4	1.5	1.5	–0.2
1981–1991	5.4	6.1	6.7	6.9	5.5	4.8
1991–1996	5.3	6.2	6.0	6.3	7.4	4.5
Intermediate inputs						
1966–1996	4.9	3.9	4.7	4.7	4.7	5.1
1966–1972	12.2	11.7	12.1	10.7	12.2	12.7
1972–1981	3.2	2.7	4.0	3.3	3.0	3.2
1981–1991	4.3	2.9	3.4	4.7	3.9	4.5
1991–1996	0.1	–1.1	–0.4	0.0	0.6	0.3
Total factor productivity						
1966–1996	0.8	0.7	0.8	0.8	0.7	0.8
1966–1972	1.0	0.9	1.4	1.1	0.8	0.9
1972–1981	0.7	0.7	0.6	0.7	0.6	0.7
1981–1991	0.8	0.6	0.6	0.7	0.8	0.8
1991–1996	0.7	0.4	0.6	0.6	0.5	0.8

Source: Authors' estimates.

sizes from 1966 to 1996, the distribution of output shares shifted from small establishments to large establishments. Specifically, the share of output for large establishments with 300 or more employees in total output increased from 57.9 percent in 1966 to 61.0 percent in 1996. In contrast, the share of output for smaller establishments with 299 or fewer employees declined. Among the sub-groups of smaller establishments,

smallest establishments with 30–49 employees lost the largest share from 8.3 percent to 6.1 percent, while the remaining sub-groups of relatively larger establishments experienced a smaller decline.

Turning to output growth for different sectors, one observes wide variations. Roughly speaking, light and traditional manufacturing sectors such as textiles and material-intensive manufacturing sector such as chemicals and metal products

exhibited low growth rates, while high-tech sectors such as electric machinery and transport machinery achieved high growth rates. These sectoral differences in the patterns of output growth are also found for the establishments of different sizes.

Turning to the changes in inputs, one finds that the changes in labor inputs showed sizeable fluctuations over the 1966–1996 period. During the high growth period of 1966–1972, labor inputs increased significantly at the average annual rate of 2.1 percent. However, during the low growth period of 1972–1981, labor inputs declined. Labor inputs increased slightly again from 1981 to 1991 in response to an upturn in economic growth, but from 1991 to 1996 labor inputs declined again at the average annual rate of 2.0 percent. Examining the rate of change in labor inputs for the establishments of different sizes over time, one observes greater fluctuations in the use of labor inputs by large establishments when compared with small establishments. This finding indicates that large establishments are more active in adjusting labor inputs to deal with economic situation. To put it differently, one may argue that small establishments contributed to the stability of employment. This pattern changed during the prolonged recession of the 1990s, because small establishments did reduce labor inputs as much as large establishment in terms of percentage from 1991 to 1996. Serious business situations faced by small establishments forced them to cut down labor inputs.

Capital inputs increased notably in the high growth period at the average annual rate of 12.2 percent. After recording a low rate of 0.6 percent during the 1972–1981 period, the average annual rate of growth of capital inputs increased to 5.4 percent in 1981–1991 and remained at around the similar level through 1991–1996. It is important to note that the smaller establishments showed a higher rate of increase in capital inputs than large establishments for the entire 1966–1996 period.

The changes in the use of intermediate inputs show a very similar pattern observed for outputs, indicating that the production relationship between intermediate inputs and outputs was more or less fixed over time. Intermediate inputs increased at an average annual rate of 12.2 percent during the rapid economic growth period of 1966–1972, then

the rate of their growth declined sharply through the mid-1990s, registering at 0.1 percent for 1991–1996. Similar to the pattern observed for output growth, the rate of growth in the use of intermediate inputs is greater for large establishments when compared with smaller establishments.

In sum, over the 1966–1996 period output growth declined significantly, indicating a transition from a high growth period in the earlier stage of economic development to a low growth period in the matured stage of economic development. Output of smaller establishments grew less than that of large establishments, leading to a shift in output structure from smaller establishments to large establishments. We observe an interesting contrast between small establishments and large establishments in the use of labor and capital inputs. Small establishments expanded capital inputs faster than large establishments, while small establishments expanded labor inputs more slowly than large establishments. As a result of these changes, the gap in capital-labor ratio between small and large establishments narrowed over time.

These differences in the growth rates of labor and capital inputs reflect the differences in the availability of resources for small and large establishments. As a result of rapid economic growth and sectoral shift in production from manufacturing to services, recruitment of workers for the manufacturing sector became difficult. The situation was particularly acute for small establishments, because working condition such as wage rates and fringe benefits for small establishments was in general less favorable than that for large establishments. Faced with the shortage of labor, small establishments resorted to the increase in capital inputs through active fixed investment to expand or maintain their business. To undertake fixed investment, small establishments could utilize financial resources provided by various financial lending institutions. Thanks to SME promotion policies pursued by the government, public SME lending institutions were actively supplying the fund for fixed investment to SMEs. Moreover, the availability of financial resources to SMEs from the private financial institutions increased as large firms shifted from borrowing from financial institutions to self-financing such as issuing bonds for acquiring financial resources.⁵

Technological progress: TFP growth

The results of the computation of TFP growth by using equation (2) are shown in Tables I and II. An examination of the computed TFP for overall manufacturing shown at the bottom of Table I points out relatively small variations in TFP among the four periods under study. For the high growth period of 1966–1972, TFP increased at the average annual rate of 1.0 percent, while the corresponding rates for the following three periods are lower at 0.7–0.8 percent. Observing a substantial decline in output growth rates from the mid-1960s to the mid-1990s, one finds that the contribution of TFP growth to output growth increased during the period. Specifically, for

1966–1972, only 8 percent of output growth was attributable to TFP growth, while for 1991–1996 as much as 78 percent of output growth was accounted for by TFP growth.

The differences in the TFP growth rates among the establishments of different sizes are very small for the 1972–1991 period, during which the output growth rate was averaged about 4 percent. However, one observes noticeable differences for the 1966–1972 period of high economic growth and the 1991–1996 period of prolonged recession. For the 1966–1972 period medium-sized establishments with 50–99 employees performed best with 1.4 percent TFP growth, and both small and large establishments recorded TFP growth at 0.9 percent. For the 1991–1996 period large estab-

TABLE II
Annual growth rate of TFP (%)

	1966– 1972	Size of establishments in terms of employees					1972– 1981	Size of establishments in terms of employees				
	Total	30–49	50–99	100–199	200–299	300–	Total	30–49	50–99	100–199	200–299	300–
0. Total	0.97	0.94	1.40	1.05	0.83	0.88	0.70	0.68	0.63	0.70	0.65	0.72
1. Food	1.21	0.38	2.74	1.02	0.92	0.85	0.06	0.36	0.12	0.32	–0.10	–0.10
2. Textile and apparel	0.72	0.67	0.73	0.56	0.72	0.78	0.96	1.00	0.97	1.00	1.04	0.76
3. Chemical	1.13	1.23	1.07	1.33	0.59	1.03	0.40	0.71	0.73	0.62	0.83	0.27
4. Metal prod	0.96	1.01	0.85	1.03	1.10	0.88	0.53	0.50	0.45	0.35	0.23	0.61
5. General machinery	1.28	1.55	1.81	1.33	1.53	1.09	0.85	1.09	0.71	1.02	0.90	0.81
6. Elec machinery	1.37	1.57	1.47	1.34	0.82	1.38	1.46	1.71	1.65	1.72	1.85	1.38
7. Trans machinery	0.33	1.14	0.99	0.86	0.45	0.24	1.04	1.16	1.03	0.95	0.81	1.04
8. Precision machinery	1.25	1.51	1.40	1.24	1.37	1.17	1.71	2.10	1.91	2.10	1.90	1.54
9. Other manuf	0.97	0.97	0.93	1.04	0.54	1.17	0.22	0.23	0.23	0.29	0.27	0.20
	1981– 1991	Size of establishments in terms of employees					1991– 1996	Size of establishments in terms of employees				
	Total	30–49	50–99	100–199	200–299	300–	Total	30–49	50–99	100–199	200–299	300–
0. Total	0.76	0.63	0.60	0.71	0.77	0.81	0.69	0.44	0.61	0.57	0.51	0.77
1. Food	–0.50	–0.52	–0.23	–0.64	–0.31	–0.68	–0.13	–0.03	–0.12	–0.10	–0.07	–0.17
2. Textile and apparel	0.36	0.39	0.39	0.38	0.19	0.32	0.46	0.44	0.34	0.56	0.16	0.59
3. Chemical	0.43	0.81	0.87	1.12	0.53	0.08	0.23	0.14	0.93	0.41	0.21	0.08
4. Metal prod	0.33	0.26	0.23	0.51	0.63	0.23	0.43	0.25	0.47	0.11	0.04	0.72
5. General machinery	0.38	0.50	0.50	0.34	0.35	0.33	–0.23	–0.38	–0.27	–0.25	–0.25	–0.18
6. Elec machinery	1.28	1.49	1.45	1.28	1.36	1.25	1.04	1.62	1.61	1.43	1.17	0.91
7. Trans machinery	0.06	0.40	0.53	0.38	0.52	–0.02	0.06	–0.09	–0.40	–0.05	–0.17	0.10
8. Precision machinery	0.61	0.87	0.82	0.35	0.59	0.60	0.43	–0.08	0.67	0.71	–0.10	0.26
9. Other manuf	0.28	0.26	0.29	0.21	0.48	0.21	0.09	0.07	0.04	0.11	–0.12	0.11

Note: Originally, the figures are computed for 19 sectors and then aggregated; 19 sectors are food, textiles, apparel, wooden products, furniture, paper and pulp, printing, chemicals, petroleum, rubber, leather, glass, iron and steel, nonferrous metals, fabric metals, general machinery, electric machinery, transport machinery, and precision machinery.

Source: Authors' computation.

lishments achieved highest TFP growth at 0.8 percent, while the small establishments fared worse at 0.4 percent. An examination of the changes in TFP growth rates for the groups of different sizes over time reveals that the TFP growth rate declined sharply for small establishments, while the corresponding rate for large establishments stayed more or less at the same level. Despite relatively low growth rate of TFP for small establishments, the contribution of TFP growth to output growth was significantly higher for small establishments than large establishments.

Wide variations in TFP growth rates are observed for different manufacturing sub-sectors and for different periods (Table II). Accordingly, it is difficult to discern consistent patterns regarding sectoral TFP performance throughout the 1966–1996 period. However, one may observe that the machinery sectors, especially electric machinery, registered relatively high TFP growth, while resource intensive sectors such as food, chemicals, and metal products, and traditional sectors such as wooden products and leather products (included in other manufacturing) recorded low TFP growth. It is interesting to find that for electric machinery, which recorded the highest TFP growth among manufacturing sub-sectors, small establishments exhibited better TFP performance than large establishments, in contrast to the patterns observed for other sectors. One may argue that good performing small establishments contributed to high TFP performance of the electric machinery sector, in which many small establishments are involved with other establishments through subcontracting arrangements.

So far we have examined the change in TFP for the Japanese manufacturing sector from the mid-1960s to the mid-1990s. In the remainder of this section, we analyze the differences in the level of TFP among the establishments of different sizes.

The methodology for the computation is basically the same as the one used for the TFP growth accounting. The only difference is that instead of taking the difference of outputs and inputs between the two periods the corresponding differences between the establishments of different sizes are measured.

The results of the computation for 1966 and 1996 are shown in Table III. In the computation the level of TFP for the establishments of the

average size for 1966 are used as an criterion for comparison, that is, the TFP level of the establishments of the average size for 1966 is set to unity. According to our computation, in 1966 large establishments show the highest TFP level at 1.013, while the establishments with 50–99 employees show the lowest level at 0.978. Putting it differently, the gap in TFP levels between large establishments and those with 50–99 employees was 3.6 percent. In 1996 the TFP level of manufacturing sector increased by 26.1 percent from the 1966 level. Large establishments fared more favorably than small establishments. The TFP level of large establishments increased by 26.7 percent from 1.013 in 1966 to 1.284 in 1996, while small establishments with 30–49 employees performed unfavorably by increasing the TFP levels by 22.4 percent from 0.982 to 1.202 over the same period. As a result of these changes, the TFP gap between large establishments and small establishments widened to 6.8 percent in 1996.

Generally, small establishments are shown to have lower TFP levels than large establishments, as the average TFP levels for larger establishments are higher than the corresponding values for smaller establishments in 1966 and 1996. But in several sectors, such as the machinery sectors, small establishments show higher TFP levels than large establishments in 1996. One reason for this may be that in the machinery sectors there are a number of small but innovative establishments engaged in parts and components production. By contrast, in metal production such as iron and steel, for which large-scale facilities are required for production, TFP levels of large establishments are higher, probably indicating that computed TFP levels captured not only technological factors but also scale economies.

4. Determinants of technological progress by SMEs

In the previous section we examined technological progress measured by TFP growth and the level of TFP for establishments of different sizes from the mid-1960s to the mid-1990s. In this section we investigate the factors determining TFP growth and TFP levels. Before conducting a statistical analysis of the determinants of TFP growth and TFP levels, we examine R&D activities of

TABLE III
The level of TFP by establishment size (1966 average = 1.0)

	Size of Establishments in terms of employees					
	Total	30–49	50–99	100–199	200–299	300–
1966						
0. Total	1.00	0.98	0.98	0.98	0.99	1.01
1. Food	1.00	0.97	0.95	0.96	0.98	1.06
2. Textile and apparel	1.00	1.01	1.01	1.00	1.00	0.99
3. Chemical	1.00	0.97	0.97	0.97	1.01	1.01
4. Metal prod	1.00	1.01	1.00	1.00	0.99	1.00
5. General machinery	1.00	1.00	1.00	1.00	0.98	1.00
6. Elec machinery	1.00	0.97	0.96	0.97	0.98	1.01
7. Trans machinery	1.00	0.99	0.98	0.98	0.99	1.00
8. Precision machinery	1.00	0.99	1.00	1.01	1.01	1.00
9. Other manuf	1.00	0.98	0.99	0.98	1.00	1.02
1996						
0. Total	1.26	1.20	1.23	1.23	1.23	1.28
1. Food	1.02	0.97	1.11	0.98	1.00	1.03
2. Textile and apparel	1.21	1.22	1.21	1.21	1.18	1.19
3. Chemical	1.20	1.22	1.27	1.28	1.22	1.15
4. Metal prod	1.17	1.16	1.15	1.16	1.15	1.19
5. General machinery	1.20	1.25	1.23	1.21	1.19	1.18
6. Elec machinery	1.48	1.57	1.53	1.49	1.47	1.47
7. Trans machinery	1.13	1.22	1.18	1.17	1.14	1.12
8. Precision machinery	1.37	1.42	1.44	1.41	1.37	1.32
9. Other manuf	1.12	1.09	1.10	1.11	1.10	1.14

Note: See the note in Table II.

Source: Authors' computation.

SMEs, because R&D is considered to play an important role in achieving technological progress.

R&D activities by SMEs

The results of the survey conducted by the Small and Medium Enterprise Agency in 1968 bring out interesting observations on the patterns of R&D activities by SMEs (Table IV). The results show that the smaller the firm, the less concerned with R&D activities. At least two reasons may be given for the observation. One is that very small firms are not engaged in production activities requiring R&D, and the other is that small firms have no resources, human as well as financial resources, to be spent on R&D activities, even if they were interested in such activities.

R&D takes various forms, that is, in-house activities and joint-research among others. There are significant differences in the patterns of R&D

activities among the firms of different sizes. In-house R&D has an important role in R&D activities for large firms. Among the SMEs, in-house R&D is important for the firms with 50–299 employees; 30.3 percent of the firms in that group conduct in-house R&D.⁶ For the smaller SMEs, participation in R&D seminars is an important form of R&D activity for acquiring technologies. For medium to large SMEs (20–299 employees), technological assistance provided by parent firms is an important source of technologies.⁷ Although not shown in Table IV, other useful sources of technologies for SMEs include competitors in the same industry, material and equipment suppliers, and foreign firms.⁸

It is somewhat a surprise to find that SMEs are as active as large firms in conducting R&D jointly with the public research institutes and other types of research institutes such as those belonging to the universities and industry associations. Wide

TABLE IV
Research and Development by SMEs: 1968

	Firm size (number of employees)			
	1–19	20–49	50–299	300–
In-house R&D with full-time researchers	3.5	9.8	30.3	44.1
Collaborative R&D with universities and other research institutes	5.5	7.1	6.8	8.9
Use of public R&D institutes	7.8	9.0	7.3	8.4
Technical assistance from parent firms	5.5	10.6	10.3	7.9
Participating in seminars	34.9	37.9	44.8	40.6
Other R&D activities	5.0	4.9	5.9	5.9
Not considering R&D activities	19.8	14.9	6.1	3.0

Source: Chushokigyo Keiei Jittai Chosa [Survey on the Current Management Conditions of Small and Medium Firms], Small and Medium Enterprise Agency, September 1968.

use of public testing and R&D research institutes by SMEs was particularly notable for light manufacturing sectors, as more than 40 percent of SMEs in wood products, textiles, ceramics, and casting surveyed by the Small and Medium Enterprise Agency used the public testing and research institutes.⁹

Reliance on external institutions for R&D is rational for SMEs. Since R&D activities are subject to scale economies, it is not profitable for a small firm with limited resources and limited market power to conduct R&D alone. Joint-research activity is more attractive. Recognition of this point indicates the importance of the availability of public R&D institutes to SMEs, which are interested in improving technological capability.

Determinants of technological progress by SMEs: A statistical analysis

In the statistical analysis the following four variables are tested for the effect on cross-sectoral and time-series variations in TFP: the number of industrial patents held per establishment (PAH), the number of industrial patents introduced/acquired from external sources per establishment (PAI), the share of public loans in total amount of loans (PUB), and the share of establishments engaged in subcontracting in total number of establishments (SUB). All of the data are taken from a series of *Kogyo Jittai Kihon Chosa Hokoku Sho* (Report on Comprehensive Survey of Manufacturers) 1971, 1976, 1981, and 1987.

Possession of industrial patents indicates technological capability. Thus PAH is expected to have a positive impact on TFP growth and TFP levels. Table V shows PAH for different sectors and for establishments of different sizes in 1987. As expected, large establishments possess a substantially greater number of patents compared to small establishments. In 1987 the average number of industrial patents held by large establishments was 174.1, while the corresponding number for small establishments (10–49 employees) was much smaller at 3–4. There are wide variations in PAH among different sectors. Electric machinery had the highest number, while food and textiles had very low numbers. These sectoral differences in PAH are consistent with our expectations that the production of electric machinery requires technology intensive methods, while the production of food and textiles does not. Having observed sectoral differences in PAH, one notices that these differences are mainly due to the differences in the number of patents held by large establishments, and the number of patents held by a small establishment is not so different among different sectors.

Acquisition of technologies from external sources is an important means of improving technological capability of the firms. This is particularly true for small firms, because they cannot rely on their own technological capability because of shortage of human and financial resources. Indeed, we saw in the previous section that SMEs utilize external R&D sources to supplement their own technological capability. We would expect the

TABLE V
The number of patents developed by establishments (number per establishment)

	Total	10–29	30–49	50–99	100–199	200–299	300–
1987							
0. Total	48.6	3.9	4.5	5.8	9.3	13.7	174.1
1. Food	7.4	1.6	3.8	3.0	5.1	10.4	29.4
2. Textile and apparel	14.3	1.7	3.3	2.0	3.1	4.4	56.0
3. Chemical	68.6	8.2	6.4	10.1	12.9	22.7	175.0
4. Metal prod	46.3	5.1	3.7	4.2	6.1	7.6	108.2
5. General machinery	46.3	4.1	7.6	7.4	17.1	14.6	128.9
6. Elec machinery	212.1	4.4	2.9	3.8	7.7	14.5	448.9
7. Trans machinery	51.6	1.7	4.9	6.7	6.6	8.3	88.6
8. Precision machinery	21.9	3.0	5.8	6.1	9.5	18.0	143.6
9. Other manuf	16.0	2.5	2.3	3.8	6.1	10.4	65.1

Source: MITI, *Kogyo Jittai Kihon Chosa Hokoku Sho* [Report on Comprehensive Survey of Manufacturers], 1971 and 1987.

impact of PAI on TFP to be positive. According to Table VI, large establishments are more active in acquiring external technologies than smaller establishments. Although this observation is similar to that observed for industrial patents developed in-house, the gap in the number of patents acquired from external sources between large establishments and smaller establishments is significantly smaller when compared with the case of patents developed in-house. These findings indicate that smaller establishments rely more on external sources than internal source for the supply of industrial patents and for the acquisition of technological capability. Sectoral differences in PAI are not substantial, compared to PAH,

although generally larger numbers are reported for chemicals and machinery sectors, where technology plays a greater role in the production.

One of the problems that SMEs face in conducting business is a lack of financial resources to be used for fixed investment or working capital. The Japanese government has actively provided financial resources to SMEs to modernize their equipment and achieve high productivity. To test the importance of this, we include the proportion of policy loans in total amount of loans (PUB) as an explanatory variable. If the policy were effective, we would expect a positive impact of PUB on TFP growth. According to Table VII, the value of PUB is high for small- and medium-sized estab-

TABLE VI
The number of patents acquired from external sources (number per establishment)

	Size of establishments in terms of employees						
	Total	10–29	30–49	50–99	100–199	200–299	300–
1987							
0. Total	3.8	1.9	1.5	2.8	2.1	1.9	5.0
1. Food	3.3	1.5	2.0	10.6	1.0	0.0	1.3
2. Textile and apparel	1.8	4.9	0.6	0.6	1.3	1.3	1.8
3. Chemical	4.8	1.1	1.6	1.3	4.2	1.3	5.0
4. Metal prod	3.2	0.6	1.0	4.2	0.6	1.6	3.4
5. General machinery	3.3	2.4	1.7	1.4	1.7	2.2	6.1
6. Elec machinery	6.5	1.7	1.3	1.0	1.8	1.6	5.8
7. Trans machinery	4.1	0.0	0.0	1.0	1.0	1.0	3.3
8. Precision machinery	2.4	1.0	2.5	3.4	1.2	3.0	2.8
9. Other manuf	3.8	0.3	0.3	1.5	2.9	1.0	3.0

Source: MITI, *Kogyo Jittai Kihon Chosa Hokoku Sho* [Report on Comprehensive Survey of Manufacturers], 1971 and 1987.

TABLE VII
Policy loans and subcontracting by size of firm

	Size of establishments in terms of employees						
	Total	10–29	30–49	50–99	100–199	200–299	300–
Share of policy loans in total loans (%)							
1971	11.6	20.9	22.8	22.4	18.9	17.1	8.6
1987	13.1	16.4	19.2	19.0	17.5	13.3	9.1
Proportion of firms engaged in subcontracting (%)							
1971	58.7	55.3	57.2	47.4	47.2	42.3	0.0
1987	55.8	48.3	47.7	47.2	45.7	41.5	30.3

Source: MITI, *Kogyo Jittai Kihon Chosa Hokoku Sho* [Report on Comprehensive Survey of Manufacturers], 1971 and 1987.

lishments with the values ranging between 13 and 23 percent in 1971 and 1987. For large establishments PUB is much smaller at less than 10 percent.

Japanese industrial organization is distinctive in having well-developed subcontracting arrangements, and it is often argued that the subcontracting system provides an environment conducive to improving technological efficiency. Subcontracting enables a parent firm to specialize in one or several operations in which that firm has a competitive edge. Specialization, in turn, leads to an improvement in productivity.

Being a subcontractor to one or several parent firms provides a subcontracting firm with an environment under which technological progress is enhanced. As was noted in the previous section, many SMEs acquire technologies from their parent firm. As such, subcontractors are in a better position to improve technological capability by acquiring new technologies from their parent firms. It is not uncommon to exchange technical personnel between subcontractors and parent firms to transfer technologies from parent firms to subcontractors. Moreover, parent firms often put pressure on subcontractors to improve their technological capability by having flexible relations, in which subcontracting arrangement may be cut if subcontractors do not perform to fulfill parent firms' expectations.¹⁰ The preceding discussions suggest that SUB should have a positive effect on TFP.

A few observations may be warranted on the values of SUB in Table VII. Smaller establish-

ments exhibit high incidence of participation in subcontracting arrangement. It is interesting to note that the proportion of establishments engaged in subcontracting declined slightly from 1971 to 1987, indicating a gradual breaking up of a traditional long-term business relationships in Japan.¹¹

Results

A statistical analysis is performed to identify the determinants of TFP growth and TFP levels of the Japanese manufacturing sector with a focus on the impact associated with the differences in the establishment size. The data sample that we used for the analysis consists of 19 manufacturing sectors, seven establishment size groups, and five years (1972, 1975, 1978, 1981, and 1986), and four periods (1972–1975, 1975–1978, 1978–1981, and 1981–1986).¹² Although we computed TFP levels for nine years (1966, 1969, 1972, 1975, 1978, 1981, 1986, 1991, and 1996) and TFP growth rates for eight periods encompassing the nine years just stated, we reduced the sample period because of the availability of the information on the explanatory variables, which we use for the statistical analysis. The values for the explanatory variables, PAH, PAI, PUB, and SUB, are taken from *Kogyo Jittai Kihon Chosa Hokoku Sho*, as explained in the previous section. Since this survey was conducted only for 1971, 1976, 1981, and 1987, the necessary data for the analysis were derived by interpolation.

We first analyze the determinants of TFP growth, and then turn to the determinants of TFP

levels. For both analyses we proceed as follows. First, we conduct OLS estimation with and without time dummy variables. Then we apply estimation methods specially developed for analyzing panel data. Specifically, we first test the presence of the individual effect. If the presence of the individual effect is detected, we then test if the individual effect can be regarded as random or fixed. We tested the validity of the specification of the random effect model, and in all the cases we could reject the hypothesis by using the BP's LM test, and we could support the use of the fixed effect model by applying the Hausman test, as shown in Table VIII. Therefore, we examine the results obtained from the application of the fixed effect model.

The results of the regression analysis are shown in Table VIII. To begin with the results on the determinants of TFP growth, we obtained positive and significant impact of PAI and SUB, as expected. These findings indicate that the sectors characterized by active patent introduction and active participation in subcontracting are likely to promote technological progress. Contrary to our expectation, active patent generation is not shown to promote technological progress, because the estimated coefficient on PAH is negative and statistically insignificant. The effectiveness of policy loans on technological progress was not detected, since the estimated coefficient on PUB is negative and statistically insignificant. In addition to these variables, we tested if catching up in terms of technological capability occurred during the period under investigation by including the initial gap in the levels of TFP among the establishments of different sizes as an explanatory variable (GAP). GAP captures the difference in the TFP levels for the establishments of different sizes. For each sector the size group of establishments with the highest TFP is given unity for the value of GAP, and for the remaining size groups the values of GAP reflect their TFP gap with the highest TFP. The estimated coefficient on GAP turns out to be positive and statistically significant. This finding that the technological gap among the establishments of different size groups narrowed over time indicates successful catching up.

To test the presence of size-specific effect on TFP growth, we included size dummy variables

and their interaction terms with other variables.¹³ The estimation results show that TFP growth was particularly high for the establishments with 50–99 employees (d6), and the catching up was particularly notable for the larger establishments (GAP*d8 and GAP*d9, 200 or more employees). The results on the interaction of PAH and size dummies show that holding patent or possession of technological capability is important to promote technological progress for the establishments with 100–199 employees (d7). Though not statistically significant, use of patents obtained from external sources (PAI) is likely to be effective in promoting technological capability for the establishments of small size, since the coefficients on size dummy variables are all negative.

A lack of effectiveness of policy loans for technological progress is particularly notable for the establishments with 50–99 employees. (PUB*d6) Indeed, for the establishments with 50–99 employees, policy loans are shown to retard technological progress. It is possible that provision of policy loans reduce incentives to improve technological capability, because it enables the establishments to maintain business without making much effort. Recognizing that there are various objectives of policy loans, ranging from modernization of equipment to employment protection, one has to conduct a more detailed analysis on the impact of policy loans by relating their objectives and their impacts to examine their effectiveness. Participation in subcontracting relationships is shown to promote technological progress for small establishments (SUB). Indeed, when compared with small establishments, subcontracting relationships are shown to play only a limited role in promoting technological progress for larger establishments, as the estimated coefficients on SUB*d7, SUB*d8, and SUB*d9 turned out to be negative and the coefficient on SUB*d9 is statistically significant.

Turning to the results on the determinants of TFP levels, we come up with more or less similar findings to those obtained for TFP growth. The results from the panel estimation with the fixed effect show that patent holding (PAH), patent introduction (PAI), and participation in subcontracting (SUB) have a significantly positive impact on improving technological level. The impact of policy loans (PUB) is shown to be negative and

TABLE VIII
The determinants of TFP

OLS Estimates	Dependent variable: TFP growth		Dependent variable: TFP levels	
	Without dummies	With time dummies	Without dummies	With time dummies
GAP	0.032899***	0.03033***		
PAH	0.000227*	0.000204*	0.003908***	0.003747***
PAI	5.91E-05**	6.82E-05**	0.001148***	0.001063***
PUB	-0.0003	-0.00216	-0.031	-0.03159
SUB	0.008796***	0.009517***	0.066728***	0.060297***
C	-0.00161		1.075465***	
r ²	0.1212	0.148	0.1091	0.1475
no	511	511	641	641
Panel estimates	Random effect	Fixed effect	Random effect	Fixed effect
GAP	0.036033***	0.090519***		
PAH	0.000209*	-4E-05	0.001111*	0.000792*
PAI	5.95E-05**	1.76E-05**	0.001061***	0.000964***
PUB	-0.00032	-0.00198	-0.01733	-0.01495
SUB	0.008591***	0.005042**	0.068599***	0.075172***
C	-0.00169	-1.657	1.081893***	
BP's LM test: chi ² = 5.67 ***			BP's LM test: chi ² = 517.95 ***	
Hausman test: chi ² = 179.28 ***			Hausman test: chi ² = 10.76 **	
OLS estimates with establishment size dummies				
d6	0.006232*		0.029118	
d7	-0.00364		0.008521	
d8	0.003897		0.065682**	
d9	0.001095		0.105771***	
GAP	0.047856***			
GAP*d6	0.03274**			
GAP*d7	0.007742			
GAP*d8	0.028609*			
GAP*d9	0.025971**			
PAH	-1.8E-05		-0.00028	
PAH*d6	0.000153		0.004056*	
PAH*d7	0.000533*		0.007177*	
PAH*d8	0.000259		0.003278	
PAH*d9	-0.00013		0.000743	
PAI	0.000709		0.006122	
PAI*d6	-0.00076		-0.00964**	
PAI*d7	-0.00049		-0.0084**	
PAI*d8	-0.00065		-0.00608	
PAI*d9	-0.00066		-0.00571	
PUB	-0.00108		-0.0126	
PUB*d6	-0.0422*		0.103517	
PUB*d7	0.014895		0.107127	
PUB*d8	-0.0255		-0.01286	
PUB*d9	0.00557		-0.01296	
SUB	0.005256**		0.177368***	
SUB*d6	0.004776*		-0.0682*	
SUB*d7	-0.00152		-0.04934*	
SUB*d8	-0.00309		-0.11041**	
SUB*d9	-0.01099**		-0.12685**	
r ²	0.452		0.5425	
nob	511		641	

Notes: GAP: Gap in TFP levels, PAT: Patent holding, PAI: Use of external patents, PUB: Policy loans, SUB: Subcontracting; d6: establishments with 50–99 employees, d7: establishments with 100–199 employees, d8: establishments with 200–299 employees, d8: establishments with 300+ employees ***, **, and * indicates statistical significance of 1, 5, and 10 percent by the two-tail test.

statistically insignificant. This finding may be interpreted in such a way that the sectors suffering from low TFP levels tend to receive policy loans.

The results of the estimation with size dummy variables and their interaction with other explanatory variables reveal several interesting observations, which are mostly consistent with the findings on TFP growth. Small establishments are found to register lower TFP levels compared with larger establishments, as the estimated coefficients on d8 and d9 are positive and statistically significant. This observation is consistent with the results in Table III. In-house technological capability indicated by patent holding (PAT) is shown to increase TFP levels for the establishments with 50–199 employees, while the use of industrial patents from external sources (PAI) is shown to prove effective in raising TFP levels for the small establishments with 30–49 employees. Subcontracting (SUB) is shown to provide an environment conducive to improve technological levels for small establishments with 30–49 employees.

5. Conclusions

Our analysis of TFP growth and TFP levels by establishment size reveals that small firms on average have lower TFP growth rates and lower TFP levels when compared with larger ones. However, there are several important exceptions to these patterns. In several machinery sectors, small establishments have not only higher TFP growth rates but also higher TFP levels. These observations indicate large variations in technological performance among small establishments in different sectors.

The results on the determinants of TFP growth and TFP levels showed that the use of external patents play important roles in promoting technological progress. These findings argue in favor of public support for improving technological capability and for facilitating the use of patents. Subsidies for R&D and for the purchase of patents appear to be justified on this ground. These policies should prove particularly effective for small- and medium-sized establishments. It is important to note that public assistance should be given directly to promote technological activities and not to support other kinds of activities through

multi-purpose policy loans. Indeed, our results indicate that provision of policy loans has a negative impact on technological progress.

Acknowledgements

For helpful comments and discussions the authors thank Al Berry, Bee Yan Aw, and other participants of the project entitled The Role of Small and Medium Enterprises in Development organized by the World Bank Institute.

Notes

¹ Since the methodology used in this analysis is basically the same as that used by a number of studies, our discussion on the methodology is brief. See, for example, Jorgenson and Nishimizu (1978) and Jorgenson et al. (1987) for detailed discussion.

² A large number of studies examined the change in technology level and the difference in the level of technology for a variety of countries and for different time periods. For the case of Japan, see, for example, Jorgenson and Nishimizu (1978), Jorgenson et al. (1987), and Jorgenson and Kuroda (1990).

³ Nishimizu and Page (1991) provides concise discussion on the interpretation of technological change measured by the methodology applied here.

⁴ The data for the analysis are taken from MITI, *Kogyo Tokei Hyo [Census of Manufacturers]*, which are deflated to be expressed in real terms. Specifically, values of output, material inputs, labor compensation, and the value of tangible assets are used for output, material inputs, labor inputs, and capital inputs, respectively. These data are deflated to make the comparison between the different time periods sensible by using the following price indices. The price indices of output and material inputs are taken from *SNA Input-Output Table* (Economic Planning Agency). The price index of hourly labor service is taken from *Monthly Survey* (Ministry of Labor). The price index of capital services, p_K , is estimated by using the following formula, $p_K = p_I(r + \delta - (p_I - p_{I-1})/p_I)$, where p_I is the price index of capital goods reported in *Fixed Capital Formation Matrix* (MITI), r is nominal rate of return, and δ is the depreciation rate (= depreciation/ $p_I K$).

⁵ See Itoh and Urata (1994) for detailed discussion on this point.

⁶ Various types of support for in-house R&D have been provided by the central and local governments. They include preferential tax treatment and preferential loans. See Itoh and Urata (1994) for the details.

⁷ A study of SMEs in silverware, textiles, and machinery parts industries by Itoh and Urata (1994) reveals that in the early stages of industry development public technical assistance proved useful to the SMEs. But once the industry attained a certain level of development, technical assistance from public sources lost its effectiveness, and instead technical assistance from parent firms and equipment suppliers became quite useful.

⁸ Small and Medium Enterprise Agency (1968).

⁹ See the results from the survey conducted by the Science and Technology Agency in 1961, which was reported in Small and Medium Enterprise Agency (1963).

¹⁰ Itami and others (1988) points out that severe competition among subcontractors was induced by parent firms in the Japanese automobile sector.

¹¹ The value of SUB for the establishments with more than 300 employees are shown to be zero in 1971. This is because the survey was conducted on SMEs and it excluded large firms.

¹² See Table II for the 19 manufacturing sectors. Seven establishment size groups include the employees with following sizes: 30–49, 50–99, 100–199, 200–299, 300–499, 500–999, and 1000–.

¹³ In the estimation we included time dummy variables and industry dummy variables, but because of space we do not report the estimated results on these dummy variables.

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