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Foreign Technology Acquisition Policy and Firm Performance in Japan, 1957-1970: The Japanese Industrial Policy Revisited[†]

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Abstract

We examine the cause and effect of technology acquisition policy on firm performance, using firm-level data between 1957 and 1970. Our results indicate that in the technology acquisition licensing, the government screened a firm's application, based on (i) the industry that the firm belonged to and (ii) firm's sales ranking in the industry. As a result, large but inefficient firms tended to acquire more technologies before the deregulation. Despite such screening process, the technology acquisition policy did not result in a serious failure. The firms that acquired technology grew much faster than those did not during the regulation period. (99 words)

Key words: Technology acquisition policy, the productivity of firm
JEL Classification code: D21 (Firm Behavior), L5 (Regulation and Industry Policy), N0 (Economic History)

1. Introduction

The evaluation of the Japanese industrial policy has experienced substantial changes since the 1980s. Recent studies by Beason and Weinstein (1996) and Porter, Takeuchi and Sakakibara (2000) claimed that industrial policy had failed to pick up the growing industries. and had sustained inefficient sectors. In the 1980s, however, many economists and political scientists thought it to be one of the major sources of the success of the Japanese economy (see for example, Komiya, Okuno and Suzumura, 1984; Okimoto, 1984; Tyson, 1992; Noland 1993). Indeed, the evaluation is unstable and highly sensitive to the general performance of the Japanese economy.[1]

In this connection, several studies have stressed the importance of relationship between industrial policy and productivity growth (Beason and Weinstein, 1996; Branstetter and Sakakibara, 1998; Okazaki and Korenaga, 1999).[2] But only a few studies focused on one of most important but controversial industrial policies that might directly affect on the productivity growth: the foreign technology acquisition policy, which was intensively implemented in the 1950s and 1960s, based on the licensing of foreign technology acquisition by the Ministry of International Trade and Industry (MITI).

Our motivation comes from two lines of researches. One is the literature on the technology acquisition policy, specifically the licensing of technology acquisition itself. The studies in this line are mainly based on macro and industry level data and descriptive materials. Among them, Ozaki (1972) and Peck and Tamura (1976) provided with many significant stylized facts on technology acquisition policy in Japan. According to Ozaki (1972) and Tamura and Peck (1976), the regulation on foreign technology acquisition, which had been strictly implemented in the 1950s, started to be relaxed in the early 1960s. As will be described in the next section, we can identify three periods in the postwar history of technology acquisition policy until the end of the high economic growth, namely the periods 1952-62, 1963-68, and 1969-72. In the first period, the government strictly controlled technology acquisition, and licenses were concentrated on intermediate goods industries. In the second period, liberalization of the control started, and acquisitions by consumption and export goods industries increased. Finally in the third period, liberalization substantially progressed.

The other line is the microeconometric analysis of the technology acquisition. Odagiri (1983) analyzed correlation among R&D expenditure, patent royalty payments and sales growth, using firm level data from 1969 to 1980. He found the positive and significant correlation between patent royalty payments and R&D expenditure, which

[1] Some studies stressed that the Japanese industrial policy did not affect very much on the firm behavior, including international trade. See for example, Saxonhouse (1983) and Weinstein (1995). Similarly, Okimoto and Saxonhouse (1986) presented the evidence that the role of public R&D was quite limited.

[2] Another aspect is an effect of industrial policy on welfare. See for example, Noland (1993).

are interpreted that those two expenditures were complementary. The correlation between patent royalty payments and the growth of sales was not significant, though. On the other hand, Montalvo and Yafeh (1994) analyzed determinants of technology acquisition, based on a model of firm's decision making on technology transfer, using firm level count data of licensing from 1977 to 1981. They found that large part of the technological catch up was driven by large firms, especially those with *keiretsu* relationship.

Each line of studies has significant contributions to the literature. But the link between two lines, namely the link between technology acquisition policy and firm performance is not fully explored yet. The first line of studies ignored the aspect of firm heterogeneity while the second line did not pay much attention to the role of industrial policy. To shed light on the nature and consequences of industrial policy, more detailed analysis is needed.

This paper proposes the framework to integrate these two lines of studies. That is, we examine the cause and effect of technology acquisition policy on firm performance with detailed historical review of the Japanese technology acquisition policy, using firm-level data. Sample period is between 1957 and 1970, which includes the years when the regulation was relaxed as well as the years with rigid regulation. Data used in this paper cover more than 1,100 firms and more than 3,600 acquired technologies.

The paper is organized as follows. Next section presents the historical overview. Third section discusses the data used in our analysis. Fourth section examines the cause and effect of technology acquisition on firm performance, and final section concludes.

2. Historical Overview

The legal framework of the technology acquisition licensing policy was provided by the Foreign Investment Law of 1950. The Foreign Investment Law aimed at licensing only those capital imports which were "desirable" to the Japanese economy, and at the same time protecting the capitals which were licensed with respect to remitting price and earnings (The Bureau of Corporations, MITI, 1960). For this purpose, the Law regulated contracts on technological assistance which lasted longer than one year and whose price was paid with foreign currencies, as well as acquisition of the stocks of Japanese firms by foreign investors. If a Japanese firm intended to have foreign technological assistance, it should apply a license to the competent Ministers, namely the Minister of Finance and the Head of a relevant Ministry. The competent Ministers screened the applications, consulting with the Foreign Investment Council.

The Foreign Investment Law prescribed the following positive and negative criteria for licensing foreign capital including technology assistance (Article 8).

Acquisition should be approved only if it would directly or indirectly contribute to the balance of payments, or development of important industries or public works. At the same time, acquisition should not be approved, if it was unfair or illegal, or if it gave negative influence on Japan's economic recovery.

Let us describe the licensing procedure of technology acquisition, taking the case of a firm under the jurisdiction of the MITI. A firm intending to acquire foreign technology placed an application form to the Bank of Japan, which passed the form to the Industrial Fund Section of the MITI. The Industrial Fund Section informed the application to the relevant bureaus to request their opinions on it. Then, the Industrial Fund Section held a meeting with the applicant firm, the bureau in charge of the applicant, the bureau in charge of the industry which mainly used the products of the applicant, the Institute of Industrial Technology, and Agency of Patent. After that, the relevant bureaus informed their opinions again to the Industrial Fund Section, which, in turn, coordinated those opinions to have the MITI's opinion. Meanwhile, the Ministry of Finance and the Bank of Japan decided their opinions respectively, and those opinions came up for discussion at the secretary meeting of the Foreign Investment Council. If the secretary meeting decided it to be approved, it was passed to the Foreign Investment Council to be approved. If the secretary meeting decided it not to be approved, the meeting advised the applicant to withdraw it. If the applicant refused withdrawal, a formal decision of rejection was made.

The first step of deregulation was taken in 1961. The positive criteria mentioned above implied the idea that only "desirable" foreign technology should be acquired. On the other hand, in the revision of the Foreign Investment Law in 1961, the positive criteria for technology acquisition were abolished, and technology acquisition came to be approved in principle, if it was not harmful. Namely, foreign technology acquisition was approved, unless it would impede similar domestic technology which had been or would be applied to business, unless it would unduly suppress small and medium-sized firms, unless it would destroy the order of an industry, or unless an acquiring firm had not enough capability to assimilate the technology (Year Book of Capital Import, 1962, p.2).

After a small change of regulation in 1966, deregulation substantially progressed in 1968. The new procedure of foreign technology acquisition was as follows. Examination of an individual application by the government was required only with respect to the technology of the airplane, weapon, gun powder, nuclear power, space development, computer and petrochemical industry. With respect to the other technologies, the Bank of Japan approved acquisition, unless the relevant Minister gave a special instruction within one month from the application, on the ground that the technology acquisition would give a serious influence on the Japanese economy. These criteria were for the technology acquisition whose price was larger than fifty thousand dollars or not fixed. Otherwise, the Bank of Japan immediately approved technology acquisition (Year Book of Capital Import, 1968-1969, pp.11-12)□

Figure 1 presents the number of firms, the number of firms that acquired technology, and the number of acquired technologies in our data set.[3] Three findings stand out in this figure. First, both the number of firms with acquired technologies and the number of acquired technologies increased steadily throughout the period. The number of firms with acquired technologies increased from 46 in 1957 to 259 in 1970. Similarly, the number of acquired technologies grew from 70 in 1957 to 686 in 1970.

=== Figure 1 ===

Second, the number of acquired technologies increased dramatically in 1962-63 and 1969-70, which is the period right after the regulation on technology acquisition was relaxed. The number of acquired technologies grew from 136 in 1962 to 291 in 1963. Further, it increased from 505 in 1969 to 686 in 1970. These results imply that the technology acquisition regulation in Japan effectively constrained firms to acquire foreign technologies in the 1950s and 1960s.

Finally, some firms repeatedly acquired technologies. The number of firms with acquired technologies did not increase not so rapidly as the number of firms and the number of acquired technologies between 1957 and 1970. Despite the rapid increases in the number of acquired technologies, most firms did not acquire any technology. This fact suggests that firm and/or industry specific factors might play a significant role in acquiring technologies.

Table 1 summarizes the number of firms and the number acquired technologies, by industry. We split the samples into three periods (1957-61, 1962-68, 1969-70), referring to the deregulations in 1961 and 1968. Table 1 indicates that acquired technologies were concentrated in certain industries. Major importers were electric machinery, general machinery and chemicals. From 1957 to 1970, the number of acquired technologies was 872 in electric machinery, 745 in general machinery, and 663 in chemicals, which accounted for 62.6 percent of the total acquired technologies.

=== Table 1 ===

Note that the concentration changed between 1957 and 1970. The share of acquired technologies by these three sectors declined from 65.6 percent in 1957-61 to 58.8 percent in 1969-70. On the other hand, textiles and wholesale trade grew from 2.2 percent and 2.0 percent in 1957-61 to 5.2 percent and 7.2 percent in 1969-70, respectively. In other words, industries other than the three major importers started

[3] The detail description of the data will be provided in Section 3.

acquiring technologies after the deregulation.

3. Data

Our sample firms consist of the Japanese firms listed at the Tokyo Stock Exchange in the period 1957-1970. The sample period covers the high economic growth period, and the years when the regulation was relaxed as well as the years with rigid regulation. Two main data sources are used. Technology acquisition data come from the Japan Economic Research Institute (1973), *Kigyobetsu Gaishi Donyu Soran* (*Complete List of Capital Imports by Firm*). We define a technology acquisition as an import of foreign technology by a firm.

Other firm level data come from the *Financial Database of the Japan Development Bank* (the JDB database), which is compiled from the financial reports of each firm. We merged these two data referring to the company name as a key.[4] We omit firms that once disappeared and reappeared in the JDB database between 1957 and 1970, and firms with unreasonable numbers in the number of workers, total wage payments, value-added, tangible assets, and technology acquisition year. After the sample selection, the number of firms is from 349 in 1957 to 1,150 in 1970 (unbalanced panel). The number of technologies acquired by these firms between 1957 and 1970 is 3,631 (Figure 1).

Table 2 indicates the difference of total factor productivity (TFP) and labor productivity between the firms with acquired technologies and the firms without them. Two notable findings are in this table. First, the productivity of firms with acquired technologies was substantially higher than that of the firms those without them. In 1970, firms with acquired technologies were 33.1 percent higher in TFP and 33.9 percent higher in labor productivity than firms without. Second, this productivity difference is observed only after 1961. Before 1960, the firms with acquired technologies present much lower productivity than those without.

=== Table 2 ===

Two questions are raised from this systematic difference of productivity between firms with acquired technologies and firms without. First, did firms with acquired technologies present higher productivity before they acquired technologies? Second, did firms with acquired technologies achieve higher productivity growth after they acquired technologies? To address these questions, the following section examines

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[4] We trace the name of company using *Tosyo Toukei Nenpou* (*Annual Securities Statistics*) and *Tosyo Yoran* (*Facto Book*) by Tokyo Stock Exchange. The firms that change their names are regarded as the same companies if they are not merged or acquired. The firms that were merged or acquired are dropped from our sample because the JDB database does not allow us to trace back the information of such companies before merger and acquisition.

the determinants and the effects of technology acquisition in the dynamic framework.

4. Determinants and Effects of Technology Acquisition

4.1. Did good firms acquire technologies?

Suppose that a firm has to pay some fixed cost to introduce a foreign technology. This cost is a sort of search cost. Once a firm succeeded in acquiring a technology, this fixed cost is not required to acquire another technology for a certain period. In other words, the fixed cost is required, only if the firm acquired a technology first after a certain period since it acquired a technology last time. We define this period as one year. Denote this fixed cost as C, and the profit of a firm that excludes this fixed cost as $\tilde{\pi}_{it}$. Assume that $\tilde{\pi}_{it}$ depends on the characteristics of a firm, X_{it}, and policy effects, G_{it}: Then the profit of firms π_{it} is written as:

$$\pi_{it} = \tilde{\pi}_{it}(X_{it}, G_{it}) - C(1 - Y_{it-1}),$$

(1)

where Y_{it-1} is a dummy variable that takes value one if the firm acquires technology at year $t-1$, and zero otherwise.

In the dynamic framework, the firm decides to acquire a technology if the sum of current and future profit, π^*_{it}, is larger than the fixed cost. Denote the discount rate of future profit as δ. Then, π^*_{it} is written as follows:

$$Y_{it} = \begin{cases} 1 & \text{if} \quad \pi^*_{it} > C(1 - Y_{it-1}) \\ 0 & \text{otherwise} \end{cases}$$

(2)

where $\pi^*_{it} = \pi_{it} + \delta\left(E[V(\bullet) \mid Y_{it-1} = 1] - E[V(\bullet) \mid Y_{it-1} = 0]\right)$. In the empirical analysis, we specify the regression equation as follows:

$$Y_{it} = \begin{cases} 1 & \text{if} \quad \gamma X_{it} + \lambda G_{it} - C(1 - Y_{it-1}) + \varepsilon_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

(3)

where ε_{it} is a disturbance term.

There are several estimation strategies for this dynamic binary choice model with unobserved heterogeneity. For instance, Roberts and Tybout (1997) employed a probit model with random effects while Bernard and Jensen (1999) uses a linear probability model with fixed effects. However, the linear probability model requires instruments, which is not easy to find out. Hence, we follow Roberts and Tybout (1997) and employ the probit model with random effects of the form:

$$Y_{it} = \alpha + \beta Y_{it-1} + \gamma X_{it-1} + \lambda G_{it-1} + \eta_i + \mu_{it},$$

(4)

where η_i is firm specific random effect and μ_{it} is pure disturbance term ($\varepsilon_{it} = \eta_{it} + \mu_{it}$). To avoid possible simultaneity problems, we lag one year all plant characteristics and the government effects.

The dependent variable Y_{it} is a dummy variable that takes value one if the firm acquires technology at year t and zero otherwise. As for firm characteristics X_{it-1}, we use productivity, size, capital and R&D intensities, liquidity constraint, and the past experience of technology acquisition.

Productivity

We use productivity as a key factor to effect on the profit of firm. Since TFP and labor productivity present high correlation, we use TFP in our analysis to avoid multicoliniality.[5] In computing TFP, we employ deterministic (non-stochastic) method developed by Caves, Christensen and Diewart (1982) and extended by Good, Nadiri, Roller and Sickles (1983). This index uses a separate hypothetical firm as a reference point for each cross-section of observations and chain-links the reference points together over time in the same way as the conventional Tornqvist index of productivity growth. In our analysis, 1957 is a reference year and TFP of hypothetical firm in 1957 equals to one. Detailed explanation of the methodology and the data is in the appendix.

Firm size

Firm size can be an important factor for a firm in acquiring a technology. The scale of sales is a possible measure of firm size (Montalvo and Yafeh, 1994). However, it is difficult to compare the value of sales across industries, since it highly depends upon industry. Therefore, we use the sales ranking of each firm in a given industry rather than value of sales itself so that we can examine the relative importance

[5] For the summary statistics and correlation of variables, see Appendix Tables 1 and 2.

of each firm in the industry.[6] Sales data are from the JDB database.

Capital and R&D intensities

As Cohen and Levinthal (1989) argued, R&D plays an important role not only in the innovation but also in the development of absorptive capacity that includes the firm's ability to exploit outside knowledge of a more intermediate sort. This in turn implies that the R&D enable firm to adopt new technologies more easily. Similarly, the capital stock could play a similar role during the 1960s. To control the difference of absorptive capacity, we use capital and R&D intensities. Capital intensity is defined as capital stock-labor ratio, while R&D intensity is defined as the R&D-sales ratio. All variables are from the JDB database. Capital stock is estimated from tangible assets, following the way developed by Nishimura, Nakajima and Kiyota (2004).

Liquidity constraint

Montalvo and Yafeh (1994) pointed out the importance of liquidity in the firm's decision to acquire a technology. Firms without liquidity constraint are more likely to have a chance to acquire a new technology. In order to examine the effects of liquidity constraint, we use cash-flow, defined as the sum of profits and depreciation costs divided by sales. All the data come from the JDB database.

Past experience

One-year lag of technology dummy might not fully capture the effects of past experience since the experience can be accumulated through time. Hence, we also test the alternative specification that uses the cumulative number of acquired technologies instead of the technology acquisition dummy. The cumulative number of acquired technologies is defined as the sum of acquired technologies starting from 1957. Data are obtained from the Japan Economic Research Institute (1973).

Policy variables

As for policy variables, G_{it-1}, we focus on industry targeting and deregulation on technology acquisition. To capture the impacts of industry targeting, we use subsidies and the JDB loans, following Beason and Weinstein (1996).[7] The subsidies are obtained from Economic Planning Agency (1991), while the JDB loans are obtained from Development Bank of Japan (2002). Since we did not get these variables at firm

[6] We define an industry at the two-digit level. This is because large firms are more likely to produce many products across industries but two-digit level can generally cover most products that firm will produce.

[7] Horiuchi and Sui (1993) also emphasized the role of the JDB loans as one of industrial policy tools.

level, we take the ratio of the policy variables relative to the value added in that industry.

The effect of deregulation is captured by the deregulation period dummy. This variable captures the effects of deregulation on the technology acquisition and takes one if the regulation is relaxed and zero for otherwise. Since the deregulations were conducted twice in 1961 and 1968, two dummy variables are employed. One is a dummy variable that takes value one for the period 1962-68 and zero otherwise. The other takes value one for the period 1969-70 and zero otherwise. If the regulation works effectively, the deregulation contributes to the increase in firm's acquisition of technologies.

We also investigate the cross-effects of deregulation and firm characteristics. If the government focuses on some firm characteristics in its screening process, the firm characteristics will show the different impacts before and after the regulation. We assume that the government focused on productivity, firm size and past experience in the screening process, and examine the coefficients of cross-term between these variables and deregulation dummy.

=== Table 3 ===

Table 3 presents the regression results of equation (4) with the random-effects model. Major findings are summarized as follows. First, the coefficients of deregulation period dummies indicate positive and significant signs. Further, the coefficient is larger for the period 1969-70 than 1962-68. This result implies that firms could acquire more technologies after 1962, particularly after 1969. In other words, even after we control various firm characteristics and industry effects, the significant effect of the regulation is confirmed.

Second, TFP does not have any effect on technology acquisition, as the coefficients do not show statistically significant level. However, once we introduce cross-term between TFP and deregulation period dummy, we observe significantly positive impacts of TFP on technology acquisition especially for 1962-68. Productivity came to matter after the regulation was relaxed.

Third, the signs of coefficients in sales ranking also change after the regulation was relaxed. Ranking in sales shows negative and statistically significant signs, which implies that the higher a firm's rank of sales in a given industry, the more the firm likely to acquire technologies. However, this relationship is reversed after the regulation was relaxed, as we observe significantly positive coefficients on the cross-term between sales ranking and period dummies. The result suggests that even a firm with low sales ranking could acquire technology after the deregulation.

Fourth, although the technology acquisition in the previous period does not have a significant effect on the current technology acquisition, the cumulative number of technology acquisitions has positive and significant effects, as the coefficients on the cumulative number of technology acquisition shows positive and statistically significant signs. Further, the coefficients of the cumulative number of technologies reversed after 1962. The negative and significant coefficients on cross-term between the cumulative number of technology acquisition and period dummies imply that the firms without the past experience of technology acquisition could acquire technologies after the deregulation.

Finally, the cash flow presents the positive and significant signs. This result implies that the liquidity is matter in acquiring technology, which is consistent with the findings of Montalvo and Yafeh (1994).

4.2. Did good firms acquire many technologies?

The analyses thus far have concentrated on whether a firm acquired technologies or not. There is yet another version of argument, that is, how many technologies a firm acquired. As we confirmed from Figure 1, some firms repeatedly acquired technologies. Why did some firms acquire many technologies? To address this question, we examine the determinants of the number of technologies acquired by a firm. We assume that the relationship between characteristics of a firm and the number of technologies it acquired, is similar to equation (4), substituting the dummy variables in the left hand side for the number of acquired technologies.

Note that the dependent variable has following characteristics: discrete, non-negative and often takes a value of zero. As was discussed in Montalvo and Yafeh (1994), the Poisson regression is a possible approach to deal with this type of data since the Poisson regression is designed to investigate the relationship between a dependent variable that represents the number of events occurred within a given period and the exogenous variables that determine its frequency.

Suppose that the number of acquired technologies z_{it} is drawn from a Poisson distribution with parameter γ_{it}, which is related to the firm characteristics, X_{it}, and policy tools, G_{it}. Suppose that the relationship between γ_{it}, X_{it} and G_{it} is described as the log linear form: $\ln \gamma_{it} = \beta X_{it} + \lambda G_{it}$. The Poisson density function is

$$\Pr(Z_{it} = z_{it}) = \exp(-\gamma_{it-1}) \frac{\gamma_{it}^{z_{it}}}{z_{it}!}, \quad \text{where } \gamma_{it} = \exp(\beta X_{it} + \lambda G_{it})$$

(5)

The firm characteristics are the same as those used in the estimation of equation (4). Similar to the previous regression, we take one-year lag for the regressors to reduce possible simultaneity problem.

=== Table 4 ===

The determinants of the number of acquired technologies are presented in Table 4 (random-effects Poisson regressions). Similar to Table 3, the coefficients of deregulation period dummies indicate positive and significant signs. Furthermore, the coefficient is larger for the period 1969-70 than 1962-68. This result implies that the regulation effectively constrained the number of acquired technologies before 1968, especially before 1961.

The coefficients of TFP, sales ranking and cash flow show significant and the same signs as those in Table 3. Namely, the TFP came to matter in acquiring technologies along with the deregulation, while the positive effect of the sales rank declined at the same time. Liquidity has significant influence on the firm's decision to acquire technologies.

Significantly negative signs are observed in the coefficients of the JDB loans. In other words, the JDB loans negatively affected on the technology acquisition. This result suggests that the JDB loans might be used not for the support of technology acquisition, but for other purposes such as adjustment of declining industries. There were several major tools for the industrial policy in Japan, including technology licensing, JDB loans and subsidies. These policy tools might be allocated to different purposes. We will return to this issue later. Finally, the coefficients of the cumulative number of technologies do not present statistically significant signs. Although the past experience had a strong effect on whether a firm acquired a technology or not, as we saw above, it did not have any significant effect on how many technologies a firm acquired.

4.3. Effects of Technology Acquisition on Firm Performance

Let us now check the opposite causal arrow, namely whether the technology acquisition has positive effects on firm performance or not. To test the effects of technology acquisition on dynamic corporate performance, following the method of Bernard and Jensen (1999), we run a simple regression of changes in performance measures, X_{it-1}, on technology acquisition status, and other exogenous factors.

$$\begin{aligned}\%\Delta X_{it} &= \frac{1}{T}\left(\ln X_{it} - \ln X_{it-1}\right)\\ &= \alpha + \beta Y_{it-1} + \gamma \text{Char.s}_{it-1} + \lambda G_{it-1} + \varepsilon_{it},\end{aligned}$$

(6)

where Y_{it-1} is a dummy variable that takes value one if the firm acquires technology, and zero otherwise. Char.s_{it-1} is a vector of firm characteristics at the initial period and G_{it-1} is a vector of the government effects.[8] Hence, the coefficient β represents the gaps in the annual average growth rate of the performance between firms with acquired technologies and firms without. We introduce cross-term between technology acquisition dummy and deregulation period dummies for 1962-68 and 1969-70, in order to capture the effects of deregulation. The other firm characteristics for the initial year are the same as those used in section 4.1.

=== Table 5 ===

Table 5 shows the results of regression equation (6) with the random-effects model. The coefficients of technology acquisition present significantly positive signs for labor productivity, value-added, capital-labor ratio and R&D-sales ratio before deregulation. This implies that firms with acquired technologies achieved much faster growth of labor productivity, value-added, capital and R&D intensities than firms without. However, these positive effects are only confirmed before 1961. Along with the deregulation, the positive effects of technology acquisition disappeared, as the coefficients of cross-terms present negative and significant signs.

5. Concluding Remarks

Concluding the paper, we would like to summarize the major results and discuss their implications on the industry policy debate. Our results are summarized as three points. First, until the deregulation in 1968, the government regulation effectively constrained technology acquisition in Japan. As a matter of fact, after the deregulation, the number of acquired technologies sharply increased. Second, the characteristics of the firms that acquired technologies were substantially different between the regulation period and the deregulation period. Whereas large firms, which did not have advantage in productivity, were more likely to acquire technologies before the deregulation, small firms with higher productivity came to acquire more technologies after the deregulation. Finally, the positive impact of technology acquisition on firm performance is confirmed. The firms that acquired technologies grow much faster than firms during the regulation periods.

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[8] Firm characteristics include TFP, the number of workers, average wages, capital-labor ratio, R&D-sales ratio, cash-flow while government effects include the JDB loans and subsidy. Year dummies and industry dummies are also included.

These results imply that in the technology acquisition licensing, the government screened a firm's application, based on (i) the industry which the firm belonged to and (ii) its sales ranking in the industry, and that as a result, large but not relatively efficient firms tended to acquire more technologies before the deregulation. In other words, if there had not been for technology acquisition licensing, smaller but more efficient firms would have acquired more technologies.

Despite such screening process, technology acquisition policy worked relatively well. During the regulation period, the firms that acquired technology grew much faster than those did not. This implies that the government successfully picked up the firms that would grow after the technology acquisition whether it was by luck or not. In this sense, the screening of the acquiring firms by the government did not result in a serious failure.

The role of subsidy and the JDB loans in technology acquisition should be interpreted carefully. The subsidy and the JDB loans did not play an important role for firms in acquiring technologies. In particular, the JDB loans have negative and significant impacts on the technology acquisition. Similarly, Beason and Weinstein (1996) argued that Japanese industrial policy fail to pick up the winner based on the negative correlation between subsidy/the JDB loans and the TFP growth. However, these negative impacts do not mean the failure of industrial policy. These policy tools were mainly applied for the purposes other than promoting growing industries, including adjustment of declining industries and construction of the social infrastructure. In the 1950s and 1960s, such industries as mining, transportation and electricity continued to have large share of the total JDB loans (Development Bank of Japan, 2002, pp.854-855).

Of course, a part of the growth enhancing effect of technology acquisition in the regulation period might be due to the first mover advantage or the rent based on restricted access to the foreign technologies, as benefits of technology acquisition disappeared after the deregulation. To control the type of technologies in detail could be one possible avenue to discriminate these possibilities. These problems will be a future topic to be explored.

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Appendix: Construction of Multilateral TFP Index

Methodology

We use multilateral TFP index developed by Caves, Christensen and Diewart (1982) and extended by Good, Nadiri, Roller and Sickles (1983). The multilateral index relies on a single reference point that is constructed as a hypothetical firm that has the arithmetic mean values of log output, log input, and input cost shares over firms in Japan in each year. Each firm's logarithmic output and input levels are measured relative to this reference point in each year and then the reference points are chain-linked over time. Suppose that the TFP of the hypothetical firm is equal to one. The TFP index for firm i in year t is defined as:

(a)
$$\ln\theta_{it} \approx \left(\ln Q_{it} - \overline{\ln Q_t}\right) + \sum_{s=2}^{t}\left(\overline{\ln Q_s} - \overline{\ln Q_{s-1}}\right) - \sum_{j=1}^{J}\frac{1}{2}\left(s_{ijt} + \bar{s}_{jt}\right)\left(\ln X_{it} - \overline{\ln X_t}\right) - \sum_{s=2}^{t}\sum_{j=1}^{J}\frac{1}{2}\left(\bar{s}_{js} + \bar{s}_{js-1}\right)\left(\overline{\ln X_s} - \overline{\ln X_{s-1}}\right)$$

where $\ln Q_{it}$, $\ln X_{it}$, and s_{ijt} are the log output, log input of factor j, and the cost share of factor j for firm i, respectively. $\overline{\ln Q_t}$, $\overline{\ln X_t}$, and $\bar{s}_{jt}$ are the same variables for the hypothetical reference firm in year t and are equal to the arithmetic mean of the corresponding variable over all firms in the year. The first term of the first line in the above equation is the deviation of the firm's output from the output of the reference point in the industry in year t, and the second term is the cumulative change in the output reference point between year t and the initial year, $t = 1$. The two terms in the second line perform the same operation for each factor input j, and are weighted by the average of the cost shares for firm i and the reference point in year t. The index measures TFP of each firm in each year relative to that of the hypothetical firm in the initial year. Since our initial year is 1957, we set TFP of the hypothetical firm in 1957 as one. In this connection, all related variables are adjusted as 1957 constant prices.

Data

Output

There are two ways to define output: gross output and net output, or value-added. In terms of production technologies, gross output is more appropriate than value-added. However, it is difficult to obtain price deflators for the inputs and outputs of non-manufacturing sectors. Since our observations cover non-manufacturing as well as manufacturing firms, we define value-added as outputs. The value-added deflator is obtained from Economic Planning Agency (1991).[9]

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[9] For the detail of industry mapping between the JDB database and Economic Planning Agency

Inputs

Inputs are consists of labor and capital. Labor is defined as man-hour. Working hour data are from Ministry of Health, Labour and Welfare (various years). Capital stock is estimated from tangible assets of the JDB database, following Nishimura, Nakajima and Kiyota (2004).

Costs

Labor cost is defined as total wage payments. Capital cost is defined as real capital stock, K_{it}, times user cost, p_{Kt}. The user cost is defined as follows.

$$p_{Kt} = p_{It}\left(\frac{1-\tau_t\phi_i}{1-\tau_t}\right)\left(r_t + \delta_{it} - \frac{\dot{p}_{It}}{p_{It}}\right),$$

where p_{It} is investment goods deflator, τ_t is corporate tax on business income, ϕ_i is the present value of the depreciation deduction on unit nominal investment, r_t is interest rate, and δ_{it} is depreciation rate. Investment goods deflator is obtained from Toyo Keizai (2002) while corporate tax is from Ministry of Finance, website (2003). The variables ϕ_i is derived so that the following equations are satisfied:

$$\phi_i = \sum_{t=1}^{T}\frac{(1-\delta_{it})^{t-1}\delta_{it}}{(1+r_t)^{t-1}} \quad \text{and} \quad (1-\delta_{it})^T \approx 0.1$$

The second equation means that the end point of the depreciation period is defined as the time when the accumulated depreciation cost approximately equals to 90 percent of initial investment. Interest rate is defined as bond yield (annual average) from Bank of Japan (1967) for 1957-65, and Bank of Japan (1976) for 1966-1970. Depreciation data are from KEO Data Base.[10]

(1991), see Okazaki and Kiyota (2003).

[10] Although capital cost and depreciation rates are certainly different by company, according to its managerial condition and production technology, the limitation of data availability forces us to assume that capital cost is common to all firms and a depreciation rate is differentiated only between industries. KEO Data Base (KDB) has been developed at Keio Economic Observatory. We thank Koji Nomura for the provision of information about KDB. For the detail of industry mapping between the JDB database and KDB, see Okazaki and Kiyota (2003).

Figure 1. Number of Firms, Number of Firms with Acquired Technologies, and The Number of Acquired Technologies, 1957-70

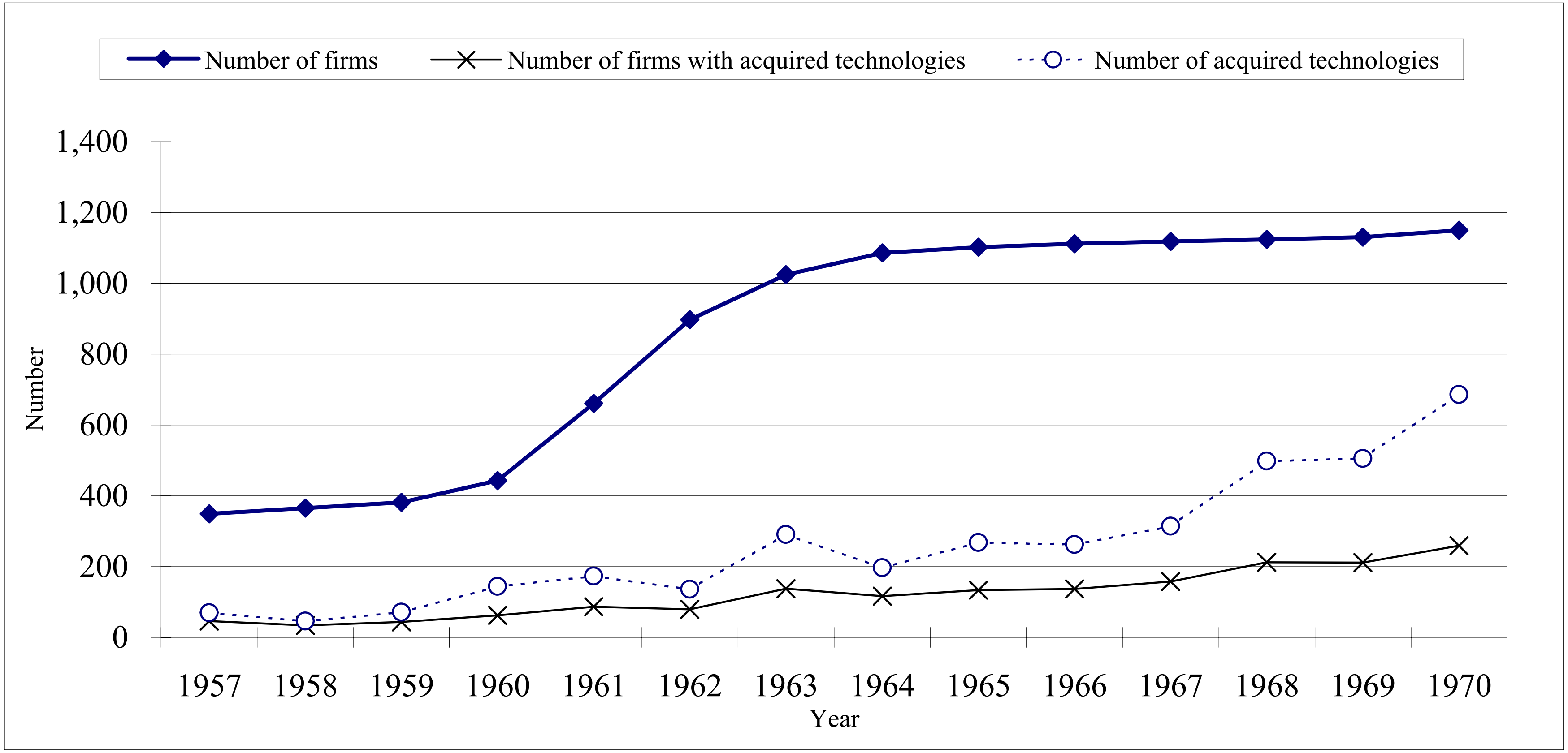

Table 1. Number of Firms That Import Technology and the Number of Imported Technologies

	Number of firms				Acquired technologies							
					Number				Share (%)			
Industry	1957-61	1962-68	1969-70	**1957-70**	1957-61	1962-68	1969-70	**1957-70**	1957-61	1962-68	1969-70	**1957-70**
Food products and beverages	175	485	145	**805**	4	10	10	**24**	1.5%	1.3%	1.5%	**1.4%**
Textiles	198	435	126	**759**	7	31	33	**71**	2.6%	4.1%	4.9%	**4.2%**
Pulp and paper products	97	250	74	**421**	11	19	21	**51**	4.1%	2.5%	3.1%	**3.0%**
Chemicals	266	641	192	**1,099**	57	131	113	**301**	21.1%	17.3%	16.7%	**17.7%**
Drugs and medicines	53	178	55	**286**	12	20	24	**56**	4.4%	2.6%	3.6%	**3.3%**
Rubber products	24	94	28	**146**	8	10	12	**30**	3.0%	1.3%	1.8%	**1.8%**
Glass, Cement and its products	129	381	115	**625**	6	31	21	**58**	2.2%	4.1%	3.1%	**3.4%**
Iron and steel	95	258	76	**429**	10	22	19	**51**	3.7%	2.9%	2.8%	**3.0%**
Non-ferrous metals	84	210	64	**358**	21	40	30	**91**	7.8%	5.3%	4.4%	**5.3%**
Fabricated metal products	45	237	74	**356**	2	6	4	**12**	0.7%	0.8%	0.6%	**0.7%**
General machinery	236	902	276	**1,414**	37	133	105	**275**	13.7%	17.6%	15.5%	**16.2%**
Electric machinery	179	707	222	**1,108**	60	149	117	**326**	22.2%	19.7%	17.3%	**19.2%**
Transport equipment	157	515	158	**830**	14	52	56	**122**	5.2%	6.9%	8.3%	**7.2%**
Precision equipment	52	142	42	**236**	8	37	24	**69**	3.0%	4.9%	3.6%	**4.1%**
Other manufacturing	36	194	60	**290**	3	11	21	**35**	1.1%	1.5%	3.1%	**2.1%**
Construction	48	503	165	**716**	1	10	11	**22**	0.4%	1.3%	1.6%	**1.3%**
Wholesale trade	108	415	125	**648**	9	44	46	**99**	3.3%	5.8%	6.8%	**5.8%**
Retail trade	47	206	66	**319**	0	0	9	**9**	0.0%	0.0%	1.3%	**0.5%**
Total	2,029	6,753	2,063	**10,845**	270	756	676	**1,702**	100.0%	100.0%	100.0%	**100.0%**

Note: Sectoral classification is based on SNA with some modification.
Source: See main text.

Table 2. The Difference of Economic Performance Between
(Mean)

	TFP		Labor productivity	
Year	Firms with tech.	Firms without	Firms with tech.	Firms without
1957	2.43	3.13	2,694	3,643
1958	0.98	3.32	1,365	3,831
1959	0.93	2.85	1,225	3,558
1960	0.95	2.77	1,552	3,662
1961	2.72	2.27	4,235	3,174
1962	5.16	2.12	7,034	3,096
1963	2.40	2.15	3,750	3,215
1964	3.06	2.02	4,832	3,317
1965	2.76	2.04	4,618	3,433
1966	3.79	1.93	6,343	3,297
1967	2.74	2.24	5,019	3,839
1968	3.00	2.28	5,495	4,140
1969	3.52	2.29	6,967	4,277
1970	3.22	2.42	6,595	4,925

Notes: 1) TFP is an index (the TFP of hypothetical firm in 1957 = 1).
2) Firms with tech: firms with acquired technologies. Firms without: firms without acquired technologies.

Table 3. Determinants of Technology Acquisition I: Technology Acquisition Dummy

N

Table 4. Determinants of Technology Acquisition II: number of acquired technologies

N

Table 5. Effects of Technology Imports on the Performance of Firm

Dependent variables: 1-year growth	TFP	Labor productivity	Value-added	Number of workers	Average wage	Capital-labor ratio	R&D-sales ratio
Technology acquisition policy variables							
Technology import dummy	0.099	2.868**	3.540**	0.188	-0.302	3.099***	0.034*
	[0.07]	[2.02]	[2.56]	[0.23]	[0.27]	[2.95]	[1.67]
Tech. Acq. dummy * period 1 (1962-68)	-1.347	-4.563***	-3.914**	0.901	-0.206	-3.947***	-0.019
	[0.83]	[2.89]	[2.55]	[1.03]	[0.17]	[3.39]	[0.82]
Tech. Acq. dummy * period 2 (1969-70)	-1.956	-4.497**	-4.061*	0.655	0.190	-1.993	-0.067**
	[0.89]	[2.10]	[1.94]	[0.55]	[0.11]	[1.26]	[2.20]
Observations	9,415	9,415	9,415	9,415	9,415	9,415	9,415
R-squared (overall)	0.050	0.040	0.050	0.110	0.050	0.070	0.130
Dependent variables: 3-year growth	**TFP**	**Labor productivity**	**Value-added**	**Number of workers**	**Average wage**	**Capital-labor ratio**	**R&D-sales ratio**
Technology import dummy	-0.592	1.279*	1.410**	-0.121	-0.476	2.323***	0.017*
	[0.87]	[1.93]	[2.05]	[0.27]	[0.86]	[4.09]	[1.74]
Tech. Acq. dummy * period 1 (1962-68)	-0.157	-1.974***	-1.462*	0.591	0.307	-2.324***	-0.003
	[0.21]	[2.68]	[1.92]	[1.20]	[0.50]	[3.69]	[0.29]
Observations	7,453	7,453	7,453	7,453	7,453	7,453	7,453
R-squared (overall)	0.140	0.100	0.080	0.160	0.110	0.110	0.370

Notes: 1) Random-effect model is used for estimation.
2) ***, **, * indicate level of significance at 1%, 5% and 10% and figures in brackets indicate t-statistics.
3) Estimated coefficients indicate the gaps of growth rate between foreign-owned and domestically-owned firms.
4) Year dummies and industry dummies are included (not reported). The coefficients of year dummies are presented in Figure 2.
5) We also include firm characteristics as control variables. See main text, for more detail.

Appendix Table 1. Basic Indicators of Variables

	N	Mean	S.D.	Minimum	Maximum
Technology acquisition dummy	9,415	0.15	0.35	0.00	1.00
Number of acquired technologies	9,415	0.29	1.08	0.00	22.00
Cumulative number of technologies	9,415	1.40	5.44	0.00	165.00
Capital-labor ratio	9,415	1.85	1.66	0.08	24.23
Sales (ranking in industry)	9,415	33.13	27.41	1.00	137.00
TFP	9,415	2.31	7.49	0.05	118.04
Cash-flow	9,415	0.10	0.06	-0.36	0.50
Subsidy	9,415	0.06	0.09	0.01	0.52
JDB loans	9,415	0.00	0.01	0.00	0.04
Research and development	9,415	0.16	0.51	0.00	9.01

Note: For the definition of variables and sources, see main text.

Appendix Table 2. Correlation Matrix of Variables

	Tech. D	Tech. Acq.	Cum. Tech.	KL ratio	Rank	TFP	Cash-flow	Subsidy	JDB	R&D
Technology acquisition dummy [Tech. D]	1.00									
Number of acquired technologies [Tech. Acq.]	0.65	1.00								
Cumulative number of acquired technologies [Cum. Tech.]	0.43	0.81	1.00							
Capital-labor ratio [KL ratio]	0.07	0.04	0.07	1.00						
Sales (ranking in industry) [Rank]	-0.19	-0.18	-0.18	-0.15	1.00					
TFP	0.02	0.01	0.00	-0.08	-0.12	1.00				
Cash-flow	0.07	0.05	0.04	0.11	0.04	-0.26	1.00			
Subsidy	-0.05	-0.03	-0.04	0.05	-0.02	-0.04	-0.12	1.00		
JDB loans	0.04	0.01	0.00	0.13	0.03	-0.14	0.21	-0.17	1.00	
Research and Development [R&D]	0.07	0.03	0.05	0.02	0.07	-0.07	-0.04	-0.02	0.08	1.00

Note: For the definition of variables and sources, see main text.