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Technical Inefficiency and Firm Behavior: A Panel Study of Japanese Small and Medium Manufacturing Firms

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Technical Inefficiency and Firm Behavior: A Panel Study of Japanese Small and Medium Manufacturing Firms*

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Abstract

This study examines the technical inefficiency of Japanese small and medium manufacturing firms by using the panel data of the *Basic Survey on Small and Medium Enterprises* (2009-2018).

We estimate the stochastic frontier production function with four production factors (regular workers, non-regular workers, capital stock, and materials) and calculate the technical inefficiency of individual firm by applying a true random effects model which can distinguish technical inefficiency from firm heterogeneity.

Our evidence is summarized as follows. First, technical inefficiency is overestimated when the number of total workers is used as production input for the conventional stochastic frontier model which forces firm heterogeneity into the same term as technical inefficiency. Second, the inefficient firms are smaller, rely more on non-regular workers, exhibit poorer firm performance, have higher debt-asset ratios, pay lower interest rates and are inactive in capital investment as well as R&D investment. Third, inactive capital investment and high debt-asset ratios are mainly responsible for causing the technical inefficiency.

Keywords: stochastic frontier model, true random effects model, capital investment,
R&D investment, debt-asset ratio, regular workers, non-regular workers
JEL Classification Number: D22, E22, E23, J24

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1. Introduction

The technical inefficiency in production is a big concern for firm managers as well as policy makers. This is because improving the technical inefficiency of the firm might achieve better firm performance and gain competitiveness. Then the important question to be posed is how to improve the technical inefficiency. To achieve this goal, we have to identify the inefficient firms and compare the behavioral difference between the inefficient firms and the efficient ones, if any.

The purpose of this study is to identify the inefficient firms and compare the characteristics of the inefficient firms and the efficient ones by making use of the panel data of Basic Survey on Small and Medium Enterprises (BSSME) by Small and Medium Enterprise Agency from 2009 to 2018. Specifically, the stochastic frontier model is employed to identity the inefficient firms and then investigate the behavioral differences between the inefficient firms and the efficient ones.[1] It is frequently argued that small and medium enterprises (SMEs) are more inefficient than large firm in Japan, but there are no empirical studies that examined the technical inefficiency of the SMEs.[2] The BSSME is an ideal data source to investigate this issue.

This study contributes to the existing literature of the technical inefficiency in three points. First, we incorporate the possibly different effects of regular workers and non-regular workers on production in estimating the production function. It is frequently argued that inefficiency of production is due to the existence of non-regular workers who might have lower productivity than regular workers. When regular workers and non-regular workers have different marginal effects on production, use of total workers rather than separate use of regular workers and non-regular workers as a factor input of production function leads to misspecification of production function. Then inefficiency term might pick up the differential impact of regular workers and non-regular workers on production. Our approach is free of this misspecification bias since we use non-regular workers and regular workers as

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[1] See Greene (1997) and Kumbhakar and Lovell (2000) for a comprehensive survey of stochastic frontier model of technical and cost efficiency.

[2] There are quite a few studies that examined the technical efficiency of the Japanese banking firms. For example, see Fukuyama (1993), McKillop et al. (1996), Altunbas et al. (2000), Drake and Hall (2003), Assaf et al. (2011) and Fukuyama and Weber (2015) among others. Altunbas et al (2000) use stochastic frontier model (SFM), while Assaf et al. (2015) calculate efficiency measures, using the Bayesian distance frontier approach. The other studies are based on the data envelopment analysis (DEA). Ogawa (2020) examines the technical efficiency of the Japanese rice farmers, using the SFM.

separate independent variables in estimating the production function.

Second, we use a true random effects model developed by Greene (2005a,b). The conventional panel data stochastic frontier model forces firm heterogeneity into the same term as the technical inefficiency. Thus, measures of inefficiency might be mixed measure of firm heterogeneity and the technical efficiency. The true random effects model overcomes this shortcoming.

Third, we pin down the source of the technical inefficiency by comparing quantitatively the effects of four candidates causing the inefficiency: firm size, investment activities, financial conditions and labor conditions of the firms, on the technical inefficiency.

Let us preview our findings. First, as for the specification of production function, translog production function is preferred to Cobb-Douglas production function by Wald test. Second, technical inefficiency was overestimated when the total workers, rather than separate treatment of regular workers and non-regular workers, is used as a factor input in the conventional stochastic frontier model which forces firm heterogeneity into the same term as technical inefficiency. Our study suggests that the conventional inefficiency term might include cross-firm heterogeneity in addition to the technical inefficiency. Third, as for the characteristics of the inefficient firms, we find that the inefficient firms are smaller, rely more on non-regular workers, exhibit poorer firm performance in terms of operation profit rate and profitability of investment, measured by marginal q, have higher debt-asset ratio and pay lower interest rate. Moreover, the inefficient firms are inactive in capital investment as well as R&D investment. Fourth, inactive capital investment and high debt-asset ratio are mainly responsible for creating the technical inefficiency. Our evidence implies that getting rid of excessive debt helps the inefficient firms correct the inefficient bank-firm relationship, start capital investment and get out of the inefficiency trap.

This study is organized as follows. The next section describes the data set used for the analysis. In section 3, a model for estimating the technical inefficiency is formulated, and the estimated results thereof are indicated. In section 4, the characteristics of the efficient and inefficient firms, based on the efficiency indices, are compared. In section 5, we investigate the determinants of the technical inefficiency and then discuss the measures to improve the efficiency. Section 6 concludes this study.

2. Data Set and Their Characteristics

The data employed in the analysis is the panel data of the Basic Survey on Small and Medium Enterprises (*Cyusho Kigyo Jittai Kihon Chosa*) by the Small and Medium Enterprise Agency. The sample period covers 10 years from 2009 to 2018. Our sample firms are manufacturing firms whose equity capital is less than or equal to 300 million yen or the number of employees is less than or equal to 300 persons. Sampled firms are divided into three sub-industries: machinery industry, light industry and heavy industry. Machinery industry includes general-purpose, production and business-oriented machinery, electronic components and devices, electrical machinery, equipment and supplies, information and communication electronics equipment and transport equipment. Total number of observations of machinery industry is 8,542. Light industry includes food products and beverages, textile products, timber, furniture, printing, rubber products, leather and other manufacturing industry. Total number of observations of light industry is 20,585. Heavy industry includes pulp, paper and paper products, chemicals, petroleum and coal products, non-metallic mineral products, basic metal and fabricated metal products. Total number of observations of heavy industry is 9,332. The panel data is sparse in the sense that 89.2 percent of firms in machinery industry, 87.5 percent of firms in light industry and 89.1 percent of firms in heavy industry stay in the panel data only one year. Our data set is an unbalanced panel data.

Now an explanation is in order on the procedure of data construction. Most of the basic data are obtained from balance sheet and profit-and-loss statements of individual firms. The real output (Y) is calculated by dividing sales by the output deflator of the System of National Accounts (SNA) corresponding to each industry.[3] The labor input (N) has two components. One is the number of regular employees (NR) and the other is the number of non-regular employees (NNR) that include part-time workers, temporary workers and seconded workers. The capital stock (K) is calculated by deflating the nominal tangible fixed asset of three types (buildings and structures, instruments, tools, vessels and vehicles, and machine equipment) by the corresponding price indices and summing up them. We use the deflators of gross fixed capital formation (buildings and structures and machinery and equipment) in the SNA. The materials (M) were calculated by dividing the expenditure on nine types of items (cost of goods purchased, material cost, outsourcing cost, other cost of goods sold, cost of utilities, freight and packing cost, sales charges, advertisement expenses, other costs of sales expenses and administrative expenses) by the intermediate input deflator in the SNA and summing up them.

Table 1 shows the descriptive statistics of the real output, four production factor inputs and other

[3] The base year of the deflator is 2011.

important firm attributes.[4] The firm attributes include labor productivity, defined as the real output divided by the total employees, ratio of regular employees to total employees, real total assets, defined as the total assets divided by the output deflator, debt-asset ratio, defined as the ratio of total debt to total assets, operating profit ratio and the borrowing interest rate, defined as the interest and discount expenses divided by the sum of short-term borrowing, long-term borrowing and corporate bond debt. The means of real output, capital stock, material input and total assets are all above the medians and exhibits a right-skewed distribution. The mean ratio of regular employees is slightly below 50 percent, while the median ratio of regular employees hovers around 50 percent. The mean of debt-asset ratio is above 0.8 in all industries. The mean of debt-asset ratio is notably high in light industry, above 0.95.

3. Identification and Estimation of Technical Inefficiency

We estimate the stochastic frontier production function, which comprises four production factors (regular workers, non-regular workers, capital stock, and materials), and calculate technical inefficiency indices of production for individual firm. The index of inefficiency is calculated under two production functions, the Cobb-Douglas production function and translog production function and the two specifications about the technical inefficiency. In both specifications we assume that the inefficiency term is a random variable. In one specification we assume that the technical inefficiency is time invariant random variable which is uncorrelated with the regressors. Then we estimate the inefficiency parameters by the generalized least squares (GLS).[5]

A drawback of this specification is that firm heterogeneity cannot be distinguished from technical inefficiency. That is, measured inefficiency might be picking up firm heterogeneity in addition to or even instead of technical inefficiency. The true random effects model, developed by Greene (2005a,b), overcomes this shortcoming. The true random model is a variant of random parameters model, retaining the basic nature of stochastic frontier model. The formulations of the true random model reinterpret the time invariant term as firm-specific heterogeneity due to omitted time invariant factors such as firms' organizational characteristics. Another virtue of the true random model is to relax time invariancy of technical inefficiency and assume that the technical inefficiency is time-varying random variable.

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[4] We discard the observations less than 2.5 percentile and more than 97.5 percentile of the variables in each industry.

[5] See Schmidt and Sickles (1984) for details of estimation.

In the conventional random effects model the stochastic frontier production function is specified as

$$\ln Y_{it} = f(lnNR_{it}, lnNNR_{it}, lnK_{it}, lnM_{it}) - u_i + v_{it} \qquad (1)$$

where Y_{it} ：output in year t

NR_{it} ：regular employees in year t

NNR_{it} ：non-regular employees in year t

K_{it} ：capital stock in year t

M_{it} ：material input in year t

u_i ：time invariant random variable representing inefficiency, $u_i \geq 0$

v_{it}: disturbance term

i is an index of individual firm

In the true random effects model the stochastic frontier production function is specified as

$$\ln Y_{it} = f(lnNR_{it}, lnNNR_{it}, lnK_{it}, lnM_{it}) + w_i - u_{it} + v_{it} \qquad (2)$$

where Y_{it} ：output in year t

NR_{it} ：regular employees in year t

NNR_{it} ：non-regular employees in year t

K_{it} ：capital stock in year t

M_{it} ：material input in year t

w_i ：time invariant random variable representing firm heterogeneity

u_{it} ：time-varying random variable representing inefficiency, $u_{it} \geq 0$

v_{it}: disturbance term

As for the specification of the production function, the Cobb-Douglas function is written as

$$f(lnNR_{it}, lnNNR_{it}, lnK_{it}, lnM_{it}) = \alpha_R lnNR_{it} + \alpha_N lnNNR_{it} + \alpha_K lnK_{it} + \alpha_M lnM_{it} \qquad (3)$$

When the production function is the translog type, it is written as

$$f(lnNR_{it}, lnNNR_{it}, lnK_{it}, lnM_{it}) = \alpha_R lnNR_{it} + \alpha_N lnNNR_{it} + \alpha_K lnK_{it} + \alpha_M lnM_{it}$$
$$+\alpha_{RR}(lnNR_{it})^2 + \alpha_{RN}(lnNR_{it})(lnNNR_{it}) + \alpha_{RK}(lnNR_{it})(lnK_{it}) + \alpha_{RM}(lnNR_{it})(lnM_{it})$$

$$+\alpha_{NN}(lnNNR_{it})^2 + \alpha_{NK}(lnNNR_{it})(lnK_{it}) + \alpha_{NM}(lnNNR_{it})(lnM_{it})$$
$$+\alpha_{KK}(lnK_{it})^2 + \alpha_{KM}(lnK_{it})(lnM_{it}) + \alpha_{MM}(lnM_{it})^2 \qquad (4)$$

We assume that u_{it} is distributed as exponential in the true random effects model. It is assumed that the disturbance term (v_{it}) is i.i.d. normal as $N(0, \sigma_v^2)$. The parameter estimates of the true random effects model are obtained by simulated maximum likelihood technique.

The year dummies and sub-industry dummies are also added to the explanatory variables. Table 2 shows the results of the stochastic frontier production function. First, let us compare the estimation results of the Cobb-Douglas production function with those of the translog production function. Significantly positive values are obtained for all the coefficient estimates of the Cobb-Douglas production function, irrespective of industry. On the other hand, the estimation results of the translog production function are not entirely satisfactory since many of the coefficient estimates are not significant due to multicollinearity.

It is straightforward to test the validity of the Cobb-Douglas production function by the Wald test. The null hypothesis is that all the coefficients of the quadratic terms are zero. Table 3 shows the test statistics. It is evident that the null hypothesis is decisively rejected in all the industries. Therefore the production behavior of Japanese manufacturing SMEs is well characterized by the translog production function. Table 4 shows the mean elasticity of regular worker, non-regular worker, capital and material input calculated from the translog production function. Surprisingly, the output elasticity with respect to factor inputs calculated from the parameter estimates of the translog production function are quite close to those obtained under the Cobb-Douglas production function, although the Cobb-Douglas production function is rejected as the specification of production technology. It should be also noted that there are close similarities of the output elasticity with respect to factor inputs across industries. The material input elasticity takes largest value, ranging from 0.65 (machinery industry) to 0.71 (light industry). The regular worker elasticity takes the second largest value and ranges from 0.20 (light industry) to 0.24 (heavy industry). The non-regular worker elasticity is from 0.08 (heavy industry) to 0.10 (light industry). The capital elasticity takes the smallest value and is in the narrow range of 0.01 to 0.02.

Now we compare the technical inefficiency estimates of time-invariant random effects model with those of the true random effects model. We calculate the technical inefficiency measure of Jondrow et al. (1982) for individual firm based on the coefficient estimates of the production function as follows. For time-invariant random effects model,

$$\mathrm{E}[u_i \mid \varepsilon_{it}] \quad (5)$$

where $\varepsilon_{it} \equiv v_{it} - u_i$

For the true random effects model,

$$\mathrm{E}[u_{it} \mid \varepsilon_{it}] \quad (6)$$

where $\varepsilon_{it} \equiv v_{it} - u_{it}$

Table 5 shows the mean of the technical inefficiency estimates and degree of technical efficiency under two different random effects model.[6] The estimates of technical inefficiency of time-invariant random effects model is much larger than those of the true random effects model, irrespective of industry. When the production technology is specified as the Cobb-Douglas type, the technical efficiency varies from 23.05% to 33.84% in the time-variant random effects model, while the technical efficiency varies from 90.58% to 94.08% in the true random effects model. When the production technology is specified as the translog production function, the technical efficiency varies from 37.57% to 46.71% in the time-variant random effects model, while the technical efficiency varies from 88.34% to 90.51% in the true random effects model. It is clear that measured inefficiency might be picking up firm heterogeneity in addition to technical inefficiency in the time-invariant random effects model. Our estimation results suggest that measured inefficiency is overestimated in the time-invariant random effects model.

Technical inefficiency under the misspecified production function

It might be argued that technical inefficiency arises from the existence of non-regular workers who might have lower productivity than regular workers. When regular workers and non-regular workers have different marginal effects on production, use of total workers, rather than separate use of regular workers and non-regular workers, as an explanatory variable of production function might create misspecification bias in the parameter estimates and thus lead to fallacious statistical inferences of the technical inefficiency. To gauge the effect of this misspecification on the estimates of technical inefficiencies, we estimate the production function with three input factors (total workers, capital stock, and materials), and calculate technical inefficiency indices for individual firm. The estimates of technical inefficiency under the misspecified production function in the true random effects model are shown in Table 6. The estimates of technical inefficiency under the misspecified model are larger than

[6] Degree of technical efficiency is calculated as exp(-ε) where ε is technical inefficiency measure.

those under the correctly specified model, irrespective of industry. Thus the misspecification of production technology that the output elasticity of non-regular is identical with that of regular workers might create upward biases of the technical inefficiency.

Based on the above results, we conclude that the technical inefficiency is precisely estimated by the translog production function in the true random effects model. Therefore, the subsequent analysis is based upon the estimates of the technical inefficiency obtained by the translog production function in the true random effects model.[7]

4. Comparison of Characteristics between the Efficient Firms and the Inefficient Firms

Based on the median of the inefficiency measures of the stochastic frontier model estimated in the preceding section, the manufacturing firms are divided into an efficient firm group and an inefficient firm group, and the characteristics of their behaviors are examined. We compare the behavioral characteristics of the efficient and inefficient firms based on the following 16 items:

1) Real output
2) Number of workers
3) Capital stock
4) Material input
5) Total assets
6) Labor productivity
7) Ratio of regular workers
8) Operating profit rate
9) Debt-asset ratio
10) Borrowing interest rate
11) Proportion of firms that made capital investment
12) Investment rate
13) Marginal q
14) Proportion of firms that made R&D investment

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[7] The analysis in the subsequent sections is almost entirely unaffected even if we use the inefficiency indices that are obtained under the assumption of the Cobb-Douglas production function in the true random effects model.

15) R&D investment rate

16) Proportion of firms that have patents

Some explanation is in order on the above variables. Items 1 to 5 compare the firm's production activities as well as the firm size. Items 6 to 10 provide information on the firm's performance and financial conditions. Items 11 to 16 compare the firm's investment behavior. The driving force of investment activities is marginal q (Mq), present discounted value of maximized profit rate divided by the investment goods price. In other words, the marginal q is defined as:

$$Mq_t = \frac{1}{p_t^I} E_t\left[\sum_{j=0}^{\infty} \beta_{t+j}(1-\delta)^j \pi_{t+j}\right] \qquad (7)$$

where p_t^I : price of investment goods in period t

$\beta_{t+j} = \prod_{i=1}^{j}(1+r_{t+i})^{-1}, \quad (j = 1,2,\cdots), \quad \beta_t \equiv 1$

r_{t+i} : borrowing interest rate in period t+i

δ : depreciation rate

π_{t+j} : profit rate, defined as the maximized profit divided by the capital stock at the end of t+j-1 period

$E_t[\cdot]$: expectation operator conditional on the information set available for the firm in period t

In constructing the marginal q series special attention should be paid to the stochastic property of the two underlying factors: borrowing interest rate (r_t) and profit rate (π_t). The profit rate is defined as the ratio of operating profit to the beginning-of-period capital stock. It is assumed that the borrowing interest rate and the profit rate follow random walk independently. In other words,

$$r_{t+1} = r_t + u_{t+1} \qquad (8)$$

$$\pi_{t+1} = \pi_t + v_{t+1} \qquad (9)$$

where u_{t+1}, v_{t+1} : stationary white noise

Then it can be shown that the marginal q is simply written as

$$Mq_t = \frac{\pi_t}{p_t^I}\frac{1}{r_t+\delta} \qquad (10)$$

We use the median of the depreciation rate for each industry. That is, the depreciation rate is 18.22 %, 16.53% and 18.29% for machinery industry, light industry and heavy industry, respectively.

Table 7 shows the mean difference as well as its standard error of the 16 items described above between the efficient and inefficient firm groups. We observe the following differences in firm characteristics between the efficient firms and the inefficient firms, irrespective of industry.

1) The efficient firm is significantly larger than the inefficient firm in terms of real output, number of workers, capital stock, material input and total assets.[8]
2) As for the composition of workers, the proportion of regular workers is significantly higher for the efficient firm.
3) The efficient firm exhibits better performance in terms of labor productivity and operation profit rate.
4) As for the financial conditions, the efficient firm has lower debt-asset ratio, but pays higher borrowing interest rate. [9] Lower borrowing cost for the inefficient firm suggests that banks make ever-greening lending to zombie SMEs for procrastination of non-performing loans. Our evidence is consistent with the findings of Imai (2016).
5) The investment behavior of the efficient firm is more active than that of the inefficient one. The proportion of firms that make capital investment as well as R&D investment is significantly higher for the efficient firm group. Capital investment rate is higher for the efficient firm group, which might reflect higher profitability of investment, measured by marginal q. In fact the marginal q is below unity for the inefficient firm group, irrespective of industry. The proportion of firms that have patent is also higher for the efficient firm group of machinery and light industries.

5. Technical Inefficiency and Investment Behavior

We compared the characteristics of the inefficient firms with those of the efficient firms in the previous section. In this section we examine the source of the technical inefficiency. We categorize the determinants of the technical inefficiency into four groups: firm size, financial conditions of the firm,

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[8] There is no statistical difference in capital stock between the efficient firms and the inefficient firms of machinery industry.

[9] There is no statistical difference in borrowing interest rate between the efficient firms and the inefficient firms of heavy industry.

labor conditions of the firms and investment activities. Then we make quantitative comparison of the effects of four variables: firm size, investment activities, improvement of financial conditions and utilization of regular workers, on improving the technical inefficiency.

It turns out that start of capital investment is effective in raising the technical efficiency. Therefore we discuss the measures to get a firm started on capital investment.

Determinants of technical inefficiency

We estimate the technical inefficiency function by using the following four types of explanatory variables: firm size, investment activities, financial condition and composition of the labor force. Dependent variable is the technical inefficiency measure (*INEFFICIENCY*) obtained under the translog production function estimated by the true random model. Firm size is measured by the logarithm of real total asset (*LSIZE*). There are two important investment activities for firm: capital investment and R&D investment. We specify firm's investment activities by binary variables and quantitative variables. In the binary specification investment activities are represented by two dummy variables. One is whether a firm made current capital investment or not, denoted by *INVDUM*. The other is whether a firm made current R&D investment or not, denoted by *RDINVDUM*. In the quantitative specification we use investment rate (*IK*), ratio of current investment to capital stock, for capital investment and the ratio of R&D investment to sales (*RDINVSALES*) for R&D investment.

The firm's financial condition is measured by the debt-asset ratio (*DEBT*). We measure the composition of the firm's labor force by the ratio of regular workers of firm's labor force (*REGEMP*). Specifically, the following technical inefficiency equation is estimated by the random effects panel model. [10]

$$(INEFFICIENCY)_{it} = \alpha_0 + \alpha_1(LSIZE)_{it} + \alpha_2(INVDUM)_{it} + \alpha_3(RDINVDUM)_{it} \\ + \alpha_4(DEBT)_{it} + \alpha_5(REGEMP)_{it} + \varepsilon_{it} \tag{11}$$

or

$$(INEFFICIENCY)_{it} = \alpha_0 + \alpha_1(LSIZE)_{it} + \alpha_2(IK)_{it} + \alpha_3(RDINVSALES)_{it} \\ + \alpha_4(DEBT)_{it} + \alpha_5(REGEMP)_{it} + \varepsilon_{it}$$

[10] The year dummies and sub-industry dummies are also added as explanatory variables. The coefficient estimates of the year dummies and sub-industry dummies are omitted.

(12)

where $INEFFICIENCY$: technical inefficiency measure

$LSIZE$: logarithm of real total asset

$INVDUM$: dummy variable that takes unity when a firm made current capital investment and zero otherwise

$RDINVDUM$: dummy variable that takes unity when a firm made current R&D investment and zero otherwise

IK: ratio of capital investment to capital stock

$RDINVSALES$: ratio of R&D investment to sales

$DEBT$: debt-asset ratio

$REGEMP$: proportion of regular workers out of total workers

ε: disturbance term

The estimation results are shown in Table 8. Firm size has significantly negative effect on technical inefficiency. That is, larger firm is more technically efficient. Debt-asset ratio has significantly positive effect on technical inefficiency.[11] This implies that the firm with excessive debt suffers from technical inefficiency. As was seen in the previous section, inefficient firms tend to have higher debt-asset ratio but pays lower borrowing interest rate. This evidence hints that the inefficient firm with high debt-asset ratio survives partly by the ever-greening lending by financial institutions. Hiring more regular workers significantly mitigates the technical inefficiency.

As for the investment activities, activating capital investment enhances technical efficiency significantly, but increasing R&D investment does not improve the technical inefficiency. Capital investment accompanies acquisition of new plant or machines that embody advanced technology, which immediately contributes to enhancing technical efficiency, but there is always some uncertainty

[11] It might be argued that improvement in technical inefficiency enables the firms to earn more profit, increase internal fund and thus lower the debt-asset ratio. It implies that improvement in technical inefficiency causes the debt-asset ratio, not the other way around. The causality between a change in technical inefficiency and improvement of firms' financial condition might be tested rigorously by panel VAR analysis, but the sparse nature of our panel data that only a few firms provide more than one year observations prevents us from estimating panel VAR model.

whether R&D investment will show successful results and increase efficiency.

It is an interesting exercise to compare quantitatively the effects of each explanatory variable of the inefficiency equation on improving the technical inefficiency. Specifically, we calculate the extent to which the technical inefficiency decreases when the logarithm of firm size, debt-asset ratio, the proportion of regular workers out of total workers or the investment rate changes from the mean value of the inefficient firms to that of the efficient firms. As for the effect of start of capital investment on decreasing the technical inefficiency, we simply calculate how much the technical inefficiency decreases when a firm starts capital investment. [12] [13] Table 9 shows the effects of each variable on improving the technical inefficiency in percentage terms.

Start of capital investment has the largest effect on reducing the technical inefficiency. The technical inefficiency is reduced by 7.5% in machinery industry, 7.55% in heavy industry and 9.83% in light industry. Large effect of starting capital investment is contrasted with smaller effect of increasing capital investment marginally for the firms that already made capital investment. The effect of increasing capital investment for the firms that already made capital investment on reducing the technical inefficiency is less than 1%, irrespective of industry. Our analysis shows that start of capital investment (extensive margin) is more effective in improving the technical efficiency than marginal increase of existing investment project (intensive margin).

Decrease in debt-asset ratio, which exhibits the second largest effect on improving the technical efficiency, decreases the technical inefficiency by 4.86% in machinery industry to 5.81% in heavy industry. Other measures, such as expansion of firm size and hiring more regular workers, have limited impact on improving the technical efficiency since the effects on reducing the technical inefficiency are less than 1%.

<u>What motivates firms to start capital investment?</u>

Our evidence above shows that start of capital investment is effective in improving the technical efficiency. Now we discuss the measures to get a firm started on capital investment by estimating a binary investment model. Note that the proportion of firms that made capital investment is 29.9% in

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[12] We do not calculate the effects of R&D investment on the technical efficiency since most of the coefficient estimates are statistically insignificant or do not take the sign expected by the theory.

[13] See Table 7 for the mean value of firm size, debt-asset ratio, the proportion of regular workers out of total workers and the investment rate for the efficient firms and the inefficient firms.

light industry, 35.7% in machinery industry and 38.7% in heavy industry, as was shown in Table 1. Therefore, we use the random effects probit model to estimate the parameter estimates of investment function. The specification of the investment function is a standard one that includes profitability of investment or marginal q (*Mq*) and debt-asset ratio (*DEBT*), measure of financial conditions of the firm. The dependent variable ($INVDUM$) is a dummy variable that takes unity when a firm made current capital investment and zero otherwise.

Table 10 shows the estimation results of the investment function. In all the industries marginal q has significantly positive effect on the probability that capital investment is positive. On the other hand, debt-asset ratio has significantly negative effect on the probability that capital investment is positive, irrespective of industry. Now we calculate the marginal effect of marginal q and the debt-asset ratio on the probability that capital investment is positive. When marginal q increases from the mean value of the inefficient firms to that of the efficient firms, the probability that capital investment is positive rises only by 1.95%, 1.74% and 1.60% for machinery industry, light industry and heavy industry, respectively. However, when debt-asset ratio decreases from the mean value of the inefficient firms to that of the efficient firms, the probability that capital investment is positive rises by 5.10%, 3.98% and 5.29% for machinery industry, light industry and heavy industry, respectively. Combining the estimation results of the investment function with the evidence above, getting rid of excessive debt is quite effective in gaining the technical efficiency by correcting the inefficient bank-firm relationship and starting capital investment.

6. Concluding Remarks

This study examined the technical inefficiency of the Japanese small and medium manufacturing firms by using the panel data of *Basic Survey on Small and Medium Enterprises* collected by Small and Medium Enterprise Agency from 2009 to 2018.

We estimated the stochastic frontier production function with four production factors (regular workers, non-regular workers, capital stock, and materials), and calculated technical inefficiency of individual firm by applying a true random effects model which can distinguish technical inefficiency from firm heterogeneity.

Our evidence is summarized as follows. First, technical inefficiency was overestimated when the number of total workers, rather than separate treatment of regular workers and non-regular workers, is used as a production input in the conventional stochastic frontier model which forces firm heterogeneity into the same term as technical inefficiency. Second, we find that the inefficient firms are smaller, employ more non-regular workers, exhibit poorer firm performance, have higher debt-asset ratio and pay lower interest rate. Moreover, the inefficient firms are inactive in capital investment as well as R&D investment. Third, inactive capital investment and high debt-asset ratio are mainly responsible for creating the technical inefficiency. Given our findings, getting rid of excessive debt is an important task for the inefficient firm, which helps correct the inefficient bank-firm relationship, start capital investment and gain the technical efficiency.

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Table 1 Descriptive Statistics of Major Variables

	machinery industry			light industry			heavy industry		
	mean	median	standard deviation	mean	median	standard deviation	mean	median	standard deviation
Real output (ten thousand yen) 1)	47,825.2	10,295.2	88,338.4	41,585.1	7,163.8	83,668.1	57,356.9	13,005.7	98,911.1
Number of regular employees (persons)	18.5	5.0	28.9	14.4	3.0	25.2	19.1	5.0	29.3
Number of non-regular employees (persons）	8.5	4.0	11.7	8.1	4.0	11.4	8.1	4.0	10.9
Capital stock (ten thousand yen） 2)	7,927.8	1,303.6	16,608.1	7,041.3	835.1	16,057.0	9,697.2	1,505.9	19,145.9
Material input (ten thousand yen） 3)	31,758.3	5,121.7	65,382.0	28,347.9	3,500.9	62,317.4	39,825.7	6,737.3	74,154.4
Labor productivity (ten thousand yen/person) 4)	1,223.2	990.3	939.6	1,127.4	829.9	964.0	1,474.9	1,104.3	1,184.5
Ratio of regular employees （%）	49.4	55.6	28.1	42.1	50.0	28.6	49.2	56.0	28.1
Total asset (ten thousand yen) 5)	44,524.4	8,775.1	82,786.6	36,839.9	5,155.3	77,110.0	52,637.9	9,874.5	94,434.6
Debt-asset ratio	0.8614	0.7398	0.6699	0.9589	0.8139	0.7376	0.8446	0.7498	0.6430
Operating profit ratio (%)	0.35	1.05	9.14	-0.54	0.00	8.02	0.52	0.78	7.74
Borrowing interest rate (%)	1.54	1.48	1.14	1.45	1.36	1.18	1.52	1.43	1.15
Proportion of firms that made capital investment (%)	35.7	0.0	47.9	29.9	0.0	45.8	38.7	0.0	48.7
Investment rate (%)	7.2	0.0	17.4	5.8	0.0	15.6	7.9	0.0	17.5
Marginal q	1.81	1.17	5.94	1.10	0.79	5.71	1.58	1.08	5.10
Proportion of firms that made R&D investment (%)	10.3	0.0	30.4	7.4	0.0	26.1	8.9	0.0	28.5
R&D investment rate (%)	0.03	0.00	0.16	0.02	0.00	0.13	0.03	0.00	0.15
Proportion of firms that have patents (%)	11.3	0.0	31.6	11.2	0.0	31.5	10.8	0.0	31.0

Notes: 1)~ 5) real values in 2011 price

Source: The Small and Medium Enterprise Agency, *Basic Survey on Small and Medium Enterprises*

Table 2 Estimation Results of Stochastic Frontier Production Function: Machinery industry

	(1)	(2)	(3)	(4)
	random effects model (GLS)		true random effects model	
lnNR	0.2362 ***	1.1978 ***	0.2398 ***	1.2524 ***
	(55.36)	(29.63)	(58.30)	(32.64)
lnNNR	0.0872 ***	0.5056 ***	0.0880 ***	0.5050 ***
	(21.99)	(14.28)	(22.77)	(14.96)
lnK	0.0166 ***	-0.0127	0.0174 ***	-0.0068
	(6.50)	(-0.53)	(6.99)	(-0.30)
lnM	0.6592 ***	-0.5753 ***	0.6507 ***	-0.6933 ***
	(182.22)	(-13.69)	(183.77)	(-17.21)
$(\ln NR)^2$		0.0652 ***		0.0706 ***
		(20.69)		(23.43)
(lnNR)(lnNNR)		-0.0192 ***		-0.0228 ***
		(-4.31)		(-5.36)
(lnNR)(lnK)		-0.0083 ***		-0.0074 ***
		(-2.93)		(-2.74)
(lnNR)(lnM)		-0.0994 ***		-0.1063 ***
		(-24.47)		(-27.24)
$(\ln NNR)^2$		0.0195 ***		0.0204 ***
		(6.41)		(7.10)
(lnNNR)(lnK)		0.0079 ***		0.0069 ***
		(2.90)		(2.68)
(lnNNR)(lnM)		-0.0452 ***		-0.0438 ***
		(-11.90)		(-12.04)
$(\ln K)^2$		0.0038 ***		0.0055 ***
		(3.21)		(4.96)
(lnK)(lnM)		-0.0028		-0.0061 ***
		(-1.14)		(-2.68)
$(\ln M)^2$		0.0680 ***		0.0745 ***
		(28.34)		(32.40)
Constant term	3.6857 ***	9.3582 ***	3.8668 ***	10.1221 ***
	(96.49)	(42.79)	(99.39)	(48.39)
σ_u	0.2075	0.1816	0.0989	0.1239
σ_v	0.1485	0.1424	0.1843	0.1445
Number of observations	6790	6790	6790	6790

Notes: The coefficient estimates of year dummies are suppressed.

The values in parhenthesis are t-values.

*,**, *** significant at 10%, 5% and 1% level, respectively

NR: regular workers NNR: non-regular workers K: capital stock M: material input

σ_u: standard deviation of inefficieny distribution

σ_v: standard deviation of disturbance distribution

Table 2(continued) Estimation Results of Stochastic Frontier Production Function: Light industry

	(1)	(2)	(3)	(4)
	random effects model (GLS)		true random effects model	
lnNR	0.2029 ***	1.2538 ***	0.2177 ***	1.3295 ***
	(60.73)	(42.91)	(64.78)	(49.04)
lnNNR	0.0978 ***	0.5935 ***	0.1031 ***	0.6246 ***
	(30.58)	(22.75)	(31.91)	(24.52)
lnK	0.0118 ***	-0.0244	0.0076 ***	-0.0819 ***
	(5.69)	(-1.39)	(3.72)	(-4.71)
lnM	0.7121 ***	-0.5804 ***	0.7032 ***	-0.6813 ***
	(236.33)	(-18.39)	(232.58)	(-22.66)
$(lnNR)^2$		0.0664 ***		0.0687 ***
		(28.88)		(31.95)
(lnNR)(lnNNR)		-0.0043		-0.0045
		(-1.36)		(-1.46)
(lnNR)(lnK)		-0.0023		-0.0082 ***
		(-1.12)		(-4.17)
(lnNR)(lnM)		-0.1135 ***		-0.1150 ***
		(-36.40)		(-39.86)
$(lnNNR)^2$		0.0197 ***		0.0208 ***
		(8.45)		(9.14)
(lnNNR)(lnK)		-0.0005		-0.0009
		(-0.25)		(-0.45)
(lnNNR)(lnM)		-0.0471 ***		-0.0497 ***
		(-16.23)		(-17.65)
$(lnK)^2$		0.0037 ***		0.0056 ***
		(4.30)		(6.73)
(lnK)(lnM)		-0.0021		0.0007
		(-1.13)		(0.38)
$(lnM)^2$		0.0709 ***		0.0738 ***
		(39.01)		(42.68)
Constant term	3.0689 ***	9.0328 ***	3.2355 ***	9.9617 ***
	(100.90)	(55.07)	(98.64)	(61.96)
σ_u	0.2126	0.1833	0.0605	0.0996
σ_v	0.1024	0.0916	0.1552	0.1035
Number of observations	8624	8624	8624	8624

Notes: The coefficient estimates of year dummies are suppressed.

The values in parhenthesis are t-values.

*,**, *** significant at 10%, 5% and 1% level, respectively

NR: regular workers NNR: non-regular workers K: capital stock M: material input

σ_u: standard deviation of inefficieny distribution

σ_v: standard deviation of disturbance distribution

Table 2 (continued) Estimation Results of Stochastic Frontier Production Function: Heavy industry

	(1)	(2)	(3)	(4)
	random effects model (GLS)		true random effects model	
lnNR	0.2401 ***	1.4340 ***	0.2496 ***	1.4827 ***
	(59.39)	(44.11)	(63.25)	(48.34)
lnNNR	0.0797 ***	0.4939 ***	0.0875 ***	0.5097 ***
	(20.57)	(16.33)	(22.33)	(17.21)
lnK	0.0154 ***	0.0169	0.0132 ***	0.0071
	(6.28)	(0.87)	(5.44)	(0.38)
lnM	0.6733 ***	-0.7827 ***	0.6618 ***	-0.9182 ***
	(195.74)	(-23.15)	(194.22)	(-27.87)
$(\ln NR)^2$		0.0758 ***		0.0781 ***
		(28.49)		(30.99)
(lnNR)(lnNNR)		-0.0111 ***		-0.0112 ***
		(-2.82)		(-2.91)
(lnNR)(lnK)		-0.0043 *		-0.0073 ***
		(-1.85)		(-3.30)
(lnNR)(lnM)		-0.1259 ***		-0.1277 ***
		(-35.48)		(-37.24)
$(\ln NNR)^2$		0.0194 ***		0.0184 ***
		(6.77)		(6.73)
(lnNNR)(lnK)		0.0021		0.0048 *
		(0.85)		(1.95)
(lnNNR)(lnM)		-0.0402 ***		-0.0430 ***
		(-11.82)		(-13.00)
$(\ln K)^2$		0.0025 **		0.0039 ***
		(2.52)		(4.16)
(lnK)(lnM)		-0.0030		-0.0044 **
		(-1.44)		(-2.18)
$(\ln M)^2$		0.0782 ***		0.0840 ***
		(39.24)		(43.30)
Constant term	3.5248 ***	10.2221 ***	3.7413 ***	11.2169 ***
	(103.13)	(58.70)	(104.60)	(65.82)
σ_u	0.2222	0.1871	0.0790	0.1164
σ_v	0.1115	0.0981	0.1945	0.1477
Number of observations	7165	7165	7165	7165

Notes: The coefficient estimates of year dummies are suppressed.

The values in parhenthesis are t-values.

*,**, *** significant at 10%, 5% and 1% level, respectively

NR: regular workers NNR: non-regular workers K: capital stock M: material input

σ_u: standard deviation of inefficieny distribution

σ_v: standard deviation of disturbance distribution

Table 3 The Wald test of the Cobb-Douglas Production function

	machinery industry	light industry	heavy industry
Conventional random effects model	1422.1 (0.00)	2690.7 (0.00)	2663.9 (0.00)
The true random effects model	1789.6 (0.00)	3383.3 (0.00)	3289.4 (0.00)

Notes: The values in parenthesis are p-value.

Table 4 The mean elasticity of regular worker, non-regular worker, capital and material input

	Conventional random effects model					
	machinery industry		light industry		heavy industry	
	The Cobb-Douglas production function	The translog production function	The Cobb-Douglas production function	The translog production function	The Cobb-Douglas production function	The translog production function
regular worker	0.2362	0.2285	0.2059	0.1901	0.2401	0.2206
non-regular worker	0.0872	0.0864	0.0978	0.1050	0.0797	0.0794
capital	0.0166	0.0263	0.0118	0.0204	0.0154	0.0271
material input	0.6592	0.6649	0.7121	0.7153	0.6733	0.6875

	The true random effects model					
	machinery industry		light industry		heavy industry	
	The Cobb-Douglas production function	The translog production function	The Cobb-Douglas production function	The translog production function	The Cobb-Douglas production function	The translog production function
regular worker	0.2398	0.2306	0.2177	0.1980	0.2496	0.2268
non-regular worker	0.0880	0.0871	0.1031	0.1056	0.0875	0.0856
capital	0.0174	0.0298	0.0076	0.0202	0.0132	0.0284
material input	0.6507	0.6497	0.7032	0.7006	0.6618	0.6681

Table 5 Comparison of the mean of the technical inefficiency estimates

(1) machinery industry

	The Cobb-Douglas production function		The translog production function	
	time-invariant random effects model	The true random effects model	time-invariant random effects model	The true random effects model
techincal inefficiency measure	1.0836	0.0989	0.7613	0.1240
degree of technical efficiency	0.3384	0.9058	0.4671	0.8834

(2) light industry

	The Cobb-Douglas production function		The translog production function	
	time-invariant random effects model	The true random effects model	time-invariant random effects model	The true random effects model
techincal inefficiency measure	1.2156	0.0610	0.8198	0.0997
degree of technical efficiency	0.2965	0.9408	0.4405	0.9051

(3) heavy industry

	The Cobb-Douglas production function		The translog production function	
	time-invariant random effects model	The true random effects model	time-invariant random effects model	The true random effects model
techincal inefficiency measure	1.4676	0.0862	0.9789	0.1166
degree of technical efficiency	0.2305	0.9174	0.3757	0.8899

Notes: Degree of technical efficiency is calculated as $\exp(-\varepsilon)$ where ε is technical inefficiency measure.

Table 6 The technical inefficiency estimates for the translog production function with three factor inputs (total workers, capital stock and materials)

(1) machinery industry

	The Cobb-Douglas production function		The translog production function	
	Four factor inputs	Three factor inputs	Four factor inputs	Three factor inputs
techincal inefficiency measure	0.0989	0.1197	0.1240	0.1348
degree of technical efficiency	0.9058	0.8872	0.8834	0.8739

(2) light industry

	The Cobb-Douglas production function		The translog production function	
	Four factor inputs	Three factor inputs	Four factor inputs	Three factor inputs
techincal inefficiency measure	0.0610	0.0768	0.0997	0.1083
degree of technical efficiency	0.9408	0.9261	0.9051	0.8974

(3) heavy industry

	The Cobb-Douglas production function		The translog production function	
	Four factor inputs	Three factor inputs	Four factor inputs	Three factor inputs
techincal inefficiency measure	0.0862	0.0879	0.1166	0.1317
degree of technical efficiency	0.9174	0.9159	0.8899	0.8766

Notes: Degree of technical efficiency is calculated as $\exp(-\varepsilon)$ where ε is technical inefficiency measure.

Table 7 Comparison of Characteristics between Efficient and Inefficient Firms

(1) machinery industry

	inefficient firms	efficient firms	mean difference	
Real output (ten thousand yen) 1)	42,800	57,726	-14,926***	(-8.03)
Number of regular workers (persons)	21.3	23.4	-2.11***	(-3.04)
Number of non-regular workers (persons)	9.2	9.6	-0.44	(-1.58)
Capital stock (ten thousand yen) 2)	9,072	9,313	-241	(-0.62)
Material input (ten thousand yen) 3)	31,567	35,618	-4,051***	(-2.90)
Labor productivity (ten thousand yen/person) 4)	1,115	1,523	-408***	(-19.17)
Ratio of regular employees (%)	56.18	59.88	-3.70***	(-7.12)
Total asset (ten thousand yen) 5)	41,983	56,113	-14,130***	(-7.66)
Debt-asset ratio	0.9217	0.6871	0.2346***	(16.81)
Operating profit ratio (%)	-2.55	3.66	-6.21***	(-27.41)
Borrowing interest rate (%)	1.65	1.70	-0.05*	(-1.84)
Proportion of firms that made capital investment (%)	35.84	46.38	-10.54***	(-8.87)
Investment rate (%)	6.12	9.55	-3.43***	(-7.76)
Marginal q	0.35	3.54	-3.19***	(-22.02)
Proportion of firms that made R&D investment (%)	8.75	13.32	-4.56***	(-6.02)
R&D investment rate (%)	0.03	0.04	-0.02***	(-4.28)
Proportion of firms that have patents (%)	10.14	15.26	-5.12***	(-6.36)

Notes: 1)~ 5) real values in 2011 price

*, **, *** significant at 10%, 5%, 1% level, respectively. The values in parenthesis are t-values of the mean difference.

Table 7 (continued) Comparison of Characteristics between Efficient and Inefficient Firms

(2) light industry

	inefficient firms	efficient firms	mean difference	
Real output (ten thousand yen) [1)]	39,318	57,541	-18,223***	(-10.87)
Number of regular workers (persons)	17.7	19.9	-2.21***	(-4.03)
Number of non-regular workers (persons)	9.5	10.6	-1.10***	(-4.21)
Capital stock (ten thousand yen) [2)]	8,502	9,675	-1,173***	(-3.30)
Material input (ten thousand yen) [3)]	29,698	39,438	-9,740***	(-7.50)
Labor productivity (ten thousand yen/person) [4)]	1,089	1,507	-418***	(-20.51)
Ratio of regular employees (%)	50.9	54.07	-3.18***	(-6.59)
Total asset (ten thousand yen) [5)]	37,233	53,804	-16,571***	(-10.17)
Debt-asset ratio	1.0017	0.7839	0.2178***	(15.59)
Operating profit ratio (%)	-3.08	2.41	-5.49***	(-31.01)
Borrowing interest rate (%)	1.56	1.63	-0.07***	(-2.88)
Proportion of firms that made capital investment (%)	31.7	42.9	-11.15***	(-10.77)
Investment rate (%)	5.05	8.38	-3.33***	(-9.37)
Marginal q	-0.03	2.69	-2.71***	(-22.50)
Proportion of firms that made R&D investment (%)	6.94	9.81	-2.87***	(-4.82)
R&D investment rate (%)	0.02	0.03	-0.00	(-0.96)
Proportion of firms that have patents (%)	13.18	14.68	-1.50**	(-2.02)

Notes: 1)~ 5) real values in 2011 price

*, **, *** significant at 10%, 5%, 1% level, respectively. The values in parenthesis are t-vaules of the mean difference.

Table 7 (continued) Comparison of Characteristics between Efficient and Inefficient Firms

(3) heavy industry

	inefficient firms	efficient firms	mean difference	
Real output (ten thousand yen) [1)]	48,266	73,249	-24983***	(-12.14)
Number of regular workers (persons)	20.7	22.9	-2.16***	(-3.35)
Number of non-regular workers (persons)	8.5	9.1	-0.59**	(-2.37)
Capital stock (ten thousand yen) [2)]	11,270	12,097	-827*	(-1.84)
Material input (ten thousand yen) [3)]	42,932	50,103	-7,171***	(-4.20)
Labor productivity (ten thousand yen/person) [4)]	1,363	1,889	-526***	(-19.76)
Ratio of regular employees (%)	56.3	59.12	-2.82***	(-5.72)
Total asset (ten thousand yen) [5)]	52,029	68,283	-16,254***	(-7.76)
Debt-asset ratio	0.9242	0.6874	0.2368***	(17.61)
Operating profit ratio (%)	-1.81	3.60	-5.42***	(-29.26)
Borrowing interest rate (%)	1.61	1.66	-0.05	(-1.61)
Proportion of firms that made capital investment (%)	39.25	51.01	-11.76***	(-10.07)
Investment rate (%)	6.62	11.03	-4.41***	(-10.02)
Marginal q	0.28	3.13	-2.84***	(-23.70)
Proportion of firms that made R&D investment (%)	7.91	10.50	-2.60***	(-3.81)
R&D investment rate (%)	0.03	0.03	-0.00	(-1.12)
Proportion of firms that have patents (%)	11.03	12.26	-1.23	(-1.62)

Notes: 1)~ 5) real values in 2011 price

*, **, *** significant at 10%, 5%, 1% level, respectively. The values in parenthesis are t-values of the mean difference.

Table 8 The Determinants of technical inefficiency

(1) use of investment dummy

	constant	investment dummy	R&D investment dummy	log size	debt	regemp	R-squared Number of observations
machinery industry	0.1609***	-0.0093***	0.0068*	-0.0041***	0.0269***	-0.0210***	0.0678
	(13.96)	(-3.77)	(1.88)	(-4.41)	(13.41)	(-3.65)	6,535
light industry	0.1045***	-0.0098***	-0.0001	-0.0010	0.0226***	-0.0234***	0.073
	(13.29)	(-5.66)	(-0.02)	(-1.57)	(17.05)	(-6.02)	8,262
heavy industry	0.1788***	-0.0088***	0.0081**	-0.0057***	0.0286***	-0.0259***	0.0836
	(15.74)	(-3.95)	(2.15)	(-6.47)	(13.96)	(-4.55)	6,917

(2) use of investment ratio

	constant	investment rate	R&D investment sales ratio	log size	debt	regemp	R-squared Number of observations
machinery industry	0.1684***	-0.0255***	-0.9937	-0.0051***	0.0257***	-0.0158***	0.0756
	(15.76)	(-4.36)	(-1.64)	(-6.10)	(13.37)	(-2.83)	6,058
light industry	0.1129***	-0.0218***	0.2270	-0.0020***	0.0224***	-0.0241***	0.0735
	(14.50)	(-4.64)	(0.40)	(-3.25)	(16.66)	(-6.11)	7,928
heavy industry	0.1790***	-0.0257***	0.0523	-0.0061***	0.0275***	-0.0235***	0.0878
	(16.70)	(-4.94)	(0.08)	(-7.48)	(13.83)	(-4.22)	6,541

Notes: The numbers in parenthesis are t-values.

*,**,*** significant at the 10%, 5% and 1% level.

Table 9 Which factor is effective in decreasing technical inefficiency? Quantitaive evaluation

(1) use of investment dummy (%)

	investment dummy	firm size	debt-asset ratio	proportion of regular workers out of total workers
machinery industry	-7.50	-0.96	-5.09	-0.63
light industry	-9.83	-0.37	-4.94	-0.74
heavy industry	-7.55	-1.33	-5.81	-0.63

(2) use of investment ratio (%)

	investment rate	firm size	debt-asset ratio	proportion of regular workers out of total workers
machinery industry	-0.71	-1.19	-4.86	-0.47
light industry	-0.73	-0.74	-4.89	-0.77
heavy industry	-0.97	-1.42	-5.58	-0.57

Table 10 Marginal effects on the probability that capital investment is positive

	machinery industry	light industry	heavy industry
marginal q	0.0061*** (6.09)	0.0064*** (7.20)	0.0056*** (4.79)
debt-asset ratio	-0.2173*** (-19.10)	-0.1828*** (-20.75)	-0.2236*** (-19.66)