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Abstract

I study a model of replacement problem with liquidity constraint, where the land is used as a collateral as well as a factor of production. The collateral value of the land restricts the available funds for the firm, which works as a capacity constraint of firms. Due to this constraint, the replacement can be enhanced when the positive technology and/or demand shocks arrives. This stands in contrast with some types of replacement models, where the positive demand shocks delay the replacement. The rise of the land price enlarges the available funds for the firms which requires the efficient use of the land, when the firms are under liquidity constraint. It also raises the user's cost of land, hence, the replacement of machine is enhanced. The effects of the land price on the the multi-factor productivity and replacement are examined by the data of Japan during 1970 and 1998. The estimated results show that the rise of the land price enhance the replacement and improves the multi-factor productivity in the non-service sectors, but I do not observe the direct relationship between the replacement and the land price in the service sectors. These results are consistent with the view that the land price affects the replacement decisions and productivity in non-service sectors. In service sectors, however, the other factors such as the quality of investments could be important.

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1 Introduction

The replacement decision of the machine is an important factor to determine the quality of capital and productivity of firms. In the economy where the technology is embodied in capital, the frequent replacement of capital implies the increase of productivity. In this paper, I propose a model of replacement and show how the land price affects the replacement decision of the firms with and without liquidity constraint. I investigate the predictions of the model by using the Japanese data after 1970, when the land price has significantly fluctuated.

In Japan, the land price rose rapidly in the late 80s and has dropped after the 90s. As Table 1 shows, the change is significant. In the same periods, the multi-factor productivity has changed its direction in 1990. But the direction of changes depend on industries. Table 2 shows the multi-factor productivity of Japan.[1] As this table shows, the multi-factor productivity of non-service sectors has declined after 1990s, but the direction is opposite for the service industries. Many factors affect the multi-factor productivity, because the calculated multi-factor productivity, basically based on the Solow's residual, is affected by returns to scale and labor hoarding. But in this paper, I focus on the replacement decisions of the firms, and investigate how they affect the quality of capital and the productivity, when the land price fluctuate. For this purpose, I first develop a model of replacement decisions of the firms with and without liquidity constraint. In the model, the land is used as a factor of production but also works as a collateral to mitigate the liquidity constraint. Since the liquidity constraint restrict the available funds of firms, the firms consider the most efficient use of available funds.

Such restrictions work as capacity constraints for the firms, and have important implications on the replacement decisions of firms. In order to understand it, think about the rise of demand in one industry. In response to the rise of demand, the firms would like to expand their capacity but the financial constraints prevent it. In some cases, the firms tend to destroy less efficient machine and purchase new machine in order to save the available funds.

This implication is related to the literature of the machine replacement models. In the vintage capital model of Solow (1956), the labor input works as a fixed costs, and the introduction of new technology raise the labor demand and the wages, which make the use of old, less efficient capital unprofitable (Boucekkine, Germain, and Licandro (1997) for more recent theoretical work). The similar mechanisms work in different models such as machine replacement problems in Rust (1987), Jovanovic and Rob (1997), and Cooper, Haltiwanger, and Power (1999). In their models,

[1] Construction of data is explained later.

the embodied technological advance enhances the replacement, because the embodied technological advance makes the existing machine relatively more obsolescent and less attractive.[2] There, investments are directly related to the replacement, because there is a capacity constraint of capital, in the sense that one firm owns only one machine to operate. That capacity constraint is critical for the replacement decisions, because the firm would operate two machines (old and new machines) without such constraints. The assumption of such capacity constraints can be supported by several reasons such as the limited ability of the manager to operate multiple machines. My model add one possible constraint in the sense that the capital capacity is constrained by the available funds. One advantage of my model is that I can make the capacity constraint endogenous, and analyze how the land price explicitly affect the replacement by changing the capacity itself.

The optimal replacement decisions are also studied in the creative destruction models (Caballero and Engel (1999) and Aghion and Howitt (1994)). In those models, there are no capacity constraints, and the replacement is mainly determined by its profitability that is the productivity minus the fixed costs. For example, when the labor costs are fixed costs, the models predicts more replacement when fixed costs (wage rates) increase or the productivity declines, because the old machine is less profitable. Especially, the positive demand shock delays the replacement. This relationship is apparently correct for job destruction model (Caballero and Hammour (1994)), where more job destruction (i.e., more replacement) is observed in recession. For the case of machine replacement, Cooper and Haltiwanger (1993) observed that the machine replacement is more likely to occur during downturns where the resource cost of replacement is lower. Campbell (1998) also finds the negative relation between the replacement and the output by using the exit rates as a proxy for the replacement. Clearly, this prediction is different from the vintage capital model above, where the investment is equal to the replacement, thus, the replacement is more frequent in the economic boom.

In this paper, I propose a model to mitigate these opposing views by introducing the liquidity constraint. Due to the liquidity constraint, the available funds restrict the capital that the managers can purchase. In this respect, the model is closer to the replacement model, since, there, the number of capital is restricted. As a result, the positive demand shocks enhance the replacement. On the other hand, I can show that the firms may delay the replacement in the economic booms, when the liquidity constraint is not so restrictive. That is more in line with the creative destruction model.

My model is closely related to the literature of investment under liquidity constraint (Kiyotaki

[2]In Greenwood, Hercowitz, and Krusell (1997), the firms destruct less efficient, old machine by using the old machine more intensively when the positive embodied technical shocks arrive.

and Moore (1997), Bernanke, Gertler, and Gilchrist (1999), Carlstrom and Fuerst (1997)), although they do not take the replacement decisions into account. As I show it later, the decisions of investments and replacements are different, although they are related.

The model predicts the effects of the land price on the replacement decisions and multi-factor productivity. There are two effects for the firms with liquidity constraint when the land price rises. The first effect is caused by the rise of capital costs. This raises the fixed costs of holding capital and increases the replacement, which improve the productivity of remaining capital (thus, raises the multi-factor productivity). The second effect is caused by the weakening of the liquidity constraint. When the land price rises, the firms can purchase more new capital, thus, increases the replacement. As a result, I show that the rise of the land price enhances the replacement and improve the productivity for the firms under the liquidity constraint.

On the other hand, when the firm face no liquidity constraint, only the first effect works without the second effect. Thus, the replacement is also enhanced, but the degree is smaller. In addition, when the land price rises very rapidly, then holding the land itself produces the net capital gains, and the land is considered as an asset rather than a cost of production. In such cases, the situation is reversed, and the rise of land price reduces the total cost of capital (including the land and machine) and allow the firms to use less efficient capital. This is possible explanation why the land price reduces the multi-factor productivity when the land price rises rapidly. And this effect is stronger for the firms without liquidity constraint.

In order to understand the validity of the model, I use the Japanese data for estimation. It is important to use the Japanese data since the land prices have fluctuated significantly over the past few decades. I focus on the two types of Japanese data in estimation: the multi-factor productivity and the replaced value of capital. In the first estimation, I use the multi-factor productivity whose trends are summarized in Table 2. The data is taken from Fukao, Inui, Kawai, and Miyagawa (2003), who calculate the multi-factor productivity from the Japan Industrial Database (the JIP Database). They take into accounts the effect of intermediate goods, capital utilization rates, and quality of labor. Since they do not consider the effect of production of scale, this number is affected by the business cycles.[3]

In the second estimation, I use the replaced capital as an dependent variable. The data of the replaced capital is estimated from the Quarterly Review of Non-financial enterprizes in Japan. This data allow us directly to examine the effect of the land prices on the replacement, although

[3]Especially, when there is an increasing return to scale, the calculated multi-factor productivity has an upward bias (downward bias, respectively) in case of economic booms (recessions).

the data may include noises, because it is the book value of replaced capital. By using the single equation GMM, I have the results that the rise of land prices enhance the replacement and raises the productivity in the non-service sectors. But the effects of the land price on the replacement is not clear for service sectors. Thus, the overall result is consistent with the model in the non-service sector, although it is not clear in the service sectors. The multi-factor productivity in the service sectors may be more affected by the reasons other than the replacements.

The rest of this paper is organized as follows: Section 2 presents a basic model. In section 3, I present the data of Japan and conduct the estimation. In section 4, alternative explanation is considered and the related result in the US is also discussed.

2 Model

I follow the strand of the literature in which the firms invest under the liquidity constraint (Kiyotaki and Moore (1997), Bernanke, Gertler, and Gilchrist (1999)). I consider the discrete time model, and all aggregate variables such as the aggregate shock of A_t, the product price (P_t), the price of land Q_t, and the capital price (P_t^I) are realized at the beginning of the period. There is a measure of firms (thus infinitely many) who are risk-neutral and have ability to produce the goods competitively. Then, the firms, who have the existing capital stock of K_{t-1} and the land of T_{t-1}, choose the amount of investments (I_t) and land (T_t). They also borrow the necessary funds (B_t) from the banks. After this transaction is completed, the idiosyncratic shock of ϵ_t^j is realized for each machine, and the firms make the optimal destruction decisions of machine. The production is conducted at the end of period, and the repayment of borrowing and the second hand markets for capital and land opens at the beginning of the next period. Thus, due to this assumption, the capital gain or loss may happen by holding the asset and capital, although there is no uncertainty during the production process.

The efficiency of each machine is denoted by ϵ_t^j, which follows an iid process (across machines and time) whose mean is one and cdf is defined by $F_\epsilon(\epsilon)$. In this economy, each firm uses the continuum of capital; therefore, each firm faces no uncertainty concerning ϵ_t^j. I will show that the optimal policy is to set the cut-off level of $\underline{\epsilon}_t$, below which the machine is destroyed.[4] Denote the capital level before and after the machine destruction by K^b and K, respectively. They have the

[4]I assume that there are no second hand markets during the period. Thus, the firms need to destroy the machine in order to prevent the fixed costs.

following relationship:

$$K_t^b = I_t + K_{t-1}, \quad K_t = \bar{F}_\epsilon(\underline{\epsilon}_t) K_t^b. \tag{1}$$

In the above expression, I_t is the amount of investment, and $\bar{F}_\epsilon$ is the fraction of ϵ above the critical value $(\underline{\epsilon})$, i.e., $\bar{F}_\epsilon(\underline{\epsilon}) = 1 - F_\epsilon(\underline{\epsilon})$.

The aggregate production function depends on the total number of capital measured in terms of the efficiency unit:

$$K_t^e = \int_j \epsilon_t^j \, dj = K_t^b \int_{\underline{\epsilon}_t}^{+\infty} \epsilon' \, dF_\epsilon(\epsilon') = \Phi(\underline{\epsilon}_t) \, K_t. \tag{2}$$

where the integral in the first equation is taken over the existing capital stock in the firm, and Φ is an average quality of capital after destruction, and defined by $\Phi(\underline{\epsilon}_t) = \int_{\underline{\epsilon}} \epsilon \, dF_\epsilon / \bar{F}_\epsilon$.

The total flow profit from operating the continuum of capital after machine destruction is derived as follows:

$$P_t \, A_t K_t^e - c_f K_t = P_t \, A_t \Phi(\underline{\epsilon}_t) \, K_t - c_f K_t. \tag{3}$$

Here, A_t is the aggregate productivity in the economy.[5] P_t is a product price, and c_f is a fixed cost in holding one unit of capital. I assume that the constant returns to scale technology.[6]

Following the literature of investment models under liquidity constraint, I assume the risk neutral firms with the discount factor of β, who delay their own consumption in the future. They lose the ability of producing the goods with probability z. After that event, they are pure consumers. In order to assure these situations in the steady state, I assume the following:

Assumption 1 $P_t \, A_t - c_f - \tau(R_t Q_t - Q_{t+1}) + P_{t+1}^I > R_t \, P_t^I, \quad \beta R_t < 1.$

The first assumption is to ensure that the investment project is profitable so that all of the available resources are used for investments as long as the managers have ability to produce the goods. By the second condition, the firms consume immediately after they lose the production ability. The amount of investments are restricted by the following flow of funds equation:

$$P_t^I (I_t + K_{t-1}) + Q_t T_t \leq W_t + B_t, \tag{4}$$

where B_t stands for the amount of the loan, and Q_t is the land price. W_t is a net wealth of the firm after repaying the debt:

$$W_t = P_{t-1} \, A_{t-1} \, \Phi(\underline{\epsilon}_{t-1}) K_{t-1} - c_f K_{t-1} + Q_t T_{t-1} + P_t^I K_{t-1} - R_{t-1} B_{t-1}, \tag{5}$$

[5]When the labor input is included in production, this term is considered as the reduced form after optimally adjusting the labor input. I ignore the fluctuation of wage rates.

[6]I study the effects of the increasing returns to scale in the Appendix.

where R_t is one plus the interest rate of risk-free assets.

Next, consider how the land is used in the production process. Here, in order to simplify the analysis, I assume the Leontief production function, in which each machine requires τ amount of land for production.[7] Specifically,

$$T_t = \tau K_t, \tag{6}$$

where τ is a constant. Now I consider the two types of firms: the first type of firms is constrained by liquidity, and the other type is not.

Firms without liquidity constraints

When the firms are not constrained by liquidity, they invest as much as possible to the limit of available investment project, $\bar{K}_t$, because the rate of returns is higher than the return on the other assets (R_t).

$$K_t^b \leq \bar{K}_t. \tag{7}$$

Here, note that the limited number of projects is the amount of capital before destruction. Thus, the firms are constrained by the number of profitable projects rather than the loanable funds. By denoting the value function of firms by V, we can define the maximization problem for the firms as follows:

$$\begin{aligned} V(S_t, W_t) \quad = \quad & \max_{\underline{\epsilon}_t, K_t, B_t} E_t \Big(\beta(1-z)V(S_{t+1}, W_{t+1}) + \beta z W_{t+1}\Big), \\ & s.t. \Big(\frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} + \tau Q_t\Big) K_t \leq W_t + B_t, \\ & \quad W_{t+1} = \Big(P_t\, A_t \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P_{t+1}^I\Big) K_t - R_t B_t, \\ & \quad K_t \leq \bar{K}_t \bar{F}_\epsilon(\underline{\epsilon}_t), \end{aligned} \tag{8}$$

where S_t is a vector of aggregate variables, $S_t = (P_t, P_t^I, Q_t)$. The first constraint is the flow of funds equation (4), where I use the definition of investments, (1). The second constraint is the definition of net wealth, (5). The last constraint is from (7). The Bellman's equation reflect the assumption that the firms lose their abilities to produce the goods with probability z, in which case they consume all of their net wealth. Otherwise, they continue to operate, then their value is $V(S_{t+1}, W_{t+1})$.

[7] In the Appendix, I consider the case in which the fixed amount of land (T_t) is used for production. This is another extreme case. In this alternative assumption, the land price is not directly included in the first order condition. Thus, without scale of returns, the land price does not affect the replacement decisions.

It is clear that the value function is an increasing function of W without uncertainty. In that case, the optimal cutoff point ($\underline{\epsilon}_t$) is derived by maximizing W_{t+1}. By substituting the constraints, W_{t+1} is

$$W_{t+1} = \Big(P_t\, A_t\, \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P^I_{t+1} - \tau R_t Q_t\Big) \bar{F}_\epsilon(\underline{\epsilon}_t)\bar{K}_t - R_t P^I_t \bar{K}_t + R_t W_t.$$

I assume the interior value of $\underline{\epsilon}_t$ by the following assumption.

Assumption 2 $c_f + \tau(R_t Q_t - Q_{t+1}) - P^I_t > 0.$

Then, the first order condition is,

$$P_t\, A_t\, \underline{\epsilon}_t - c_f - \tau(R_t Q_t - Q_{t+1}) + P^I_{t+1} = 0. \tag{9}$$

The first term is the marginal revenue in operating the marginal quality of machine. The other terms are the fixed costs of holding machine. The last term is the return when they sell the machine in the next period. The cost of machine, P^I_t, is not included in deciding the optimal destruction, since the cost is already sunk. The intuition is standard and same as Caballero and Hammour (1994): The firms delay the destruction of machine when the demand (the product price) increases or the fixed costs decline.

The effects of the land price depend on cases. When $R_t Q_t > Q_{t+1}$, it is costly to hold the land. In that case, the rise of land price raises the fixed cost of holding the machine, because some amount of land is required for production. But, when the land price is expected to rise significantly ($R_t Q_t < Q_{t+1}$), the land is considered as an asset to produce the net profit. Then, the rise of land price increase the rate of return on holding the machine. Then, the less efficient machine (i.e., machine with low ϵ) can survive, since its low return is compensated by the higher return on the land.[8]

Proposition 1 *Without uncertainty and liquidity constraint, the unexpected rise of P_t and/or A_t lower $\underline{\epsilon}$. The proportionate increase of Q_t and Q^I_{t+1} raises $\underline{\epsilon}$ when $R_t Q_t > Q_{t+1}$, but lowers $\underline{\epsilon}$ when $R_t Q_t < Q_{t+1}$.*

Firms under liquidity constraints

[8] When the returns on the land is greater than R_t, the demand for the safe asset is zero without uncertainty. In order to justify the situation, I need to assume that only managers can hold the land.

Next, consider the optimal decision of firms under liquidity constraint. I assume that the lending relationship ends in one period and lenders have no ways to enforce the loan contracts to firms except for the use of the land as collateral. Thus, the minimum amount that the banks can ensure is the expected market value of collateralized land. Whenever the banks lend more than that amount, the managers use the entire resource for their private use. Suppose that the fraction, γ, of land holding can be used as a collateral. Then, the limit of loanable funds is,

$$R_t B_t \leq \gamma E_t Q_{t+1} T_t. \tag{10}$$

The maximization problem in this case is similar to (8), but now the amount of loan (B) is restricted by (10). By assuming that the firms borrow all available funds, we have the maximization problem of the firms under the liquidity constraint:

$$\begin{aligned} V(S_t, W_t) &= \max_{\underline{\epsilon}_t, K_t} E_t \Big(\beta(1-z)V(S_{t+1}, W_{t+1}) + \beta z W_{t+1}\Big), \\ & \quad s.t. \ \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} K_t + \tau Q_t K_t \leq W_t + \tau \frac{\gamma}{R_t} Q_{t+1}^* K_t, \\ & \quad W_{t+1} = \Big(P_t\, A_t\, \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P_{t+1}^I - \tau\gamma Q_{t+1}^*\Big) K_t, \end{aligned} \tag{11}$$

where Q_{t+1}^* is an expected value of Q_{t+1}. Again, without any uncertainty, the value function is an increasing function of W_{t+1}. Then, the maximization is:

$$\begin{aligned} \max_{\underline{\epsilon}_t, K_t} \quad & \Big(P_t\, A_t\, \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P_{t+1}^I - \tau\gamma Q_{t+1}\Big) K_t, \\ & s.t. \ \Big(\frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} + \tau Q_t - \tau \frac{\gamma}{R_t} Q_{t+1}\Big) K_t \leq W_t. \end{aligned}$$

Under the current assumption, the firms invest as much as possible, and the constraint is binding. Then, by eliminating the capital (K_t) in the expression, the maximization is to maximize the rate of return on the wealth.

$$\max_{\underline{\epsilon}_t} \quad \frac{P_t\, A_t\, \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P_{t+1}^I - \tau\gamma Q_{t+1}}{\frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} + \tau Q_t - \tau \frac{\gamma}{R_t} Q_{t+1}} W_t. \tag{12}$$

Under the assumption 2, the solution is interior. The first order condition is,

$$\frac{P_t\, A_t\, \Phi(\underline{\epsilon}_t) - c_f + \tau Q_{t+1} + P_{t+1}^I - \tau\gamma Q_{t+1}}{\frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} + \tau Q_t - \tau \frac{\gamma}{R_t} Q_{t+1}} = \frac{P_t A_t (\Phi(\underline{\epsilon}_t) - \underline{\epsilon}_t) \bar{F}_\epsilon(\underline{\epsilon}_t)}{P_t^I}, \tag{13}$$

In order to understand the proposition, I modify the equation (13):

$$\begin{aligned} P_t A_t \underline{\epsilon}_t - c_f - \tau\Big(R_t Q_t - Q_{t+1}\Big) + P_{t+1}^I &= \tau\Big(Q_t - \frac{\gamma}{R_t} Q_{t+1}\Big)\Big(\frac{P_t A_t (\Phi(\underline{\epsilon}_t) - \underline{\epsilon}_t) \bar{F}_\epsilon(\underline{\epsilon}_t)}{P_t^I} - R_t\Big), \\ &= \tau\Big(Q_t - \frac{\gamma}{R_t} Q_{t+1}\Big)\Big(\frac{W_{t+1}}{W_t} - R_t\Big). \end{aligned} \tag{14}$$

The second equation comes from the first order condition of (13) and the definition of wealth, (12). Thus, the second bracket on the right-hand side is the excess return on the investments over the market interest rate (i.e., $W_{t+1}/W_t - R_t$), which is always positive under the current assumption.

Without liquidity constraint, the right-hand side is always zero, which is clear from the optimal condition of the firms without the liquidity constraint, (9). The firms without liquidity constraint simply makes the marginal product equal to the marginal costs. The firms under the liquidity constraint, however, have additional constraint. Due to the liquidity constraint, the firms compare two alternative choices: keep to use the machine of marginal quality or replace it with the new machine. By keeping the marginal machine, the firms get the benefits expressed in the left-hand side. On the other hand, when they replace it with the new one, then τ units of land are available for replacement, but they do not have liquidity to purchase the new machine. In order to buy the new machine, they need to sell some amount of land, but it reduces the borrowing limit of firms (say, by ΔB_t). By selling τ units of land, the total amount of money free for purchasing the machine and land is $\tau(Q_t - \Delta B_t) = \tau(Q_t - (\gamma/R_t)Q_{t+1})$. For each unit of money, the return is W_{t+1}/W_t. As the right-hand side of the first equation shows, this benefit is calculated based on the expected returns on the new machine, since the quality of new machine is uncertain.

From this equation, several properties are clear. First, the critical value of $\underline{\epsilon}_t$ is always higher for the firms with liquidity constraint than those without it, by comparing this expression with (9). This is because the financial constraint restricts the use of available funds, inducing more efficient use of land. Second, under the liquidity constraint, the rise of land prices raises the replacement when the growth rate of the land price is low. In addition, it can be shown that the effect on the marginal quality of machine, $\underline{\epsilon}_t$, is stronger for the firms with the liquidity constraint than for those without it. Equation (14) shows this point intuitively. As the left-hand side of the equation shows, the land price raises the quality of marginal machine directly since the rental price of land rises. This effect is same for both the firms with and without liquidity constraint. But the firms under the liquidity constraint have an additional shock that is shown on the right-hand side of (14). As the financial constraint is relaxed, the firms can spend more on purchasing the new machine which is potentially more productive. That enhances more replacement. Although the effect on the right-hand side is more complicated, I can show that this intuition is basically true when the land price does not decline so heavily.

Third, the positive demand shocks (the rise of P_t) and technology shocks (the rise of A_t) increase the replacement of machine in some cases. As shown in the equation (14), the rise of P_t and A_t raises the returns of both the marginal machine (LHS) and the replaced machine (RHS).

When this industry is land intensive (high τ) and/or this firms are more heavily constrained by liquidity (low γ), the available funds by destroying one machine is larger. As a result, the total return of replacement is higher than that of keeping the marginal machine. As a result, the firms are more selective in choosing the quality of machine. This property is similar to the standard machine replacement problem where the firm can operate only one machine. In those models, the replacement happens because the number of machine is exogenously given. In my model, however, the number of available machine is determined by the available funds which are endogenously determined. Without liquidity constraint, the model would become a standard creative destruction model, where the destruction of machine is solely determined by the productivity and the fixed costs.

I can summarize the result in the following proposition:

Proposition 2 *Without aggregate uncertainty but under the liquidity constraint, the (unexpected) proportionate increase of* P_t^I *and* P_{t+1}^I *reduces* $\underline{\epsilon}_t$*. The (unexpected) rise of* P_t *and/or* A_t *raise* $\underline{\epsilon}_t$*, when* $\tau(1-\gamma)Q_{t+1} + P_{t+1}^I > c_f$*, but they reduce* $\underline{\epsilon}_t$*, otherwise. The proportionate increase of* Q_t *and* Q_{t+1} *raises* $\underline{\epsilon}_t$*, when* $Q_{t+1}/Q_t < g_1^*$ *for some* $g_1^* > R_t$*. Otherwise, it reduces* $\underline{\epsilon}_t$*. The change of* $\underline{\epsilon}_t$ *is greater for the firms under the liquidity constraint than those without it, when* $Q_{t+1}/Q_t > g_2^*$ *for some* $g_2^* < R_t$*.*

Proof. See the Appendix.

3 Data and Estimation

I conduct two types of estimation. In the first estimation, I investigate the effect of land prices on the multi-factor productivity. Next, I directly estimate the effect on the replaced value of plant and equipment investments.

For the first estimation, the data of multi-factor productivity is taken from Fukao, Inui, Kawai, and Miyagawa (2003). They are yearly data, whose sample periods is from 1970 to 1998. In calculating the multi-factor productivity, the authors adjusted the labor quality, the capacity utilization rates in calculation, but not the returns to scale. I eliminate this bias by including the output as an explanatory variables in estimation. Specifically, I directly estimate the production function with the elasticity of scale of ν. The specific form of function is same as in the basic model which includes $\underline{\epsilon}_t$, but I allow for the returns to scale and the variable capacity utilization rates.

$$Y_t = A_t\Big(\Psi(\underline{\epsilon}_t)u_tK_t\Big)^{\nu}, \tag{15}$$

where u_t is the capacity utilization of the firm. By taking the log and difference, and assuming that $\ln A_t$ follows the random walk with drift ($\ln A_t = \ln A_{t-1} + \eta_t + a_0$),[9] we have,

$$d\,(y_t - u_t - k_t) = a_0 + \nu\, d\, \ln \Psi(\underline{\epsilon}_t) + (\nu - 1)(d\, u_t + d\, k_t) + \eta_t, \tag{16}$$

where $x_t = \ln X_t$. On the other hand, the multi-factor productivity calculated in JIP database is,

$$dMFP_t = d\, y_t - d\, u_t - d\, k_t. \tag{17}$$

By eliminating the $d\, u_t + d\, k$ from the above expression, we have,

$$\nu\, d\, MFP_t = a_0' + \nu\, d\, \ln \Psi\Big(\underline{\epsilon}_t(A_t, Q_t/P_t, P_t^I/P_t)\Big) + (\nu - 1) d\, y_t + \eta_t. \tag{18}$$

Here, the marginal quality of capital, $\underline{\epsilon}$, is replaced by the policy function, where the state variables are $(A_t, Q_t/P_t, P_t^I/P_t)$.[10] Equation (9) implicitly defines this function when the firms are not under liquidity constraint, while this function is (14) when the firms are constrained by the liquidity. By taking the log and linealization, we have,

$$d\, MFP_t = a_0 + a_2\, d\,(q_t - p_t) + a_3\, d\,(p_t^I - p_t) + a_4 d\, y_t + \eta_t. \tag{19}$$

The effects on the MFP are same as those on $\underline{\epsilon}$: The rise of p^I decreases $\underline{\epsilon}$ and MFP. The rise of Q_t increases $\underline{\epsilon}$ and MFP for the firms, especially for the firms under the liquidity constraint. But it can reduces the $\underline{\epsilon}$ and MFP in some cases. The effects of Y is positive when there is an increasing return to scale. Since the current explanatory variables are affected by the current productivity shock, I use the GMM without serial correlation. I use the lagged variables (both dependent and explanatory variables) as the instruments of estimation. Since I take the first difference and need to have enough lags, the estimated sample period is 1977 to 1998 (22 years).

Table 3 shows the estimated results for service and non-service industries. The sign conditions of variables are correct for the output and the capital price. For the land prices, the effects are opposite for service and non-service industries. The land price raises the efficiency of capital for the non-service, while it reduces MFP for service sectors. One explanation in relation to the model is that the firms are more liquidity constrained in the non-service industries, which justifies the positive effect on productivity. On the other hand, the rise of the land prices is so high for the

[9]The aggregate technology growth may be correlated with the past explanatory variables such as the past factor inputs (Hall (1988)). I, however, use my current formulation partly because I assume that $\underline{\epsilon}$ can explain these movements of the Solow residuals, and partly because of the difficulty of obtaining effective instruments.

[10]I omitted the interest rates for estimation.

service industry that the firms consider the land as assets than the cost of capital. This reduces the productivity of capital.

I also estimate the effect of the land prices on the replaced value of capital directly. The replaced value of the plant and equipment is constructed based on the Financial Statements Statistics of Corporations prepared by the Ministry of Finance of Japan. It reports the book value of discarded and sold equipments quarterly.[11] Since the reported data are book values after deducting depreciation, these values are subject to the depreciation methods and price changes over time. Thus, I constructed the values of replaced capital on the constant price basis. I use the benchmark year method in calculating the present value of capital stock, investments, and replaced capital (although the benchmark year method is not necessary in calculating the replaced capital, it is important to construct the capital stock to see if the produced capital and the replaced capital are consistent. Refer to the Appendix for the detail). This approach, using the replaced values of capital, looks better than the estimation of multi-factor productivity, since we can study the effect of the land price directly, but there is a problem of measurement error as the replaced series are originally book values.

Figure 1 shows the trends of these series. The level of replaced capital is fairly stable if I compared them with the investments.[12] But, the yearly fluctuation is large and the magnitudes are almost same as those of investments. It is also important to find that the trends of the growth rates of the replaced equipments are much different from those of investments. Figure 2 reports the replacement ratio by industry and firm size. It is noteworthy that the small size (non-manufacturing) firms increased the replacement during the late 80s, when the land price rose rapidly.

In order to estimate the effect of the land price, I estimate the relationship between $\underline{\epsilon}_t$ and R_t derived from the model. In the model, $K_t^b = K_{t-1}$, thus,

$$\frac{R_t}{K_{t-1}} = \frac{(1-\bar{F}_\epsilon(\underline{\epsilon}_t))(I_t + K_t^b))}{K_t^b} = F\Big(\underline{\epsilon}_t(A_t, Q_t/p_t, P_t^I/p_t, R_t/p_t)\Big)\big(\frac{I_t}{K_{t-1}} + 1\big). \tag{20}$$

By taking the log and linealizing the expression, we have,

$$d\,r_t = b_0 + b_1\,d\,(q_t - p_t) + b_2\,d\,(p_t^I - p_t) + b_3\,d\,i_t + b_4\,d\,y_t + \eta_t, \tag{21}$$

where r_t is a replacement rate ($r_t = \ln R_t/K_{t-1}$), and i_t is an investment rate ($i_t = \ln I_t/K_{t-1}$). Here, I include the effect of output to see the effect of the demand and technology shocks. Since

[11] Although it is quarterly, I use the annualized data to avoid the possible serial correlation and to keep the consistency with the JIP data. In addition, the quarterly land price is not available.

[12] It may be due to the book value nature of this series.

the F is an increasing function, the critical value ($\underline{\epsilon}_t$) and the replacement (r_t) move in the same direction: the rise of p^I decreases $\underline{\epsilon}$ and r_t. The rise of Q_t increases $\underline{\epsilon}$ and MFP for the firms when the land prices are not expected to rise so high. Otherwise, the effect may be negative. The effect of investments, i_t, is positive. The effects of output, y_t, is negative, when the positive shocks to the output delays the replacement as indicated by the creative destruction model. It is positive, when the technological progress is embodied and the machine replacement model is more relevant. In order to avoid the simultaneous bias, I use the single equation GMM without serial correlation. The instruments are the first-differenced lagged variables (both dependent and explanatory variables).

The results are shown in Table 4. The table shows that the effect of capital price is negative as expected in non-service sectors, but not clear in the service sectors. Investments raises the replacements in the service industry which is consistent with the model, but not true in non-service sectors. The effects of output are negative for both sectors, which indicate the positive productivity shocks delay the replacement, which is more in line with the creative destruction model, and it is more consistent with the case of the firms without liquidity constraint.

The effects of land price is positive for the non-service sectors. This result is consistent with the first estimation in Table 3: The rise of land prices enhance the replacement and raises the productivity. But the effect of the land price is not clear for service sectors. Thus, the effect on the replacement may not be so important to characterize the overall decline of productivity growth during the estimated periods when the land prices rose sharply. But overall, the coefficients are not so robust for the specification of instruments and the choice of explanatory variables. In addition, the sample size is small. Thus, we need to interpret the estimation results with caution.

4 Discussion

Other interpretations

There is a vast literature for the costly external finance (Jensen and Meckling (1976) and Myers and Majluf (1984)). In those models, the increase of asset prices leads to the increase of free cash flow and expands the investments. The managers may choose the inefficient way of investments when the cash flow is abundant when the firms prefer the growth over the profit (Jensen (1986)).[13]. Clearly, this paper is not an alternative to those models but complements them by introducing different perspective, since my model focuses on the replacement problem rather

[13]The possibility of the over-investment may not be applied to Japan according to Hoshi, Kashyap, and Scharfstein (1991).

than the investment problem. As we have seen in the introduction, the movements of replacements and investments are different. In addition, my model shows that the rise of the land prices can reduce the efficiency of capital even for the large firms where the agency problems are less important.

Reallocation effects

In the United States, the significant amount of total productivity of industry is affected by the reallocation effect, in the sense that the high productivity firms expands, while the low productivity firms lose their shares. This reallocation effect also works when the asset price rises. When the productivity of liquidity constrained firms are higher than others, then the expansion of those firms improve the aggregate productivity of the economy (Kiyotaki and Moore (1997), for example). Jermann and Quadrini (2002) show that the reallocation effect was important in the early 90s in US, when the stock prices went up.

The situation, however, looks different in Japan. By using the plant level data in Japan, Fukao and Kwon (2003) shows that the effect of reallocation is not so strong. Second, the share of the small firms in investments did not expand in the late 80s when the stock and land prices rose rapidly. As is clear from the direct observation, there are no major discrepancies of investment behaviors by firm sizes, especially during the late 80s. This situations stand in contrast with those in US, and justify to focus on the behaviors of individual firms as in the current paper.

Appendix

Alternative assumtion on the use of land in production process.

In this Appendix, I consider the case in which the fixed amount of land is used for production.

$$T_1 = 1.$$

In addition, the technology exhibits the returns to scale whose elasticity of scale is denoted by ν. Let's consider the two cases, the firms without and with liquidity constraint, in turn.

Firms without liquidity constraints

When the firms are not liquidity constrained, they face the condition of available projects, (7). Then, the maximization problem is similar to (8):

$$\begin{aligned} V(S_t, W_t) &= \max_{\underline{\epsilon}_t, K_t, B_t} E_t\Big(\beta(1-z)V(S_{t+1}, W_{t+1}) + \beta z W_{t+1}\Big), \\ & \quad s.t.\ \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} K_t + Q_t \le W_t + B_t, \\ & \qquad W_{t+1} = p_t\, A_t\, \Phi(\underline{\epsilon}_t)^\gamma K_t^\gamma - c_f K_t + Q_{t+1} + P_{t+1}^I K_t - R_t B_t, \\ & \qquad K_t \le \bar{K}_t \bar{F}_\epsilon(\underline{\epsilon}_t), \end{aligned} \tag{A.1}$$

Without uncertainty, the optimal cutoff point ($\underline{\epsilon}$) is derived by maximizing W_{t+1}. By substituting the constraints, W_{t+1} is

$$W_{t+1} = p_t\, A_t\, (\Phi(\underline{\epsilon}_t))^\gamma (\bar{F}_\epsilon(\underline{\epsilon}_t)\bar{K}_t)^\gamma - c_f \bar{F}_\epsilon(\underline{\epsilon}_t)\bar{K}_t + Q_{t+1} + P_{t+1}^I \bar{F}_\epsilon(\underline{\epsilon}_t)\bar{K}_t - R_t P_t^I \bar{K}_t - R_t Q_t + R_t W_t.$$

The first order condition is,

$$\gamma p_t\, A_t\, (\Phi(\underline{\epsilon}_t)\bar{F}_\epsilon(\underline{\epsilon}_t)\, \bar{K}_t)^{\gamma-1}\, \underline{\epsilon}_t - p_t\, c_f + P_{t+1}^I = 0. \tag{A.2}$$

It is clear that the land price is not included in this first order condition.

Proposition 3 *Suppose that there is no uncertainty in the aggregate variables. Then, the unexpected rise of P_t and/or A_t lower $\underline{\epsilon}$. The land price does not affect this decision.*

Firms under liquidity constraints

As in (10), the limit of loanable funds is,

$$R_t B_t \le \gamma E_t Q_{t+1} T_t, \tag{A.3}$$

The maximization problem for the firms is similar to (11):

$$\begin{aligned} V(S_t, W_t) &= \max_{\underline{\epsilon}_t, K_t} E_t \Big(\beta(1-z)V(S_{t+1}, W_{t+1}) + \beta z W_{t+1}\Big), \\ & s.t. \ \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} K_t + Q_t \leq W_t + \frac{\gamma}{R_t} Q_{t+1}^*, \\ & \quad W_{t+1} = p_t\, A_t\, \Phi(\underline{\epsilon}_t)^\gamma K_t^\gamma - c_f K_t + Q_{t+1} + P_{t+1}^I K_t - \gamma Q_{t+1}^*, \end{aligned} \tag{A.4}$$

Again, without any uncertainty, the value function is an increasing function of W_{t+1}. Then, the maximization is:

$$\begin{aligned} \max_{\underline{\epsilon}_t, K_t} \quad & p_t\, A_t\, \Phi(\underline{\epsilon}_t)^\gamma K_t^\gamma - c_f K_t + Q_{t+1} + P_{t+1}^I K_t - \gamma Q_{t+1}, \\ & s.t. \ \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon})} K_t + Q_t \leq W_t + \frac{\gamma}{R_t} Q_{t+1}. \end{aligned}$$

The first order conditions are:

$$\begin{aligned} \gamma\, p_t\, A_t\, \Phi(\underline{\epsilon}_t)^\gamma K_t^{\gamma-1} - c_f + P_{t+1}^I &= \lambda_t \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon}_t)}, \\ \gamma\, p_t\, A_t\, \Phi(\underline{\epsilon}_t)^{\gamma-1} K_t^\gamma \frac{\partial \Phi}{\partial \underline{\epsilon}_t} &= \lambda_t \frac{P_t^I}{\bar{F}_\epsilon(\underline{\epsilon}_t)^2} f_\epsilon(\underline{\epsilon}_t)\, K_t. \end{aligned}$$

Combining together and eliminating λ_t, we have the optimal condition for $\underline{\epsilon}_t$

$$\gamma\, p_t\, A_t\, \Phi(\underline{\epsilon}_t)^{\gamma-1} K_t^{\gamma-1} \underline{\epsilon}_t - c_f + P_{t+1}^I = 0. \tag{A.5}$$

Substituting the budget constraint into the above expression to remove K_t, we can show the following expression:

$$\gamma\, p_t\, A_t \left((P_t^I)^{-1}(W_t - Q_t + \frac{\gamma}{R_t} Q_{t+1})\right)^{\gamma-1} \left(\Phi(\underline{\epsilon}_t) \bar{F}_\epsilon(\underline{\epsilon}_t) \underline{\epsilon}_t^{\frac{1}{\gamma-1}}\right)^{\gamma-1} = c_f - P_{t+1}^I. \tag{A.6}$$

It is clear that the land price affect the replacement decision except for the case of constant return to scale ($\gamma = 1$). Also, note that the definition of the wealth produces the following relation:

$$W_t - Q_t + \frac{\gamma}{R_t} Q_{t+1} = p_{t-1}\, A_{t-1}\, \Phi(\underline{\epsilon}_{t-1})^\gamma K_{t-1}^\gamma - c_f K_{t-1} + P_t^I K_{t-1} - \gamma E_{t-1} Q_t + \frac{\gamma}{R_t} Q_{t+1}. \tag{A.7}$$

Thus, the unexpected rise of the current and future land prices, Q_{t+j} $(j \geq 0)$, increases the first bracket of the left-hand side of (A.6). When $\gamma > 1$, we can show that $\underline{\epsilon}_t$ is lowered (low destruction) when the second bracket of the left-hand side is an increasing function of $\underline{\epsilon}_t$. This condition is satisfied when,

$$(\mathbf{C1}): \qquad \Phi(\underline{\epsilon}_t) \bar{F}_\epsilon(\underline{\epsilon}_t) > (\gamma - 1) \underline{\epsilon}_t^2 f_\epsilon(\underline{\epsilon}_t), \tag{A.8}$$

where f_ϵ is a density of $F_\epsilon(\epsilon)$. This condition is satisfied when γ is close to one, ϵ is low, and f_ϵ is small. Intuitively, when the land price rises, the investments increase, and so does the output. Then, when there is an increasing return to scale technology, the productivity of the firm improves. As in the case of no liquidity constraint, the improvement of productivity reduces the replacement decision. But, the effect on the multi-factor productivity is uncertain, because the reduction of machine replacement lower the multi-factor productivity, but the increased output raises the productivity due to the increasing returns to scale.

Proposition 4 *When there is no uncertainty and the condition (C1) holds, the unexpected rise of P_t and/or A_t lowers $\underline{\epsilon}$. The increase of Q_{t+1} also reduces $\underline{\epsilon}$.*

Proof of Proposition 2.

By rearranging the expression of (13), we have,

$$P_t^I\Big(\tau(1-\gamma)Q_{t+1}+P_{t+1}^I-c_f\Big)=P_t\,A_t\Big(\tau(Q_t-\frac{\gamma}{R_t}Q_{t+1})\Big(\Phi(\underline{\epsilon}_t)-\underline{\epsilon}_t\Big)\bar{F}_\epsilon(\underline{\epsilon}_t)-\underline{\epsilon}_tP_t^I\Big) \quad \text{(A.9)}$$

First, I consider the effect of the rise of P^I. Suppose that both sides of the equation are positive. Then, the right-hand side declines due to the rise of P^I, but the left-hand side increases. In order to keep the equality, $\underline{\epsilon}_t$ must fall, since the left-hand side is a decreasing function of $\underline{\epsilon}_t$. We can do the same thing when both sides are negative.

Next, consider the effect of the increase of A_t (the effect of P_t is exactly same). Suppose that both sides of the equation are positive, that is, $\tau(1-\gamma)Q_{t+1}+P_{t+1}^I>c_f$. Then, the increase of A_t raises the right-hand side, so $\underline{\epsilon}_t$ must rise in order to restore the equality. When both sides are negative, then we can get the opposite conclusion.

Now, I investigate the effect of the proportionate rise of Q_t and Q_{t+1}. By taking the total differentiation of equation (14) with respect to $\underline{\epsilon}_t$ and Q_t keeping $g_t=Q_{t+1}/Q_t$ unchanged, we have the following partial derivative:

$$\Big[\frac{\partial\,\underline{\epsilon}_t}{\partial\,Q_t}\Big]^{Liquidity\,Const.}=\frac{\tau\Big(R_t-g_t+(1-\frac{\gamma}{R_t}g_t)(\frac{W_{t+1}}{W_t}-R_t)\Big)}{P_tA_t\Big(1+\tau(1-\frac{\gamma}{R_t}g_t)Q_t\frac{\bar{F}_\epsilon(\underline{\epsilon}_t)}{P_t^I}\Big)}. \quad \text{(A.10)}$$

The denominator is always positive, but the numerator is positive if and only if,

$$R_t>g_t-(1-\frac{\gamma}{R_t}g_t)(\frac{W_{t+1}}{W_t}-R_t). \quad \text{(A.11)}$$

When we define the critical value of g_1^* that holds the above expression with equality, then $\underline{\epsilon}_t$ rises if and only if $g_t<g_1^*$. Note also that $g_1^*>R_t$.

Lastly, I compare the effect of the land price on $\underline{\epsilon}_t$ for the firms with and without liquidity constraints. The effect with the liquidity constraint is shown in (A.10). The effect without the liquidity constraint is derived from the first order condition of (9).

$$\left[\frac{\partial \epsilon_t}{\partial Q_t}\right]^{W/O\, Liquidity\, Const.} = \frac{\tau(R_t - g_t)}{P_t A_t}. \tag{A.12}$$

By comparing the two expressions, I can show that the effect is greater for the firms with the liquidity constraint if and only if,

$$(R_t - g_t)\frac{\tau Q_t \bar{F}_\epsilon(\underline{\epsilon}_t)}{P_t^I} < \frac{W_{t+1}}{W_t} - R_t. \tag{A.13}$$

It is always true when $g_t \geq R_t$. When $g_t < R_t$, we can define the critical value of g_2^* that satisfies the above expression with equality. Then, the above inequality is true if and only if $g_t > g_2^*$. Clearly, $g_2^* < R_t$. Q.E.D.

Construction of replaced value of capital.

In constructing the replaced value of capital, I use the quarterly financial statement published by the Ministry of Finance. Although the industry total is only available for this database, it reports the quarterly data for fifty years (from the second quarter of 1954 to present). The reported data includes the value of capital stock, investments, and replaced values of capital stocks by industry and firm size. Since all of them are book values, I constructed these variables of the constant price basis. For the calculation, I use the benchmark year method. First, the investment series are divided by the deflators of investment goods to produce the real series (taken from SNA accounts). Then, the value of the initial capital stock (in the first year of 1955) is set six times higher than the book value. This choice is arbitrary, but the choice does not affect the trend fifteen years later (after 1970), which I use for estimation.

By initially using the yearly depreciation rate of 5%, I construct the tentative capital stock series by using the following formula:

$$K_t = I_t + (1 - 0.05)K_{t-1}. \tag{A.14}$$

As a result, we can get the tentative series of replaced capital as $\widetilde{R}_t^a = 0.05K_{t-1}$. Now I use the actual replaced value of capital, $\widetilde{R}_t^b$. Since this is the values when they were purchased, I inflated the data by using the price of investment goods for the past four years.

$$\widetilde{R}_t^r = \frac{\widetilde{R}_t^b}{P_t + P_{t-1} + ... + P_{t-3}}. \tag{A.15}$$

The lag for inflation (four years) comes from the fact that the cross correlation between the investments and replacements are largest when the lag of correlation is two years. Since this replaced value is net of depreciation, I multiply the series by some constant to recover the gross value of capital. The constant is determined by taking the ratio of $\widetilde{R}_t^a$ to $\widetilde{R}_t^r$ (but not exactly same). If I compare the two series, $\widetilde{R}_t^a$ and $\widetilde{R}_t^r$, then the long-term trends are quite similar, which confirms the validity of data construction.

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Table 1. The trend of the land price of Japan

	1980/1970	1990/1980	1998/1990
Total industries	6.38%	9.12%	-6.36%

Source: Ministry of Land, Infrastructure, and Transport of Japan.
Note: Growth rates of the commercial areas in the three major urban regions in Japan. Unit: Annual rates.

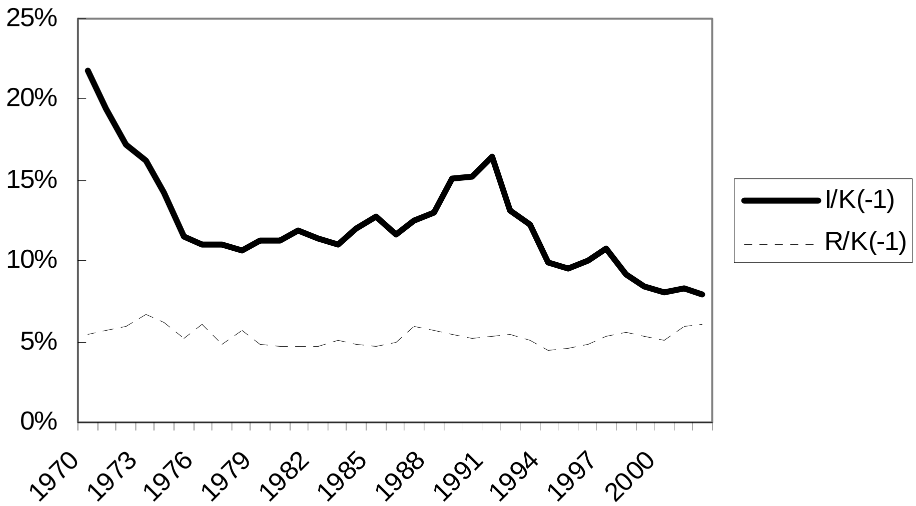
Table 2. Multi-factor productivity of Japan

	1980/1970	1990/1980	1998/1990
Total industries	0.10%	0.25%	0.08%
Non-service	0.66%	0.73%	0.05%
Service	-0.52%	-0.37%	0.12%

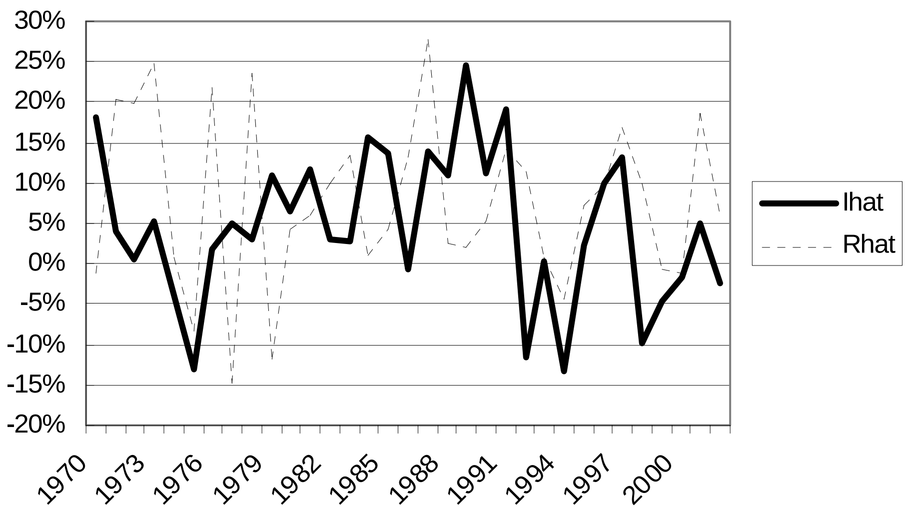
Source: JIP Database (2003), Table 6-14.
Note: The numbers are annual rates over the corresponding years.

Figure 1. Trends of investment – capital ratio and replacement capital ratio

(1) Level



(2) Growth rate

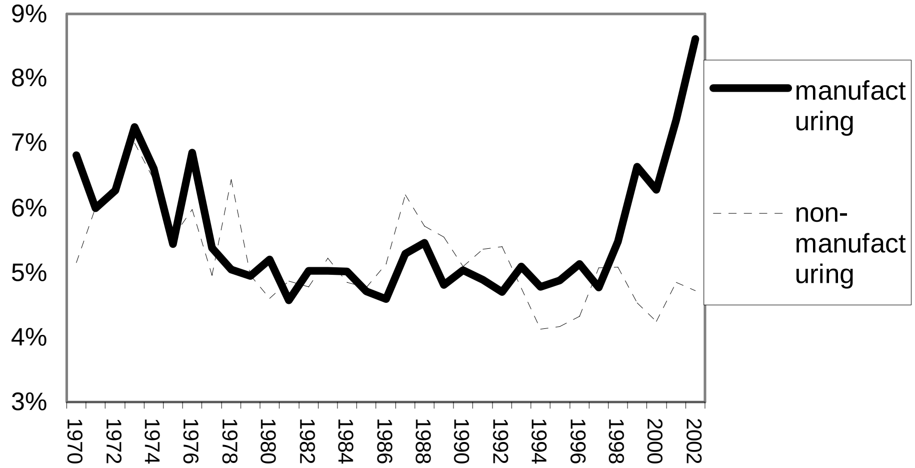


Source: Author's calculation based on "Quarterly Financial Statement of Incorporation," by Ministry of Finance of Japan.

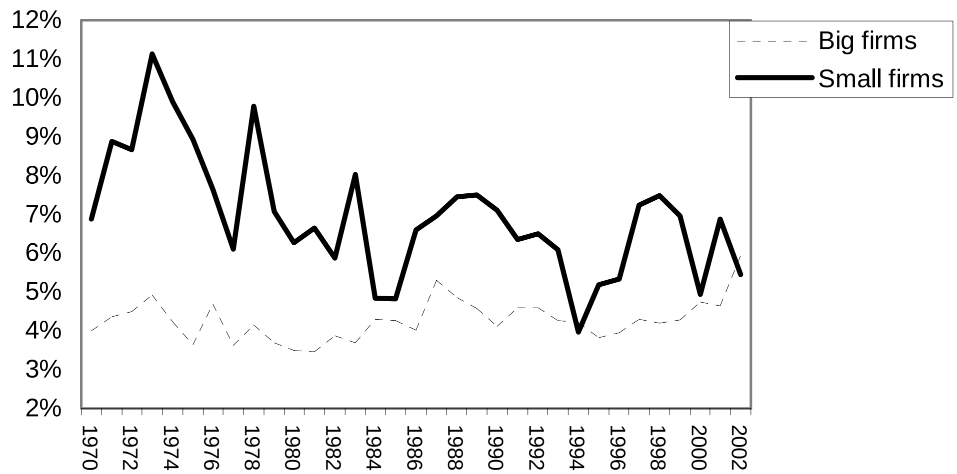
Note: Growth rate is the rate from the 4 quarters before.

Figure 2. Replacement - Capital ratio by industry and firm size

(1) Industry



(2) By firm size



Source: Author's calculation based on "Quarterly Financial Statement of Incorporation," by Ministry of Finance of Japan.

Note: Growth rate is the rate from the 4 quarters before.

Big firms: Firms with capital of 1 billion yen or more in all industry.

Small firms: Firms with capital of less than 100 million yen in non-manufacturing industry.

Table 3. Estimation: Dependent variable is MFP

	Non-service Industry			Service Industry		
	Theta	SE	t-value	Theta	SE	t-value
Capital price	-0.0728	0.0336	-2.1690	-0.4406	0.1428	-3.0857
Land price	0.0217	0.0073	2.9612	-0.0550	0.0148	-3.7151
Output	0.1746	0.0232	7.5291	0.1273	0.0913	1.3947
Constant	0.0010	0.0010	0.9594	-0.0131	0.0034	-3.8880

	J-stat	Critical J	p-value	J-stat	Critical J	p-value
Over-identification	15.95	27.59	0.6181	19.79	27.59	0.3601
Null = only constant	254.66	7.81	0.0000	41.35	7.81	0.0000

Notes: estimation period: 1977 to 1998.
Instruments: The first-differenced MFP, land prices, production, and capital prices.
5 Lags are taken for each instrument (i.e., variables of 2 years to 6 years before).

Note: Estimation period is 1977 to 1998.
Instruments: the first-differenced MFP, land price, production, and capital prices.
5 lags are taken for each instrument (i.e., variables of 2 to 6 years before).

Table 4. Estimation: Dependent variable is replaced value of capital

	Non-service Industry			Service Industry		
	Theta	SE	t-value	Theta	SE	t-value
Capital price	-0.1661	0.0091	- 18.1745	0.0021	0.0576	0.0372
Investment	-0.1397	0.0475	-2.9438	0.2023	0.0597	3.3897
Land price	0.0372	0.0038	9.8968	0.0011	0.0118	0.0918
Output	-0.0747	0.0228	-3.2786	-0.1271	0.0437	-2.9086
Constant	0.0007	0.0006	1.1209	0.0038	0.0013	2.9265

	J-stat	CriticalJ	p-value	J-stat	Critical J	p-value
Over-identification	18.1474	26.2962	0.40	16.8151	26.2962	0.49
Null = only constant	379.0942	9.4877	0.00	33.0418	9.4877	0.00

Note: Estimation period is 1977 to 1998.
Instruments: the first-differenced R/K, land price, investment, production, and capital prices.
4 lags are taken for each instrument (i.e., variables of 2 to 5 years before).

Table 5 Effects on MFP by industry

	Coefficients Capital Price	Land Price	Output	Constant
11 Livestock products	0.369	-0.065	0.228	0.006
12 Processed marine products	0.116	0.000	0.131	0.003
13 Rice polishing, flour milling	0.308	-0.137	0.111	0.001
14 Other foods	0.860	-0.064	0.772	0.026
15 Beverages	-0.068	-0.091	1.197	-0.024
16 Tobacco	0.237	-0.075	0.417	-0.009
17 Silk	-2.179	1.107	4.108	-0.027
18 Spinning	0.119	-0.068	0.224	0.002
19 Fabrics and other textile products	-0.021	0.074	0.372	0.017
20 Apparel and accessories	0.814	-0.058	0.328	0.018
21 Lumber and wood products	-0.039	-0.106	0.298	0.010
22 Furniture	0.236	-0.098	0.235	0.000
23 Pulp, paper, paper products	0.312	-0.020	0.184	0.009
24 Publishing and printing	-0.022	-0.001	0.194	0.000
25 Leather and leather products	0.280	-0.121	0.416	-0.007
26 Rubber products	0.266	-0.090	0.491	0.015
27 Basic chemicals	0.264	-0.036	0.404	0.003
28 Chemical fiber	0.128	-0.010	0.127	0.006
29 Other chemicals	0.087	0.009	0.484	0.010
30 Petroleum products	0.353	0.033	0.172	-0.001
31 Coal products	-0.127	0.120	0.616	-0.006
32 Stone, clay & glass products	0.448	0.043	0.572	-0.011
33 Steel manufacturing	0.172	-0.073	0.292	0.005
34 Other steel	0.071	0.060	0.428	0.006
35 Non-ferrous metals	0.206	-0.074	0.510	0.003
36 Metal products	0.109	-0.040	0.197	-0.004
37 General machinery equipment	0.475	-0.122	0.385	0.001
38 Electrical machinery	0.329	-0.038	0.254	-0.001
39 Equipment and supplies for household use	0.297	-0.124	0.355	-0.004
40 Other electrical machinery	-0.078	0.191	0.125	0.002
41 Motor vehicles	-0.019	0.110	0.173	0.006
42 Ships	0.103	-0.007	0.059	-0.002
43 Other transportation equipment	0.212	0.064	0.298	-0.004
44 Precision machinery & equipment	0.161	-0.050	0.233	-0.004
45 Other manufacturing	0.139	-0.056	0.274	0.002
46 Construction	-0.041	0.030	0.197	-0.002
47 Civil engineering	0.288	-0.022	0.322	-0.003
48 Electricity	0.163	0.031	0.351	-0.007
49 Gas, heat supply	-0.028	0.039	0.611	-0.020
50 Waterworks	0.192	0.119	0.137	0.010
51 Water supply for industrial use	0.227	-0.003	0.329	-0.013
52 Waste disposal	0.196	0.046	0.664	-0.007
53 Wholesale	0.105	-0.010	0.697	-0.034
54 Retail	0.375	-0.292	0.733	-0.015
55 Finance	0.127	-0.090	0.697	-0.018
56 Insurance	0.175	0.013	0.540	-0.012
57 Real estate	0.140	-0.216	0.770	-0.007
58 Housing	0.317	-0.253	0.960	-0.055
59 Railway	-0.642	0.099	-0.837	0.021
60 Road transportation	0.211	0.165	0.370	-0.008
61 Water transportation	0.359	-0.053	0.593	-0.015
62 Air transportation	0.177	-0.191	0.810	0.007
63 Other transportation, packing	0.090	0.005	0.248	-0.014
64 Telegraph, telephone	0.221	0.015	0.823	-0.031
65 Mail	-0.102	0.055	0.684	-0.026
66 Education (private, non-profit)	-0.016	0.067	0.891	-0.022
67 Research	0.298	-0.067	0.431	-0.005
68 Medical, hygiene (private)	0.525	-0.036	0.410	0.011
69 Other public services	0.233	-0.062	0.580	-0.031
70 Advertising	1.477	0.220	0.313	0.015
71 Rental of office equipment and goods	0.295	-0.043	0.625	-0.005
72 Other services for businesses	0.820	-0.488	0.194	-0.018
73 Entertainment	-0.388	0.022	0.348	-0.028
74 Broadcasting	0.477	-0.199	0.563	-0.020
75 Restaurants	0.285	-0.214	0.731	-0.032
76 Inns	0.503	-0.009	0.313	0.001
77 Laundry, hair-cutting , public bath	0.666	-0.137	0.570	-0.004
78 Other services for individuals	0.666	-0.002	0.413	0.008
79 Education (public)	0.076	-0.010	0.604	-0.016
80 Medical, hygiene (public)	0.057	0.064	0.599	-0.017
81 Public administration	0.408	-0.142	0.640	-0.031
82 Medical, hygiene (non-profit)	0.163	-0.002	0.358	-0.012
83 Others(non-profit)	0.190	-0.013	0.387	-0.026

Table 5 Effects on MFP by industry (continued

	Standard Errors			
	Capital Price	Land Price	Output	Constant
11 Livestock products	0.107	0.026	0.063	0.003
12 Processed marine products	0.097	0.028	0.098	0.004
13 Rice polishing, flour milling	0.056	0.041	0.113	0.005
14 Other foods	0.044	0.043	0.133	0.002
15 Beverages	0.021	0.016	0.084	0.002
16 Tobacco	0.177	0.031	0.102	0.004
17 Silk	0.119	0.110	0.103	0.003
18 Spinning	0.039	0.049	0.062	0.006
19 Fabrics and other textile products	0.025	0.013	0.024	0.002
20 Apparel and accessories	0.131	0.048	0.068	0.004
21 Lumber and wood products	0.064	0.038	0.056	0.003
22 Furniture	0.026	0.028	0.052	0.002
23 Pulp, paper, paper products	0.118	0.021	0.030	0.002
24 Publishing and printing	0.006	0.012	0.024	0.001
25 Leather and leather products	0.112	0.032	0.067	0.004
26 Rubber products	0.052	0.012	0.017	0.001
27 Basic chemicals	0.084	0.043	0.059	0.002
28 Chemical fiber	0.016	0.014	0.018	0.001
29 Other chemicals	0.031	0.022	0.030	0.002
30 Petroleum products	0.036	0.012	0.027	0.001
31 Coal products	0.065	0.054	0.181	0.010
32 Stone, clay & glass products	0.112	0.059	0.113	0.005
33 Steel manufacturing	0.101	0.020	0.030	0.002
34 Other steel	0.047	0.015	0.089	0.004
35 Non-ferrous metals	0.030	0.009	0.030	0.001
36 Metal products	0.049	0.022	0.071	0.003
37 General machinery equipment	0.124	0.015	0.044	0.002
38 Electrical machinery	0.071	0.010	0.013	0.001
39 Equipment and supplies for household use	0.067	0.017	0.022	0.001
40 Other electrical machinery	0.082	0.028	0.020	0.002
41 Motor vehicles	0.039	0.013	0.010	0.002
42 Ships	0.094	0.022	0.044	0.002
43 Other transportation equipment	0.097	0.077	0.047	0.007
44 Precision machinery & equipment	0.022	0.004	0.005	0.001
45 Other manufacturing	0.173	0.027	0.027	0.002
46 Construction	0.057	0.021	0.051	0.002
47 Civil engineering	0.060	0.024	0.039	0.002
48 Electricity	0.039	0.011	0.030	0.001
49 Gas, heat supply	0.083	0.017	0.101	0.003
50 Waterworks	0.034	0.046	0.073	0.006
51 Water supply for industrial use	0.090	0.045	0.077	0.004
52 Waste disposal	0.081	0.073	0.107	0.008
53 Wholesale	0.072	0.054	0.057	0.005
54 Retail	0.033	0.009	0.058	0.002
55 Finance	0.021	0.012	0.039	0.002
56 Insurance	0.057	0.033	0.043	0.002
57 Real estate	0.028	0.018	0.021	0.003
58 Housing	0.102	0.047	0.084	0.006
59 Railway	0.470	0.077	0.293	0.012
60 Road transportation	0.152	0.048	0.162	0.006
61 Water transportation	0.025	0.016	0.024	0.001
62 Air transportation	0.053	0.045	0.043	0.003
63 Other transportation, packing	0.145	0.048	0.032	0.002
64 Telegraph, telephone	0.044	0.022	0.048	0.003
65 Mail	0.026	0.021	0.059	0.006
66 Education (private, non-profit)	0.012	0.015	0.028	0.001
67 Research	0.009	0.012	0.030	0.002
68 Medical, hygiene (private)	0.041	0.031	0.034	0.004
69 Other public services	0.067	0.037	0.067	0.003
70 Advertising	0.234	0.099	0.086	0.010
71 Rental of office equipment and goods	0.063	0.025	0.019	0.002
72 Other services for businesses	0.046	0.064	0.088	0.012
73 Entertainment	0.240	0.088	0.203	0.020
74 Broadcasting	0.110	0.064	0.132	0.005
75 Restaurants	0.032	0.011	0.038	0.003
76 Inns	0.047	0.021	0.044	0.003
77 Laundry, hair-cutting , public bath	0.016	0.017	0.009	0.001
78 Other services for individuals	0.305	0.089	0.100	0.007
79 Education (public)	0.130	0.110	0.107	0.009
80 Medical, hygiene (public)	0.068	0.023	0.079	0.002
81 Public administration	0.094	0.033	0.075	0.008
82 Medical, hygiene (non-profit)	0.094	0.014	0.125	0.004
83 Others(non-profit)	0.045	0.026	0.054	0.003

Table 5 Effects on MFP by industry (continued

	t-values			
	Capital Price	Land Price	Output	Constant
11 Livestock products	3.454	-2.544	3.606	1.867
12 Processed marine products	1.195	-0.005	1.344	0.595
13 Rice polishing, flour milling	5.531	-3.332	0.979	0.162
14 Other foods	19.601	-1.490	5.813	16.143
15 Beverages	-3.185	-5.576	14.211	-10.861
16 Tobacco	1.340	-2.401	4.109	-1.982
17 Silk	-18.348	10.098	40.073	-9.660
18 Spinning	3.018	-1.393	3.623	0.406
19 Fabrics and other textile products	-0.849	5.838	15.248	7.287
20 Apparel and accessories	6.235	-1.215	4.807	4.927
21 Lumber and wood products	-0.604	-2.804	5.313	3.875
22 Furniture	9.109	-3.459	4.554	0.091
23 Pulp, paper, paper products	2.638	-0.942	6.229	3.924
24 Publishing and printing	-3.629	-0.102	8.242	-0.244
25 Leather and leather products	2.495	-3.841	6.190	-1.851
26 Rubber products	5.074	-7.745	29.796	11.823
27 Basic chemicals	3.157	-0.836	6.881	1.283
28 Chemical fiber	8.042	-0.708	6.948	7.359
29 Other chemicals	2.835	0.401	15.933	4.082
30 Petroleum products	9.890	2.690	6.321	-1.769
31 Coal products	-1.951	2.208	3.398	-0.616
32 Stone, clay & glass products	3.986	0.739	5.061	-2.005
33 Steel manufacturing	1.705	-3.671	9.604	3.151
34 Other steel	1.492	4.085	4.812	1.522
35 Non-ferrous metals	6.973	-8.306	17.288	2.085
36 Metal products	2.221	-1.823	2.791	-1.306
37 General machinery equipment	3.845	-8.398	8.704	0.702
38 Electrical machinery	4.651	-3.657	20.166	-0.919
39 Equipment and supplies for household use	4.427	-7.234	15.812	-2.499
40 Other electrical machinery	-0.949	6.925	6.406	0.717
41 Motor vehicles	-0.495	8.539	16.997	2.934
42 Ships	1.103	-0.336	1.348	-0.797
43 Other transportation equipment	2.196	0.839	6.353	-0.600
44 Precision machinery & equipment	7.276	-11.377	43.067	-6.137
45 Other manufacturing	0.804	-2.087	10.166	0.936
46 Construction	-0.729	1.431	3.876	-1.208
47 Civil engineering	4.848	-0.910	8.282	-1.537
48 Electricity	4.142	2.952	11.559	-6.859
49 Gas, heat supply	-0.333	2.278	6.072	-5.949
50 Waterworks	5.580	2.558	1.868	1.713
51 Water supply for industrial use	2.520	-0.064	4.257	-3.039
52 Waste disposal	2.420	0.640	6.182	-0.904
53 Wholesale	1.451	-0.194	12.231	-7.545
54 Retail	11.320	-33.781	12.593	-7.083
55 Finance	5.960	-7.503	17.887	-10.949
56 Insurance	3.092	0.383	12.708	-5.187
57 Real estate	4.952	-11.792	36.322	-2.793
58 Housing	3.101	-5.436	11.484	-8.666
59 Railway	-1.368	1.286	-2.856	1.749
60 Road transportation	1.387	3.447	2.280	-1.352
61 Water transportation	14.222	-3.225	24.558	-13.990
62 Air transportation	3.326	-4.207	18.971	2.399
63 Other transportation, packing	0.622	0.104	7.728	-5.975
64 Telegraph, telephone	5.066	0.688	17.080	-10.400
65 Mail	-3.903	2.600	11.665	-4.546
66 Education (private, non-profit)	-1.266	4.538	31.748	-23.339
67 Research	31.977	-5.563	14.191	-3.331
68 Medical, hygiene (private)	12.839	-1.162	11.971	2.884
69 Other public services	3.477	-1.680	8.618	-9.782
70 Advertising	6.311	2.236	3.620	1.499
71 Rental of office equipment and goods	4.677	-1.735	33.212	-2.642
72 Other services for businesses	17.700	-7.666	2.214	-1.513
73 Entertainment	-1.614	0.243	1.716	-1.413
74 Broadcasting	4.325	-3.127	4.263	-4.232
75 Restaurants	9.005	-18.951	19.079	-12.945
76 Inns	10.678	-0.399	7.095	0.353
77 Laundry, hair-cutting , public bath	41.443	-8.311	64.740	-3.282
78 Other services for individuals	2.183	-0.025	4.127	1.217
79 Education (public)	0.583	-0.086	5.647	-1.942
80 Medical, hygiene (public)	0.836	2.805	7.629	-6.943
81 Public administration	4.349	-4.289	8.510	-3.912
82 Medical, hygiene (non-profit)	1.727	-0.114	2.856	-3.007
83 Others(non-profit)	4.208	-0.479	7.240	-7.618

Table 5 Effects on MFP by industry (continued

	J-statistics			Null=all coefficinets are zeros		
	J	5% critical	p value	Statistics	5% critical v	p value
11 Livestock products	15.700	27.587	0.635	29.987	7.815	0.000
12 Processed marine products	18.781	27.587	0.425	28.876	7.815	0.000
13 Rice polishing, flour milling	12.679	27.587	0.818	47.065	7.815	0.000
14 Other foods	15.412	27.587	0.654	19804.277	7.815	0.000
15 Beverages	19.192	27.587	0.398	1628.682	7.815	0.000
16 Tobacco	18.175	27.587	0.465	190.069	7.815	0.000
17 Silk	17.581	27.587	0.506	5361.939	7.815	0.000
18 Spinning	13.155	27.587	0.792	61.172	7.815	0.000
19 Fabrics and other textile products	16.500	27.587	0.580	373.233	7.815	0.000
20 Apparel and accessories	21.564	27.587	0.259	73.785	7.815	0.000
21 Lumber and wood products	14.620	27.587	0.706	49.419	7.815	0.000
22 Furniture	15.885	27.587	0.622	106.814	7.815	0.000
23 Pulp, paper, paper products	19.068	27.587	0.406	68.040	7.815	0.000
24 Publishing and printing	15.439	27.587	0.652	243.070	7.815	0.000
25 Leather and leather products	18.738	27.587	0.427	106.139	7.815	0.000
26 Rubber products	17.611	27.587	0.504	1868.877	7.815	0.000
27 Basic chemicals	14.736	27.587	0.698	468.521	7.815	0.000
28 Chemical fiber	19.137	27.587	0.401	132.343	7.815	0.000
29 Other chemicals	13.268	27.587	0.786	395.849	7.815	0.000
30 Petroleum products	18.562	27.587	0.439	1737.044	7.815	0.000
31 Coal products	16.131	27.587	0.606	32.235	7.815	0.000
32 Stone, clay & glass products	19.160	27.587	0.400	128.964	7.815	0.000
33 Steel manufacturing	18.086	27.587	0.471	112.411	7.815	0.000
34 Other steel	16.241	27.587	0.598	53.335	7.815	0.000
35 Non-ferrous metals	13.547	27.587	0.770	342.333	7.815	0.000
36 Metal products	15.908	27.587	0.621	25.704	7.815	0.000
37 General machinery equipment	20.125	27.587	0.340	129.402	7.815	0.000
38 Electrical machinery	19.111	27.587	0.403	496.239	7.815	0.000
39 Equipment and supplies for household use	18.699	27.587	0.430	353.463	7.815	0.000
40 Other electrical machinery	19.889	27.587	0.354	673.065	7.815	0.000
41 Motor vehicles	15.319	27.587	0.660	707.332	7.815	0.000
42 Ships	17.789	27.587	0.491	21.642	7.815	0.000
43 Other transportation equipment	18.385	27.587	0.451	197.614	7.815	0.000
44 Precision machinery & equipment	17.186	27.587	0.533	2353.212	7.815	0.000
45 Other manufacturing	17.197	27.587	0.532	1509.153	7.815	0.000
46 Construction	17.844	27.587	0.488	68.017	7.815	0.000
47 Civil engineering	14.648	27.587	0.704	261.690	7.815	0.000
48 Electricity	16.691	27.587	0.567	259.080	7.815	0.000
49 Gas, heat supply	19.865	27.587	0.355	123.389	7.815	0.000
50 Waterworks	17.743	27.587	0.495	133.314	7.815	0.000
51 Water supply for industrial use	19.085	27.587	0.405	82.271	7.815	0.000
52 Waste disposal	17.091	27.587	0.539	173.650	7.815	0.000
53 Wholesale	16.802	27.587	0.559	705.140	7.815	0.000
54 Retail	13.383	27.587	0.780	2402.970	7.815	0.000
55 Finance	13.958	27.587	0.746	355.856	7.815	0.000
56 Insurance	17.182	27.587	0.533	345.098	7.815	0.000
57 Real estate	16.497	27.587	0.580	1410.789	7.815	0.000
58 Housing	20.925	27.587	0.293	275.741	7.815	0.000
59 Railway	13.301	27.587	0.784	22.810	7.815	0.000
60 Road transportation	20.090	27.587	0.342	107.723	7.815	0.000
61 Water transportation	13.310	27.587	0.784	1209.009	7.815	0.000
62 Air transportation	16.529	27.587	0.578	746.255	7.815	0.000
63 Other transportation, packing	13.918	27.587	0.749	125.556	7.815	0.000
64 Telegraph, telephone	16.037	27.587	0.612	615.495	7.815	0.000
65 Mail	18.697	27.587	0.430	169.259	7.815	0.000
66 Education (private, non-profit)	19.651	27.587	0.369	2339.541	7.815	0.000
67 Research	14.973	27.587	0.683	1049.723	7.815	0.000
68 Medical, hygiene (private)	14.843	27.587	0.691	1895.507	7.815	0.000
69 Other public services	20.758	27.587	0.303	153.408	7.815	0.000
70 Advertising	18.519	27.587	0.442	206.381	7.815	0.000
71 Rental of office equipment and goods	18.238	27.587	0.461	6295.240	7.815	0.000
72 Other services for businesses	17.617	27.587	0.503	1492.949	7.815	0.000
73 Entertainment	17.871	27.587	0.486	21.006	7.815	0.000
74 Broadcasting	19.572	27.587	0.374	48.533	7.815	0.000
75 Restaurants	14.361	27.587	0.722	651.871	7.815	0.000
76 Inns	18.326	27.587	0.455	267.448	7.815	0.000
77 Laundry, hair-cutting , public bath	17.841	27.587	0.488	23642.518	7.815	0.000
78 Other services for individuals	15.818	27.587	0.627	44.757	7.815	0.000
79 Education (public)	16.047	27.587	0.611	139.002	7.815	0.000
80 Medical, hygiene (public)	18.550	27.587	0.440	183.545	7.815	0.000
81 Public administration	18.247	27.587	0.460	491.746	7.815	0.000
82 Medical, hygiene (non-profit)	15.903	27.587	0.621	35.379	7.815	0.000
83 Others(non-profit)	20.401	27.587	0.323	117.511	7.815	0.000