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Investment Distortion by Collateral Requirements: Evidence from Japanese SMEs (Revised)

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Abstract

We examine the significance of the distortionary effect of the collateral requirement on investments in assets pledgeable for collateral by small and medium-sized enterprises (SMEs). The theory predicts that the binding collateral constraint causes overinvestment if the price of pledgeable assets is expected to rise steeply while it causes underinvestment otherwise. Our structural estimation of the Euler equation under a collateral constraint using the dataset on Japanese SMEs in the 1980s and 1990s shows that the collateral constraint is binding when the price of a pledgeable asset is declining, whereas it is not when the price is increasing. This finding indicates that the binding collateral constraint primarily causes the problem of underinvestment for many SMEs in a recession and casts doubt on the welfare effect of the loan-to-value (LTV) ratio cap as a macroprudence policy because of the subsequent prolonged economic slump.

Keywords: Collateral constraint, Investment, Small and medium-sized enterprises, Real estate prices, Loan-to-value ratio.
JEL Classification: E22, G31, R30

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1 Introduction

Collateral is a standard contract arrangement to reduce the cost of an adverse selection and the agency cost by enabling a bank to screen out risky borrowers (Bester, 1985) and by enhancing the borrower's incentive to choose a safer project (Stiglitz and Weiss, 1981) and repay a loan properly (Boot et al., 1991; Hart and Moore, 1994). However, it has been well recognized in the theoretical literature that the collateral requirement can distort the resource allocation within each firm. For example, if collateral confines the investment of a firm, its investment is restricted to an insufficient and suboptimal level (Kiyotaki and Moore, 1997). Or, instead, a firm may hold the assets that can be pledged as collateral, such as land and other tangible assets, at a higher than technologically optimal level and hold the other assets less (Tomoda and Okamura, 2010; Geanakoplos and Zame, 2013; Gottardi and Kubler, 2015). The primary concern of the present study is this distortionary effect of the collateral requirement.

Figure 1 illustrates our research motivation well. The figure shows the ratio of idle land to total land, excluding that for the purpose of resale, held by each class of companies in Japan; those publicly traded on the first section of the Tokyo, Osaka, and Nagoya stock exchanges; those traded on the second or other sections and exchanges for smaller firms; and those not publicly traded.[1] The latter two classes of companies are smaller and more bank dependent than the first one. The figure clearly indicates that the idle land ratio is higher for these more bank-dependent classes.

One possible interpretation is that a firm holds idle land because it cannot obtain funds to make use of it for its business due to a severe credit constraint imposed by collateral value. Another possible interpretation is that a firm keeps idle land so that it can use it as collateral when the firm needs additional funds.[2] The first interpretation is consistent with the theory that the collateral constraint confines the amount of investment and leads to under-investment. The second interpretation is consistent with the theory that the additional value of the land's being used as collateral induces over-investment in land. Which of these explanations is better

[1] The data is collected from *Kigyo No Tochi Shutoku Jokyo Tou Ni Kansuru Chosa* (the survey on corporate land holding) conducted by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT). The tables featuring data since the 2000 survey are available from http://tochi.mlit.go.jp/torihiki/corporate-torihikijyoukyou. The data from before 2000 is kindly provided by MLIT. We gratefully acknowledge it here.

[2] The third possible interpretation is that firms avoid revealing unrealized losses resulting from the sharp decline in the land price in the 1990s. However, this interpretation is not convincing, since those listed on the second and other sections in the stock exchange do not decrease the idle land ratio even after the compulsory adaptation for publicly traded companies with a potential capital loss of the impairment accounting in 2006.

suited to reality is an important empirical question to determine an appropriate policy response to avoid the inefficiency.

To answer this question, first we analyze the Euler equation of corporate investments under the collateral constraint, which limits the borrowing for investments to an amount within the collateral value. The analysis shows that the collateral constraint brings under-investment if it is binding, and the market price of assets that are pledgeable as collateral is expected to go down or go up slowly. However, the collateral constraint can bring over-investment in assets pledgeable as collateral when the constraint is binding and the market price of assets to be used for collateral is expected to increase at a higher speed.

We test these theoretical predictions by using the microdata of small and medium-sized enterprises (SMEs) in the manufacturing sector in Japan collected from the annual survey of the Financial Statements Statistics of Corporations by Industry (FSSCI) from 1983 to 2002, which is available for researchers by permission of the Ministry of Finance Japan. The ordinary least squares estimation of the impact of the market value of land on investment and the structural estimation by the maximum likelihood of the Euler equation under the collateral constraint show that the collateral constraint was not binding in the 1980s, when the land price was skyrocketing, whereas it was binding in the 1990s, when the land price was plummeting after the land-price bubble burst in 1991. According to the theory, this result means that the collateral constraint brought under-investment rather than over-investment. An additional structural estimation with an explicit linear specification of the Lagrange multiplier for the collateral constraint shows that the constraint is more likely to bind when the market value of collateralizable assets is expected to decline and the lending attitude of banks is more reluctant.

Our dataset provides a unique and appropriate stage for our empirical study at two points. The first point is that the dataset enables us to collect a reasonably sized sample consisting of SMEs, including land-holding information. SMEs are more dependent on bank lending and thus more vulnerable to the collateral constraint. We also expect to obtain less noisy land-holding information from SMEs, since the location of the land held by SMEs is more likely to be closer to their head office, which is usually the only available address information for each firm. The second point is that the dataset covers a reasonable length of time during the periods before and after the land-price bubble in Japan, the peak of which was 1991. This feature of our dataset enables us to examine the impact of the land price on the effect of the collateral constraint.

Of course, the dataset also has a shortcoming in that we cannot obtain panel data for a long enough period to control for the firm-level fixed effect in the structural estimation because of the sampling method of the survey. Despite of this shortcoming, it is interesting to detect the effect of collateral constraints for SMEs before and after the bubble for its possible tremendous impact on the subsequent recession.

Several studies have shown the positive impact of collateral values, especially the real estate price, on borrowing and investment by firms (e.g., Ogawa et al., 1996; Ogawa and Suzuki, 1998; Gan, 2007; Chaney et al., 2012).[3] More recently, Ono et al. (2014) find a counter-cyclical loan-to-value ratio based on Japanese SME data. This implies that the speed of the land-price hike is greater than that of the increase in borrowing during a land-price bubble. They interpret this to be because the collateral constraint was not binding in the 1980s, whereas it was in the 1990s. Our study adds more direct evidence for the factors that cause collateral constraint to bind and the quantitative assessment for the investment distortion in the post-bubble period, such as in the 1990s in Japan.

The finding that the collateral constraint is more likely to bind during a land-price decline and less likely during a land-price hike has important policy implications. First, this indicates that the collateral constraint is more likely to bring under-investment, and so it is reasonable to adopt a policy to promote uncovered lending after a bubble burst instead of tightening the requirement for the credit standard. Second, regulators have discussed the introduction of the loan-to-value regulation as a part of the macroprudential policy after the global financial crisis in 2007-09. The above finding casts doubt on the effectiveness of this type of regulation in the context of SME lending since our finding suggests that the loan-to-value regulation is effective not in the midst of the real estate bubble but after the burst of it and that it exacerbates the economic slump due to the under-investment problem.

The remaining part of this paper is organized as follows: In Section 2, we derive the Euler equation under the collateral requirement and show the conditions for over-investment and under-investment. In Section 3, we add several explicit assumptions about the functional form

[3]The seminal study by Ogawa et al. (1996) finds that land holding loses the liquidity constraint by the structural estimation of the constrained Euler equation with the aggregated data of the quarterly FSSCI in the period from 1970 to 1990. Ogawa and Suzuki (1998) finds a nonlinearity in this effect with the panel data of Japanese publicly traded companies in the machinery sector from 1970 to 1993. Gan (2007) finds evidence that those with larger land holdings before the burst of the land-price bubble in Japan faced a more severe credit constraint in the subsequent period based on the dataset of Japanese publicly traded companies. Chaney et al. (2012) finds a positive impact of the real estate price on the collateral value and the investment of publicly traded companies in the United States in the period from 1993 to 2007.

and derive the equation for the structural estimation. Section 4 is a detailed description of the dataset. We describe the result of the preliminary OLS and the panel fixed-effect regression in Section 5. We show the main result of the structural estimation of the Euler equation in Section 6. Section 7 presents the policy implications of our finding. Section 8 is the conclusion.

2 Model

Our basic setup for the derivation of the optimal investment schedule follows the standard model to derive the Euler equation (e.g., Hubbard and Kashyap, 1992; Whited, 1992) except that we replace the borrowing constraint with the collateral constraint, which explicitly takes into account the market value of the collateral, similar to the model introduced by Kiyotaki and Moore (1997).

Firm i maximizes the total expected present value of its equity at time t,

$$\max_{\{k_{is},l_{is},N_{is},B_{is}\}_{s=t}^{\infty}} V_{it} \equiv d_{it} + E_t\left[\sum_{s=t+1}^{\infty}\left\{\prod_{j=1}^{s-t}\beta_{it+j}\right\}d_{is}\right], \tag{1}$$

under the following constraints at each time s;

$$K_{is} = k_{is} + (1-\delta_{is})K_{is-1}, \tag{2}$$

$$L_{is} = l_{is} + L_{is-1}, \tag{3}$$

$$E_t(d_{is}) \geq 0, \tag{4}$$

$$\lim_{T\to\infty}\left\{\prod_{j=1}^{T-s}\beta_{is+j}\right\}B_{iT} = 0, \tag{5}$$

$$B_{is} \leq E_t(q_{is+1})L_{is} + E_t(s_{is+1})K_{is}. \tag{6}$$

β_{it} is the discount factor of firm i for period t. d_{it} is the cash flow attributable to shareholders at time t, i.e., dividend plus retention,

$$\begin{aligned} d_{it} = (1-\tau_t)[&p_{it}F(L_{it-1},K_{it-1},N_{it}) - w_{it}N_{it} - \phi(k_{it},l_{it},K_{it-1},L_{it-1}) - \delta_{it}K_{it-1} \\ &- R_{it-1}B_{it-1}] + B_{it} - B_{it-1} + \delta_{it}K_{it-1} - q_{it}l_{it} - s_{it}k_{it}. \end{aligned} \tag{7}$$

τ_t is the effective tax rate at time t. p_{it} is the product price. L_{it} is the real units of land held by firm i, K_{it} is the other real fixed assets, and N_{it} is a combination of variable inputs. $F(L_{it-1},K_{it-1},N_{it})$ is the real output of the firm at time t produced by using the already installed capital, land and the currently acquired variable inputs. F is assumed to be strictly increasing and strictly concave in every input. We also assume that inputs are complementary with each other, i.e., all cross partial derivatives of the production function with respect to inputs are strictly positive. w_{it} is the nominal unit cost of N_{it}. δ is the depreciation rate of K_{it}. The depreciation is exempt from corporate tax while it remains as internal funds in the common accounting practice.

l_{it} is the real investment in land. k_{it} is the real investment in other fixed assets. $\phi(l_{it}, k_{it}, L_{it}, K_{it})$ is the adjustment cost for investment in land l_{it} and other fixed assets k_{it}. We assume that $\phi(0, 0, K_{it-1}, L_{it-1}) = 0$, $\partial\phi/\partial l_{it}|_{l_{it}=0} = 0$, $\partial\phi/\partial k_{it}|_{k_{it}=0} = 0$, and $\partial^2\phi/\partial l_{it}^2$ and $\partial^2\phi/\partial k_{it}^2$ are positive for any l_{it}, k_{it}, L_{it-1}, and K_{it-1}. These assumptions imply that the adjustment cost is a smooth, U-shaped curve with a bottom at $(k_{it}, l_{it}) = (0, 0)$. We assume that $\partial\phi/\partial K_{it-1}$ and $\partial\phi/\partial L_{it-1}$ are negative to take into account the learning-by-doing effect. To ensure the second-order condition for the maximization problem, we assume that $\partial^2\phi/\partial K_{it-1}^2$, $\partial^2\phi/\partial L_{it-1}^2$, and $\partial^2\phi/\partial K_{it-1}\partial L_{it-1}$ are positive; and that the cross partial derivatives $\partial^2\phi/(\partial K_{it-1}\partial k_{it})$, $\partial^2\phi/(\partial L_{it-1}\partial l_{it})$, $\partial^2\phi/(\partial L_{it-1}\partial k_{it})$, $\partial^2\phi/(\partial K_{it-1}\partial l_{it})$ are negative.

R_{it} is the interest rate of loans and debts, of which principal is denoted by B_{it}. q_{it} and s_{it} are the unit land price and the unit fixed asset price, respectively.

The first constraint is the usual transition equation of the real capital. The second constraint is the transition equation of land. Land is not depreciated. The third constraint is the budget constraint for the firm. The fourth one is the transversality condition to prevent the solution from exploding to infinity. The last one is the collateral constraint, in which we are most interested. The firm can borrow an amount less than or equal to the expected value of the asset pledgeable as collateral at the end of the period; capital K_t and land L_t.

After plugging the transition equations (2) and (3) into k_{it} and l_{it} in the objective function V_{it}, the Lagrange function for the problem is

$$\begin{aligned} \mathcal{L} \equiv\ & d_{it} + E_t\left[\sum_{s=t+1}^{\infty}\left\{\prod_{j=1}^{s-t}\beta_{it+j}\right\}d_{is}\right] + \sum_{s=t}^{\infty}\Omega_{is}d_{is} \\ & + \sum_{s=t}^{\infty}\lambda_{is}(E_t(q_{is+1})L_{is} + E_t(s_{is+1})K_{is} - B_{is}), \end{aligned} \tag{8}$$

where Ω_{it} and λ_{it} are the non-negative Lagrange multipliers, and

$$\begin{aligned}d_{it} = (1-\tau_t)[&p_{it}F(L_{it-1}, K_{it-1}, N_{it}) - w_{it}N_{it} - \delta_{it}K_{it-1}\\ &- \phi(K_{it} - (1-\delta_{it})K_{it-1}, L_{it} - L_{it-1}, K_{it-1}, L_{it-1}) - R_{it-1}B_{it-1}]\\ &+ B_{it} - B_{it-1} + \delta_{it}K_{it-1} - q_{it}(L_{it} - L_{it-1}) - s_{it}(K_{it} - (1-\delta_{it})K_{it-1}).\end{aligned} \tag{9}$$

The first-order conditions with respect to K_{it}, L_{it}, B_{it}, and N_{it+1} are, respectively,

$$-(1+\Omega_{it})\left\{(1-\tau_t)\frac{\partial\phi}{\partial k_{it}} + s_{it}\right\} + \beta_{it+1}(1+\Omega_{it+1})E_t\left[\frac{\partial d_{it+1}}{\partial K_{it}}\right] + \lambda_{it}E_t(s_{it+1}) = 0, \tag{10}$$

$$-(1+\Omega_{it})\left\{(1-\tau_t)\frac{\partial\phi}{\partial l_{it}} + q_{it}\right\} + \beta_{it+1}(1+\Omega_{it+1})E_t\left[\frac{\partial d_{it+1}}{\partial L_{it}}\right] + \lambda_{it}E_t(q_{it+1}) = 0, \tag{11}$$

$$1+\Omega_{it} - \beta_{it+1}(1+\Omega_{it+1})\{(1-\tau_{t+1})R_{it} + 1\} - \lambda_{it} = 0, \tag{12}$$

$$(1-\tau_t)(1+\Omega_{it+1})\left\{p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\frac{\partial F(L_{it}, K_{it}, N_{it+1})}{\partial N_{it+1}} - w_{it+1}\right\} = 0, \tag{13}$$

where

$$\begin{aligned}E_t\left[\frac{\partial d_{it+1}}{\partial K_{it}}\right] &= E_t\left[(1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\frac{\partial F(L_{it}, K_{it}, N_{it+1})}{\partial K_{it}}\right]\\ &+ E_t\left[(1-\tau_{t+1})\left\{(1-\delta_{it+1})\frac{\partial\phi}{\partial k_{it+1}} - \frac{\partial\phi}{\partial K_{it}} - \delta_{it+1}\right\} + \delta_{it+1} + s_{it+1}(1-\delta_{it+1})\right],\end{aligned} \tag{14}$$

$$\begin{aligned}E_t\left[\frac{\partial d_{it+1}}{\partial L_{it}}\right] &= E_t\left[(1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\frac{\partial F(L_{it}, K_{it}, N_{it+1})}{\partial L_{it}}\right]\\ &+ E_t\left[(1-\tau_{t+1})\left\{\frac{\partial\phi}{\partial l_{it+1}} - \frac{\partial\phi}{\partial L_{it}}\right\} + q_{it+1}\right].\end{aligned} \tag{15}$$

ϵ_D is the price elasticity of product demand, and θ is a parameter to indicate the mode of competition; $\theta = 1$ if firm i is a monopoly, θ equals the market share of firm i if firm i is in a Cournot competition; or $\theta = 0$ if firm i is in the perfect competition or a symmetric Bertrand competition. We assume that the elasticity and the mode of competition are time invariant and common to all sectors. Since the Lagrange function is linear in B_t, the first-order derivative of the Lagrange function with respect to B_{it} (12) can be a positive or negative constant. However, it must be zero when a firm chooses a finite positive B_{it}, as in the real data.

Plugging equation (12) into $1 + \Omega_{it}$ of equations (10) and (11) and dividing both sides by

$\beta_{it+1}(1+\Omega_{it+1})$ gives

$$-\{(1-\tau_{t+1})R_{it}+1\}\left\{(1-\tau_t)\frac{\partial\phi}{\partial k_{it}}+s_{it}\right\}+E_t\left(\frac{\partial d_{it+1}}{\partial K_{it}}\right)$$
$$+\Lambda_{it}\left\{E_t(s_{it+1})-s_{it}-(1-\tau_t)\frac{\partial\phi}{\partial k_{it}}\right\}=0, \tag{16}$$
$$-\{(1-\tau_{t+1})R_{it}+1\}\left\{(1-\tau_t)\frac{\partial\phi}{\partial l_{it}}+q_{it}\right\}+E_t\left(\frac{\partial d_{it+1}}{\partial L_{it}}\right)$$
$$+\Lambda_{it}\left\{E_t(q_{it+1})-q_{it}-(1-\tau_t)\frac{\partial\phi}{\partial l_{it}}\right\}=0, \tag{17}$$

where $\Lambda_{it}\equiv\lambda_{it}/(\beta_{it+1}(1+\Omega_{it+1}))$.

Each of the FOCs consists of three components. For example, the first term of the FOC with respect to the land holding (eq. 17) is the marginal cost to purchase and adjust land for the business use with a tax exemption. The second term, the derivative of d_{it+1}, captures the marginal revenue from land holding through production and resale. The third term starting with Λ_{it} captures the marginal contribution of land holding to the corporate value through relaxing the collateral constraint. For example, if the expected land price $E_t(q_{it+1})$ is high enough to surpass the cost of purchasing and adjusting land, the marginal increase in the land holding relaxes the collateral constraint (6) and the liquidity constraint (4). This effect is recognized by the owner of the firm as a positive contribution to the corporate value if the collateral constraint is binding and Λ_{it} is positive. The last effect implies the distortion in investment due to the collateral constraint.

To see how the binding collateral constraint distorts the asset allocation, we linearize equations (16), (17), and (13) with respect to K_{it}, L_{it}, and N_{it+1} around the optimal K^*_{it}, L^*_{it}, and N^*_{it+1} without the collateral constraint (6), following the analysis by Hazama and Uesugi (2015).

$$\begin{pmatrix} M_{KK} & M_{KL} & M_{KN} \\ M_{KL} & M_{LL} & M_{LN} \\ M_{KN} & M_{LN} & M_{NN} \end{pmatrix}\begin{pmatrix} K_{it}-K^*_{it} \\ L_{it}-L^*_{it} \\ N_{it+1}-N^*_{it+1} \end{pmatrix}+\Lambda_{it}\begin{pmatrix} x_K \\ x_L \\ 0 \end{pmatrix}\approx 0, \tag{18}$$

where

$$M_{KK} \equiv -\{(1-\tau_{t+1})R_{it}+1\}(1-\tau_t) \left.\frac{\partial^2 \phi}{\partial k_{it}^2}\right|_* + E_t\left[\frac{\partial^2 d_{it+1}}{\partial K_{it}^2}\right], \tag{19}$$

$$M_{KL} \equiv -\{(1-\tau_{t+1})R_{it}+1\}(1-\tau_t) \left.\frac{\partial^2 \phi}{\partial k_{it}\partial l_{it}}\right|_* + E_t\left[\frac{\partial^2 d_{it+1}}{\partial K_{it}\partial L_{it}}\right], \tag{20}$$

$$M_{LL} \equiv -\{(1-\tau_{t+1})R_{it}+1\}(1-\tau_t) \left.\frac{\partial^2 \phi}{\partial l_{it}^2}\right|_* + E_t\left[\frac{\partial^2 d_{it+1}}{\partial L_{it}^2}\right], \tag{21}$$

$$M_{KN} \equiv (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial N_{it+1}\partial K_{it}}\right|_*, \tag{22}$$

$$M_{LN} \equiv (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial N_{it+1}\partial L_{it}}\right|_*, \tag{23}$$

$$M_{NN} \equiv (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial N_{it+1}^2}\right|_*, \tag{24}$$

$$x_K \equiv E_t[s_{it+1}] - s_{it} - (1-\tau_t)\left.\frac{\partial \phi}{\partial k_{it}}\right|_*, \tag{25}$$

$$x_L \equiv E_t[q_{it+1}] - q_{it} - (1-\tau_t)\left.\frac{\partial \phi}{\partial l_{it}}\right|_*, \tag{26}$$

and

$$\begin{aligned}\frac{\partial^2 d_{it+1}}{\partial K_{it}^2} &= (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial K_{it}^2}\right|_* \\ &+ (1-\tau_{t+1})\left\{(1-\delta_{it+1})\left.\frac{\partial^2 \phi}{\partial k_{it+1}\partial K_{it}}\right|_* - \left.\frac{\partial^2 \phi}{\partial K_{it}^2}\right|_*\right\},\end{aligned} \tag{27}$$

$$\begin{aligned}\frac{\partial^2 d_{it+1}}{\partial K_{it}\partial L_{it}} &= (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial K_{it}\partial L_{it}}\right|_* \\ &+ (1-\tau_{t+1})\left\{(1-\delta_{it+1})\left.\frac{\partial^2 \phi}{\partial k_{it+1}\partial L_{it}}\right|_* - \left.\frac{\partial^2 \phi}{\partial K_{it}\partial L_{it}}\right|_*\right\},\end{aligned} \tag{28}$$

$$\frac{\partial^2 d_{it+1}}{\partial L_{it}^2} = (1-\tau_{t+1})p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left.\frac{\partial^2 F}{\partial L_{it}^2}\right|_* + (1-\tau_{t+1})\left\{\left.\frac{\partial^2 \phi}{\partial l_{it+1}\partial L_{it}}\right|_* - \left.\frac{\partial^2 \phi}{\partial L_{it}^2}\right|_*\right\}. \tag{29}$$

$x|_*$ indicates that x is evaluated at the optimum without the collateral constraint.

Solving the system of equations (18) gives,

$$\begin{pmatrix} K_{it}-K_{it}^* \\ L_{it}-L_{it}^* \\ N_{it+1}-N_{it+1}^* \end{pmatrix} \approx \frac{-\Lambda_{it}}{|M|}\begin{pmatrix} (M_{LL}M_{NN}-M_{LN}^2)x_K + (M_{LN}M_{KN}-M_{LK}M_{NN})x_L \\ (M_{KN}M_{LN}-M_{KL}M_{NN})x_K + (M_{KK}M_{NN}-M_{KN}^2)x_L \\ (M_{KN}M_{LN}-M_{KN}M_{LL})x_K + (M_{KN}M_{KL}-M_{KK}M_{LN})x_L \end{pmatrix}, \tag{30}$$

where $|M|$ is the determinant of the large matrix in the left hand side of eq. (18). Given that the second-order condition for the maximization is satisfied, the following conditions are satisfied,

$$|M| < 0, \tag{31}$$

$$M_{LL}M_{NN} - M_{LN}^2 > 0,\ M_{KK}M_{NN} - M_{KL}^2 > 0, \tag{32}$$

$$M_{LL} < 0,\ M_{KK} < 0,\ M_{NN} < 0. \tag{33}$$

The assumptions with respect to the complementarity in the production function and the adjustment cost imply that

$$M_{KL} > 0,\ M_{KN} > 0,\ M_{LN} > 0. \tag{34}$$

The solution (30) implies the following proposition.

Proposition 1 (Distortion by the collateral constraint) *Suppose the collateral constraint (6) of firm i is binding at time t, i.e., $\Lambda_{it} > 0$.*

1. *If $x_k = 0$ and $x_l < 0$, then firm i commit under-investments in all inputs, i.e., $K_{it} < K^*_{it}$, $L_{it} < L^*_{it}$, and $N_{it+1} < N^*_{it+1}$.*
2. *If $x_k = 0$ and $x_l > 0$, then firm i commit over-investments in all inputs, i.e., $K_{it} > K^*_{it}$, $L_{it} > L^*_{it}$, and $N_{it+1} > N^*_{it+1}$.*

This proposition means that the firm under-invests in all inputs if the price of one of collateralizable assets is expected to go down or go up slowly and so $x_l < 0$, whereas the firm over-invests in all inputs if the price of it is expected to go up substantially and so $x_l > 0$. In other words, a firm is more likely to commit over-investment in an economic boom, but it is more likely to commit under-investment in a slump.

We can obtain more precise conditions for over- and under-investments in L as shown in the following proposition.

Proposition 2 (Distortion in L_{it} by the collateral constraint) *Suppose the collateral constraint (6) of firm i is binding at time t, i.e., $\Lambda_{it} > 0$.*

1. *Under-investment in L_{it}: $L_{it} < L^*_{it}$ if*

$$E_t(q_{it+1}) - q_{it} < Ax_K + (1-\tau_t)\left.\frac{\partial \phi}{\partial l_{it}}\right|_*, \tag{35}$$

where

$$A \equiv \frac{M_{KL}M_{NN} - M_{KN}M_{NL}}{M_{KK}M_{NN} - M^2_{KN}} < 0. \tag{36}$$

2. *Over-investment in L_{it}: $L_{it} \geq L^*_{it}$ if*

$$E_t(q_{it+1}) - q_{it} \geq Ax_K + (1-\tau_t)\left.\frac{\partial \phi}{\partial l_{it}}\right|_*. \tag{37}$$

3 Estimation Model

In order to detect whether the collateral constraint is binding and how it distorts corporate investments, we need to estimate the coefficient Λ and the other unobservable parameters that determine the shape of the adjustment cost function and the production function.

To estimate these unknowns, we explicitly assume the adjustment cost function as follows:

$$\phi_{it} \equiv \phi(k_{it}, l_{it}, K_{it-1}, L_{it-1}) = \frac{\alpha_t}{2} \cdot \frac{(k_{it} + l_{it})^2}{K_{it-1} + L_{it-1}}, \tag{38}$$

where $\alpha_t \equiv \alpha_0 \mathbf{1}[k_{it} + l_{it} \geq 0] + \alpha_1 \mathbf{1}[k_{it} + l_{it} < 0]$, $\alpha_0 \geq 0$ and $\alpha_1 \geq 0$. We address the possible difference in adjustment costs when the investment is positive and negative by this specification. The derivatives of the adjustment cost function are

$$\frac{\partial \phi_{it}}{\partial l_{it}} = \frac{\partial \phi_{it}}{\partial k_{it}} = \frac{\alpha_t (k_{it} + l_{it})}{K_{it-1} + L_{it-1}}, \tag{39}$$

$$\frac{\partial \phi_{it}}{\partial L_{it-1}} = \frac{\partial \phi_{it}}{\partial K_{it-1}} = -\frac{\alpha_t}{2} \cdot \left(\frac{k_{it} + l_{it}}{K_{it-1} + L_{it-1}} \right)^2. \tag{40}$$

We assume that the production function is homogeneous of degree $h(> 0)$ with respect to every input L, K, and N. Thus, we obtain the following expression by the usual calculation,

$$hY_{it} = \frac{\partial Y_{it}}{\partial K_{it-1}} K_{it-1} + \frac{\partial Y_{it}}{\partial L_{it-1}} L_{it-1} + \frac{\partial Y_{it}}{\partial N_{it}} N_{it}, \tag{41}$$

where $Y_{it} \equiv F(L_{it-1}, K_{it-1}, N_{it})$. Plugging the FOC (13) into the last term and rearranging it, we get

$$\frac{\partial Y_{it}}{\partial K_{it-1}} K_{it-1} + \frac{\partial Y_{it}}{\partial L_{it-1}} L_{it-1} = hY_{it} - \frac{w_{it} N_{it}}{p_{it+1} \left(1 - \frac{1}{\epsilon_D}\right)}. \tag{42}$$

Our estimation model is derived by adding (16) multiplied by K_{it} and (17) multiplied by L_{it}, i.e.,

$$\begin{aligned}
&- \{(1 - \tau_{t+1}) R_{it} + 1\} \left\{ (1 - \tau_t) \left(\frac{\partial \phi_{it}}{\partial k_{it}} \cdot K_{it} + \frac{\partial \phi_{it}}{\partial l_{it}} \cdot L_{it} \right) + s_{it} K_{it} + q_{it} L_{it}) \right\} \\
&+ E_t \left(\frac{\partial d_{it+1}}{\partial K_{it}} \cdot K_{it} + \frac{\partial d_{it+1}}{\partial L_{it}} \cdot L_{it} \right) + \Lambda_{it} \left\{ (E_t(s_{it+1}) - s_{it}) K_{it} + (E_t(q_{it+1}) - q_{it}) L_{it} \right\} \\
&- \Lambda_{it} (1 - \tau_t) \left(\frac{\partial \phi_{it}}{\partial k_{it}} \cdot K_{it} + \frac{\partial \phi_{it}}{\partial l_{it}} \cdot L_{it} \right) = 0,
\end{aligned} \tag{43}$$

where

$$
\begin{aligned}
&E_t\left(\frac{\partial d_{it+1}}{\partial K_{it}} \cdot K_{it} + \frac{\partial d_{it+1}}{\partial L_{it}} \cdot L_{it}\right) \\
&= E_t\left[(1-\tau_{t+1})\left\{p_{it+1}\left(1-\frac{\theta}{\epsilon_D}\right)\left(\frac{\partial Y_{it+1}}{\partial K_{it}} \cdot K_{it} + \frac{\partial Y_{it+1}}{\partial L_{it}} \cdot L_{it}\right) + (1-\delta_{it+1})\frac{\partial \phi_{it+1}}{\partial k_{it+1}} \cdot K_{it}\right\}\right] \\
&\quad + E_t\left[(1-\tau_{t+1})\left\{-\delta_{it+1}K_{it} - \frac{\partial \phi_{it+1}}{\partial K_{it}} \cdot K_{it} + \frac{\partial \phi_{it+1}}{\partial l_{it+1}} \cdot L_{it} - \frac{\partial \phi_{it+1}}{\partial L_{it}} \cdot L_{it}\right\}\right] \\
&\quad + E_t\left[\delta_{it+1}K_{it} + s_{it+1}(1-\delta_{it+1})K_{it} + q_{it+1}L_{it}\right] \\
&= E_t\left[(1-\tau_{t+1})\left\{\eta p_{it+1}Y_{it+1} - w_{it+1}N_{it+1} + \frac{\alpha_{t+1}(k_{it+1}+l_{it+1})(K_{it+1}+L_{it+1})}{K_{it}+L_{it}}\right\}\right] \\
&\quad + E_t\left[\tau_{t+1}\delta_{it+1}K_{it} + s_{it+1}(1-\delta_{it+1})K_{it} + q_{it+1}L_{it}\right], \qquad (44)
\end{aligned}
$$

where $\eta \equiv h\left(1-\frac{\theta}{\epsilon_D}\right)$. The last expression is derived by plugging in the assumptions (39), (40), and (42) and the transition equations (2) and (3). We can avoid estimating the marginal product of capital and that of land directly by this transformation.

Rearranging equation (43) by coefficients to be estimated after plugging in (39), (40), and (44); replacing the expected value by the actual value minus the mean-zero error term ϵ_{it}; and adding the industry dummies ι_i, the year fixed effect y_t, and the regional dummies f_i, we obtain the following exact specification for the structural estimation.

$$\alpha_t X_{1it} + \alpha_{t+1}X_{2it} + \eta X_{3it} + X_{4it} + \Lambda(X_{5it} + \alpha_t X_{6it}) + \iota_i + y_t + f_i + \epsilon_{it} = 0, \qquad (45)$$

where

$$X_{1it} \equiv -(1-\tau_{it+1})(1-\tau_{it})R_{it+1}(k_{it}+l_{it})(K_{it}+L_{it})/(K_{it-1}+L_{it-1}), \qquad (46)$$

$$X_{2it} \equiv (1-\tau_{t+1})(k_{it+1}+l_{it+1})(K_{it+1}+L_{it+1})/(K_{it}+L_{it}), \qquad (47)$$

$$X_{3it} \equiv (1-\tau_{it+1})p_{it+1}Y_{it+1}, \qquad (48)$$

$$
\begin{aligned}
X_{4it} \equiv &-(1-\tau_{it+1})w_{it+1}N_{it+1} + (s_{it+1} + (\tau_{it+1} - s_{it+1})\delta_{it+1})K_{it} + q_{it+1}L_{it} \\
&- \{(1-\tau_{t+1})R_{it} + 1\}(s_{it}K_{it} + q_{it}L_{it}) \qquad (49)
\end{aligned}
$$

$$X_{5it} \equiv (s_{it+1} - s_{it})K_{it} + (q_{it+1} - q_{it})L_{it}, \qquad (50)$$

$$X_{6it} \equiv -(1-\tau_{it})(k_{it}+l_{it})(K_{it}+L_{it})/(K_{it-1}+L_{it-1}), \qquad (51)$$

$$\alpha_t \equiv \alpha_0 \mathbf{1}[k_{it}+l_{it} \geq 0] + \alpha_1 \mathbf{1}[k_{it}+l_{it} < 0] \qquad (52)$$

and $\{\alpha_0, \alpha_1, \eta, \Lambda\}$ are the coefficients to be estimated.

We estimate this model using the quasi maximum likelihood estimation under parametric constraints implied by the theory, i.e., $\Lambda \geq 0$, $\alpha_0 \geq 0$ and $\alpha_1 \geq 0$, and the assumption that the error term ϵ_{it} is distributed according to the mean-zero normal distribution $N(0, \sigma^2)$. To incorporate these sign restrictions, we replace Λ with $\tilde{\Lambda}^2$, α_0 with a_0^2, and α_1 with a_1^2. We estimate $\tilde{\Lambda}$, a_0, and a_1 and report the square of each of these estimates as the estimates of Λ, α_0, and α_1, respectively.[4]

4 Data

4.1 Financial Statements Statistics of Corporations by Industry

The most important part of our dataset is collected from the microdata of the annual survey for the Financial Statements Statistics of Corporations by Industry (FSSCI), which is conducted by the Ministry of Finance Japan.[5] We use the data recorded for the period from 1983 to 2002, two decades including the extreme boom and bust of the Japanese land price, which peaked in 1991. The survey asks for the major items of the balance sheet in the latest and the previous accounting periods, including the book value of land holdings and the amounts of loans outstanding from financial institutions, and the latest income statement. The target of the survey from 1983 to 1995 consists of every company with stated capital of 500 million Japanese yen (JPY) or more; companies with stated capital of 100 million JPY or more but less than 500 million JPY, which is randomly selected by a probability proportional to capital size; and those with less than 100 million JPY capital, which are randomly selected with equal probability by capital size class. The threshold of 500 million JPY is revised to 600 million JPY after 1996. The process of random selection by a probability proportional to capital size is as follows: calculate the cumulative summation of stated capital from the smallest company, and then select a company every time the cumulative summation reaches 500 million JPY (from 1983 to 1995) or 600 million JPY (after 1996).

The advantage of using this dataset is that we can obtain the land-holding information and the location information of the head offices of SMEs during the period including the extreme boom and bust of the land price. The first point is that SMEs are more likely to face a binding collateral constraint since they are expected to depend on secured loans for their financing due to their relatively low credit quality. The second point is that we are more likely to obtain a

[4] Another way to impose the non-negative constraint is to replace Λ with the exponential function $\exp(\tilde{\Lambda})$ and estimate $\tilde{\Lambda}$. However, if the true value of Λ is close to zero, which is likely in our estimation, $\tilde{\Lambda}$ explodes to negative infinity. We adapt the method in the main text to achieve convergence when the true Λ is closer to zero.

[5] The survey method is described on the website of the Ministry of Finance Japan; http://www.mof.go.jp/english/pri/reference/ssc/outline.htm (last visited on January 9, 2015).

reasonable estimate for the market value of land held by SMEs than for that held by larger firms. We need to connect the land-price information by location information to obtain an estimate of the market value of the land, but the only available location information is the address of the head office of each firm. Therefore, the land-price measurement error is far more serious for larger companies with a large number of offices and factories in a wide variety of regions.[6] Therefore, we focus on the observation of SMEs, whose number of full-time employees at the first observation is 300 or less or whose stated capital at the first observation is 300 million JPY or less[7] despite the fact that the dataset contains the full panel of information on larger firms. We also limit our attention to the manufacturing sector, since the production function and the adjustment cost function in the other sectors are expected to be quite different.

We obtain two main datasets by matching the FSSCI with the two types of land-price information published by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in the *Land Market Value Publication* at the city or town where the head office of a company is located[8] and other relevant price index and tax rates for each year. All price information (product price, capital price, and land-price indexes) is normalized at the level in each sector and in each city as of the year 2000.

The first main dataset is the one constructed by using the highest commercial land price in the city, including the 23 special wards in Tokyo, or the town where the head office of a firm is located (we call it *the commercial-land data* hereafter). The other is the dataset constructed by using the average residential land price in each city and town (we call it *the residential-land*

[6]Land-holding information both on the book-value basis and on the square-meter basis is available for publicly traded companies, but it is almost impossible to calculate the market value of land, since the sizes of individual offices and factories, which are located all over the country, are not available.

[7]These criteria are taken from the legal definition of SMEs in the manufacturing sector in Japan. Company IDs for SMEs in the Financial Statements Dataset are recycled. To avoid the error of treating different companies as the same company, we treat companies as different if the company name and the head office address change simultaneously.

[8]The details of the process to match land-price information are as follows: The firm-location information in the microdata of the Financial Statements Statistics includes the prefecture ID and the full address information in Japanese characters, half-width *kana*, as of the survey for each year. First, we prepare the matching table of the latest version of the standardized city/town code, JIS code, and the half-width kana city/town name including older names before mergers or name changes from 1983 to 2014. The latest JIS code is collected from the website of the Local Authorities Systems Development Center, https://www.j-lis.go.jp/lasdec-archive/cms/1,0,14.html, on October 15, 2014. The merger and other name-change information is collected from a copyright-free website provided by a private company, Musashino Wing Co., Ltd., which is available (as of October 15, 2014) at http://www.dictator.co.jp/overlook/terms.html. Second, we match the financial statement data and the JIS code data by the prefecture ID; organization-level ID, which indicates whether the head office location is a city, ward, or town and the city/ward/town name in kana after cleaning up misspellings; and the variation of expressions, as much as possible in the financial statement data. Third, we match the dataset in the second step with the city/town-level (including the 23 special wards in Tokyo) land-price information collected from NIKKEI NEEDS by the JIS code.

data hereafter). The sample correlation between these two land-price measures in our dataset is 0.417; not high enough to conclude that the difference is negligible. We cannot tell a priori which price information is suitable for the analysis of the manufacturing sector, since the offices and factories could be located in an area closer to a commercial district or closer to a residential district. The detail of the definition of the variables required to estimate the model (45) is described in the appendix.

The measure of the land holdings of each firm is constructed from the balance sheet information and the city/town-level land-price information. The book value of land on the balance sheet includes not only the part used in operation but also that not used. Strictly speaking, the latter part of land has to be subtracted from the land input in the production function in the structural estimation. However, we cannot do so because we lack in information about the land usage of each firm. The holding of unused land is captured by a lower estimate of the productivity of land in our estimation under the assumption of the strict concavity of the production function.

We drop the following outliers before the estimation; companies with an interest rate R_{it} greater than 0.2 or negative, those with zero sales $p_{it}Y_{it}$, those with a depreciation rate greater than 1, and those in the top or bottom 1% in each year from 1984 to 2001 with respect to $\frac{k_{it}+l_{it}}{K_{it-1}+L_{it-1}}$, $\frac{k_{it+1}+l_{it+1}}{K_{it}+L_{it}}$, $p_{it+1}Y_{it+1}$, $K_{it}+L_{it}$, δ_{it+1}, and $w_{it+1}N_{it+1}$. We also drop those in the top 1 % in each year with respect to the number of employees, as well as the stated capital to exclude de facto large companies with a smaller number of employees but larger capital or with a larger number of employees but smaller capital.

4.2 Descriptive Statistics

We need at least three consecutive periods of information from the balance sheet and the income statement for our empirical studies. Given that the ranking of capital size does not change that much over time, we expect that we are more likely to obtain observations for those whose stated capital is between 100 million JPY and 500/600 million JPY under the above sampling method. Table 1 shows that our dataset covers 6.8% of the entire SME manufacturer sample in the FSSCI microdata for the 1980s and 10.3% of that for the 1990s. The observations are distributed reasonably across various sectors in manufacturing (Table 2).

Table 3 shows the descriptive statistics of the variables for the estimation of the model (45) and in the preliminary linear regression analysis described in the next section. More than 90% of companies record capital of 300 million JPY or more and 50 or more employees. On the other hand, 90% of firms employ fewer than 500 persons. Thus, our dataset mostly consists of medium-sized enterprises, as is expected from the sampling procedure.

Figure 2 shows the time series of the mean investment ratio in each of the datasets. The investment ratio keeps increasing in the bubble period of the late 1980s, and it decreases after the land-price crash in 1991 (Figure 4). The investment ratio recovered from 1994 to 1997, but it dropped sharply again in response to the Japanese banking crisis in 1997 and 1998. Figure 2 also shows the time series of the diffusion index of the lending attitude of financial institutions (all enterprises) from *TANKAN*, the Short-Term Economic Survey of Enterprises in Japan (quarterly), conducted by the Bank of Japan. The diffusion index is the difference, (% ratio of firms replying "accommodative") − (% ratio of firms replying "severe"). The high diffusion index indicates that firms perceive that the lending attitude of financial institutions is lax. The diffusion index shows a negative correlation with the investment ratio. It is very high in the 1980s, but it dropped sharply at the burst of the asset bubble in 1991. The lending attitude gradually became looser until 1996, but it turned tighter again due to the banking crisis in 1997 and 1998.

Figure 3 shows the time series of the mean interest rate of borrowing. The development of the rate is in accordance with the monetary policy by the Bank of Japan. The interest rates decreased from 1985 to 1987 due to the monetary expansion in response to the sharp appreciation of the Japanese yen against the U.S. dollar after the Plaza Accord. However, it increased from 1989 to 1990 due to the monetary tightening to cool down overheated asset prices. It continued to decline after the bubble burst and throughout the 1990s. Despite of the decline of the borrowing cost, the ratio of bank loans to total assets, B_{it}/A_{it}, hardly varies.

Figure 4 shows the time series of the sample mean of the land price and the capital-good price index. The values are listed in Table 4. The land price increased in the 1980s. The price hike was extreme in the commercial district in large cities. The land price peaked in 1991. The move of the capital price index is more modest than that of the land price although it kept declining in the 1990s in response to the prolonged economic slump. Thus, we expect that the time-series variation in terms of over- or under-investment is more likely to be found with respect to land collateral.

5 Preliminary Regression Analysis

Before estimating the structural model, we run the following cross-sectional regression at each time t to obtain a rough picture of the time-series variation in the effect of the collateral constraint, particularly with land as collateral.

$$\frac{k_{it} + l_{it}}{K_{it-1} + L_{it-1}} = \beta_0 + \beta_1 \cdot D\_land\_value_{it} + \gamma' \mathbf{x} + \nu_{it}, \tag{53}$$

where i is the index of each company, $\mathbf{x}$ is the vector of control variables, βs and γ are the coefficients to be estimated, ν_{it} is the error term, and

$$D\_land\_value_{it} \equiv L_{it-1} \times (q_{it+1} - q_{it})/10000. \tag{54}$$

$D\_land\_value_{it}$ is a proxy variable for the expected change from the accounting period t to $t+1$ in the market value of land held at the beginning of period t. We expect that the coefficient of this variable is positive and significant if the land collateral constraint is binding. A positive coefficient indicates that the investment intensity is increasing in the expected market value of collateral at the hand of a company. In the preliminary regression analysis, we drop the outliers in terms of D_land_value in the top or bottom 1 % of the entire sample after deleting outliers, as explained above.

The set of control variables $\mathbf{x}$ includes (1) productivity measures regarding land and capital in the previous year, Y_{it-1}/L_{it-2} and Y_{it-1}/K_{it-2}; (2) a current-period profitability measure, $cash\_flow_{it}/K_{it-1}$, where the cash flow is defined by operating income plus depreciation; (3) the firm's real capital size at the beginning of the current period, $K_{it-1}+L_{it-1}$; and (4) current-period financial soundness measures, R_{it}, $leverage_{it}$ (interest-bearing debt ÷ total assets), and int_cover_{it}, the interest coverage ratio defined by (operating income + depreciation) ÷ interest payments. We also include the regional and industry dummy variables.

First, we run a cross-section regression for each year from 1984 to 2001 by OLS with robust standard errors. The summary of the results is listed in Table 5.[9] The estimated coefficient of the $D\_land\_value_{it}$ is negative for the 1980s in both the commercial-land data and the residential-land data and is statistically significant for many years in the former dataset while it is less significant in the latter. The coefficient is positive and significant for many years in the 1990s,

[9] The table reports the coefficient of the D_land_value only. The estimated coefficients of the other firms are omitted from the table.

particularly in the latter half of the 1990s, which includes the period of the banking crisis in Japan in 1997 and 1998.

The land price increased precipitously in the 1980s, but it declined sharply in the 1990s (Figure 4). Therefore, this result indicates that the collateral constraint was not binding in the 1980s thanks to the sharp increase in the collateral value of land relative to the increase in borrowing. On the other hand, the collateral constraint is strongly binding in the latter half of the 1990s, in which the collateral value of land diminishes and confines corporate investment. For example, the result from the commercial-land data indicates that a company with 10,000 square meters of land facing an 8% land-price decrease in 1998 (Table 5) reduced its investment rate by 3.4%. This is economically significant, for the sample mean of the investment ratio in 1996-1999 was 12.1 % (commercial-land data) or 14.2 % (residential-land data).

To control the unobservable fixed effect of each firm more rigorously, we also estimated the linear model with the firm-level fixed effect for each of the two sub-periods; the period from 1984 to 1991, in which the land price keep going up, and the period from 1992 to 2001, in which the land price kept going down. Table 6 shows the result from the fixed-effect model. The result is consistent with that of the cross-section regression. The coefficient of the $D\_land\_value_{it}$ is positive and significant only for the period of 1992-2001 (Column (2) in each panel of Table 6). Many of the control variables have a statistically significant coefficient. The investment ratio is higher when the lagged average productivity Y_{it-1}/L_{it-2} or Y_{it-1}/K_{it-2} is higher. Those companies with larger existing fixed assets $K_{it-1} + L_{it-1}$ and those who are already highly leveraged $leverage_{it}$ invest less. The loan interest rate R_{it} has a significant and positive correlation with the investment ratio. This is probably because the loan interest rate is higher when the demand for loanable funds for investment is high. $Cash\_flow_{it}/K_{it-1}$, which has been found to have positive impacts on investment in many existing studies, has a positive and significant coefficient, especially in the post-bubble period in both datasets.

The finding that the collateral constraint is not binding in the period of the bubble in the late 1980s is consistent with the finding by Ono et al. (2014) that the loan-to-value ratio was counter-cyclical and kept declining in the late 1980s. The finding for the 1990s is consistent with the finding by Gan (2007) that the sharp decline of the land price in the 1990s significantly confined the investment by publicly traded companies that hold a large amount of land.

6 Result of the Structural Estimation

According to the sharp contrast in the preliminary regression before and after 1991, the peak year of the land price, we modify the structural model (45) to allow Λ to vary before and after 1991, i.e., we specify Λ as follows,

$$\Lambda = \Lambda_0 \mathbf{1}[year \leq 1991] + \Lambda_1 \mathbf{1}[year \geq 1992], \tag{55}$$

where $\mathbf{1}[x]$ is the indicator function, which is equal to one if x is true or zero otherwise. We estimate this structural model by the quasi-maximum likelihood estimation with the non-negative constraint with respect to α_0, α_0, Λ_0 and Λ_1 as mentioned before. Based on the result of the preliminary regression, we expect that Λ_0 is not significant and that Λ_1 is positive and significant.

Table 7 shows the results of the structural estimation of (45). Column (i) reports the result from the commercial-land data. Column (ii) reports the result from the residential-land data. The Lagrange multiplier for the period 1984–1991, Λ_0, is almost zero, whereas that for the period from 1992 to 2001, Λ_1, is positive and statistically significant at a 1% level in both datasets. This result is consistent with the preliminary result.

The estimated Λ_1 in the residential-land data suggests that the Lagrange multiplier λ is about 4.6 under the assumption that the discount factor β is equal to 1/1.034 (the average of the year-by-year sample mean of R from 1992 to 2001 is 3.4%) and the non-negative cash-flow constraint is not binding, i.e., $\Omega = 0$. This means that the estimated shadow value of a unit of land evaluated by a market price is 4.6. This indicates that, for example, if a firm had residential land of 3,308m^2 in 1997 (sample mean in 1997) in the Ota ward of Tokyo, a municipality with a large cluster of small manufacturers, the average market value of it is 1.83 billion JPY. The market value is reduced to 1.73 billion JPY in 1998. This 100-million JPY reduction of the collateral value reduces the equity value of the firm by about 460 million JPY. Given the average capital cost of 3.4%, the annual loss of the free cash flow is about 15.6 million JPY. The impact is economically significant since it accounts for about 4.6% of the sample mean of free cash flow, 336.4 million JPY (Panel 3). In other words, the collateral constraint pushed down the average corporate value of firms with residential land by 4.6% in 1998.

Table 8 shows the results of the structural estimation of the firs-order difference of (45) to control for the unobserved firm characteristics more sharply. Again, the estimated Lagrange multiplier in the period before 1991 is not statistically significant, whereas it is significant in the period after 1991. However, the estimated values of them are much smaller than those in the previous table, probably due to the diminished variation in variables.

7 Determinants of Λ

We have estimated the average Λ in each of the two periods in the baseline model. However, Λ can differ by firms and years since the tightness of the collateral constraint depends on the expected change of collateral values, the lending attitude of banks, and the level of indebtedness of each firm. To investigate important determinants of the tightness of the collateral constraint and estimate the Λ_{it} that each firm faces in each year, we assume the following linear model of Λ_{it},

$$\Lambda_{it} = \lambda_0 + \lambda_{\Delta q}\Delta q_{it+1} + \lambda_{\Delta q<0}\{\Delta q_{it+1} \times \mathbf{1}[q_{it+1} - q_{it} < 0]\} + \lambda_{B/A}B_{it}/A_{it} + \lambda_{DI}DI_t, \quad (56)$$

where $\Delta q_{it+1} \equiv q_{it+1} - q_{it}$ and DI_t is the diffusion index of the lending attitude of financial institutions, which is shown in Figure 2.

We estimate the model (45) after replacing Λ with a variable Λ_{it} (equation 56). We do not impose the non-negative constraint to avoid the complication in interpreting the marginal effect of each coefficient in equation (56).

Table 9 is the result of the augmented estimation. $\lambda_{\Delta q}$ is not statistically significant. This result is consistent with the the baseline result. $\lambda_{\Delta q<0}$ is negative and statistically significant at the 1% significance level in the commercial-land data, whereas it is not in the residential-land data. Consequently, the estimates with the residential-land data show the significant constant term. This result suggests that manufacturers have more land in commercial districts and the residential-land data is more contaminated by a measurement error. The negative $\lambda_{\Delta q<0}$ indicates that the collateral constraint is more likely to bind if firms and banks expect the decline in land price in the next period. λ_{DI} is negative and statistically significant at the 1% significance level in both datasets. The collateral constraint is less likely to bind when banks are more willing to lend.

To illustrate the relative importance of these determinants, the estimated contribution of each coefficient in equation (56) with the commercial-land data is plotted in Figure 5. The lax lending attitude in the 1980s mostly accounts for the low Λ. The land-price decline is the most important determinant in the period from 1991 to 1994 right after the burst of the land-price bubble. The land-price effect remains high after that, but the lax lending attitude cancels it in 1995 and 1996. After that, the lending attitude gets reverses and severely constrains the investment by firms in the banking crisis in 1998. The land-price decline continues to be a significant cause of the tight collateral constraint throughout the 1990s and the early 2000s.

To see the cross-sectional variation of Λ_{it} in each year, we count the number of firms with and without a binding collateral constraint. We classify a firm as one with a biding constraint if the estimated Λ_{it} is positive and significant at a 1% significance level and as one without a binding constraint otherwise. In addition, we count the number of firms with excessive land holdings and those with insufficient land holdings among binding firms by applying the result in Proposition 2. We classify a firm as an insufficient land holder if its estimate of $q_{it+1} - q_{it} - (1 - \tau_t)\frac{\partial \phi}{\partial l_{it}}$ is negative and as an excessive land holder if its estimate is positive. To simplify the calculation, we assume that the first term of RHS of (35) is zero, i.e., the complementarity among inputs in the production function and that in the adjustment cost function are very small. Given that x_k is likely to be positive in the period before 1990, our calculation over-estimates the number of firms that holds insufficient land in the period, whereas it under-estimates in the period after 1991, in which x_k is more likely to be negative.

Table 10 is the result of these calculations. Most firms are not bound by the collateral constraint in the period before 1990, when the land price keep increasing. However, the situation changes at the burst of the bubble in 1991. The ratio of firms with a binding constraint jumps up in 1991 from zero to 50%. The ratio increases to about 70% in 1993. The ratio declines in 1995 and 1996 due to the lax lending stance of banks, but the ratio begins to increase again and reaches 99.5% in the 1998 banking crisis. The ratio declines somewhat but remains as high as 60% after the crisis. Most firms with the binding constraint suffer from the problem of under-investment and become deficient in land holdings. Our estimate of Λ_{it} shows that the collateral constraint is more likely to bind when the land price is declining. Our proposition predicts that the problem of under-investment matters more in this case.

8 Policy Implications

The estimation result clearly shows that the collateral constraint is binding only during the period in which the market value of collateral is declining and that most of the binding firms suffer from the problem of under-investment. The optimal level of collateral requirement is determined by the trade-off between the reduction of the information cost and the distortion cost, on which we focus. The derivation of the exactly optimal level of collateral requirement is beyond the scope of this paper. However, our estimates indicate that under-investment resulting from the binding collateral constraint is an important cause of the lack of aggregate investments and the prolonged economic slump in the 1990s in Japan. This finding has two policy implications: one concerns the promotion and provision of lending less dependent on collateral in the economic downturn, and the other concerns the loan-to-value regulation, which is considered an important tool for the macroprudence policy.

Promotion of lending less dependent on collaterals. Consistent with our findings, the Japanese government instituted several policies to support the supply of loans without a collateral provision for SMEs in the 2000s. For example, National Life Finance Corporation (currently Japan Finance Corporation, Micro Business and Individual Unit), a government-owned policy bank targeting micro businesses, continues providing non-collateral loans on a large scale. The ratio of uncovered corporate loans has exceeded 70 % since the late 1990s.[10] Likewise, the Japan Finance Corporation for Small and Medium Enterprises (currently Japan Finance Corporation, Small and Medium Enterprise Unit), another government-owned policy bank targeting SMEs, started a non-collateral lending program in 2005.[11] In addition to the above direct lending by the government, the Japanese Financial Service Agency (JFSA) started a promotion for regional banks to provide loans less dependent on collateral in the campaign "Relationship Banking No Kinou Kyoka Ni Kansuru Action Program" (Action Program Concerning Enhancement of Relationship Banking) in 2003. The press release by JFSA announced: "We require thorough loan reviews and the introduction of covenants and a scoring model for each financial institution in order to promote lending dependent more on operating cash flow and not excessively on collateral and guarantees" (translated by the author)[12]

[10] The ratio of loans without or with decreased collateral was 78.5 % in terms of the number of contracts (out of 488,701 contracts) in the fiscal year 1998 (April 1998 - March 1997) (source: website of the Ministry of Finance Japan: http://www.mof.go.jp/about_mof/councils/unyosin/report/1a1505c.htm). The ratio remains the same level currently; 76.1 % (out of 265,919 contracts) (source: website of JFC, Micro Business and Individual Unit, http://www.jfc.go.jp/n/company/national/condition.html)

[11] The JFC SME Unit started no-collateral lending in April 2005. The maximum loan size is 80 million JPY for each company and the maximum maturity is 5 years. The loan-size cap was lifted in August 2008.

[12] "Relationship Banking No Kinou Kyoka Ni Kansuru Action Program" (Action Program Concerning Enhancement of Relationship Banking), Section I. 4. (1), page 4, JFSA, March 28, 2003.

These policies are interpreted as a response to the under-investment problem and can be evaluated as policies to help improve economic efficiency according to our model and estimation.

Loan-to-value (LTV) regulation. The LTV regulation is discussed among policy makers internationally in the context of the macroprudence regulation after the 2007-09 global financial crisis. Our finding that the collateral constraint is less likely to bind in the period of a real estate boom means that the LTV cap is also less likely to be effective in such a period because the speed of the increase in collateral market value can exceed that of the increase in borrowing, as shown by Ono et al. (2014). Even worse, the cap is more likely to be effective in the period of an economic downturn after the boom and can aggravate the slump by intensifying under-investment. Our result suggests that the problem of counter-cyclicality needs to be addressed when implementing the LTV regulation.

9 Concluding Remarks

We have obtained evidence that the collateral constraint is more likely to bind in the period when the market value of collateral decreases and that it results in under-investment both from the linear regression and the structural estimation by using the SME data before and after the burst of the land-price bubble in Japan in the 1980s and 1990s. The estimates reveal that under-investment due to the collateral requirement during the phase of land-price implosion is more significant and is a serious problem. Our analysis gives a clear answer to the first question in the introduction, why do SMEs hold idle land? The answer, based on our analysis, is that it is because SMEs face a liquidity constraint confined by the value of collateral. As a result, they cannot make the additional investment required to make the best use of the land.

Important empirical questions remain. For example, we assume that the land price is exogenously determined. However, it could be more reasonable to treat the land price as an endogenous variable by aggregating the Euler equation and introducing the supply function of land. The equilibrium land-price dynamics and their interaction with corporate investment have been analyzed in theoretical studies (e.g., Kiyotaki and Moore, 1997; Geanakoplos and Zame, 2013; Brumm et al., 2015; Gottardi and Kubler, 2015). However, the empirical examination of these dynamics remains a challenging research subject.

Appendix: Construction of Variables

The definition of and construction process for each variable are listed below. The source of information is the survey of the Financial Statements Statistics of Corporations by Industry unless otherwise noted.

- A_{it}: total assets (book value) of firm i at t (million JPY).
- B_{it}: bank loans outstanding (book value) of firm i at t (million JPY).
- BK_{it} (book value of capital): book value of construction in progress and other tangible fixed assets (million JPY).
- DEP_{it}: nominal depreciation between the period from $t-1$ to t (million JPY).
- s_{it} (price of K): (Corporate Goods Price Index of investment goods at t) $\div$100 (2000 base, Bank of Japan).[13]
- q_{it} (price of L): land-price index (normalized to 1 in the base year 2000 in every city) constructed from the Land Market Value Publication (Ministry of Land, Infrastructure, Transport and Tourism) at t. We use two versions of the price information at the city, special ward in Tokyo, and town levels contained in NIKKEI NEEDS. One is the highest price of commercial land. The other is the average price of residential land.
- L_{it} (real land): $bland_{it} \times M\_B_t / q_{it}$ for the first observation of each firm, where $bland_{it}$ is the book value of the land of firm i at t and M_B_t is the aggregate market-to-book ratio of land at t,[14] i.e., the ratio of the land of private non-financial corporations at the end of the calendar year in the stock data of SNA (National Accounts of Japan; 93SNA, benchmark year: 2000)[15] over the total book value of land at the end of the calendar year of all companies with stated capital of 10 million JPY or more except for the financial and insurance sectors[16] (see Table 9 for the values).

[13] Available from the BoJ website: http://www.stat-search.boj.or.jp/index_en.html. Item PR'PRCG_17K032001.

[14] Hoshi and Kashyap (1990) and Hayashi and Inoue (1992) adapt this type of adjustment for the first observation of each firm.

[15] Available from the Cabinet Office website; http://www.esri.cao.go.jp/en/sna/data/kakuhou/files/2004/18annual_report_e.html.

[16] Available from the website of the Policy Research Institute of the Ministry of Finance Japan; http://www.mof.go.jp/english/pri/reference/ssc/historical.htm.

Table A1: Aggregate market to book ratio of land

year	M_B	year	M_B	year	M_B
1983	6.297	1990	7.035	1997	3.014
1984	5.957	1991	5.467	1998	2.802
1985	5.759	1992	4.536	1999	2.261
1986	6.284	1993	3.989	2000	2.043
1987	7.280	1994	3.764	2001	1.971
1988	6.915	1995	3.303	2002	1.819
1989	7.743	1996	3.228		

For the other observations,[17]

$$L_t = \begin{cases} L_{t-1} + \frac{bland_t - bland_{t-1}}{q_t} & \text{if} \quad bland_t \geq bland_{t-1}, \\ L_{t-1} + \frac{bland_t - bland_{t-1}}{q_t / M\_B_t} & \text{if} \quad bland_t < bland_{t-1} \end{cases} \tag{57}$$

- K_{it} (real capital): BK_{it}/s_{it}.
- k_{it} (real investment in capital): $(BK_{it} - BK_{it-1} + DEP_{it})/s_{it}$.
- τ_t (effective tax rate): $tax \times (1 + R_{it})/(1 + R_{it} + \text{enterprise tax})$, where tax = (corporate tax rate) $\times$ (1 + prefecture and city civil tax rate) + (enterprise tax rate). See Hayashi (1990) for more detail. The historical information of each tax rate is collected from the websites of the relevant government offices.[18] We use the statutory rate for regional taxes, enterprise taxes, and civil taxes despite the fact that each prefecture or city is allowed to impose rates higher than the statutory rate.
- r_t (risk-free rate): 9-year Japanese government bond secondary market yield (source: Ministry of Finance Japan).[19]
- R_{it}: (interest payment at time t) $/B_{it-1}$, or 9-year Japanese government bond secondary market yield r_t if the firm does not issue any debt.
- δ_{it} (depreciation rate): DEP_{it} / BK_{it-1}.

[17] Hoshi and Kashyap (1990) and other extant studies adopt the LIFO (last-in-first-out) assumption for land sale. However, we could not apply this to our dataset because of the short length of the time series in our dataset due to the random sampling.

[18] The national corporate tax rate is available on the website of the Ministry of Finance Japan; http://www.mof.go.jp/tax_policy/summary/corporation/082.htm. The other rates of regional taxes are available from the website of the Ministry of Internal Affairs and Communications; http://www.soumu.go.jp/main_sosiki/jichi_zeisei/czaisei/czaisei_seido/pdf/ichiran06_h26/ichiran06_h26_17.pdf.

[19] The 10-year JGB secondary market yield is not available before July 1986.

- p_{it} (product price): Corporate Goods Price Index ÷100 (2000 base; domestic goods) in each of the 16 manufacturing sectors: processed foodstuffs; textile products; lumber and wood products; pulp, paper, and related products; plastic products; petroleum and coal products; ceramic, stone and clay products; iron and steel; nonferrous metals; metal products; general machinery and equipment; electrical machinery and equipment; transportation equipment; precision instruments; and other manufacturing industry products.[20]

- Y_{it} (real output): total sales plus inventory of final products (book value) in the period from $t-1$ to t divided by p_{it}.

- $w_{it}N_{it}$ (nominal cost of other variable inputs): (cost of sales + selling, general, and administrative expenses − depreciation).

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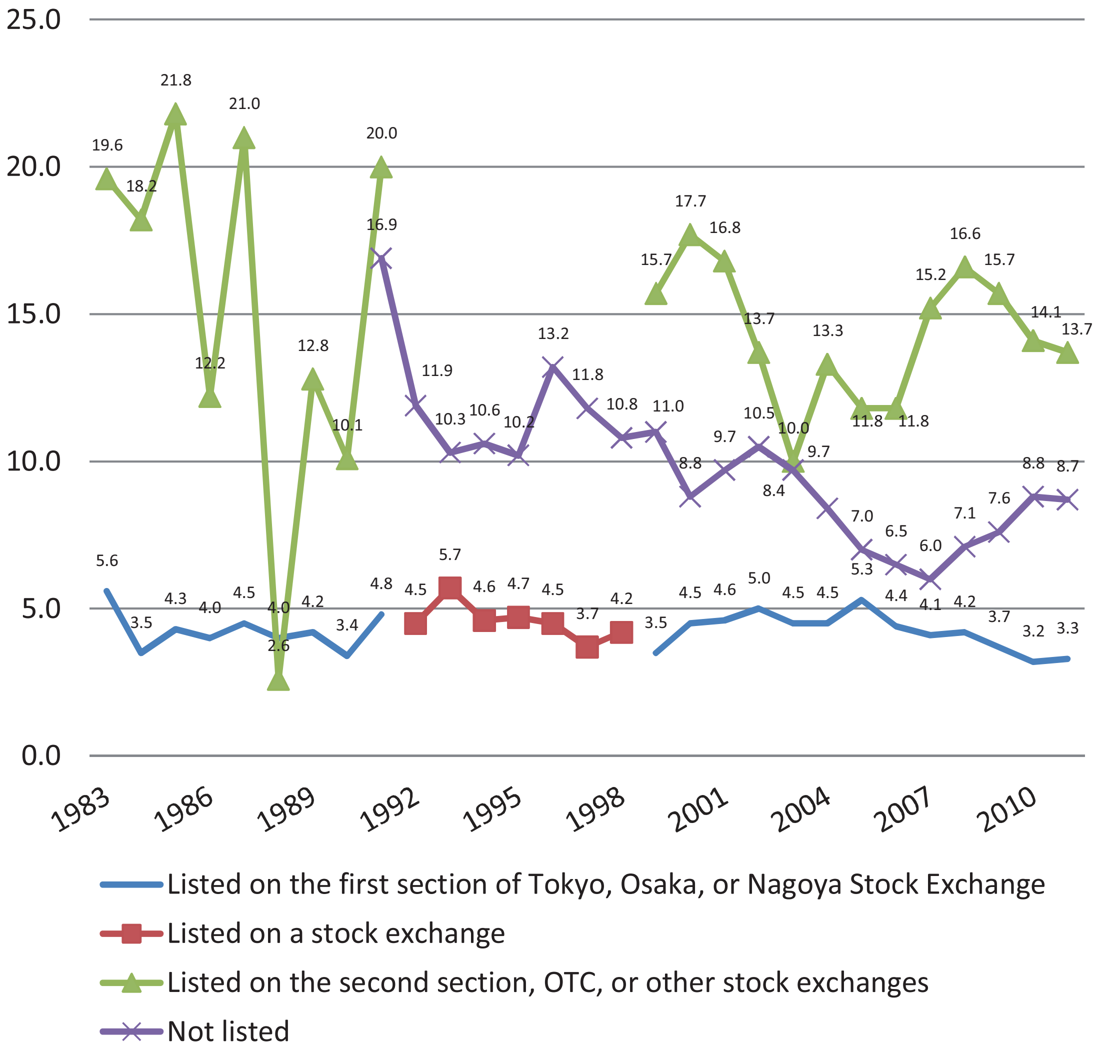
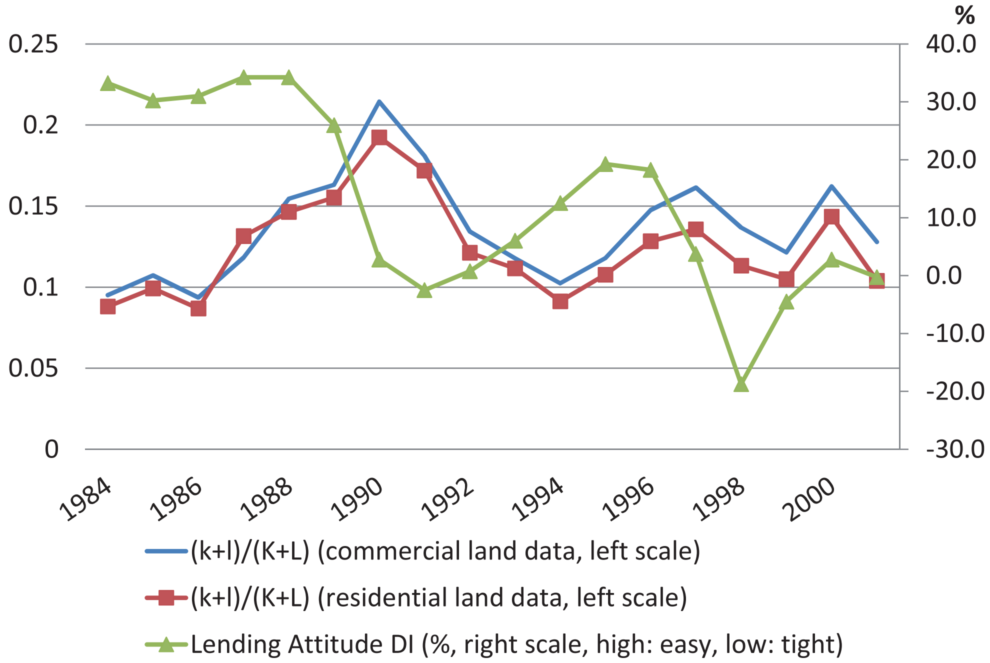
Figure 1: Percentage ratio of the idle land (square meters) over the total land holding (square meters), excluding those for resale purpose



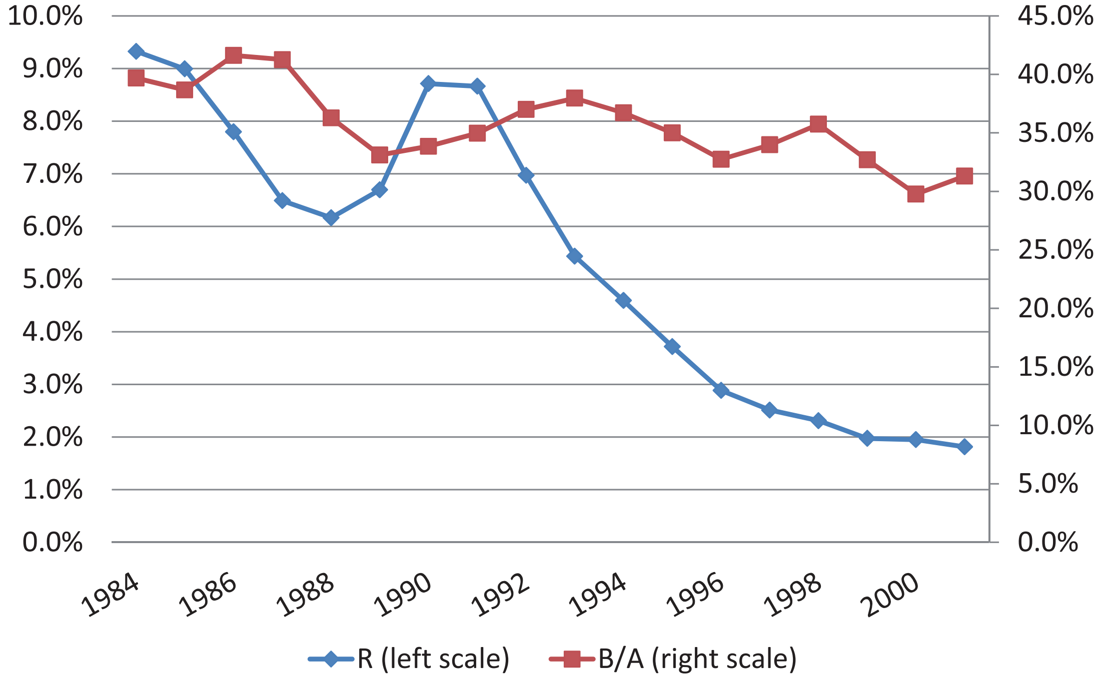
Source: *Kigyo No Tochi Shutoku Jokyo Tou Ni Kansuru Chosa* (the survey on corporate land holdings), Japanese Ministry of Land, Infrastructure, Transport and Tourism.

Figure 2: Investment ratio $\frac{k_{it}+l_{it}}{K_{it-1}+L_{it-1}}$ (sample mean) and the lending attitude of financial institutions



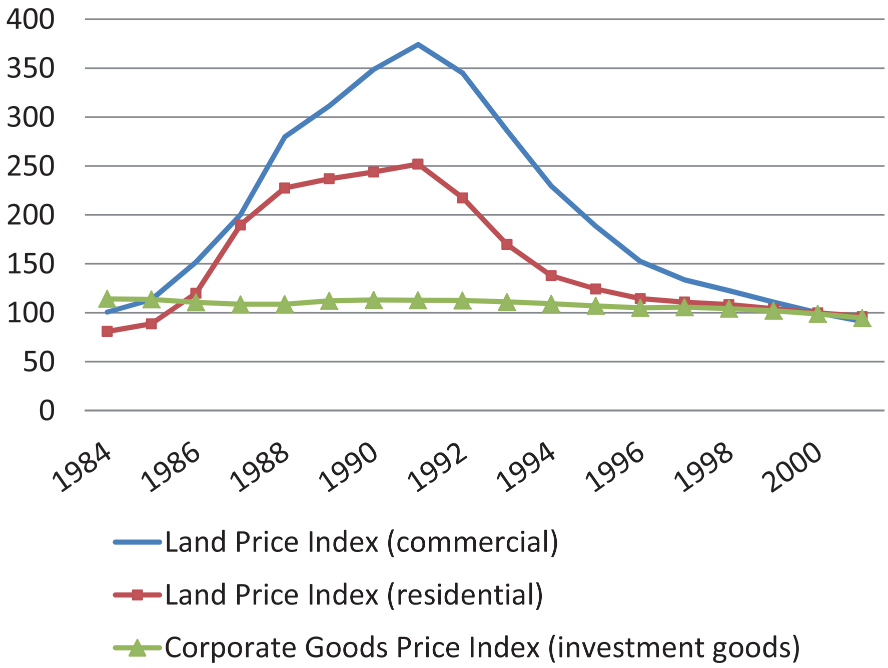
(Note) The investment ratios (commercial-land data and residential-land data) are the sample means from our dataset. A detail definition is presented in the Appendix. Lending Attitude DI is from the diffusion index of the lending attitude of financial institutions (all enterprises) in *TANKAN*, Short-Term Economic Survey of Enterprises in Japan (quarterly), conducted by the Bank of Japan. The diffusion index is the difference, (% ratio of firms replying "accommodative") − (% ratio of firms replying "severe"). The average of the June, September, and December surveys in the current calendar year, and the March survey in the next calendar year is assigned for each observation in the current year.

Figure 3: Loan interest rate R_{it} and leverage B_{it}/A_{it}



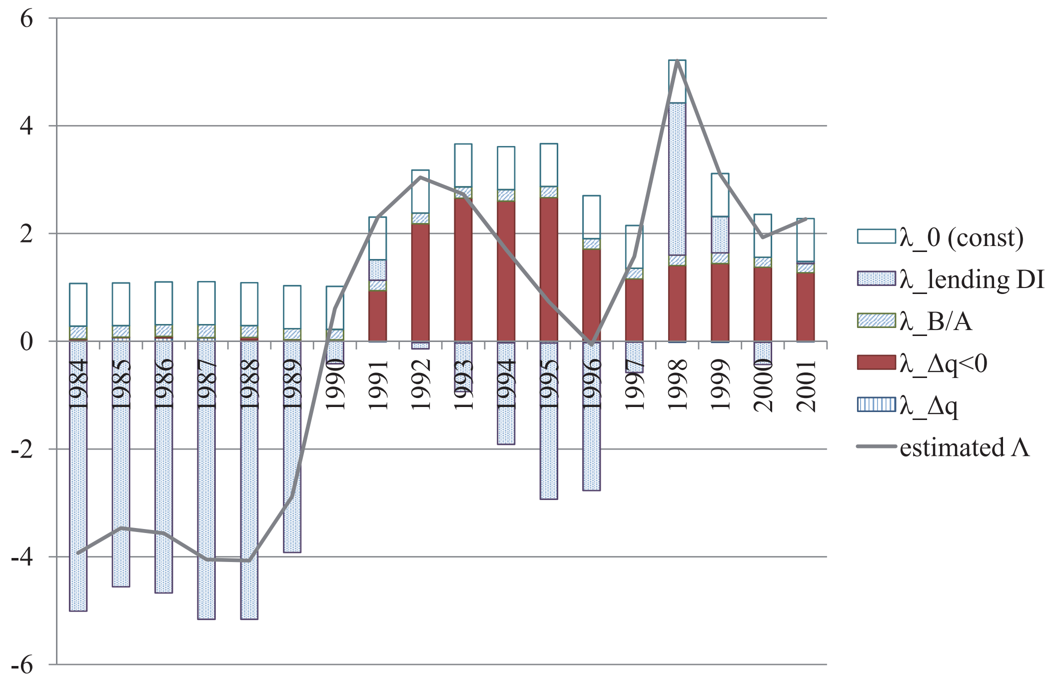
(Note) Each variable is the sample mean in each year in our dataset.

Figure 4: Land price and capital price indexes



(Note) All values are from Table 4. See the note for Table 4.

Figure 5: Estimated contribution of each factor to Λ



(Note) A contribution (est.coef. $\times$ covariate) by each coefficient in Eq. (56) to the estimated Λ is plotted by using the estimates in Column (i) of Table 7. The estimated Λ is the sum of these contributions.

Table 1: Number of observations for each year

(Note) The number of observations in each year is the number of sample firms whose financial information for the accounting period ending in the period from April in each year to March in the next calendar year is reported. The starting month of a fiscal year of the government and most companies in Japan is April.

	A. Commercial land data	B. Residential-land data	C. SME manufacturers in the original data	A/C (%)
1984	614	626	9,461	6.5
1985	663	678	10,168	6.5
1986	700	710	11,016	6.4
1987	766	791	10,970	7.0
1988	817	833	11,213	7.3
1989	876	901	11,767	7.4
1990	937	955	11,934	7.9
1991	1,057	1,083	11,739	9.0
1992	1,202	1,233	11,804	10.2
1993	1,301	1,336	11,774	11.0
1994	1,360	1,396	11,603	11.7
1995	1,216	1,292	11,742	10.4
1996	1,212	1,242	11,675	10.4
1997	1,197	1,224	11,576	10.3
1998	1,230	1,246	11,231	11.0
1999	1,203	1,230	10,929	11.0
2000	1,265	1,299	10,586	11.9
2001	1,274	1,305	10,255	12.4
Total	18,890	19,380	201,443	9.4

Table 2: Number of observations for each industrial class

Industry class	A. Commercial-land data	B. Residential-land data
Food	2,142	2,259
Textile	485	494
Apparel	161	158
Timber products	145	146
Pulp/paper	333	337
Printing	480	487
Chemical	3,698	3,715
Petroleum/coal products	305	304
Ceramic	1,002	1,001
Steel	723	749
Non-ferrous metal	844	881
Metal products	1,230	1,249
Machinery	1,552	1,623
Electronic appliances	2,460	2,549
Transport. equipment	825	859
Precision machine	494	498
Shipbuilding	177	178
Other manufacturers	1,834	1,893
Total	18,890	19,380

Table 3: Descriptive statistics

(a) Commercial-land data

	N	mean	sd	min	p10	med	p90	max
stated capital$_{it}$	18,890	1159.475	1410.869	2	300	600	2,556	16,662
# employees$_{it}$	18,890	252.870	233.900	1	52	195	522	1,997
$D\_land\_value_{it}$	18,502	-0.008	0.106	-0.510	-0.086	-0.002	0.043	0.740
$cash\_flow_{it}/K_{it-1}$	18,502	0.590	8.955	-743.982	0.047	0.360	1.078	865.909
$leverage_{it}$	18,502	0.352	0.366	0.000	0.000	0.315	0.678	21.365
int_cover_{it}	18,502	0.217	4.823	-128.377	0.000	0.118	0.617	433.548
operating cash flow	18,502	836.874	1359.020	-8,484	34	524	1,934	80,549
free cash flow	18,502	338.132	1322.072	-25,175	-347	231	1,238	75,102
τ_{it}	18,890	0.397	0.206	0.000	0.000	0.501	0.553	0.571
R_{it}	18,890	0.049	0.036	0.000	0.014	0.042	0.096	0.200
s_{it}	18,890	1.073	0.054	0.947	0.988	1.088	1.130	1.141
q_{it}	18,890	2.022	1.350	0.193	0.949	1.489	4.016	11.645
p_{it}	18,890	1.044	0.124	0.742	0.969	1.013	1.150	1.826
$p_{it+1}Y_{it+1}$	18,890	11432.550	11203.460	18	2,237	8,164	24,356	118,809
$w_{it+1}N_{it+1}$	18,890	9982.143	10029.580	31	1,920	7,074	21,364	97,580
B_t/A_t	18,890	0.353	0.340	0.000	0.002	0.322	0.677	20.130
$K_{it}+L_{it}$	18,890	4658.159	5116.378	0.880	622.244	3091.375	10430.460	51125.020
Y_{it}/K_{it-1}	18,890	16.020	214.835	0.035	1.837	5.202	16.669	23912.980
Y_{it}/L_{it-1}	18,890	1161.044	4888.689	0.052	1.347	7.400	2591.115	113248.500
$\frac{k_{it}+l_{it}}{K_{it-1}+L_{it-1}}$	18,890	0.138	0.239	-0.613	0.002	0.068	0.360	2.857
δ_{it+1}	18,890	0.168	0.079	0.000	0.087	0.156	0.260	0.643

(b) Residential-land data

	N	mean	sd	min	p10	p50	p90	max
stated capital$_{it}$	19,380	1156.441	1402.510	2	300	600	2,523	16,662
# employees$_{it}$	19,380	251.832	231.736	1	53	195	519	1,997
$D\_land\_value_{it}$	18,982	-0.005	0.072	-0.416	-0.047	-0.001	0.021	0.562
$cash\_flow_{it}/K_{it-1}$	18,982	0.628	7.010	-65.129	0.049	0.358	1.073	865.909
$leverage_{it}$	18,982	0.353	0.364	0.000	0.000	0.317	0.680	21.365
int_cover_{it}	18,982	0.237	4.898	-128.377	0.000	0.119	0.617	433.548
operating cash flow	18,982	831.089	1358.323	-8,484	34	520	1,917	80,549
free cash flow	18,982	336.417	1311.860	-25,175	-342	231	1,232	75,102
τ_{it}	19,380	0.396	0.206	0.000	0.000	0.501	0.553	0.571
R_{it}	19,380	0.049	0.036	0.000	0.014	0.042	0.096	0.200
s_{it}	19,380	1.073	0.054	0.947	0.988	1.088	1.130	1.141
q_{it}	19,380	1.496	1.151	0.419	0.847	1.097	2.453	6.733
p_{it}	19,380	1.045	0.125	0.742	0.969	1.013	1.150	1.826
$p_{it+1}Y_{it+1}$	19,380	11377.710	11136.520	18	2,261	8,121	24,220	118,809
$w_{it+1}N_{it+1}$	19,380	9943.347	9987.276	31	1,948	7,052	21,273	98,121
B_t/A_t	19,380	0.354	0.338	0.000	0.003	0.324	0.678	20.130
$K_{it}+L_{it}$	19,380	5444.550	5933.372	1	688	3,611	12,513	61,380
Y_{it}/K_{it-1}	19,380	15.400	207.128	0.035	1.849	5.215	16.624	23912.980
Y_{it}/L_{it-1}	19,380	1136.345	4826.555	0.024	1.027	5.039	2498.351	113248.500
$\frac{k_{it}+l_{it}}{K_{it-1}+L_{it-1}}$	19,380	0.124	0.233	-0.517	0.001	0.058	0.328	3.469
δ_{it+1}	19,380	0.168	0.078	0.000	0.088	0.156	0.259	0.643

Table 4: Land price and capital price indexes (base year 2000 = 100)

(Note) Land-price index is the sample average of the highest commercial-district land price and the average residential-district land price in each municipality as of January 1st in each year as reported by the Land Market Value Publication (Japanese Ministry of Land, Infrastructure, Transport and Tourism). The values are normalized so that the sample average in 2000 equals 100. Corporate Goods Price Index is the average from April to March in the next year of the monthly index published by the Bank of Japan. The value is normalized so that the average from April 2000 to March 2001 equals 100.

	Land Market Value Publication		Corporate Goods Price Index
	Commercial district	Residential district	Investment goods
Year	(sample mean)	(sample mean)	
1984	100.6	80.9	114.1
1985	113.5	88.7	113.6
1986	151.7	120.0	110.7
1987	200.0	189.8	108.7
1988	279.9	227.5	108.8
1989	311.4	236.9	112.3
1990	348.7	243.9	113.0
1991	374.1	251.9	112.7
1992	345.0	217.5	112.5
1993	286.1	169.8	111.1
1994	229.6	137.9	109.2
1995	188.5	124.3	107.0
1996	152.5	114.6	105.1
1997	133.6	110.8	105.7
1998	122.6	108.4	104.2
1999	110.8	104.2	102.0
2000	100.0	100.0	98.8
2001	91.2	96.2	94.7

Table 5: Preliminary analysis: Cross-section regression

(Note) The dependent variable is the investment rate $(k_{it} + l_{it})/(K_{it-1} + L_{it-1})$. The model is estimated by the cross-sectional OLS in each year with industry dummies (food, textile, apparel, timber products, pulp/paper, printing, chemical, petroleum/coal products, ceramic, steel, non-ferrous metal, metal products, machinery, electronic appliances, transportation equipment, precision machine, shipbuilding, and other manufacturers; food is the base class) and regional dummies (Hokkaido, Tohoku, Kanto, Koshinetsu, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa; Hokkaido is the base class). Panel (a) shows the result from the commercial-land data and Panel (b) shows that from the residential-land data. Each row reports the estimated coefficient and the White robust standard error of D_land_value and related statistics. The set of control variables is the same as that in Table 6 excluding year dummies. The estimated coefficients of them and the constant term are omitted from the report. ***, **, and * indicate the statistical significance at a 1%, 5%, and 10% level, respectively.

(a) Commercial-land data

	Coef. of D_land_value	Robust S.E.	P-value		N	R-sq
1984	-0.032	0.056	0.562		611	0.154
1985	-0.120	0.050	0.016	**	630	0.206
1986	-0.093	0.036	0.009	***	667	0.178
1987	-0.101	0.044	0.021	**	707	0.197
1988	-0.190	0.077	0.014	**	800	0.163
1989	-0.126	0.066	0.058	*	848	0.129
1990	-0.217	0.073	0.003	***	924	0.115
1991	0.224	0.071	0.002	***	1,041	0.110
1992	0.135	0.055	0.014	**	1,148	0.072
1993	0.170	0.053	0.001	***	1,255	0.133
1994	0.096	0.044	0.030	**	1,323	0.083
1995	0.212	0.074	0.004	***	1,194	0.136
1996	0.506	0.138	0.000	***	1,203	0.080
1997	0.314	0.121	0.010	**	1,190	0.100
1998	0.420	0.125	0.001	***	1,226	0.086
1999	0.231	0.113	0.041	**	1,202	0.071
2000	0.265	0.175	0.131		1,263	0.089
2001	0.024	0.077	0.756		1,270	0.067

(b) Residential-land data

	Coef. of D_land_value	Robust S.E.	P-value		N	R-sq
1984	-0.075	0.078	0.337		624	0.155
1985	-0.146	0.058	0.012	**	648	0.203
1986	-0.072	0.084	0.394		636	0.203
1987	-0.172	0.077	0.027	**	750	0.132
1988	-0.017	0.075	0.819		823	0.151
1989	-0.050	0.083	0.545		871	0.135
1990	-0.161	0.097	0.095	*	945	0.134
1991	0.228	0.065	0.000	***	1,025	0.126
1992	0.267	0.068	0.000	***	1,167	0.079
1993	0.161	0.058	0.006	***	1,293	0.127
1994	0.059	0.099	0.552		1,384	0.092
1995	0.092	0.154	0.550		1,281	0.137
1996	0.111	0.131	0.400		1,239	0.110
1997	0.632	0.323	0.051	*	1,221	0.103
1998	0.815	0.246	0.001	***	1,244	0.115
1999	0.475	0.239	0.047	**	1,230	0.089
2000	0.847	0.318	0.008	***	1,298	0.102
2001	0.521	0.158	0.001	***	1,303	0.081

Table 6: Preliminary analysis: Fixed-effect regression

(Note) The dependent variable is the investment rate $(k_{it} + l_{it})/(K_{it-1} + L_{it-1})$. The coefficients are estimated by the firm-level fixed-effect model. Panel (a) shows the result from the commercial-land data, and Panel (b) shows that from the residential-land data. The first column lists the estimated coefficients and the firm-cluster robust standard errors from the dataset for the period from 1984 to 1991. The second column gives those from the dataset for the period from 1992 to 2001. The estimated coefficients of the year dummy variables and the constant term are omitted from the report. ***, **, and * indicate the statistical significance at a 1%, 5%, and 10% level, respectively.

(a) Commercial-land data

	(1) 1984-1991 Est. coef. (Robust S.E.)		(2) 1992-2001 Est. coef. (Robust S.E.)	
D_land_value	0.018		0.169	***
	(0.024)		(0.035)	
Y_{it-1}/L_{it-2}	8.7.E-06		7.6.E-06	**
	(7.3.E-06)		(3.0.E-06)	
Y_{it-1}/K_{it-2}	-4.4.E-06		1.6.E-04	**
	(1.1.E-04)		(6.4.E-05)	
R_{it}	0.913	***	0.819	***
	(0.166)		(0.199)	
$cash\_flow_{it}/K_{it-1}$	0.000		0.002	***
	(0.004)		(0.000)	
$K_{it-1} + L_{it-1}$	-3.4.E-05	***	-3.2.E-05	***
	(4.6.E-06)		(2.9.E-06)	
$leverage_{it}$	-0.043		-0.045	
	(0.026)		(0.034)	
int_cover_{it}	0.001		1.8.E-04	
	(0.001)		(1.7.E-04)	
year dummy	yes		yes	
firm fixed effect	yes		yes	
R-sq: within	0.072		0.079	
between	0.086		0.030	
overall	0.071		0.029	
#firms	1,768		2,613	
N	6,228		12,274	

(b) Residential-land data

	(1) 1984-1991 Est. coef. (Robust S.E.)		(2) 1992-2001 Est. coef. (Robust S.E.)	
D_land_value	0.024		0.126	**
	(0.025)		(0.051)	
Y_{it-1}/L_{it-2}	6.1.E-06		7.2.E-06	**
	(7.0.E-06)		(2.9.E-06)	
Y_{it-1}/K_{it-2}	-2.1.E-05		-5.3.E-05	
	(7.9.E-05)		(1.3.E-04)	
R_{it}	0.905	***	0.745	***
	(0.174)		(0.177)	
$cash\_flow_{it}/K_{it-1}$	0.000		0.008	*
	(0.003)		(0.004)	
$K_{it-1} + L_{it-1}$	-3.8.E-05	***	-2.6.E-05	***
	(4.9.E-06)		(2.4.E-06)	
$leverage_{it}$	-0.046	*	-0.033	
	(0.026)		(0.034)	
int_cover_{it}	0.001		1.4.E-04	
	(0.001)		(2.0.E-04)	
year dummy	yes		yes	
firm fixed effect	yes		yes	
R-sq: within	0.073		0.079	
between	0.085		0.043	
overall	0.066		0.038	
#firms	1,806		2,684	
N	6,322		12,660	

Table 7: Structural estimation

(Note) The estimated coefficients of the maximum likelihood estimation of Eq. (45) under the assumption that the error term is identically and independently distributed according to $N(0, \sigma^2)$ are reported. The S.E.s are the firm-cluster standard errors. Column (i) is the result from the commercial-land data and column (ii) is that from the residential-land data. The estimated coefficients of the year dummy variables, sector dummy variables (sectors are those listed in Table 2), regional dummy variables (Hokkaido, Tohoku, Kanto, Koshinetsu, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa; Hokkaido is the base class) and the constant term are omitted from the report. ***, **, and * indicate the statistical significance at a 1%, 5%, and 10% level, respectively.

	(i) Commercial-land data			(ii) Residential-land data		
	Coef.	S.E.		Coef.	S.E.	
Λ_0	3.32.E-17	2.94.E-15		2.25.E-22	3.36.E-18	
Λ_1	4.746	1.159	***	4.472	0.579	***
η	0.613	0.047	***	0.551	0.044	***
α_0	0.050	0.040		0.058	0.037	
α_1	0.047	0.144		2.70.E-15	2.40.E-13	
σ	13558.710	795.129	***	13027.230	716.258	***
sector dummy	yes			yes		
year dummy	yes			yes		
region dummy	yes			yes		
N	18,890			19,380		
#firms	3,051			3,121		
log pseudo-likelihood	-206538.0			-211120.6		

Table 8: Structural estimation (difference model)

(Note) The estimated coefficients of the maximum likelihood estimation of the first-order difference of Eq. (45) under the assumption that the error term is identically and independently distributed according to $N(0, \sigma^2)$ are reported. The S.E.s are the firm-cluster standard errors. Column (i) is the result from the commercial-land data and column (ii) is that from the residential-land data. The estimated coefficients of the year dummy variables, and the constant term are omitted from the report. ***, **, and * indicate the statistical significance at a 1%, 5%, and 10% level, respectively.

	(i) Commercial-land data			(ii) Residential-land data		
	Coef.	S.E.		Coef.	S.E.	
Λ_0	0.055	0.047		0.047	0.065	
Λ_1	0.219	0.126	*	0.287	0.086	***
η	0.919	0.015	***	0.908	0.015	***
α_0	0.218	0.051	***	0.200	0.040	***
α_1	1.990	0.341	***	1.619	0.178	***
σ	4150.877	277.365	***	3969.092	284.744	***
year dummy	yes			yes		
N	13,774			14,141		
#firms	2,366			2,422		
log pseudo-likelihood	-134296.7			-137241.7		

Table 9: Time-varying Λ

(Note) The estimated coefficients of the maximum likelihood estimation of Eq. (45) with the time-varying Λ specified in Eq. (56) under the assumption that the error term is identically and independently distributed according to $N(0, \sigma^2)$ are reported. The S.E.s are the firm-cluster standard errors. Column (i) is the result from the commercial-land data and column (ii) is that from the residential-land data. The estimated coefficients of the year dummy variables, sector dummy variables (sectors are those listed in Table 2), regional dummy variables (Hokkaido, Tohoku, Kanto, Koshinetsu, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu, and Okinawa; Hokkaido is the base class) and the constant term are omitted from the report. ***, **, and * indicate the statistical significance at a 1%, 5%, and 10% level, respectively.

	(i) Commercial-land data			(ii) Residential-land data		
	Coef.	S.E.		Coef.	S.E.	
λ_0	0.796	0.817		3.324	1.428	**
$\lambda_{\Delta q}$	0.002	0.001		0.005	0.003	
$\lambda_{\Delta q<0}$	-0.155	0.036	***	-0.048	0.041	
$\lambda_{B/A}$	0.573	0.986		-0.517	0.496	
λ_{DI}	-0.151	0.029	***	-0.201	0.046	***
η	0.606	0.040	***	0.557	0.025	***
α_0	0.015	0.036		0.069	0.034	**
α_1	0.975	0.398	**	0.112	0.371	
σ	12587.530	691.882	***	12280.480	357.045	***
sector dummy	yes			yes		
year dummy	yes			yes		
region dummy	yes			yes		
N	18,890			19,380		
#firms	3,051			3,121		
log pseudo-likelihood	-204629.2			-209757.5		

Table 10: Ratio of constrained firms

(Note) The number and ratio of sample firms in each category are listed. A firm is classified as "binding" if the estimated Λ in Column (i), Table 7 is positive and statistically significant at a 1 % level and as "not binding" otherwise. A firm is classified as holding "insufficient land" if the estimate of $q_{it+1} - q_{it} - (1-\tau_t)\frac{\partial\phi}{\partial l_{it}}$ is negative and as holding "excessive land" otherwise.

	(i) Collateral constraint is binding				(ii) Not biding		Total
Year	(a) insufficient land		(b) excessive land				
	#obs	(%)	#obs	(%)	#obs	(%)	
1984	0	(0.0)	0	(0.0)	614	(100.0)	614
1985	0	(0.0)	0	(0.0)	663	(100.0)	663
1986	0	(0.0)	0	(0.0)	700	(100.0)	700
1987	0	(0.0)	0	(0.0)	766	(100.0)	766
1988	0	(0.0)	0	(0.0)	817	(100.0)	817
1989	0	(0.0)	0	(0.0)	876	(100.0)	876
1990	0	(0.0)	1	(0.1)	936	(99.9)	937
1991	507	(48.0)	21	(2.0)	529	(50.0)	1,057
1992	776	(64.6)	44	(3.7)	382	(31.8)	1,202
1993	897	(68.9)	25	(1.9)	379	(29.1)	1,301
1994	745	(54.8)	32	(2.4)	583	(42.9)	1,360
1995	18	(1.5)	0	(0.0)	1198	(98.5)	1,216
1996	9	(0.7)	0	(0.0)	1203	(99.3)	1,212
1997	536	(44.8)	45	(3.8)	616	(51.5)	1,197
1998	1,140	(92.7)	84	(6.8)	6	(0.5)	1,230
1999	845	(70.2)	46	(3.8)	312	(25.9)	1,203
2000	730	(57.7)	20	(1.6)	515	(40.7)	1,265
2001	740	(58.1)	31	(2.4)	503	(39.5)	1,274
Total	6,943	(36.8)	349	(1.8)	11,598	(61.4)	18,890