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Reconsidering Business Cycles of Credit Constraints*

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Abstract

This paper reconsiders the amplification and propagation mechanism of the credit-constrained economy by highlighting the elasticity of substitution between capital and an asset used for collateral. We develop a generalized version of the Kiyotaki and Moore (1997, hereafter KM) model in which capital and land are combined in production with a constant elasticity of substitution (CES). The substitutability/complementarity between capital and land plays a crucial role in amplifying quantitative effects of the TFP shock. When the elasticity of substitution is unity as in the Cobb-Douglas production function, the amplification is small. On the other hand, when it is small and sufficiently less than unity, credit constraints amplify movements of real variables. The adjustment cost of investment, combined with the small elasticity of substitution, strengthens the amplification effect and yields an interesting propagation mechanism among the holding of land by debtors and investment.

JEL classification number: E32, E44, E23

Keywords: Collateral constraints, Business cycles, Elasticity of substitution, Adjustment cost

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1. Introduction

Ever since Fischer (1933), Kindleberger (1978), and Minsky (1986), huge literature on "credit channel" and "financial accelerator" has addressed the significant role of the credit channel in the boom and bust of the aggregate economy. Recently, an increasing literature has applied credit-constrained models developed by Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Carlstrom and Fuerst (1997), and Bernanke, Gertler and Gilchrist (1999) to the quantitative analysis to explain the observed movements of real variables.

Many researchers have attempted to identify the technology shock as the driving force of business fluctuations involving credit expansion and contraction, but the existing literature can only partially explain the observed movements (see, for example, Christiano, Motto and Rostagno, 2009). Kocherlakota (2000) and Cordoba and Ripoll (2004) added the asset price channel to the credit-constrained models, but the results are even unsatisfactory.

One direction of research seems to have taken a turn for identifying shocks that are the driving force of credit expansion/contraction. Christiano, Eichenbaum and Evans (2005), Iacoviello (2005), and Christensen and Dib (2008) introduce the monetary shock, and Christiano, Motto and Rostagno (2009), Jermann and Quardini (2009), and others do the financial shock to improve the explanation power for the observed variation in real and financial variables.

Another direction of research is to reconsider the model that explains large amplification through the channel of borrowers' balance sheet(1). The question is whether the existing credit-constrained models could exploit the transmission mechanism of the interaction between technology and finance. The behavior of financially-constrained firms that we observe in the credit boom and bust will be complicated than is supposed. For example, when facing the appreciation of the asset used as collateral, firms will have a strong motive of "precautionary saving", that is, of purchasing the collateralizable asset against the future borrowing limit as well as purchasing investment goods within the current borrowing limit. The existing models focus on the balance sheet channel through the asset price change, but are fairly indifferent to the effect through the change in the distribution of the collateralizable asset between creditors and debtors.

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(1) One direction of modeling is represented by Gertler and Kiyotaki (2011) that incorporate financial intermediation into the model of financial fractions, where financial intermediaries face the borrowing constraints as well as non-financial borrowers.

The aim of this paper is to reconsider the transmission mechanism of the credit-constrained economy by highlighting the interaction between finance and technology captured by the elasticity of substitution between capital and an asset used for collateral. In particular, we develop the generalized version of the Kiyotaki and Moore (1997, hereafter KM) model in which capital and land are combined in production with the constant elasticity of substitution (CES).

The substitutability/complementarity between capital and land plays a crucial role in amplifying quantitative effects of the TFP shock. The Cobb-Douglas technology broadly used in the literature implicitly assumes that entrepreneurs find it easy to substitute capital by other inputs. Indeed, it is doubtful whether they replace land by capital as quickly as they do labor by capital. Capital and land are more complementary in production than capital and labor at least in the short run. The estimation in the Japanese data reports that the elasticity of substitution is significantly less than unity, supporting the use of the CES-type function with the small elasticity (see Sakuragawa, 2012).

We focus on three aspects that interact with the elasticity of substitution in magnifying movements of real variables. The first is the holding of land by credit-constrained entrepreneurs, which is determined by the allocation between them and credit-unconstrained households. When credit-constrained entrepreneurs face the asset price boom, whether they buy land to increase the future debt capacity or sell land and buy cheaper capital depends on the elasticity of substitution between capital and land.

The second is the adjustment cost of investment. When entrepreneurs find it difficult to invest in capital quickly, they have the motive of buying more land in earlier periods to enhance the future debt capacity. This precautionary saving of the collateralizable asset increases the net worth over time and magnifies movements of real variables.

The third is the adjustment cost of trading land. It will capture the impacts of the liquidity/illiquidity of the collateralizable asset. Further, the experiment will answer a question if the adjustment cost and substitutability/complementarity in production have similar or different implications on the quantitative analysis.

This paper is related to a number of other works that investigates the quantitative analysis of the KM model. Kocherlakota (2000), Arias (2003), Cordoba and Ripoll (2004), and Liu, Wang and Zha (2010) use the standard production technology including the Cobb-Douglas form, reporting small effects of the technology shock(2). On the other hand, Iacoviello (2005) reports significant effects of the monetary and housing preference shocks, and Liu, Wang and Zha (2010) report significant effects of the collateral and housing preference shocks.

This paper is related also to the literature that casts doubt on the use of the Cobb-Douglas technology. Choi and Rios-Rull (2008) study business cycles by focusing on the observed changeable labor share. Antras (2004) reports that, allowing for biased technological change, the elasticity of substitution is significantly less than unity in the US aggregate production function.

This paper is related to the literature that attempts to explain the instability of the credit-constrained economy. Mendoza (2010) identifies financial crashes followed by severe recessions of emerging countries by using a nonlinear global approach that deals with both binding and non-binding credit constraints. Kocherlakota (2010) develops models of land overvaluation by introducing regulations and/or bubbles.

This paper is organized as follows. In Section 2 we set up the basic model. In Section 3 we evaluate the quantitative effects of the developed model. Section 4 concludes.

2. Model

We consider an economy with one final good, labor, and land. There are two types of continuum of infinitely-lived *patient* households and *impatient* entrepreneurs. The term "patient/impatient" captures the assumption that impatient agents have a higher subjective discount rate than patient ones.

Households consume, work, and demand land for residential use. Entrepreneurs produce the final good by hiring labor, physical capital, and land. Measures of households and entrepreneurs are both unity. All markets are perfectly competitive.

A. Households

Households maximize a lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [\log c_t' + \phi \log h_t' - \frac{B}{\varpi} (N_t')^{\varpi}] \tag{1}$$

where E_0 is the expectation operator, $\beta \in (0, 1)$ is the discount factor, c_t' is consumption, h_t' denotes the holding of housing, N_t' is the amount of labor supply, and ϕ, ϖ, and B are positive

(2) Kocherlakota (2000) uses Cobb-Douglas production function that use capital and land, and reports that the quantitative significance of the amplification is negligible when shares of capital and land sum to less than 40 percent effect, as is approximately true in the U.S. and Japan.

constants. Households lend $-b'_t$ (or borrow b'_t) and receive back $-R_{t-1}b'_{t-1}$, where R_{t-1} is the real interest rate on lending between $t-1$ and t. Letting q_1 denote the land price, and w_t the wage rate, the flow of funds is

(2) $$c'_t + q_t(h'_t - h'_{t-1}) = w_t N'_t - R_{t-1}b'_{t-1} + b'_t.$$

Optimum conditions for consumption, housing, and labor are

(3) $$\frac{1}{c'_t} = \beta E_t \frac{R_t}{c'_{t+1}},$$

(4) $$\frac{q_t}{c'_t} = \frac{\phi}{h'_t} + \beta E_t \frac{q_{t+1}}{c'_{t+1}}, \text{ and}$$

(5) $$\frac{w_t}{c'_t} = B(N'_t)^{\varpi-1}.$$

B. Entrepreneurs

Entrepreneurs produce the final good Y_t by employing labor N_t, capital K_{t-1}, and land L_{t-1}. Labor and the "composite capital" are combined with the Cobb-Douglas form, where the composite capital consists of capital and land, which are combined with the constant elasticity of substitution (CES). The constant elasticity of substitution between capital and land is motivated to capture the situation where entrepreneurs will react to the short-run shock by changing the capital/land ratio less quickly over the business cycle. We consider the following quasi-CES type technology;

(6) $$Y_t = A_t N_t^{1-\alpha}[\gamma K_{t-1}^{\frac{\sigma-1}{\sigma}} + (1-\gamma)L_{t-1}^{\frac{\sigma-1}{\sigma}}]^{\alpha\frac{\sigma}{\sigma-1}},$$

where A_t is the total factor productivity (TFP), σ is the elasticity of substitution between capital and land, and γ is the weight attached to capital and $1-\gamma$ is the weight attached to land. A larger σ implies greater substitutability. The case for $\sigma = 1$ corresponds to the Cobb-Douglas function, given by $Y_t = A_t N_t^{1-\alpha} K_{t-1}^{\gamma\alpha} L_{t-1}^{(1-\gamma)\alpha}$. Then $\gamma\alpha$ is the output share of capital and $(1-\gamma)\alpha$ is the output share of land. The case for $\sigma = 0$ corresponds to the Leontief technology in which capital and land are completely complementary(3).

Capital evolves as $K_t = (1-\delta)K_{t-1} + I_t$ $K_t = (1-\delta)K_{t-1} + I_t$, where I_t is investment. Following

(3) KM uses the Leontief-type technology that uses capital and land in the same proportion.

Cristiano, Eichenbaum and Evans (2005), the process of transforming investment in equipment into capital ready for production involves installation and adjustment costs, which increases in the rate of investment growth, $S_K(I_t, I_{t-1}) = \frac{\xi_K}{2}(\frac{I_t}{I_{t-1}} - 1)^2 I_t$. This form of function is used to derive the hump-shaped response of investment, which is empirically relevant. Following Iacoviello (2005), the trade of land may also involve the adjustment cost, $S_L(L_t, q_1, L_{t-1}) = \frac{\xi_L}{2}(\frac{L_t - L_{t-1}}{L_{t-1}})^2 q_t L_{t-1}$, due to the market thinness of the land market, regulations, and/or tax distortion. As studied later, the adjustment cost of trading land measures the liquidity/illiquidity of the collateralizable asset.

We assume that there is no enforcement mechanism to fulfill financial contracts between debtors and creditors. In this society, lenders cannot enforce on borrowers to repay their debt unless the debts are secured. In order to secure their debt, creditors can only collect land that the debtor holds(4). Anticipating the possibility of the borrower's strategic default, the creditor limits the amount of credit so that the value of debt will not exceed the value of land that the borrower holds. Creditors cannot seize capital of their debtors(5).

The borrowing constraint that the entrepreneur faces is then typically expressed as

$$(7) \qquad b_t \leq mE_t(q_{t+1}L_t / R_t),$$

where $m \leq 1$ is the parameter of the borrowing limit, which is motivated by the notion that some fraction of the value of land is dissipated in the process of bankruptcy procedure(6).

Let the discount factor of entrepreneurs be $\theta\beta$, with $\theta < 1$ so that entrepreneurs are less patient than households. Entrepreneurs maximize $E_0 \sum (\theta\beta)^t \ln c_t^E$, subject to the technology (6), the borrowing constraint (7), and the following flow of funds;

$$(8) \qquad c_t^E + I_t + S_K(I_t, I_{t-1}) + q_t(L_t - L_{t-1}) + S_L(L_t, q_t, L_{t-1}) = Y_t + b_t - R_{t-1}b_{t-1} - w_t N_t.$$

Define η_t as the time t shadow value of the borrowing constraint. The first-order conditions for an optimum are the Euler equation for consumption, the demand functions for labor, land, and capital:

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(4) Real estate, such as housing, building, and land, is an asset that has a high liquidation value because it has many potential buyers across industries (e.g., Shleifer and Vishny, 1992). "Asset liquidity creates debt capacity because liquid assets are in effect better collateral (Shleifer and Vishny, 1992, p.1358)".

(5) Almost capital goods do not have well organized secondary markets, and sell for a high discount relative to replacement costs. Ramey and Shapiro (2001) report significant sectoral specificity of physical capital in moving them into new use using equipment-level data in the aerospace industry.

(6) The bank monitoring may be compatible with the borrowing constraint. Ogawa (2003) reports the evidence of the complementary role of collateral with bank monitoring.

(9) $$\frac{1}{c_t^E} = \theta\beta E_t \frac{R_t}{c_{t+1}^E} + \eta_t,$$

(10) $$w_t = (1-\alpha)\frac{Y_t}{N_t},$$

(11) $$\frac{1}{c_t^E}[q_t + \frac{\partial S_{L,t}}{\partial L_t}] = m\eta_t E_t[\frac{q_{t+1}}{R_{t-1}}] + \theta\beta E_t \frac{1}{c_{t+1}^E}[\frac{\partial Y_{t+1}}{\partial L_t} + q_{t+1} - \frac{\partial S_{L,t+1}}{\partial L_t}], \text{ and}$$

(12) $$\frac{1}{c_t^E}(1 + \frac{\partial S_{K,t}}{\partial K_t}) = (\theta\beta)E_t \frac{1}{c_{t+1}^E}[\frac{\partial Y_{t+1}}{\partial K_t} + 1 - \delta - \frac{\partial S_{K,t+1}}{\partial K_t}] - (\theta\beta)^2 E_t \frac{1}{c_{t+2}^E}\frac{\partial S_{K,t+2}}{\partial K_t}.$$

The demand functions for labor (10) and capital (12) are standard, but the Euler equation for consumption (9) and the demand function for land (11) are not standard. In each of the latter two, the multiplier on the borrowing constraint η_t is added. In (11) the first term of the RHS expresses the "down-payment effect" that captures the reduction in the effective land price.

The assumption $\theta < 1$ guarantees that entrepreneurs are constrained by the borrowing constraint at least around steady state. In fact, it follows from (3) and (9) that the multiplier is strictly positive at the steady state; $\eta = \frac{\beta(1-\theta)}{c^E} > 0$. Therefore, the borrowing constraint will hold with equality at least around the steady state;

(13) $$b_t = mE_t(q_{1+1}L_t / R_t).$$

Finally, we describe the evolutions of the TFP, A_t, as

(14a) $$\ln A_t = (1-\rho)\ln A + \rho \ln A_{t-1} + \varepsilon_t,$$

with ε_t being an observable shock and with the coefficient of autocorrelation ρ. The value at the stady-sate of A_t is denoted by A. Assume that the variance is sufficiently small that the borrowing constraint is always binding with equality for both positive and negative shocks.

C. Equilibrium

The equilibrium is a sequence $\{Y_t, K_t, N_t, N_t', L_t, h_t', c_t', c_t^E, b_t, b_t', A_t\}_{t=0}^{\infty}$, together with the sequence of values $\{w_t, \eta_t, q_t, R_t\}_{t=0}^{\infty}$, satisfying equations (2)-(6), (8)-(13), and four market clearing conditions, $N_t = N_t'$ for labor, $h_t' + L_t = \overline{L}$ for land, $b_t + b_t' = 0$ for loans, and $Y_t = c_t' + c_t^E + K_t - (1-\delta)K_{t-1} + S_K(I, I_{t-1}) + S_L(L_t, q_{t,} L_{t-1})$ for the good, and the sequence of productivity shock (14), together with the relevant transversally conditions and $\{K_{t-1}, L_{t-1}, b_{t-1}\}$. To solve the dynamics numerically, we log-linealize the system around the steady state using the method proposed by

Uhlig (1999).

Absent shocks, the model has steady state equilibria in which entrepreneurs face the borrowing constraint. The steady state is described as 10 variables $\{h', L, N, Y, c', c^E, K, b, q, R\}$, satisfying 10 equations;

(S1) $h' + L = \overline{L},$

(S2) $Y = c' + c^E + \delta K,$

(S3) $1 = \beta R,$

(S4) $(1-\beta)\dfrac{q}{c'} = \dfrac{\phi}{h'},$

(S5) $B(N)^{\varpi} c_t' = (1-\alpha)Y$

(S6) $Y = AN^{1-\alpha}[\gamma K^{\frac{\sigma-1}{\sigma}} + (1-\gamma)L^{\frac{\sigma-1}{\sigma}}]^{\frac{\alpha\sigma}{1-\sigma}},$

(S7) $q = m(1-\theta\beta R)\dfrac{q}{R} + \theta\beta(\dfrac{\partial Y}{\partial L} + q)$, with $\dfrac{\partial Y}{\partial L} = (1-\gamma)\alpha Y[\gamma K^{\frac{\sigma-1}{\sigma}} + (1-\gamma)L^{\frac{\sigma-1}{\sigma}}]^{-1} L^{-\frac{1}{\sigma}}.$

(S8) $1 = (\theta\beta)(\dfrac{\partial Y}{\partial K} + 1 - \delta)$, with $\dfrac{\partial Y}{\partial K} = \gamma\alpha Y[\gamma K^{\frac{\sigma-1}{\sigma}} + (1-\gamma)L^{\frac{\sigma-1}{\sigma}}]^{-1} K^{-\frac{1}{\sigma}}.$

(S9) $b = mqL / R.$

(S10) $c^E + \delta K = (1-R)b + \alpha Y.$

3. Simulation Results

In this section we investigate the short-run responses of shocks on macroeconomic fluctuations.

A. Parameters

We choose parameter values following the Japanese economy. In the post-war period of

Japan, external finance has been highly dependent on bank loans that were secured by putting up land as collateral. A number of empirical researches report the important role of the collateral channel in the financial accelerator, including Ogawa, *et al.* (1996), Ogawa and Kitasaka (1998), and Ogawa and Suzuki (1998). Sakuragawa and Sakuragawa (2007) report the VAR-based response functions of aggregate variables including the land price, finding the important role of land collateral channel in propagating business fluctuations in Japan. Kwon (1998) and Bayoumi (2001) argue the important role of land collateral in the monetary transmission in their VAR analysis.

The time period is one quarter. We set the discount factor for patient households at $\beta = 0.995$, which implies the steady-state annualized real interest rate of 2 percent. We set the value of θ at 0.995, implying that the discount factor for entrepreneurs $\theta\beta$ to be 0.99. We set parameters for the labor supply function, B and ϖ to be unity and 1.01. We set the weight for housing at $\phi = 0.1$. We calculate it by substituting the ratio of expenditure to housing to consumption in the household sector taken from the National Account into (S4)(7).

Next, we consider the value of the elasticity of substitution between capital and land. According to Sakuragawa (2012), the elasticity from the Japanese annual data is 0.365(8). The estimate from the quarterly data would be better because the time period is one quarter in simulation, but we give up it due to the limitation of the data availability. However, we may safely judge that the estimate is the upper bound of the real value. We can guess that the estimate based on the annual data will be greater than the estimate that would be made on the quarterly data. Then we choose $\sigma = 1/3$, and for comparison 1/2, and 1 (the Cobb-Douglas case) for the elasticity of substitution of land and capital.

We set the "statistical" capital income share at $\alpha = 0.35$, which is the value used in Braun and Waki (2006), for example. Note that the statistical capital income includes income from both capital and land, but the parameter γ is attributed only to "real" capital. We set γ to meet $K/Y \cong 4.7$, which is the average of the quarterly data for the period 1980-2007, taken from the National Account. We set $\gamma = 0.85$ in case of $\sigma = 1/3$.

We set the entrepreneur's "loan-to-land-value ratio at $m = 0.7$, which reflects the business

(7) Iacoviello (2005) uses the same value for the US economy.

(8) Few researches have estimated the elasticity. Kiyotaki and West (2006) do not estimate but infer the elasticity to be a little greater than one in their VAR estimation using Japanese aggregate data. Ogawa (2011) estimates the cost function of Japanese manufacturing firms during the bubbly period, and reports that the elasticity between capital and land is far smaller than the one between capital and labor in many industries.

practice and tradition in the Japanese banking industry.

We set the depreciation rate on capital at $\delta = 0.02$. We set the parameter on the adjustment cost of investment ξ_K at 0 or 0.5, the value of which is extensively used in the business cycle literature. The appropriate parameter on the adjustment cost of trading land is difficult to obtain, and so we use this parameter as a shift parameter. The coefficient of the autocorrelation σ is set at 0.8. The list of parameters is shown in Table 1.

Table 1.　Parameter Values

β : discount factor for patient households	0.995	This implies a steady-state annualized real interest rate of 2 percent (one period is a quarter).
θ	0.995	The discount factor for entrepreneur $\theta\beta$ is 0.99.
α : share of “capital income”	0.35	This figure follows Braun and Waki (2006)
γ : share of capital in “capital income”	0.85	This figure is inferred from the steady-state value at $\sigma = 1/3$.
δ : depreciation rate	0.02	An annual rate of depreciation on capital equal to 8%
$\overline{N}$: labor supply per household	1	
ϕ : weight for housing in the households' utility	0.1	This figure follows Iacoviello (2005), and is almost the same inferred from the steady-state value.
m : entrepreneurs' loan-to-land-value ratio	0.7	We choose this figure from hearing in the business practice
ρ : autocorrelation coefficient of productivity shock	0.8	
B : a parameter of disutility of labor	1	
ϖ : a parameter of disutility of labor	1.01	
$\overline{L}$: endowment of land	1	

The loan interest rate in the contractual arrangement that appears in (7) is specified before the productivity shock is revealed, and usually not contingent on the shock. To motivate the inertia of loan rates in the lending practice, we calculate the loan interest rate by assuming that creditors set the same rate as the rate realized one period before.

B.　Transmission Mechanism

Financial accelerator is anticipated to work strongly and persistently through the endogenous feedback between investment and the price of land.

Figures 1A-E illustrate the effects of a one percent positive technology shock on investment, the land price, entrepreneurs' land holding, entrepreneurs' net worth, consumption, and output. Entrepreneurs incur neither adjustment cost of investment nor land[9]. Solid impulses represent the credit-constrained economy, and dotted ones the frictionless economy. The lines with circle, no marker, and square indicate the response of the economies with $\sigma = 1/3$, 1/2 and unity. In Figure 1A, investment responds more sharply as the elasticity of substitution declines from 1 to 1/2 and to 1/3. Financial friction depresses investment in the Cobb-Douglas case ($\sigma = 1$), but stimulates investment in cases of small elasticity, $\sigma = 1/2$ and $\sigma = 1/3$.

In Figure 1B, the land price react more sharply in early periods for all cases, and over the almost whole periods in cases of $\sigma = 1/2$ and $\sigma = 1/3$, compared to the frictionless economy. However, the magnitude of the rise in the price is small even at peak.

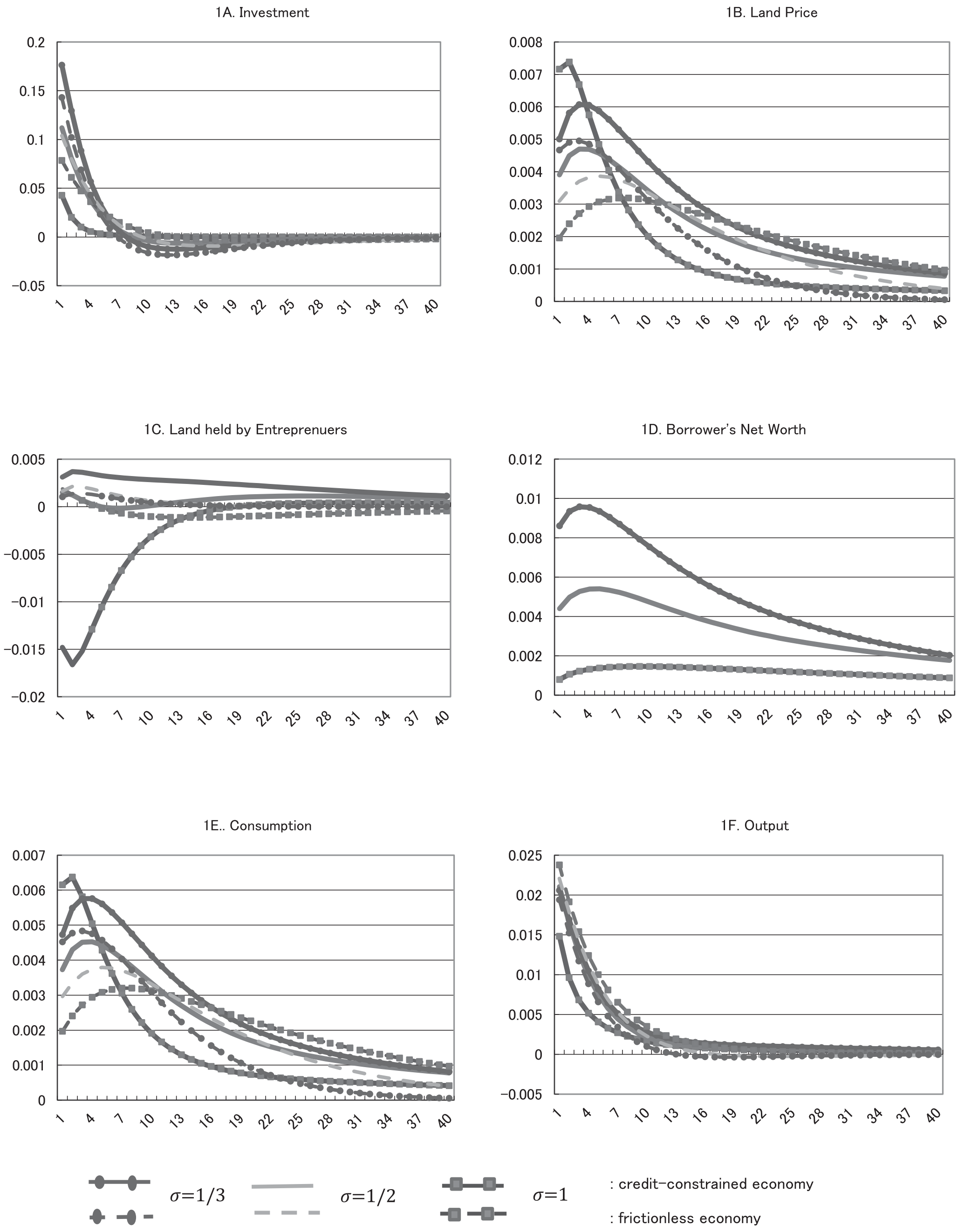
Figure 1C illustrates the impulses of land allocation. Entrepreneurs purchase land in cases of $\sigma = 1/2$ and 1/3, as the steady state analysis has predicted, but sell land in case of $\sigma = 1$. In the Cobb-Douglas case, entrepreneurs find it easy to substitute land by capital, and choose to sell land to gain the cash flow to finance investment in capital in the transition. By contrast, in cases of $\sigma = 1/2$ and 1/3, entrepreneurs find it difficult to substitute land by capital, and rather choose to hold and buy land to serve as collateral.

In Figure 1D, entrepreneurs' net worth reacts less for $\sigma = 1$, but more for $\sigma = 1/2$, and even more for 1/3. The impulses of net worth reflect the land holding of entrepreneurs more than the behavior of the land price. Figure 1E illustrates the impulses of consumption, which are similar to those of the land price[10]. In cases of $\sigma = 1/2$ and 1/3, consumption responds more when there are financial frictions. Figure 1F illustrates the impulses of output. Output reacts less relative to investment and consumption. In cases of $\sigma = 1/2$ and 1/3, investment and consumption responds more when financial friction exists, but output does not.

As the elasticity of substitution varies, the quantitative impacts on fluctuations are quite different when there is financial friction. This experiment suggests that the Cobb-Douglas function featuring the large elasticity of substitution is the source of the small amplification effect of the credit-constrained model. In particular, the strength of amplification effect seems to depend on how the holding of land changes as well as how the price reacts to the shock. In the small-elasticity cases, the response of the price is moderate, but the holding of land by entrepreneurs increases (particularly in the case for $\sigma = 1/3$), while in the Cobb-Douglas case,

(9) We set the parameter of the adjustment cost of trading land at $\xi_L = 0.1$ for MATLAB calculation.
(10) Consumption represents the aggregate consumption of entrepreneurs and households.

Figure 1. Impulse Responses to positive 1% productivity shock without adjustment costs



note) we set adjustment cost parameters, ξ_K=0 and ξ_L=0.1.

the response of the price is highest at peak, but the holding of land by entrepreneurs decreases. Consequently, the responses of net worth and thus investment are small.

We next proceed to the case when entrepreneurs incur the adjustment cost of investment. We set $\xi_K = 0.5$ and $\xi_K = 0$. We consider the cases for $\sigma = 1/2$ and 1/3. In Figure 2A, investment responds more sharply than the frictionless economy[11]. For $\sigma = 1/2$, the magnitude of investment at peak is about twice relative to the frictionless economy, and for $\sigma = 1/3$ about three times[12]. Note that the absolute magnitude tends to be small in the presence of the adjustment cost.

More land is reallocated from households to entrepreneurs in the presence of the adjustment cost. In Figure 2C, for $\sigma = 1/3$, the net increase in the land holding by entrepreneurs is about four times at peak relative to the no adjustment cost case. Accordingly, as Figure 2D illustrates, net worth shows the greater and more persistent impulses. In Figure 2E, the impulses of consumption show the larger effect than the no adjustment cost case. In Figure 2F, the impulses of output show the larger effect relative to the frictionless economy.

When the adjustment cost is combined with the small elasticity of substitution, entrepreneurs find it difficult to invest in capital quickly, and instead buy more land in earlier periods, enabling entrepreneurs to use the greater land holding to raise more loans to finance investment in later periods. Consequently, the adjustment cost of investment enables financial accelerator to work strongly and persist for long.

Table 2 depicts cumulative effects on investment, consumption, and output in case of $\sigma = 1/3$. At 40 quarters, the credit constraint amplifies the shock on consumption and output almost by three times, and on investment by 7 times. Interestingly, as the elasticity is smaller, the response is smaller in the frictionless economy, but greater in the presence of the credit constraint[13].

Figure 3 presents the impulse responses when the adjustment cost of trading land varies from $\xi_L = 0$ to 1 and 5. This experiment is made to examine the effects of the change in the liquidity of the collateralizable asset. We keep $\xi_L = 5$ for the adjustment cost of investment.

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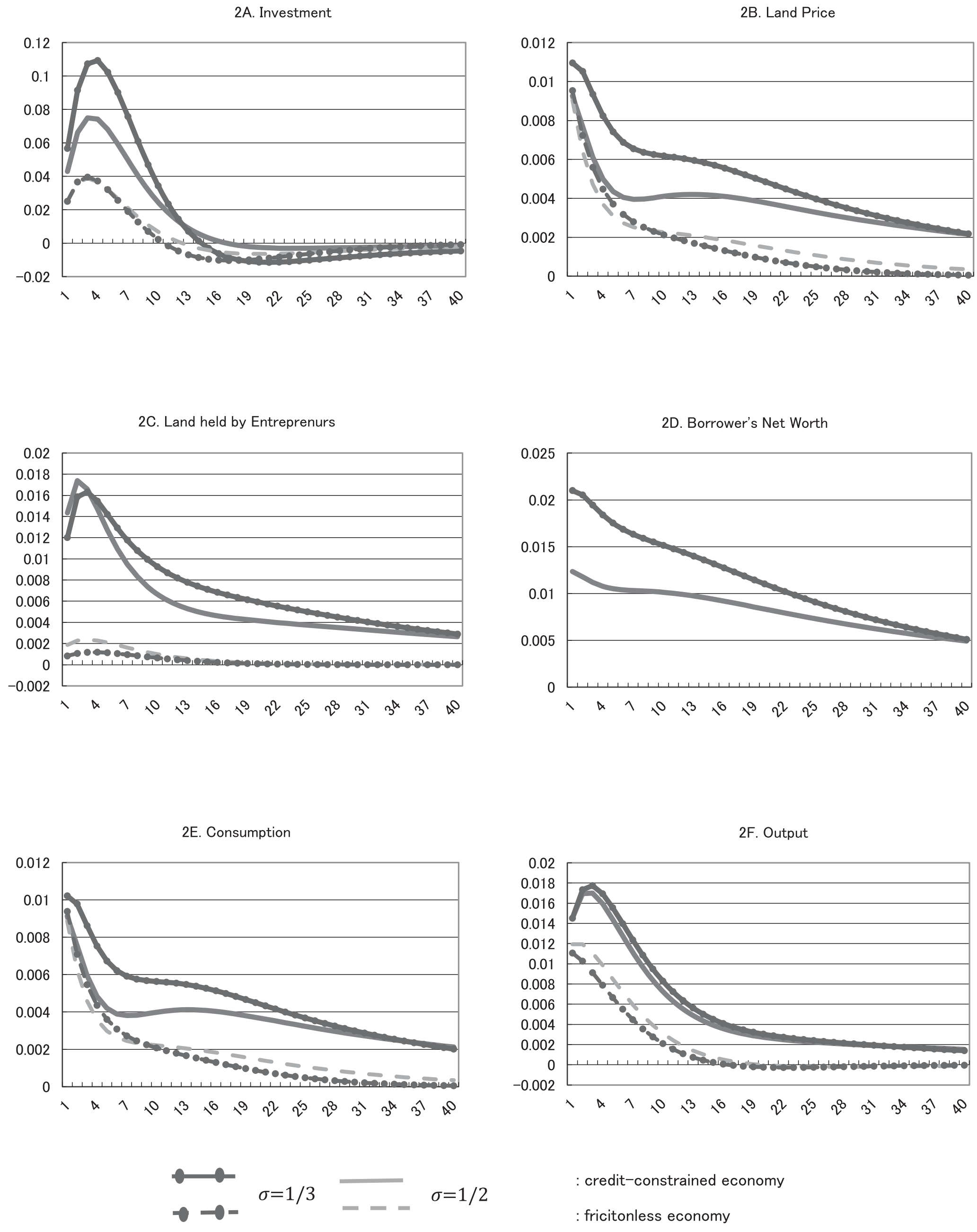
(11) The hump-shaped dynamics comes from the specific property of the adjustment cost function.

(12) One might wonder if greater amplification effects of the credit constraint arises from the difference in the initial capital/output, but this is not the case. But rather capital/output is smaller as the elasticity is small in both economies.

(13) The large amplification is comparable to Liu, Wang and Zha (2010) who reports that to a 1% housing preference shock, the estimated magnitudes of investment and output are 5.2% and 1.4% at peak are smaller than our estimates, 12% and 2% , to a 1% TFP shock, although the exact comparison is difficult.

Figure 2.　Impulse Responses to positive 1% productivity shock with adjustment cost of capital



note) we set adjustment cost parameters, ξ_K=0.5 and ξ_L=0.

Table 2. Cumulative effects (%)

A. Investment

	1-quarter	10-quarter	20-quarter	40-quarter
Credit Constraint Economy				
σ = 1/2	4.29	53.24	57.69	52.94
σ = 1/3	5.67	77.56	77.25	61.73
Frictionless Economy				
σ = 1/2	2.52	25.05	21.67	13.37
σ = 1/3	2.51	23.74	15.62	7.82

B. Consumption

	1-quarter	10-quarter	20-quarter	40-quarter
Credit Constraint Economy				
σ = 1/2	0.91	5.11	9.09	14.69
σ = 1/3	1.02	7.21	12.34	18.9
Frictionless Economy				
σ = 1/2	0.89	3.82	5.66	7.21
σ = 1/3	0.94	4.25	5.62	6.21

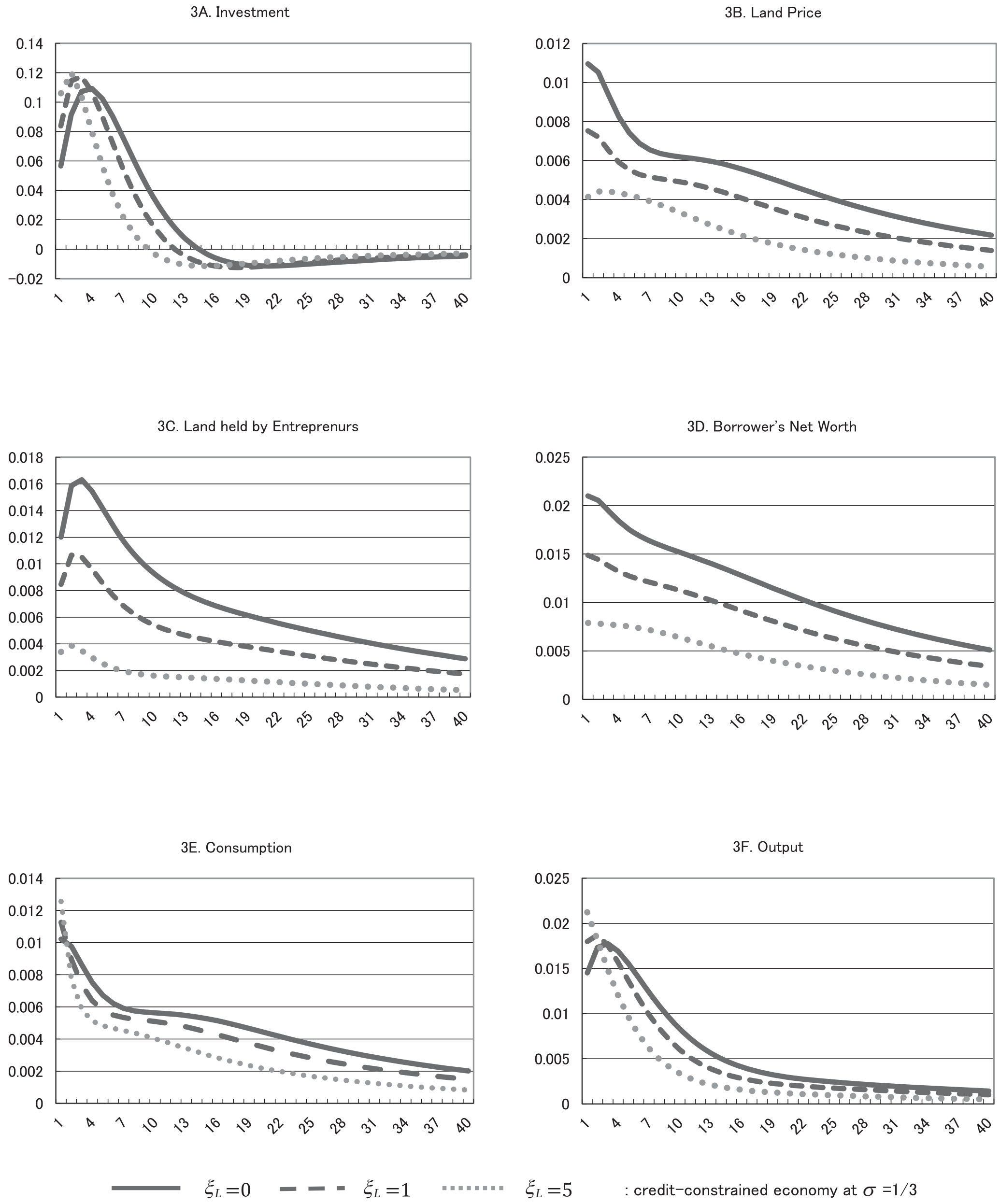
C. Output

	1-quarter	10-quarter	20-quarter	40-quarter
Credit Constraint Economy				
σ = 1/2	1.45	12.80	16.86	20.81
σ = 1/3	1.45	13.71	18.34	22.39
Frictionless Economy				
σ = 1/2	1.19	7.83	8.69	8.37
σ = 1/3	1.11	6.34	6.69	6.38

Note) These values are calculated from the results of Figure 2.

Here we illustrate the case for $\sigma = 1/3$. In Figure 3A, we find that investment peak out earlier and later declines more quickly as the adjustment cost of trading land is large. The presence of adjustment cost of trading land prevents the land price from boosting (see Figure 3C), making land more immobile (see Figure 3D), and weakening the amplification effect. The adjustment cost of trading land and the elasticity of substitution have quite different implications on the quantitative analysis.

Figure 3.　Impulse Responses to positive 1% productivity shock for various ξ_L



note) we set adjustment cost parameter, ξ_K=0.5.

4. Conclusion

We have reconsidered the amplification and propagation mechanism of the credit-constrained economy by highlighting the interaction of finance and technology captured by the elasticity of substitution between capital and land in production. The magnitude of amplification depends on whether credit-constrained entrepreneurs hold the greater (smaller) amount of land in the boom (bust), which is in turn determined by the elasticity of substitution.

The distribution of the collateralizable asset between creditors and debtors will become a significant channel for the quantitative evaluation of the credit boom and bust. Furthermore, allowing for various production functions beyond the Cobb-Douglas function may be a direction of research in the field of the quantitative analysis of macroeconomics[14].

Our findings provide a number of implications for economic policies. First, the strong expansion and contraction of credit arise from the large swing of asset prices in the collateral-dependent economy. Avoiding economic instability will require establishing an alternative financial system that does not rely on asset collateral. Second, the impact of enhancing liquidity of assets that serve for collateral is perverse. Policymakers should take into consideration the fact that enhancing liquidity magnifies macroeconomic fluctuations in the credit-constrained economy.

References

Antras, P., 2004, "Is the U.S. aggregate production function Cobb-Douglas? New estimates of the elasticity of substitution," *Contributions to Macroeconomics*, vol. 4, issue 1, article 4.

Arias, A.F., 2003, "Quantitative implications of the credit constraint in the Kiyotaki-Moore (1997) setup," Documento CEDE 2003-28, ISSN 1657-7191.

Bayoumi, T., 2001, "The morning after: explaining the slowdown in Japanese growth in the 1990s," *Journal of International Economics*, vol. 53, 241-259.

Bernanke, B. S., and M. Gertler, 1989, "Agency costs, net worth, and business fluctuations," *American Economic Review*, vol. 79, 14-31.

Bernanke, B. S., M. Gertler, and S. Gilchrist, 1999, "The financial accelerator in a quantitative business

(14) Sakuragawa and Sakuragawa (2009) extend KM to the endogenous growth model that involves the Romer-type production function with externalities, and demonstrate that the credit constraint amplifies movements of real variables under most plausible parameter values.

cycle framework," in *Handbook of Macroeconomics*, vol. 1, edited by Taylor J. B. and M. Woodford, Elsevier Science, ch. 21, 1341-1393.

Braun, A., and Y. Waki, 2006, "Monetary policy during Japan's Lost Decade," *Japanese Economic Review*, vol. 57, 324-344.

Carlstrom, C. T. and T. S. Fuerst, 1997, "Agency costs, net worth, and business fluctuations: a computable general equilibrium analysis," *American Economic Review*, vol. 87, 893-910.

Choi S. and Rios-Rull J.-V., 2008, "Understanding the dynamics of labor share: the role of noncompetitive factor prices," *Annals of Economics and Statistics*, 2009, 251-278.

Christensen, I., and A. Dib., 2008, "The financial accelerator in an estimated New Keynesian model", *Review of Economic Dynamics*, vol. 11, 155-78.

Christiano, L. J., M. Eichenbaum, and C. L. Evans, 2005, "Nominal rigidities and the dynamic effects of a shock to monetary policy", *Journal of Political Economy*, vol. 113, 1-44.

Christiano, L., R. Motto, and M. Rosagno, 2009, "Financial factors in economic fluctuations," manuscript, Northwestern University.

Cordoba, J. C. and M. Ripoll, 2004, "Credit cycles redux," International Economic Review, vol. 45, 1011-1046.

Davis, M. A., 2009, "The price and quantity of land by legal form of organization in the United States," *Regional Science and Urban Economics*, vol. 39, 350-359.

Dickey, D. A. and W. A. Fuller, 1979, "Distribution of the estimation for autoregressive time series with a unit root," *Journal of the American Statistical Association*, vol. 79, 355-376.

Engle R., and C. Granger, 1987, "Co-integration and error correction: representation, estimation, and testing," *Econometrica*, vol. 55, 251-276.

Fisher, I., 1933, "The debt-deflation theory of Great Depression," *Econometrica*, vol. 1, 337-357.

Gertler, M., and N. Kiyotaki, 2010, "Financial intermediation and credit policy in business cycle analysis," in *Handbook of Monetary Economics*, vol. 3A, edited by Friedman, B. M., and M. Woodford, North-Holland, ch. 11, 547-600.

Hayashi, F., 1990, "Taxes and corporate investment in Japanese manufacturing," in *Productivity Growth in Japan and the United States*, edited by Hulten, C. R., University of Chicago Press, ch. 10, 295-316.

Iacoviello. M., 2005, "House prices, borrowing constraints, and monetary policy in the business cycle", *American Economic Review*, Vol. 95, 739-764.

Jermann, U., and V. Quardini, 2009, "Macroeconomic effects of financial shocks," NBER Working Paper No. 15338.

Johansen, S., 1991, "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models," *Econometrica*, vol. 59, 1551-1580.

Johansen, S., 1995, *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press.

Kindleberger, C, P., 1978, *Manias, Panics, and Crashes, A history of Financial Crises, 3ed edition*, 1996, Macmillan.

Kiyotaki, N, and J. Moore, 1997, "Credit cycles", *Journal of Political Economy*, vol. 105, 211-248.

Kiyotaki, N., and K.D. West, 1996, "Business fixed investment and the recent business cycle in Japan," in *NBER Macroeconomics Annual*, edited by Bernanke, B., and J. Rotemberg, MIT press, 277-323.

Kiyotaki, N., and K. D. West, 2006, "Land prices and business fixed investment in Japan," in *Long-run Growth and Short-run Stabilization; essays in memory of Albert Ando*, edited by Klein, L. R., Edward Elgar Pub, ch. 12, 303-336.

Kocherlakota, N. R., 2000, "Creating business cycles through credit constraints, *Federal Reserve Bank of Minneapolis Quarterly Review*, Vol. 24, No. 3, 2-10.

Kwon, E., 1998, "Monetary policy, land prices, and collateral effects on economic fluctuations: evidence from Japan," *Journal of the Japanese and International Economies*, vol. 12, 175-203.

Liu, Z., P. Wang, and T. Zha, 2010, "Do credit constraints amplify macroeconomic fluctuations?" Working paper 2010-1, FRB of Atlanta

MacKinnon J. G., 1996, "Numerical distribution functions for unit root and cointegration tests," *Journal of Applied Econometrics*, vol. 11, 601-618.

MacKinnon J. G., A. A. Haug and L. Michelis, 1999, "Numerical distribution functions of likelihood ratio tests for cointegration," *Journal of Applied Econometrics*, vol. 14, 563-577.

Mendoza, E. G., 2010, "Sudden stops, financial crises, and leverage," *American Economic Review*, vol. 100, 1941-1966.

Minsky, H., 1986, *Stabilizing an Unstable Economy*, Yale University Press.

Ogawa, K, 2003, *Daifukyo no Keizai Bunseki* (in Japanese), Nippon Keizai Shinbun Sha.

Ogawa, K., 2011, "Why are concavity conditions not satisfied in the cost function? The case of Japanese manufacturing firms during the bubble period," *Oxford Bulletin of Economics and Statistics*, vol. 73, 556-580.

Ogawa, K. and S. Kitasaka, 1998, *Sisan Shijyou to Keiki Hendou* (in Japanese), *Nippon Keizai Shinbun Sha.*

Ogawa, K., S. Kitasaka, H. Yamaoka and Y. Iwata, 1996, "Borrowing constraints and the role of land asset in Japanese corporate investment decision", *Journal of the Japanese and International Economics*, vol. 10, 122-149.

Ogawa, K. and K. Suzuki, 1998, "Land value and corporate investment: evidence from Japanese panel data", *Journal of the Japanese and International Economics*, vol. 12, 232-249.

Phillips, P. C. B. and S. Ouliaris, 1990, "Asymptotic properties of residual based tests for cointegration," *Econometrica*, vol. 58, 165-193.

Phillips, P. C. B. and P. Perron, 1988, "Testing for a unit root in time series regression," *Biometrika*, vol. 75, 335-346.

Ramey, V. A., and M. D. Shapiro, 2001, "Displaced capital: a study of aerospace plant closings," *Journal of Political Economy*, vol. 109, 958-992.

Sakuragawa, M., and Y. Sakuragawa, 2007, "Land prices and business fluctuations in Japan (in Japanese)," *Mita Journal of Economics*, vol. 100, no. 2, 71(507)-93(529).

Sakuragawa, M., and Y. Sakuragawa, 2009, "Land price, collateral, and economic growth," *The Japanese Economic Review*, vol. 60, No. 4, 473-89.

Sakuragawa, Y., 2012, "Technological Substitution between Capital and land," *Journal of Atomi University Faculty of Management*, vol. 14, pp. 125-140.

Shleifer, A., and R. Vishny, 1992, "Liquidation values and debt capacity: a market equilibrium approach," *Journal of Finance*, vol. 47, 1343-1366.

Uhlig, H., 1999, "A toolkit for analyzing nonlinear dynamic stochastic models easily," in Marimon and Scot, eds., *Computational Methods for the Study of Dynamic Economics*. Oxford University Press, 30-61.