Quantitative Impacts of the Asset Price Channel in the Credit-Constrained Economy

Masaya Sakuragawa (Keio University)
Yukie Sakuragawa (Atomi University)

May 30, 2011

Abstract
This paper investigates the quantitative impact of the asset price channel in a collateral-constrained economy when real estate inelasticity supplied, so-called, “land”, is used for production and serves as collateral. Many papers in the literature use Cobb-Douglas production function to estimate the asset price channel but find small quantitative effect. The substitutability between capital and land in production plays a significant role in amplifying and propagating supply-side shocks to the economy. The estimate of the elasticity of substitution is about 0.35 in Japanese aggregate data. Our calibration reports great impact of the asset price channel.

---

We are grateful to Mario Criccini, Kazuo Ogawa, Keiichiro Kobayashi, Shinichi Fukuda, Masaharu Hanazaki, Mototsugu Shintani, Takayuki Tsuruga, Kevin Won, and participants of seminars held in Vanderbilt University, Keio University, Asahikawa, and Kobe, and the meeting of the Japanese Economic Association for valuable and insightful comments and discussions.
1. Introduction

Credit market friction is widely believed to be one of primary sources of generating business fluctuations. Ample literature has developed business cycle models of a “financial accelerator” in which the change in borrowers’ net worth affects bank borrowing and investment, including Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), Bernanke, et al. (1999), and others.

Net worth includes not only financial assets, but also non-financial assets, such as housing, buildings, and land. Real estate is a tangible asset that is used extensively across industries, and for its advantage of “asset fungibility” (e.g., Shleifer and Vishny, 1992), serves as collateral for borrowing. Kiyotaki and Moore (1997, hereafter KM) develop a model of business cycle that explains the amplification mechanism of financial accelerator through the endogenous fluctuation of the evaluation of real estate.

Episodes on the boom-bust cycles of asset prices invoke us to take the important role of this asset price channel in business fluctuations, but the evaluation of the quantitative significance is mixed. Cordova and Ripoll (2004) calibrate a small amplification effect in the exchange economy with no capital. Reviewing the literature, the small quantitative effect seems to be related to the production technology.

Kocherlakota (2000) and Arias (2003), both of which report small amplification effect, use the Cobb-Douglas production function.\(^1\) On the other hand, KM reports the fairly large quantitative effect, and they use the Leontief-type technology in which capital and land are both necessary in the same proportion.\(^2\)

The Cobb-Douglas technology assumes that firms find it as easy to substitute between capital and land as they do between capital and labor. When owners of firms anticipate the shock to be temporary, however, it is doubtful whether they replace their real estate by capital quickly. This aspect of factor adjustment is crucial for

---

\(^1\) Kocherlakota (2000) uses the 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.

\(^2\) Aghion et. al (2004) use the technology with small elasticity of substitution between capital and real estate to study the instability of the small-open economy.
understanding business cycles that explains the short-run behavior of the economy.

The aim of this paper is to investigate under what conditions the quantitative impact of the asset price channel is strong. We highlight three respects as influencing quantitative effects of financial accelerator. The first is the elasticity of substitution, that is, substitutability/complementarity between capital and land in production. The second is the allocation of land, the asset used for collateral, between credit-constrained firms and other sectors. The third is the adjustment costs of investment.

The small elasticity of substitution, the adjustment cost of investment, and reallocation of land toward credit-constrained firms amplify the quantitative effect of financial accelerator. As capital and land are more complementary, entrepreneurs find it difficult to substitute land by capital, choosing to obtain loans for financing capital by buying more land. In addition, the adjustment cost of investment prevents firms from investing in capital in early periods; instead enabling them to buy even more land, which allows them to raise loans in later periods to finance investment. These two factors work to strengthen the amplification mechanism of financial accelerator.

The small elasticity of substitution is crucial to induce land to be reallocated to credit-constrained firms, and to give rise to the greater and more persistent effect on investment. Conversely, when capital and land are substitutable, entrepreneurs find it easy to substitute land by capital, and choose not to buy but rather to sell land to gain the cash flow to finance capital. The adjustment cost of investment plays a powerful role to strengthen financial accelerator. The adjustment cost dampens investment and output in the frictionless economy, but promote investment and output in the credit constrained economy. When the elasticity of substitution is small (0.5), the output increases by 1.6% at peak in the credit-constrained economy, while it does by 1.1% in the frictionless economy.

The subject of this paper can go back to the fundamental question if the financial accelerator is virtually at work. Since Bernanke, et al. (1999) have stressed an important
role of that channel, huge literature has attempted to consider financial frictions as one of important sources of business fluctuations. To the best of my small knowledge, however, few models have reported the quantitatively significant impacts of financial accelerator. For example, Christensen and Dib (2008) show that the presence of the financial accelerator magnifies and propagates the effects of demand shocks, but dampens the effects of supply shocks - technology and investment-specific shocks on investment.

This paper is organized as follows. In Section 2 we set up the basic model. In Section 3 we feature some properties of the steady state. In Section 4 we evaluate the quantitative effects of the developed model.

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 collateralizable land. Measures of households and entrepreneurs are unity, respectively. All markets are perfectly competitive.

A. Patient Households

Households maximize a lifetime utility given by

\[ E_0 \sum_{t=0}^{\infty} \beta^t \left[ \log c_t + \phi \log h_t - \frac{B}{\sigma} (N_t')^\sigma \right] \]

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 \( \phi, \sigma, \) and \( B \) are positive 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 \(q_t\) denote the land price, and \(w_t\) the wage rate, the flow of funds is
\[
c_t^t + q_t(h'_t - h''_{t-1}) = w_t N''_t - R_{t-1} b'_{t-1} + b'_t. \tag{2}
\]
Optimum conditions are the first-order conditions for consumption, housing, and labor:
\[
\frac{1}{c^t_t} = \beta \frac{R_t}{c^t_{t+1}}, \tag{3}
\]
\[
\frac{q_t}{c^t_t} = \frac{\phi}{h'_t} + \beta \frac{q_{t+1}}{c^t_{t+1}}, \tag{4}
\]
and
\[
\frac{w_t}{c^t_t} = B(N''_t)^{\sigma-1}. \tag{5}
\]

**B. Entrepreneurs**

Entrepreneurs produce the final good \(Y_t\) by employing labor \(N_t\), capital \(K_{t-1}\), and land \(L_{t-1}\). We consider the production technology allowing for the variable elasticity of substitution between capital and land. In response to the short-run shock, firms may not be able to change the capital/land ratio quickly over the business cycle so that the short-run elasticity of substitution is expected to be smaller than the long-run one. We consider the following quasi-CES type technology;
\[
Y_t = A_t N_{t-1}^{1-\sigma} \left[ \gamma K_{t-1}^{-\sigma} + (1-\gamma) L_{t-1}^{-\sigma} \right]^{\sigma}, \tag{6}
\]
where \(A_t\) is the total factor productivity (TFP), \(\sigma\) is the elasticity of substitution between capital and land, and \(\gamma\) is the technological weight attached to capital. The larger \(\sigma\) implies greater substitutability. \(\sigma = 1\) corresponds to the Cobb-Douglas case; then (6) reduces to \(Y_t = A_t N_{t-1}^{1-\alpha} K_{t-1}^{\alpha(t-1)^{\alpha}}\). Then \(\gamma \alpha\) is the output share of capital and \((1-\gamma)\alpha\) is the output share of land. \(\sigma = 0\) corresponds to the Leontief technology in which capital and land are completely complementary.

The process to transform investment in equipment into capital ready for production involves installation and adjustment costs, \(S_k(I_t, I_{t-1}) = \frac{\xi_k}{2} (\frac{I_t}{I_{t-1}} - 1)^2 I_t\), which
increases in the rate of investment growth. Note that \( K_t = (1 - \delta)K_{t-1} + V_tI_t \). \( V_t \) is the parameter of investment efficiency. The trade of land may also involve the adjustment cost, \( S_t(L_t, q_t, L_{t-1}) = \frac{\varepsilon_t}{2} \left( \frac{L_t - L_{t-1}}{L_{t-1}} \right)^2 q_tL_{t-1} \), which will capture the market thinness of the land market and/or tax distortion to hamper the trade of land.\(^5\)

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, and cannot seize output or capital of their debtors. In this environment, 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. The borrowing constraint that the entrepreneur faces is then typically expressed as

\[
(7) \quad b_i \leq mE_t(q_{t+1}L_t / R_t),
\]

where \( m \leq 1 \) is motivated by the notion that the amount equal to a constant fraction of the value of land is dissipated in the process of bank monitoring and 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 \( E_0 \sum (\theta \beta)^t \ln c^E_t \), subject to the technology (6), the borrowing constraint (7), and the following flow of funds;

\[
(8) \quad c^E_t + I_t + S_t(I_t, I_{t-1}) + q_t(L_t - L_{t-1}) + S_t(L_t, q_t, L_{t-1}) = Y_t + b_t - R_{t-1}b_{t-1} - w_tN_t.
\]

Define \( \eta_t \) 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

---

\(^5\) Alternatively, the specification in which households incurs the adjustment cost yields the same dynamic effect. Iacoviello (2005) uses the specification in which household incurs the adjustment cost to change the stock of real estate (the housing stock).

\(^6\) The bank monitoring may be compatible with the borrowing constraint. Ogawa (2003) reports the evidence of the complementary role of collateral with bank monitoring. The value of \( m \) that is under close relationship with banks might be greater than not.
functions for labor, land, and capital:

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

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

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

and

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

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 \( \eta_t \) 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:

(13) \[ b_t = m E_t(q_{t+1}, L_t / R_t). \]

Finally, we describe the evolution of the productivity and the evolution of the investment efficiency as

(14a) \[ \ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t} \] and \( \varepsilon_{A,t} \)

(14b) \[ \ln V_t = \rho_V \ln V_{t-1} + \varepsilon_{V,t} \]

with \( \varepsilon_{A,t}, (\varepsilon_{V,t}) \) being a white noise shock process with zero mean and variance \( \sigma_{\varepsilon_t}^2 \) \( (\sigma_{\varepsilon_t}^2) \) and with the coefficient of autocorrelation \( \rho_A (\rho_V) \). 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 of variables

\[ \{Y_t, K_t, N_t, N_t, L_t, h_t, c_t, c_t^E, b_t, b_t', A_t\}_{t=0}^{\infty}, \]

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, \( h_t' + L_t = \bar{L} \) for land, \( b_t + b_t' = 0 \) for loans, and

\[ Y_t = c_t' + c_t^E + K_t - (1 - \delta)K_{t-1} + S_k(I_t, I_{t-1}) + S_L(L_t, q_t, L_{t-1}) \]

for the final 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 a unique stationary equilibrium in which entrepreneurs faces the borrowing constraint. The steady state is described as 10 variables \( \{h', L, N, Y, c', c^E, K, b, q, R\} \), given \( A \), satisfying 10 equations;

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

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

(S3) \( 1 = \beta R, \)

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

(S5) \( B(N)^\alpha c'_t = (1 - \alpha)Y \)

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

(S7) \( q = m(1 - \theta \beta R) \frac{q}{R} + \theta \beta (\frac{\partial Y}{\partial L} + q), \)

(S8) \( 1 = (\theta \beta)(\frac{\partial Y}{\partial K} + 1 - \delta), \)

(S9) \( b = mqL / R, \)

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

where \( \frac{\partial Y}{\partial L} = (1 - \gamma)\alpha Y \left[ \gamma K^{\frac{\sigma-1}{\sigma}} + (1 - \gamma)L^{\frac{\sigma-1}{\sigma}} \right]^{1-\sigma}L^{\frac{1}{\sigma}} \) and
3. Technological Substitutability and Land Allocation

In this section we investigate the steady state response of a change in the productivity shock on the land allocation, when the degree of substitutability between capital and land varies. This analysis is not intended to argue that the long-run analysis is important but intended to predict the magnitude of the asset price effect that is anticipated to vary with the technological interaction between capital and land. Note that here the labor supply is assumed constant, i.e., \( N = N \).

We investigate three production technologies that differ in the elasticity of substitution \( \sigma \). We first consider the Leontief technology in which capital and land are perfect complements, with \( \sigma = 0 \). The production function (6) is then reduced to

\[
Y_t = A_t N_t^{1-\sigma} \{\min\{K_{t-1}, L_{t-1}\}\}^\sigma ,
\]

and hence further to \( Y_t = A_t N_t^{1-\sigma} K_{t-1}^\sigma \), with the restriction \( K_{t-1} = L_{t-1} \). We use the latter equality to rewrite the entrepreneur’s flow of funds (8) as

\[
c_t^E + q_t (L_t - L_{t-1}) + \{L_t - (1-\delta)L_{t-1}\} = Y_t + b_t - R_{t-1} b_{t-1} - w_t N.
\]

Note that the adjustment costs are deleted for convenience. The entrepreneur’s first-order conditions are now (9), (10), and

\[
\frac{1}{c_t^E}(q_t + 1) = m \eta_t E_t \left( \frac{q_{t+1}}{R_{t-1}} \right) + E_t \left( \frac{\theta \beta}{c_{t+1}^E} \frac{\alpha Y_{t+1}}{K_t} + q_{t+1} + 1 - \delta \right).
\]

Rearranging terms, we finally have

\[
(1-\beta) \{1-\theta \beta (1-\delta)\} \{(1+\phi m)L - \bar{L}\} - A \bar{N}^{1-\alpha} \equiv \Phi(L).
\]

The LHS is a straight line with a positive slope, that goes through \((\bar{L}/(1+\phi m), 0)\), while the \( \Phi(.) \) function of the RHS is increasing and concave over \((0, \bar{L})\), with
\[ \lim_{L \to \infty} \Phi(L) = -\infty. \] As illustrated in Figure 1, an increase in \( A \) moves the straight line clockwise around \((\bar{L}/(1 + \phi m), 0)\), making the demand for land greater. Note that only one of the two steady states is dynamically stable. When the positive productivity shock occurs, the land is reallocated toward firms from households.

We next turn to the other extreme case when capital and land are perfect substitutes, with \( \sigma \to +\infty \). The production function (6) is then reduced to

\[ Y_t = A_t N_t^{1-\sigma} [\gamma K_{t-1} + (1 - \gamma)L_{t-1}]^\sigma. \]

Taking into account the possible corner solution, the first-order conditions for land and capital are written at the steady state as

\[
\begin{align*}
(18) & \quad 1 \geq m(1 - \theta \beta R) + \theta \beta \frac{\alpha Y}{q^* \gamma K + (1 - \gamma)L} + 1, \text{ and } \\
(19) & \quad 1 \geq \theta \beta \frac{\alpha Y}{q^* \gamma K + (1 - \gamma)L} + 1 - \delta.
\end{align*}
\]

With complementary slackness, either (18) or (19) should at least bind with equality. If (19) binds with equality, (18) should be met if the land price \( q^* \) is higher than some threshold \( q^* \). Conversely, if (18) binds with equality, (19) should be slack when \( q^* \) is smaller than the threshold.

Figure 2 illustrates the entrepreneur’s demand for land in terms of the TFP. The demand is weakly decreasing as the TFP rises. The demand is not affected by the TFP when the firm uses only capital \((\bar{A} < A)\) or only land \((A < \bar{A})\), whereas it is decreasing when the firm uses both capital and land \((\bar{A} < A < \bar{A})\).

If the TFP is great, the land price is expensive, and entrepreneurs demand capital but no land, i.e., \( L = 0 \). If the TFP is at the intermediate level, entrepreneurs demand land by

\[
L = \frac{\bar{L}}{1 + m \phi} - \frac{\phi(1 - \alpha)}{(1 - \beta) N^* (1 + m \phi) \left[1 - \theta \beta (1 - \delta) \right]^{1 - \alpha} \bar{N} A^{1 - \alpha}},
\]

which is decreasing in TFP. Finally, if the TFP is low, the land price is cheaper than capital, and entrepreneurs demand some constant amount,

\[
L = \frac{(1 - \beta) \theta \beta \bar{L}}{\phi(1 - \alpha) (1 - m (1 - \theta) \beta - \theta \beta^* + (1 + m \phi)(1 - \beta) \theta \beta^* \left[1 - \theta \beta (1 - \delta) \right]^{1 - \alpha}}.
\]

The Leontief case and other polar case reveal two offsetting effects on the land
allocation. On one hand, a rise in the TFP raises the marginal productivity of land, and induces firms to demand more land, as captured by the Leontief case. On the other hand, it makes land more expensive than capital, and induces firms to demand less land, as captured by the perfect-substitutability case.

We finally study the Cobb-Douglas case with $\sigma = 1$. The entrepreneurs’ demand for land becomes

$$L = \frac{(1-\beta)\theta\beta(1-\gamma)\alpha L}{\phi(1-\alpha)|1-m(1-\theta)\beta - \theta\beta| + (1+m\phi)(1-\beta)\theta\beta(1-\gamma)\alpha},$$

which is independent of TFP. For this case, the two effects cancel out. We summarize as

**Proposition**

Suppose that the TFP rises permanently.

1. When $\sigma = 0$, the land is reallocated from households to firms.
2. When $\sigma \to +\infty$, if the TFP is high or low, the land is never reallocated between households and firms, while if the TFP is at the intermediate level, the land is reallocated from firms to households.
3. When $\sigma = 1$, the land is never reallocated between households and firms.

The technological substitutability between capital and land significantly influences the land allocation. When the elasticity of substitution is small, entrepreneurs find it difficult to substitute land by capital, choosing to buy land to gain from putting up land as collateral. Firms become net demanders for land, and land is more allocated toward firm. By contrast, when it is high, entrepreneurs find it easy to substitute land by capital, and choose to sell land to gain the cash flow to finance investment in capital. Firms become net suppliers, and land tends to be more allocated to households. This analysis predicts that as $\sigma$ is smaller, firms accumulate more net worth over time, and the quantitative effects of financial accelerator is strong.

4. Estimation of the elasticity of substitution

As the previous section suggested, the elasticity of substitution between capital and land plays a key role in amplifying and propagating shocks to the economy. Few researches estimated the elasticity of it. Kiyotaki and West (2006) estimate indirectly the
elasticity in the VAR estimation using Japanese aggregate data, and infer that the elasticity is a little greater than one. Ogawa (2010, Oxford Bulletin of Economics and Statistics, forthcoming) estimates the cost function of Japanese manufacturing firms during the bubble period, and he reports that the elasticity is less than one. We will estimate the elasticity in Japanese aggregate data directly.

Based on the cost minimization behavior of firms facing the production function (6), the following equation for estimation is obtained;

\[
(20) \quad \log\left(\frac{K_t}{L_t}\right) = \alpha_0 - \sigma \log\left(\frac{C_{Kt}}{C_{Lt}}\right) + \epsilon_t
\]

where \( C_{Kt} \) is the user cost of capital, and \( C_{Lt} \) is the user cost of land, respectively. \( \alpha_0 \equiv \sigma \ln\frac{\gamma}{1-\gamma} \).


The estimation result by the OLS is shown at the first column of Table 1. The estimates \( \hat{\sigma} \) lies between zero and one, but the Durbin-Watson statistics are low. The OLS estimate for the coefficient is biased. We next add three variables; logarithm of foreign direct investment from Japan to overseas per GDP, the logarithm of the ratio of value-added produced by the second industry to the one by third industry, and trend. The trend captures the biased technical change for capital and land, as Antras (2004) points out. The first two variables are expected to capture other factors that explain the change in the ratio of capital to land.

The estimation results including these variables are shown at [2]-[6] of Table 1. We obtain the result that \( \hat{\sigma} \) ranges from 0.33 to 0.39. The Durbin-Watson statistics are higher, but not enough. This might reflect the so-called spurious correlations.

Table 2 reports a summary of the unit root tests on each of the series. In the top panel of Table 2, we report the results of Augmented Dickey-Fuller test and Phillips and Perron (1988)’s test of a unit root in the series against the alternative hypothesis of
trend-stationarity. It is clear from the Table 2 that for none of the four series the tests reject the null hypothesis of a unit root. In the bottom panel of the Table 2, we report the results of the same tests on each of the four series expressed in the first difference. The results indicate a rejection of the null hypothesis of the series being integrated of order two.

We conclude that all four series are nonstationary and integrated of order one. In this situation, OLS estimates will not be consistent unless a linear combination of the dependent and independent variables is stationary. We make the residual-based Augmented Dickey-Fuller test, suggested by Engle and Granger (1987), to the residuals of eq.[5] and [6] in Table 1 in order to test the null of no co-integration. The top of Table 3 shows the results. In the bottom panel of Table 3, we show the result of Johansen test, which tests the null hypothesis of the existence of r cointegrating vectors against the alternative of the existence of r+1 cointegrating vectors. We choose a model with a constant and a linear deterministic trend in data and one lag of the first difference of the variables in the estimation. The null hypothesis of zero cointegrating vectors cannot be rejected. Overall, these results for the cointegration test indicate that OLS estimates in Table 1 are not interpreted spurious regression.

5. Calibration Results

The asset price channel has been at work in Japan. In the post-war period of Japan, financial markets in Japan have been highly dependent on the banking sector and many of asymmetric information have been resolved by providing land as collateral for securing bank loans.\footnote{As a matter of fact, land is easy to develop across industries so that among many assets, land is extensively used as collateral [e.g., Shleifer and Vishny (1992)].} A number of empirical researches provide evidence of the collateral channel in the Japanese economy, including Ogawa, \textit{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.

A. Parameter Choice

We choose parameter values following the Japanese economy. 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 $\theta$ at 0.995, implying that the discount factor for entrepreneurs $\theta \beta$ to be 0.99.

We set the depreciation rate on capital at $\delta = 0.02$, which implies an annual rate of 8 percent. We set the parameter on the adjustment cost of investment $\xi_k$ at 0.6, the value of which is extensively used in the business cycle literature. The appropriate parameter on the adjustment cost of land is difficult to obtain, and so we use this parameter as a shift parameter. We set parameters for the labor supply function, $B$ and $\sigma$ to be unity and 1.01.

We set the entrepreneur’s “loan-to-land-value ratio at $m = 0.7$, which reflects the business practice and tradition in the Japanese banking industry. 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).

We set the “statistical” capital income share at $\alpha = 0.362$, 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 $\gamma$ is attributed only to “real” capital. We set $\gamma$ to meet $K/Y \approx 4.7$, 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 $\sigma = 1/2$. Following the estimation of the previous section, we examine three values for the elasticity of substitution of land and capital, $1/3, 1/2$, and 1. The coefficient of the

---

8 We do not apply a Bayesian approach to look for parameter values because quarterly data are not available for several data in the land market.

9 Iacoviello (2005) uses the same value for the US economy.
autocorrelation $\rho_A$ is set at 0.8. The list of parameters values we set is shown at Table 6.

The loan interest rate in the contractual arrangement that appears in (7) is specified before the productivity shock is revealed, and is different from the one actually repaid to investors. We motivate the inertia of loan rates in the lending practice, and calculate the loan interest rate by assuming that creditors set the same rate as the rate realized one period before.

B. Transmission Mechanism

The asset price channel is anticipated to add further amplification effects to financial accelerator through the endogenous fluctuation of the evaluation of assets used as collateral. We first consider the effects of the technology shock, and secondly those of the investment-specific shock. Hereafter all the figures illustrate impulse responses to a one percent positive productivity shock. Solid impulses represent the credit constrained economy, and dotted ones the frictionless economy.

Figures 3-5 illustrate the effects of a one percent positive technology shock. Figure 3 presents the case when firms incur neither adjustment cost of investment nor land.\(^{10}\) In Figure 3A, the impulse of investment shows the greater amplification effect as the elasticity of substitution $\sigma$ declines from 1 to $1/2$, and to $1/3$. In Figure 3B, the impulses of capital make the differential effects more transparent. Financial friction may or may not dampen investment, depending on the elasticity of substitution. Financial friction dampens investment in the Cobb-Douglas case ($\sigma = 1$), but amplifies investment in cases of $\sigma = 1/2$ and $\sigma = 1/3$.

In Figure 3C, the impulses of the land price show greater effects as $\sigma$ declines. The land allocation illustrate interesting impulses In Figure 3D, firms sell land in the Cobb-Douglas case, but purchase land in other two cases, as has been predicted by the previous steady state analysis. In case of $\sigma = 1$, entrepreneurs find it easy to substitute

\(^{10}\) We set the parameter of the adjustment cost of land at $\xi_L = 0.1$ for MATLAB calculation.
land by capital, and choose to sell land to gain the cash flow to finance investment in capital in the dynamic process. By contrast, in cases of $\sigma = 1/2$ and $1/3$, entrepreneurs find it difficult to substitute land by capital, but rather choose to serve land as collateral by buying land. In Figure 3E, borrowers’ net worth declines rapidly for $\sigma = 1$, but slowly for small $\sigma$’s. The impulses of borrowers’ net worth reflect the differential behavior in the land allocation, capturing the differential investment dynamics. In Figure 3F, the impulses of output show the small effect of the financial accelerator. Even in cases of $\sigma = 1/2$ and $1/3$, the output increase from financial accelerator is very small.

Figure 4 presents the impulse responses when firms incur the adjustment costs of investment and land, i.e. $\xi_c = 0.5$ and $\xi_c = 1$. In Figure 4A, we find greater amplification effects of financial accelerator. The quantitative effect is greater as $\sigma$ is small. Note that the impulses of investment exhibit a hump-shaped behavior. In Figure 4B, for $\sigma = 1/2$, the magnitude of capital stock at peak is about twice relative to the frictionless economy, and for $\rho = 1/3$ beyond three times. Interestingly, the adjustment cost dampens investment in the frictionless economy, but stimulates investment in the credit constrained economy. The interaction of the adjustment cost and financial friction reinforces the amplification effect.

The adjustment cost of investment does not change the impulse of the land price so much, but does change the land reallocation. The adjustment cost of investment promotes more purchase of land by firms, particularly in early periods. In Figure 4C, for $\sigma = 1/3$, the net increase in land holding is about three times at peak relative to the no adjustment cost case depicted in Figure 3D. Interestingly, in case of $\sigma = 1$, absent the adjustment cost, firms sell land, but now firms purchase land. Figure 4E illustrates the greater and more persistent impulses of net worth than the no adjustment cost case depicted in Figure 3E.

In the presence of adjustment cost of investment, firms find it difficult to invest in capital quickly, and instead buy more land in earlier periods. In subsequent periods firms use the greater land holding to raise more loans to finance investment.
Consequently, the adjustment cost of investment enables financial accelerator to work strongly and persist for long. In Figure 4F, the impulses of output show the large effect of financial accelerator. In case of \( \sigma = 1, 1/2, \text{and} \ 1/3 \), the output increases by 1.4%, 1.9%, and 1.8% at peak in the credit-constrained economy, while it does by 1.3%, 1.3%, and 1.1% in the frictionless economy.

Figure 5 presents the impulse responses when the adjustment cost of land varies from \( \xi_L = 0 \) to 1 and 5. We take \( \xi_K = 0.5 \) for the adjustment cost of investment. Here we illustrate the case for \( \sigma = 1/2 \). In Figure 5A, we find that investment peak out earlier and later declines more quickly as the adjustment cost of land is greater. The presence of adjustment cost of land prevents the land price from boosting (see Figure 5C), making land more immobile (see Figure 5D), weakening the asset price effect. Figure 5E captures the declining effect of net worth. This experiment indicates an important role of the reallocation of a collateralized asset as a transmission of the asset price channel.

Figure 6 illustrates the effects of a one percent positive investment-specific shock for the case when firms incur the adjustment costs of investment and land, i.e. \( \xi_K = 0.5 \) and \( \xi_L = 1 \). In Figure 6A, the impulse of investment shows the greater amplification effect as the elasticity of substitution \( \sigma \) declines, but the smaller effect than the frictionless economy. Investment exhibits the cyclical behavior, first the boom followed by the slump. In Figure 6B, the impulses of capital. Unlike the case for the technology shock, financial friction depresses investment. Figures 6C-D illustrate the impulses of land. The land price first declines, and gradually rises. Land is reallocated from firms to households. Firms react to a positive investment-specific shock by increasing investment and decreasing the demand for land. The adjustment for input replacement is more sluggish as \( \sigma \) goes down. When the elasticity of substitution is low, a rise in investment should be followed by the supply of the small amount of land. As Figure 6E illustrates, the decline in the market valuation of land holding leads to the decline in net worth. As Figure 6F illustrates, the investment-specific shock first stimulates investment and output, but later the collateral constraint that has turned out to work adversely.
depresses investment and output. The decline in output is greater as \( \sigma \) is so small that input replacement is sluggish.

5. Conclusion

This paper highlights three factors as generating the strong quantitative effect of the asset price channel in a credit-constrained economy, the small elasticity of substitution between capital and land in production, the adjustment cost of investment in capital, and the reallocation of the asset that serves as collateral toward credit-constrained agents. This finding gives some hint on evaluating the significance of the asset price channel as an amplification mechanism of financial accelerator.

One direction of research is to enrich the model to divide capital into tangible capital that serves as collateral and nontangible one that embodies high productivity but does not serve as collateral. This generalized model is anticipated to give rise to the stronger effect of financial accelerator than existing models of financial friction.

Other direction is to incorporate further channels of financial acceleration. In our model of imperfect enforcement both the loan and deposit rates of interest are the same, and there does not appear the channel through which the asset price affects the risk premium measured by the difference between both rates. One way is to use the costly-state-verification model, as in Bernanke, et al (1999).

References


Sha.


**Appendix**

We give brief explanations how the data series are constructed to estimate the elasticity of substitution between capital and land, $\sigma$. All data are annual, running from 1970 to 2009.
Construction of capital stock ($K_t$)

We construct capital stock from fixed assets of non-financial corporation, obtained from sectoral balance sheet data on *Annual Report on National Account*. Non-financial corporations account for most of private investment in plant and equipment. The capital stock includes both equipment and structures. The data is based on 68SNA for 1970-1979, and on 93SNA for 1980-2009. Using a technique similar to that described inDavis (2008), we used nominal data on the stock of fixed assets and on the real holding gains/losses account to construct the price index of market value of capital stock for 1980-2009. Prior 1980, the data on neutral holding gains/losses account is not available. Instead, we used data on reconciliation account which sums up neutral holding gains/losses account, real holding gains/losses account, and other. Neutral holding gains/losses account is the largest in its proportion for almost all years. We obtain the quantity of capital stock by the stock of fixed asset deflated by the price index. (See the price index of capital stock.)

Construction of the price index of capital stock ($P_{K_t}$)

We construct the price index of market value of capital stock to obtain the quantity of capital stock; the price of 2000 year is set at unity. We check the robustness by using a different price index, which is the NIPA deflator for private investment in plant and equipment. Figure A1 shows these two capital price indices.

Construction of the user cost of capital ($C_{K_t}$)

We construct the user cost of capital, following Kiyotaki and West (1996), by

$$C_{K_t} = P_{K_t} \frac{1 - \tau_z}{1 - \tau_t} \left[ 1 - \frac{\delta}{1 + i_{at}} \frac{E_t(P_{K_t+1})}{P_{K_t}} \right]$$

where $\delta$ is the depreciation rate, $1 + i_{at}$ is the nominal discount factor for the firm, $\tau_t$ is the effective corporate tax rate, $z_t$ is the present value of depreciation deductions per yen of new investment. We set the depreciation rate, $\delta$, at 0.08. The nominal discount factor for the firm, $1 + i_{at}$, is computed as the annual average of the prime loan
rates. We calculate the effective corporate tax rate, $\tau_r$, following Hayashi (1990), and Kiyotaki and West (1996), by 
$$\tau_r = \left[ \tau_{ct} (1 + \tau_i) + \tau_{gt} \right] \frac{1 + i_{st}}{1 + i_{st} + \tau_{gt}}$$, where $\tau_{ct}$ is the corporate tax rate on retained earnings, $\tau_{gt}$ is the enterprise tax rate, and $\tau_{lt}$ is the local tax rate. The present value of depreciation deductions per yen of new investment, $z_t$, is fixed at 0.571 through the whole sample. This value is the mean for 1970-1981 for the series calculated in Hayashi (1990). $E_t(\frac{P_{kt+1}}{P_{kt}})$ is the fitted value of an AR(1) process of $\frac{P_{kt+1}}{P_{kt}}$. We normalize this user cost of capital by output deflator, $P_{yt}=1$.

Construction of land ($L_t$) and land price ($P_{lt}$)

We construct the quantity of land and the price index of land, using the same way as constructing quantity and price index of the capital stock. This series come from land item in tangible non-produced asset of non-financial corporation. The volume of land held by non-financial corporation shows a gentle upward slope. The price index shows one peak at 1990.

We check the robustness by using another price index supplied by the Japan Real Estate Institute. We use annual average of the semi-annual values of weighted average of commerce and industrial uses of the index for all urban districts. The weight of land price is constructed by the following procedure. From Financial Statements Statistics of Corporation by Industry (Ministry of Finance), we obtain the value of land holding by industry. We treat the land holding by 5 industries (manufacturing, construction, electricity, power, gas & waterworks, information & telecommunication, transportation) as the industrial use, and the land holding by 4 industries (wholesale, retail, real estate, and services) as the commercial use. We get the land quantity of industrial use by land value of industrial use deflated by industrial land price index and the one of commercial use by land value of commercial use deflated by commercial land price index.

Figure A2 shows these two land price indices.
Construction of the user cost of land ($C_{Lt}$)

We construct the user cost of land, following Kiyotaki and West (2006), by

$$C_{Lt} = P_{Lt} \frac{1}{1 - \tau_t} \frac{\lambda + i_{at}}{1 + \tau_{Pt} + \tau_{ht}} \left( \frac{1 + i_{at}}{1 + \lambda \left( 1 + E\left( \frac{P_{Lt+1}}{P_{Lt}} \right) \right)} - \frac{\left( 1 + \tau_t \right)}{\lambda + i_{at}} \frac{1 + E\left( \frac{P_{Lt+1}}{P_{Lt}} \right)}{1 + E\left( \frac{P_{Lt+1}}{P_{Lt}} \right)} \right)$$

where $\tau_t$ is the effective corporate tax rate, $\tau_{Pt}$ is the tax on land acquisition, $\tau_{ht}$ is the tax on land holding, and $\lambda$ is the average period of time to hold a unit of land.

Kiyotaki and West (2006) assume that land is sold according to a Poisson process; with a constant, exogenous per period probability of sale of $\lambda$ that lies between zero and one. This is a tractable but admittedly crude way of capturing turnover in land holding. Following Kiyotaki and West (2006), we set $\lambda$ at 0.10, implying the holding period is 10 years. $E\left( \frac{P_{Lt+1}}{P_{Lt}} \right)$ is the fitted value of an AR(1) of $\left( \frac{P_{Lt+1}}{P_{Lt}} \right)$. Note we normalize this user cost by output deflator $P_{yt}=1$. 
Table 1. OLS estimation results

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable: ( \log \left( \frac{K_{t}}{L_{t}} \right) )</td>
<td>Const.</td>
<td>Const., trend</td>
<td>Const., trend</td>
<td>Const., trend</td>
<td>Const.</td>
</tr>
<tr>
<td>( \log(\frac{C_{k,t}}{C_{L,t}}) )</td>
<td>-0.664</td>
<td>-0.334</td>
<td>-0.345</td>
<td>-0.365</td>
<td>-0.365</td>
</tr>
<tr>
<td>(0.137)</td>
<td>(0.028)</td>
<td>(0.021)</td>
<td>(0.020)</td>
<td>(0.016)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>( \log(\frac{FDI_{t}}{GDP_{t}}) )</td>
<td>-0.109</td>
<td>-0.073</td>
<td>-0.036</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.020)</td>
<td>(0.016)</td>
<td>(0.018)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log(\frac{Secondary_{t}}{Tertiary_{t}}) )</td>
<td>-1.125</td>
<td>-0.853</td>
<td>-1.556</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(0.173)</td>
<td>(0.153)</td>
<td>(0.037)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj.R-square</td>
<td>0.366</td>
<td>0.978</td>
<td>0.987</td>
<td>0.990</td>
<td>0.993</td>
</tr>
<tr>
<td>D-W statistics</td>
<td>0.037</td>
<td>0.258</td>
<td>0.841</td>
<td>0.768</td>
<td>1.252</td>
</tr>
</tbody>
</table>

Note that \( \log \left( \frac{FDI}{GDP} \right) \) is logarithm of foreign direct investment from Japan to overseas per GDP, and \( \log(\frac{Secondary}{Tertiary}) \) is logarithm of the ratio of value-added produced by secondary industry (construction and manufacturing) to value-added produced by tertiary industry (electricity, power, gas & waterworks, wholesale, retail, real estate, transportation and information & telecommunication). The value in parentheses shows the standard error.
Table 2. Unit Root Tests

<table>
<thead>
<tr>
<th></th>
<th>log($\frac{K_t}{L_t}$)</th>
<th>$\log\left(\frac{C_{kt}}{C_{Lt}}\right)$</th>
<th>$\log\left(\frac{FDI_t}{GDP_t}\right)$</th>
<th>$\log\left(\frac{\text{Tertiary}}{\text{Secondary}}\right)$</th>
<th>5% critical value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternative hypothesis : Trend-stationarity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF0</td>
<td>-0.050”</td>
<td>-0.558</td>
<td>-2.554</td>
<td>-2.075</td>
<td>-3.530</td>
</tr>
<tr>
<td>ADF1</td>
<td>0.108</td>
<td>-1.056”</td>
<td>-3.095”</td>
<td>-2.806”</td>
<td>-3.533</td>
</tr>
<tr>
<td>ADF2</td>
<td>-0.383</td>
<td>-0.652</td>
<td>-2.706</td>
<td>-2.629</td>
<td>-3.537</td>
</tr>
<tr>
<td>PP1</td>
<td>-0.138”</td>
<td>-0.727</td>
<td>-2.759”</td>
<td>-2.330</td>
<td>-3.530</td>
</tr>
<tr>
<td>PP2</td>
<td>-0.189</td>
<td>-0.783”</td>
<td>-2.796</td>
<td>-2.390”</td>
<td>-3.530</td>
</tr>
<tr>
<td>PP3</td>
<td>-0.200</td>
<td>-0.814</td>
<td>-2.831</td>
<td>-2.436</td>
<td>-3.530</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$\Delta \log\left(\frac{K_t}{L_t}\right)$</th>
<th>$\log\left(\frac{C_{kt}}{C_{Lt}}\Delta\right)$</th>
<th>$\Delta \log\left(\frac{FDI_t}{GDP_t}\right)$</th>
<th>$\Delta \log\left(\frac{\text{Tertiary}}{\text{Secondary}}\right)$</th>
<th>5% critical value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternative hypothesis : Trend-stationarity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADF0</td>
<td>-4.18</td>
<td>-3.964</td>
<td>-5.579</td>
<td>-4.229</td>
<td>-3.533</td>
</tr>
</tbody>
</table>

Note that the number of the row in ADF is the Augmented Dickey Fuller test statistics and the number of the row in PP is the Phillip and Perron(1988)’s test statistics. The number following ADF or PP denotes the order of lag.
Table 3. Cointegration test

A. Residual-based Augmented Dickey-Fuller tests

<table>
<thead>
<tr>
<th>variable</th>
<th>Residuals of eq.(5)</th>
<th>Residuals of eq.(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF0</td>
<td>-4.661</td>
<td>-3.781</td>
</tr>
<tr>
<td>ADF1</td>
<td>-3.345</td>
<td>-3.827</td>
</tr>
<tr>
<td>ADF2</td>
<td>-2.911</td>
<td>-3.817</td>
</tr>
<tr>
<td>ADF3</td>
<td>-4.026</td>
<td>-4.400</td>
</tr>
</tbody>
</table>

B. Johansen Cointegration test

<table>
<thead>
<tr>
<th>test</th>
<th>Maximum-eigenvalue</th>
<th>Trace</th>
</tr>
</thead>
<tbody>
<tr>
<td>r=0 vs r=1</td>
<td>32.652</td>
<td>72.403</td>
</tr>
<tr>
<td>r=1 vs r=2</td>
<td>21.405</td>
<td></td>
</tr>
<tr>
<td>r=0 vs r=1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>r=1 vs r=2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 95% critical value | 32.118 | 25.823 | 63.876 | 42.915 |
Table 4. Parameter Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta ) : discount factor for patient households</td>
<td>0.995</td>
<td>This implies a steady-state annualized real interest rate of 2 percent (one period is a quarter).</td>
</tr>
<tr>
<td>( \theta )</td>
<td>0.995</td>
<td>The discount factor for entrepreneur ( \theta \beta ) is 0.99.</td>
</tr>
<tr>
<td>( \alpha ) : share of “capital income”</td>
<td>0.362</td>
<td>This figure follows Braun and Waki (2006).</td>
</tr>
<tr>
<td>( \gamma ) : share of capital in “capital income”</td>
<td>0.85</td>
<td>This figure is inferred from the steady-state value at ( \sigma = 1/2 ).</td>
</tr>
<tr>
<td>( \delta ) : depreciation rate</td>
<td>0.02</td>
<td>An annual rate of depreciation on capital equal to 8%.</td>
</tr>
<tr>
<td>( \xi_K ) : parameter of adjustment cost of investment in capital</td>
<td>0 or 0.5</td>
<td>We set this figure extensively used in the literature on adjustment costs of investment.</td>
</tr>
<tr>
<td>( \xi_L ) : parameter of adjustment cost of land</td>
<td>0 , (0.1), 1 or 5</td>
<td></td>
</tr>
<tr>
<td>( \bar{N} ) : labor supply per household</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>( \phi ) : weight for housing in the households’ utility</td>
<td>0.1</td>
<td>This figure follows Iacoviello (2005), and is almost the same inferred from the steady-state value.</td>
</tr>
<tr>
<td>( m ) : entrepreneurs’ loan-to-land-value ratio</td>
<td>0.7</td>
<td>We choose this figure from hearing in the business practice.</td>
</tr>
<tr>
<td>( \rho_A ) : autocorrelation coefficient of productivity shock</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>( \rho_V ) : autocorrelation coefficient of investment-specific shock</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>( B ) : a parameter of disutility of labor</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>( \sigma ) : a parameter of disutility of labor</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>( L ) : endowment of land</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
Figure 3. Impulse Responses to positive 1% productivity shock when chi_K = 0 and chi_L = 0.1

- 3A. Investment
- 3B. Capital
- 3C. Land Price
- 3D. Land Allocation (held by entreprenuers)
- 3E. Borrower's Net Worth
- 3F. Output

Legend:
- Solid line: credit constraint economy
- Dashed line: frictionless economy
- Green line: \sigma = 1
- Red line: \sigma = \frac{1}{2}
- Blue line: \sigma = \frac{1}{3}
Figure 4. Impulse Responses to positive 1% productivity shock when \( \chi_K = 0.5 \) and \( \chi_L = 1 \)

4A. Investment

4B. Capital

4C. Land Price

4D. Land allocation (held by Entrepreneurs)

4E. Borrower’s Net worth

4F. Output

- Credit-constraint economy
- Frictionless economy
- \( \sigma = 1 \)
- \( \sigma = 1/2 \)
- \( \sigma = 1/3 \)
Figure 5. Impulse Responses to positive 1% productivity shock at \( \sigma=1/2 \) when \( \chi_K=0.5 \) and various \( \chi_L \):

- 5A. Investment
- 5B. Capital
- 5C. Land Price
- 5D. Land Allocation (held by Entrepreneurs)
- 5E. Borrower’s Net Worth
- 5F. Output

\[ \chi_L=0 \quad \chi_L=1 \quad \chi_L=5 \quad \text{: credit constraint economy at } \sigma=1/2 \]
Figure 6. Impulse Responses to positive 1% investment-specific shock when $\chi_K = 0.5$ and $\chi_L = 1$

6A. Investment

6B. Capital

6C. Land Price

6D. Land Allocation (held by Entrepreneurs)

6E. Borrower’s Net Worth

6F. Output

Legend:
- Blue dashed line: credit constraint economy
- Red dashed line: $\sigma = 1/2$
- Green dashed line: $\sigma = 1/3$
- Black line: frictionless economy
Figure A1. Capital Price Indices

Figure A2. Land price indices