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Technological Substitution between Capital and Land*

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Abstract

We estimate the elasticity of substitution between capital and land in production by using the Japanese data during 1970 - 2009. We find that the estimate of the elasticity is about 0.35, significantly less than unity. This result suggests that the relation between capital and land is more complementary than the prediction of the Cobb-Douglas production function.

Keywords: elasticity of substitution, land, Japan

JEL classification codes: E23

1. Introduction

There is much literature that raises questions about the Cobb-Douglas type's production function. Arrow, Chenery, Minhas and Solow (1961) has doubts about a unitary elasticity of substitution between capital and labor, and estimates the elasticity in various countries. Chirinko (2002, 2008) surveys the research about the elasticity of substitution between capital and labor. Turnovsky (2008) investigates the role of the elasticity of substitution in economic growth and income distribution.

Kiyotaki and Moore (1997) presents a financial accelerator model in which land, as well as

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capital, is used as input for production[(1),(2)]. Kocherlakota (2000), Arias (2003), Cordoba and Ripoll (2004), and Liu, Wang and Aha (2010) apply the Kiyotaki and Moore type's DSGE analysis and investigate the effect of the mechanism quantitatively. They all use the Cobb-Douglas production function and report small amplification effects of the TFP shock[(3)]. Sakuragawa and Sakuragawa (2011) shows, however, that the elasticity of substitution is one of primary elements to decide on the size of amplification and propagation effect of the TFP shock. The Cobb-Douglas technology implicitly assumes that firms find it easy to substitute among capital and other inputs. However, because the substitution usually happens gradually and takes time, capital and land are expected to more complementary in production.

Although the elasticity of substitution between capital and land is one of the deep parameters in Kiyotaki and Moore type's DSGE model, only a few studies estimate the elasticity. Kiyotaki and West (2006) infers the elasticity to be a little greater than one in their VAR estimation using Japanese aggregate data. Ogawa (2010) 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.

In this paper, we estimate the elasticity of substitution between capital and land, by using the Japanese data from the period during 1970 to 2009. To estimate the elasticity of substitution, we regress of the capital-land ratio on the ratio of their user costs. Since the results of the unit-root tests and cointegration tests suggest that this regression would be the spurious regression, we add three explanatory variables; outward foreign direct investment, the ratio of the value-added produced by the secondary industry to the one by the tertiary industry, and time trend. We finally obtain the result that the estimate of elasticity is about 0.35, significantly less than unity. This result suggests that the relation between capital and land is more complementary than the prediction of the Cobb-Douglas production function.

There is much literature that demonstrates the importance of land in the macro economy. The movements of land prices have received researchers' attention in the analysis of Japanese

(1) Financial Accelerator theory originated with Bernanke and Gertler (1989). This clarifies a mechanism in the general equilibrium framework that the changes of financial conditions are in themselves a major factor changing economic activities. See Bernanke, Gertler and Grichrist (1999).

(2) A key factor of Kiyotaki and Moore (1997)'s model is that land is used a production factor as well as a collateral for financing. Asset price is decided endogenously in their model, and any shock amplifies and propagates the business cycles through the interaction between asset price and economic activity.

(3) Iacoviello (2005) and Liu, Wang and Aha (2010) report significant effects of the demand and financial shocks.

macro economy, because Japanese economy has tossed in the drastic movements of land price. A number of empirical researches report the important role of land prices. Ogawa, et al. (1996), Ogawa and Kitasaka (1998), and Ogawa and Suzuki (1998), Kiyotaki and West (2006) analyze the link between land prices and business investments. Kwon (1998), Bayoumi (2001), and Sakuragawa and Sakuragawa (2007) report the VAR-based response functions of aggregate variables including the land price, finding the important role of movements of land prices. Not only in Japan, but also in other Asian countries, the importance of the property prices in the macro economy has been recognized(4).

This paper is organized as follows. In section 2, we set up our model. In section 3, we analyze the model and show the measure of the elasticity of substitution between capital and land. In section 4, we describe the data. In section 5, we show the estimation results. Section 6 concludes.

2. Model

Firm produces the final good Y_t by employing labor N_t, capital K_t, and land L_t. Capital and land are combined with the constant elasticity of substitution (CES), and compose the "composite capital". Labor and the "composite capital" are combined with the Cobb-Douglas form. Focusing on the elasticity of substitution between capital and land is motivated to capture the situation where firms will react to shocks by changing the capital/land ratio less quickly over the business cycle than the capital/labor ratio. We consider the following quasi-CES type technology;

$$(1)\quad Y_t = A_t N_t^{1-\alpha}\left[\gamma K_t^{\frac{\sigma-1}{\sigma}} + (1-\gamma) L_t^{\frac{\sigma-1}{\sigma}}\right]^{\alpha\frac{\sigma}{\sigma-1}},$$

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 $Y_t=A_t N_t^{1-\alpha} K_t^{\gamma\alpha} L_t^{(1-\gamma)\alpha}$. 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

(4) For example, Liang and Cao (2007) analyze the relation between property price and lending in China, and Koh et al., (2005) analyze the relation in Asian countries.

capital and land are completely complementary. Capital evolves as

(2) $K_t = (1-\delta) K_{t-1} + I_t$,

where I_t is investment and δ is the depreciation rate.

3. Analysis

The cost minimization of firms facing the production function (1) is the following;

$$\min_{N,\,K,\,L} E_t \sum_{j=0}^{\infty} \beta^j [W_{t+j} N_{t+j} + P_{K,t+j} I_{t+j} + P_{L,t+j}(L_{t+j} - L_{t+j-1})],$$

s.t., (1) and (2). To keep the algebra uncluttered, we abstract from taxes, although these will be accounted for in our empirical work.

First-order conditions are the following;

(3) $\dfrac{\partial Y_t}{\partial N_t} = W_t$,

(4) $\dfrac{\partial Y_t}{\partial K_t} = P_{K,t} - (1-\delta) E_t \beta P_{K,t+1}$, and

(5) $\dfrac{\partial Y_t}{\partial L_t} = P_{L,t} - E_t \beta P_{L,t+1}$,

where $\dfrac{\partial Y_t}{\partial N_t} = (1-\alpha)\dfrac{Y_t}{N_t}, \dfrac{\partial Y_t}{\partial K_t} = \alpha \dfrac{Y_t}{K_t}\mu_t, \dfrac{\partial Y_t}{\partial L_t} = \alpha \dfrac{Y_t}{L_t}(1-\mu_t)$,

$\mu_t \equiv \dfrac{\gamma K_t^{\frac{\sigma-1}{\sigma}}}{\gamma K_t^{\frac{\sigma-1}{\sigma}} + (1-\gamma) L_t^{\frac{\sigma-1}{\sigma}}}$, and $1-\mu_t \equiv \dfrac{(1-\gamma) L_t^{\frac{\sigma-1}{\sigma}}}{\gamma K_t^{\frac{\sigma-1}{\sigma}} + (1-\gamma) L_t^{\frac{\sigma-1}{\sigma}}}$. We define user costs of capital and land by $C_{K,t} \equiv P_{K,t} - (1-\delta) E_t \beta P_{K,t+1}$ and $C_{L,t} \equiv P_{L,t} - E_t \beta P_{L,t+1}$. Thus, we

obtain $\dfrac{\gamma}{1-\gamma}\left(\dfrac{K_t}{L_t}\right)^{-\frac{1}{\sigma}} = \dfrac{C_{K,t}}{C_{L,t}}$.

Rearranging this equation, and adding the error term, we finally obtain the following equation;

(6) $\log\left(\dfrac{K_t}{L_t}\right) = \alpha_0 - \sigma \log\left(\dfrac{C_{K,t}}{C_{L,t}}\right) + \varepsilon_t$,

where α_0 is a constant.

4. Data description

In this section, we describe the data. In order to obtain the estimate of the elasticity of substitution between capital and land, σ, using (8), we need the data series for quantities and prices of capital stock and land. We apply the Japanese non-financial corporation to estimate. We construct the data in Davis (2008)'s way, by using mainly the sectoral balance sheet data in on *Annual Report on National Account*, published by Cabinet Office, Government of Japan for 1970-2009 (the data on 68SNA for 1970-1979, and the one on 93SNA for 1980-2009). Our data also reflect some public corporation(5). Our data are annual.

4-1. Capital stock (K_t), land (L_t) and the each price index (P_{Kt} and P_{Lt})

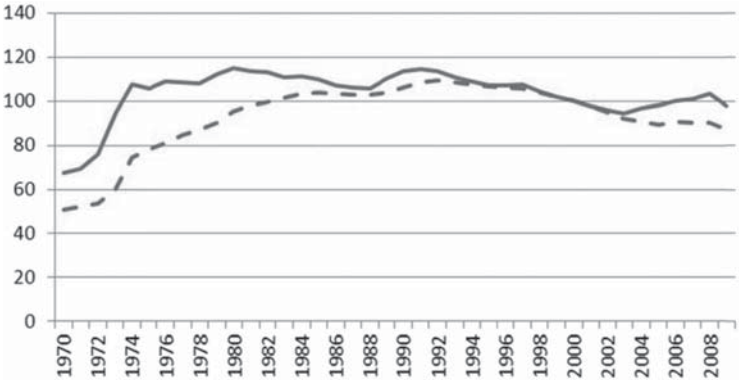
First, we explain the data construction about capital. We use the value series of capital stock, $P_{Kt} \cdot K_t$, from the data on "fixed assets" in the part of the "produced assets" at The Closing Balance Sheet Account Table. In addition, we use The Reevaluation Account Table, which is one of the sub-accounts of the reconciliation account(6). The reevaluation is composed of two accounts; one is the neutral holding gains and losses account, and the other is the real holding gains and losses account. The former account measures the changes of the value in the changes of the general price level and the latter account measures the changes of the value in the change of the relative price of the asset(7). We obtain the capital gain held to capital, $\Delta P_{Kt} \cdot K_{t-1}$, from this account. From these two data, we obtain the change rate of capital price, $\Delta P_{Kt}/P_{Kt-1}$. Normalizing the capital price in 2000 at 100, we obtain the series of capital price index. Then, using this capital price index and the value of capital, we obtain the series of

(5) Because the data of non-financial private corporations are available since 1980 when 93SNA started, we can confirm the ratio of the non-financial private sector to the non-financial sector. It is about 70 % of capital and about 95% of land in 1980.

(6) Reconciliation account is an adjustment summary of the differences between balance sheet and capital finance account. Reconciliation account is broken down into three sub-accounts, which are (a) other changes in volume of assets account, (b) reevaluation account, and (c) others.

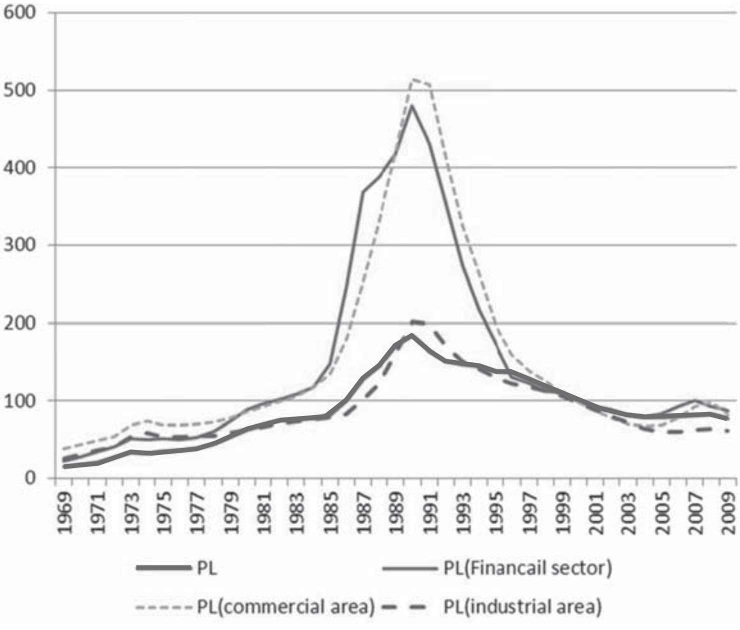
(7) The real holding gains and losses account is reported since 1980 at 93SNA, in Annual report on National account. This account isn't reported prior to 1980 at 68SNA, however.

Figure 1. Capital Price Indices



Note) The solid line shows the capital price index in the non-financial sector constructed in this paper. The dash line shows the NIPA deflator for private investment in plant and equipment.

Figure 2. Land Price Indices



Note) PL denotes the land price index in the non-financial sector constructed in this paper. For comparison, we show three differen nt indices. PL(financial sector) denotes the land price index in the financial sector which is constructed by the same method in section 3. The remainders are the indices reported by the Japanese Real Institute, and they are the price indices in commercial area (PL(commercial area)) and industrial area (PL(industrial area)), respectively.

quantity of capital (the quantity in 2000 is also normalized).

We show the capital price index (a solid line) at Figure 1. For comparison, we show the NIPA deflator for private investment in plant and equipment (a dash line) in this graph. We can see the sharp increase of price in the first half of 1970's, the movement relatively steady until in the first half of 1990's, the decline from that time to the first half of 2000's.

Next, we explain the data about land. We use the nominal value series of land, $P_{Lt} \cdot L_t$, from the data on "land" in the part of the "tangible non-produced assets" at The Closing Balance Sheet Account Table, and the capital gain held to land, $\Delta P_{Lt} \cdot L_{t-1}$, from The Revaluation Accounts of the reconciliation tables. Applying the same method as for capital stock and capital price index, we obtain the quantity of land and the real land price index.

We show the land price index (a bold solid line) in Figure 2. For comparison, we show three different indices, the one in the financial sector which is constructed by the same method in section 3, the one in commercial area reported by the Japanese Real Institute, and the one in industrial area reported by the Japanese Real Institute. We find the movements of land price index in the non-financial sector are similar to the one in industrial area.

4-2. User costs of capital (C_{Kt}) and of land (C_{Lt})

Following Kiyotaki and West (1996), we construct the user costs of capital and land.

User cost of capital is calculated from

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

where δ is the depreciation rate, $1+i_{\alpha t}$ is the (gross) nominal discount factor for the firm, τ_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, δ, at 0.08. The nominal discount factor for the firm, $1+i_{\alpha t}$, is computed as the annual average of the prime loan rates.

We calculate the effective corporate tax rate, τ_t, following Hayashi (1990), by

$\tau_t = [\tau_{ct}(1+\tau_{lt})+\tau_{gt}]\dfrac{1+i_{\alpha t}}{1+i_{\alpha t}+\tau_{gt}}$, where τ_{ct} is the corporate tax rate on retained earnings, τ_{gt} is the enterprise tax rate, and τ_{lt} is the local tax rate. Table 1 shows these tax rates in Japan, which is reported by Ministry of Finance.

The present value of depreciation deductions 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). $E_t\left(\frac{P_{Kt+1}}{P_{Kt}}\right)$ is the fitted value of an AR(1) process of $\left(\frac{P_{Kt+1}}{P_{Kt}}\right)$.

Table 1. Tax rates (%)

	Corporate tax rate on retained earnings (τ_{ct})	Enterprise tax rate (τ_{gt})	Local tax rate (τ_{lt})	
			municipality	prefecture
1970	36.75	12	8.9	5.8
1971			9.1	5.6
|	↓			
1974	40		↓	↓
1975			12.1	5.2
|	↓			
1981	42		↓	↓
1982			12.3	5
|	↓			
1984	43.3			
|	↓			
1987	42			
|	↓			
1989	40			
1990	37.5			
|	↓			
1998	34.5			
1999	30			
|				
2009	↓	↓	↓	↓

Data sources) Policy Research Institute, Ministry of Finance Japan, "Zaisei Kinnyu Tokei Geppou (in Japanese), vol.696 (2010.4)."

The user cost of land is calculated from

$$C_{Lt} = P_{Lt}\frac{1}{1-\tau_t}\frac{\lambda+i_{\alpha t}}{1+i_{\alpha t}}\left[1+\tau_{Pt}+\tau_{ht}\frac{(1+i_{\alpha t})\left\{1+E_t(P_{Lt+1}/P_{Lt})\right\}}{i_{\alpha t}+\lambda\left\{1+E_t(P_{Lt+1}/P_{Lt})\right\}-E(P_{Lt+1}/P_{Lt})}\right.$$
$$\left.-\lambda\left\{\frac{\tau_t}{\lambda+i_{\alpha t}}+\frac{(1-\tau_t)\left\{1+E_t(P_{Lt+1}/P_{Lt})\right\}}{i_{\alpha t}+\lambda\left\{1+E_t(P_{Lt+1}/P_{Lt})\right\}-E_t(P_{Lt+1}/P_{Lt})}\right\}\right]$$

where τ_t is the effective corporate tax rate, τ_{Pt} is the tax on land acquisition, τ_{ht} is the tax on land holding(8). The parameter λ is the average period of time to hold a unit of land. We assume that land is sold according to a Poisson process; with a constant, exogenous per period probability of sale of λ that lies between zero and one. This is a tractable but admittedly crude way of capturing turnover in land holding. We set λ at =0.10, implying the holding period is 10 year. $E_t\left(\frac{P_{Lt+1}}{P_{Lt}}\right)$ is the fitted value of an AR(1) of $\left(\frac{P_{Lt+1}}{P_{Lt}}\right)$.

5. Estimation Results

First, we examine time-series properties on each of the series. Table 2 and Table 3 report a summary of the unit root test results on each of the series and the results of cointegration tests. We run the augmented Dickey-Fuller (1979) 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 Table 2 that for neither of the series in levels the test results reject the null hypothesis of a unit root, and for both in the first difference the test results do not reject the null hypothesis. These results indicate that each of these two series follows $I(1)$ process. Next, we proceed to the cointegration analysis to see whether there exists a long-run cointegrating relationship between $\log(K_t/L_t)$ and $\log(C_{Kt}/C_{Lt})$. We run the residual-based Augmented Dickey-Fuller test, suggested by Engle and Granger (1987) and Johansen (1991, 1995)'s cointegration tests. The row (1) of Table 3 shows the result of residual-based Augmented Dickey-Fuller test of the null of no co-integration. The test assumes that some variables in the system contain a constant and a time trend. The test results cannot reject the null of no cointegration. In the row (2) of Table 3, we show the results of Johansen maximum-eigenvalue tests and trace tests, which test the null hypothesis of the existence of no cointegration against the alternative of the existence of one cointegrating vector, and the null hypothesis of the existence of one cointegrating vector. We choose a model with a constant and a linear deterministic trend in data and with two lags of the first difference of the variables in the estimation. The null hypothesis of zero cointegrating vectors cannot be rejected, and the null hypothesis of one cointegrating vector cannot be rejected.

(8) For acquisition of land, the real estate acquisition tax and the registration license tax are imposed at 3% and 2.8% respectively for whole estimation period. Since 1974, the special land holding tax is imposed at 3% for land acquisition. For the holding land, the fixed property tax (national tax) and the city planning tax (local tax) are imposed at 1.4% and 0.3% respectively for whole estimation period. Since 1974, the special land holding tax is imposed at 1.4% for land holding. Furthermore, the land value tax is imposed at 0.3% during 1993-1998 for land holding.

Table 2. Unit root test results

Variable	ADF	PP
(a) level		
$\log(K/L)$	−0.05(0)	−0.14(1)
$\log(C_K/C_L)$	−1.06(1)	−0.78(2)
(b) first difference		
$\Delta\ \log(K/L)$	−4.18(0)**	−4.18(0)**
$\Delta\ \log(C_K/C_L)$	−3.28(0)**	−3.29(1)**

Note) This table reports statistics testing for a unit root for $\log(K/L)$ and $\log(C_K/C_L)$. ADF is the augmented Dickey-Fuller (1979) test of a unit root against no unit root, and PP is a Phillip and Perron (1988) test. A constant and a time trend are included for series in levels and logged capital over land series in first differences (i.e. detrended test). A constant is included for logarithm the ration of user costs of capital to land in the first differences (i.e. *demeaned* test). The optimal lag length is chosen based on the SBIC in ADF test and on the Newey. West bandwidth in PP test, and the length is shown in parentheses. The sample period is 1970-2009. Critical values are, tabulated by MacKinnon (1996):

	10% (*)	5% (**)	1% (***)
Detrended test (ADF, PP)	−3.20	−3.53	−4.21
Demeaned test (ADF, PP)	−2.61	−2.94	−3.62

Table 3. Cointegration Test Results for $\log(K/L)$ and $\log(C_K/C_L)$

	Statistics	[5% critical value]
(1) Residual-based augmented Dickey-Fuller test	−1.885	[−3.80]
(2) Johansen Cointegration tests		
(a) Maximum-eigenvalue test		
Hypothesis		
No cointegration against one cointegration	9.45	[19.39]
One cointegration against two cointegration	5.40	[12.52]
(b) Trace test		
Hypothesis		
No cointegration against one cointegration	14.85	[25.87]
One cointegration against two cointegration	5.40	[12.52]

Note) ADF is the augmented Dickey-Fuller (1979) test of a no cointegration against cointegration to the residuals, suggested by Engle and Granger (1987). We assume that some variables in system contain a constant and a time trend. The lag length is one, chosen on the basis of the SBIC. Critical values are tabulated by Phillips and Ouliaris (1990).

Maximum-eigenvalue test and trace test are developed by Johansen (1991, 1995). All the tests assume linear deterministic trend. Two lags are arbitrarily used. Critical values are given by MacKinnon-Haug-Michelis (1999).

The symbols *, ** and, *** show the null hypothesis is rejected significantly at 10%, 5% and 1% respectively.

The estimation result by the OLS is shown at the first column of Table 4. The estimate $\hat{\sigma}$ lies between zero and one, but the Durbin-Watson statistics are low, as the results of a unit-root test and cointegration tests suggest. Thus, the OLS estimate for the coefficient seems biased. In this situation, OLS estimates will not be consistent unless a linear combination of the dependent and independent variables is stationary.

Table 4. OLS estimation results

	Dependent variable:	log(K/L)
$\log(C_K/C_L)$	−0.664	−0.365
	(0.137)	(0.016)
$\log(FDI/GDP)$	—	−0.073
		(0.016)
$\log(Secondary/Tertiary)$	—	−0.853
		(0.153)
constant	Yes	Yes
trend	No	Yes
Adj.R-square	0.366	0.993
D-W statistics	0.037	1.252

Note) that $\log(K/L)$ is logarithm of capital over land, $\log(C_K/C_L)$ is logarithm of the ratio of user costs of capital and land, log (FDI/GDP) is logarithm of foreign direct investment from Japan to overseas per GDP, and $\log(Secondary/Tertiary)$ is logarithm of the ratio of value-added produced by the secondary industry to value-added produced by the tertiary industry. The values in parentheses show the standard errors.

Next we consider the possibility of omitted variables. We add three variables to (6); outward foreign direct investment, the ratio of the secondary industry to the tertiary one, and time trend. The estimation equation is the following;

$$(7)\quad \log\left(\frac{K_t}{L_t}\right)=\alpha_0-\sigma\log\left(\frac{C_{Kt}}{C_{Lt}}\right)+\alpha_1\log\left(\frac{FDI_t}{GDP_t}\right)+\alpha_2\log\left(\frac{Secondary_t}{Tertiary_t}\right)+\alpha_3 trend_t+\varepsilon_t$$

where $\log(FDI_t/GDP_t)$ is the logarithm of outward foreign direct investment divided by GDP, $\log(Secondary_t/Tertiary_t)$ is the logarithm of the ratio of the value-added produced by the secondary industry to the one by the tertiary industry. When foreign direct investment is allowed for, land-intensive firms tend to change the location from home to foreign countries for taking the advantage of cheaper land prices. On the other hand, capital-intensive firms tend to change the location for the higher rate of return to capital. The former effect tends to make the coefficient α_1 positive, but the latter negative. Next, the secondary industry is more capital-intensive than the tertiary industry, and the change in the industry structure will change the capital-land ratio at the aggregate level. The coefficient α_2 is expected to be negative. Finally, the time trend captures the biased technological change(9). A detailed explanation of these data is provided in Appendix A.

We examine the time-series characters on each of the series. Table 5 reports a summary of the unit root test results on the series, $\log(FDI_t/GDP_t)$ and $\log(Secondary_t/Tertiary_t)$. It is clear from the Table 5 that for neither of the series in levels the test results reject the null hypothesis of a unit root, and for both in the first difference the test results do not reject the null hypothesis. We proceed to the cointegration analysis to see whether there exists a long-run cointegrating relationship among $\log(K_t/L_t)$, $\log(C_{Kt}/C_{Lt})$, $\log(FDI_t/GDP_t)$ and $\log(Secondary_t/Tertiary_t)$. The row (1) of Table 6 shows the results of residual-based Augmented Dickey-Fuller test of the null of no co-integration. The test assumes that some variables in system contain a constant and a time trend. The test results can reject the null of no cointegration at 10% level. In the row (2) of Table 5, we show the results of Johansen maximum-eigenvalue test and trace test. We choose a model with a constant and a linear deterministic trend in data and with two lag of the first difference of the variables in the estimation. The maximum-eigenvalue tests and the trace tests show that the null hypothesis of zero cointegrating vectors can be rejected against one cointegrating vector at 5% significant

Table 5. Unit root test results

Variable	ADF	PP
(a) level		
$\log(FDI/GDP)$	−3.10(1)	−2.76(1)
$\log(Secondary/Tertiary)$	−2.81(1)	−2.39(2)
(b) first difference		
$\Delta\log(FDI/GDP)$	−5.60(0)***	−5.60(1)***
$\Delta\log(Secondary/Tertiary)$	−4.31(0)***	−4.34(1)***

Note) This table reports statistics testing for a unit root for $\log(FDI/GDP)$ and $\log(Secondary/Tertiary)$. See the note below table 2 for the explanation for ADF and PP. A constant and a time trend are included for series in levels (i.e. *detrended* test). A constant is included for series in the first differences (i.e. *demeaned* test). Critical values are:

	10% (*)	5% (**)	1% (***)
Detrended test (ADF, PP)	−3.20	−3.53	−4.21
Demeaned test (ADF, PP)	−2.61	−2.94	−3.62

(9) See Antras (2004) for the biased technical change.

Table 6. Cointegration Test Results for $\log(K/L)$, $\log(C_K/C_L)$, $\log(FDI/GDP)$, and $\log(Secondary/Tertiary)$

	Statistics	[5% critical value]
(1) Residual-based augmented Dickey-Fuller test	−4.423*	[−4.49]
(2) Johansen Cointegration tests		
(a) Maximum-eigenvalue test		
Null Hypothesis		
No cointegration against one cointegration	33.81**	[32.12]
One cointegration against two cointegration	20.12	[25.82]
Two cointegration against three cointegration	11.61	[19.39]
Three cointegration against four cointegration	8.31	[12.52]
(b) Trace test		
Null Hypothesis		
No cointegration against one cointegration	73.85**	[63.88]
One cointegration against two cointegration	40.04*	[42.91]
Two cointegration against three cointegration	19.92	[25.87]
Three cointegration against four cointegration	8.31	[12.51]

Note) see footnote in Table 3.

level, and the null hypothesis of one cointegrating vector against two cointegrating vectors can be rejected at 5% significant level. We can conclude that there is one cointegrating equation among these variables and the OLS estimate are not interpreted spurious regression.

The OLS estimation results are shown at the left column of Table 4. The Durbin-Watson statistics are higher than the previous OLS estimation. We obtain the result that the estimate of the elasticity of substitution between capital and land, $\hat{\sigma}$, is 0.365, less than unity significantly. The estimates of $\log(FDI_t/GDP_t)$ and $\log(Secondary_t/Tertiary_t)$ are negative respectively. The increase of outward foreign direct investment reduces the capital-land ratio. The tendency that capital-intensive firms changed the location for the higher rate of return to capital dominated in Japan from 1970 to 2009. The expansion of the tertiary industry increases the capital-land ratio, as our expectation. The 1% increase in the ratio of the value-added produced by the tertiary industry to the one by the secondary industry leads to the 0.85% increase in the capital-land ratio.

6. Conclusion

In this paper, we estimate the elasticity of substitution between capital and land, using the Japanese annual data from 1970 to 2009. Our estimate of the substitution is about 0.35, significantly less than unity. This result suggests that the relation between capital and land is more complementary than the prediction of the Cobb-Douglas production function.

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Appendix A: Data description of log(FDI_t/GDP_t) and log($Secondary_t$/$Tertiary_t$)

-log(FDI_t/GDP_t)

This is the logarithm of outward foreigh direct investment divided by GDP. The series of outward foreign direct investment are constructed by combining three data sources. From 1969 to 1984, the series based on reports and notifications from Japan External Trade Organization (JETRO), from 1985 to 1995, the series based on balance of payment (before the revision) from Bank of Japan(BOJ) and from 1996 to 2010 the series based on balance of payment (after the revision) from BOJ. The series of GDP is obtained from National Accounts of Cabinet Office, Government of Japan.

-log($Secondary_t$/$Tertiary_t$)

This is the logarithm of the ratio of the value-added produced by the secondary industry to the one by the tertiary industry. The secondary industry consists of construction and manufacturing, and the tertiary industry consists of the following industries; electricity, power, gas & waterworks, wholesale, retail, real estate, transportation and information & telecommunication. Data are obtained from gross domestic product classified by economic activities from National Accounts of Cabinet Office, Government of Japan.