12. Land prices and business fixed investment in Japan*

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1. INTRODUCTION

Japan has seen episodes in which boom and bust in land prices have been accompanied by boom and bust in business fixed investment. This occurred in the late 1980s and the early 1970s. In this chapter we formally model the link between movements in land prices and in business investment, and use regressions to quantify the importance of the link. In the end, however, our estimates attribute relatively little of the movement in business fixed investment to movements in land prices.

Our model attempts to formalize the following intuition: when land prices rise due to (say) an increase in aggregate productivity, individual price-taking firms will try to economize on land by building taller structures and using more compact capital equipment. That is, all things equal, a rise in land prices will cause firms to shift towards technologies with higher ratios of capital to land. While our focus is on the behavior of a representative price-taking firm, we note that a similar shift may hold in the aggregate: in a class of growth models, an increase in aggregate productivity causes an increase in the aggregate capital–output ratio when the elasticity of substitution between capital and land is larger than one. That is, a rise in productivity will encourage business fixed investment above and beyond the usual direct effects through the cost of capital and output. A fall in aggregate productivity will have the opposite consequence.

To formalize our analysis of the link between land prices and investment, we work in the vein of the neoclassical investment model pioneered by Hall and Jorgenson (1967). We build in particular on our own work (Kiyotaki and West, 1996). We posit a dynamic model in which there are costs to adjusting capital. We depart from earlier work by assuming that land is a third factor of production, along with labor and capital. Land and capital enter the production function as a constant elasticity of substitution composite, with an elasticity that may not be one.

We log-linearize the first-order conditions for the model. The resulting expression for target capital generalizes in a natural way the target posited by Hall and Jorgenson: the 'user cost of land' joins output and the user cost of capital as determinants of target capital. Here, the 'user cost of land' adjusts land prices for taxes and the firm's opportunity cost of funds. If one abstracts from costs of adjustment, the decision rule has characteristics familiar from basic microeconomics: *ceteris paribus*, increases in the user cost of land will lead to increases in capital if and only if the elasticity of substitution is greater than one. In our dynamic model, which has costs of adjustment, the increase in capital takes the form of a long-run response to a permanent increase in the user cost of land.

We do not directly estimate the elasticity of substitution in our empirical work. But a calibration yields a positive value for a certain related parameter that is positive if and only if the elasticity is greater than one. The elasticity of substitution between land and capital exceeding one is also consistent with the stylized observation that the share of land in tangible assets has been declining over time in many developed countries (Eaton, 1988, p. 77).

Using the calibrated value, we estimate the decision rule implied by our model, using annual capital stock data for non-financial corporations during the period 1961–95. We find estimates of the land–capital relationship that are plausible. Increases in the user cost of land do cause increases in capital. Moreover, estimates of the decision rule are qualitatively similar whether we estimate it without restrictions or subject to the cross-equation restrictions implied by our model. But the quantitative effect of land on capital growth (on investment) is small. Mechanically, this appears to be attributable to the fact that our initial calibration is consistent with an elasticity only very slightly above one. And if the elasticity is exactly one, our model effectively reduces to a traditional neoclassical model, in which target capital depends only on output and the user cost of capital.

The theoretical and empirical results reported here are by no means definitive. The empirical counterparts to the variables in our model are not obvious, and standard data sources may not be adequate. It may be that with alternative measures of capital, land, or capital or land prices, our approach would yield an elasticity much greater than one, and thus suggest a more important role for land prices. And regardless of data problems, it is possible that there is a strong link between land prices and investment that cannot be modeled without considering frictions of some sort. One possibility is regulations, in particular on land use. A second is credit constraints (Ogawa et al., 1996; Kiyotaki, 1998).

It is a great honor for us to contribute this chapter to a volume in memory of Albert Ando. Albert's knowledge and advice about Japanese data were

vital to our earlier paper on Japanese investment (Kiyotaki and West, 1996). Albert played a somewhat more diffuse but even more important role as friend, mentor and fellow economist. Over the years, we discussed and debated topics ranging from rational expectations to Phillips curves to inventory models. One anecdote may illustrate the generous way Albert gave time to younger economists. One of us (West) first came in contact with Albert in connection with a Social Science Research Council grant received as a graduate student. Albert was co-chair of the committee that decided the award. The award notification included two pages of single-spaced comments signed by Albert – and this on a research proposal consisting of five double-spaced pages!

That generosity of spirit was complemented by a keen mind and seemingly boundless energy. Albert made fundamental contributions to a number of topics relevant to the present chapter, including modeling of business investment (e.g., Ando et al., 1974), measuring the cost of capital (e.g., Ando et al., 1997), and problems with measurement of Japanese data (e.g., Ando, 2000 and Ando et al., 2003). This and other work by Albert was theoretically rigorous, policy relevant, and scrupulous with data. Our own work may not measure up to the high standard set by Albert's work. But that high standard remains a goal that we both aim to achieve.

Section 2 presents the model. Section 3 describes our estimation strategy. Section 4 describes data. Section 5 presents empirical results. Section 6 concludes.

2. THE MODEL

In this section we present the partial equilibrium optimization problem and log-linear first-order conditions that provide the basis for our empirical work. Note 2 comments briefly on a general equilibrium version of our model.

We work in the vein of the neoclassical investment literature of Hall and Jorgenson (1967) and Abel and Blanchard (1986). We extend earlier work on investment to include land as a factor of production, relying in particular on our own work (Kiyotaki and West, 1996). The key element of the extension is a constant returns to scale production function in which output Y_t is Cobb–Douglas in (1) labor N_t, and (2) a composite in capital K_t and land L_t with constant elasticity of substitution:

$$\begin{aligned} Y_t &= F(N_t, K_t, L_t, A_t) \\ &= A_t N_t^{1-\alpha}\left[K_t^{1-(1/\theta)} + \gamma L_t^{1-(1/\theta)}\right]^{\alpha/[1-(1/\theta)]},\ 0<\alpha<1,\ \theta>0,\ \gamma\geq 0. \end{aligned} \quad (12.1)$$

In (12.1), A_t is total factor productivity. The elasticity of substitution between capital and land is $\theta > 0$; γ is a non-negative parameter. When $\theta = 1$, the production function reduces to one that is Cobb–Douglas in all three factors; when $\gamma = 0$, the production function reduces to one that is Cobb–Douglas in capital and labor. As we shall see, an elasticity of substitution $\theta > 1$ is key to generating a positive response of capital K_t to a rise in land prices. In (12.1) and in other equations below, the variables are real, and are measured in our empirical work in trillions of 1980 yen.

We assume that the representative competitive firm chooses output and factor inputs to maximize the expected present discounted value of real cash flow. To keep the algebra relatively uncluttered, we abstract from taxes, although these will be accounted for in our empirical work. Let W_t be the real wage, I_t gross investment, K_t the capital stock, $\tilde{P}_{It}$ the real price of a unit of capital, $\tilde{P}_{Lt}$ the real price of a unit of land. (The tilde over the price variables is used merely to distinguish them from the nominal price variables P_{It} and P_{Lt} used in the empirical work.) The firm's maximization problem is:

$$\max_{\{Yt,\,Nt,\,It,\,Kt,\,Lt\}} E_t \sum_{j=0}^{\infty} \beta_{t,t+j} \left[Y_{t+j} - \text{expenditure}_{t+j} \right] \qquad (12.2a)$$

s.t. (12.1) and

$$\text{expenditure}_{t+j} = W_{t+j}N_{t+j} + \tilde{P}_{It}\{I_t + 0.5\phi[(K_t/K_{t-1}) - G_K]^2 K_{t-1}\} + \tilde{P}_{Lt}(L_t - L_{t-1}), \quad \phi \geq 0, \qquad (12.2b)$$

$$K_t = (1-\delta)K_{t-1} + I_t, \quad 0 < \delta \leq 1. \qquad (12.2c)$$

In (12.2a), output price is the numeraire (effected in our empirical work by using the output price deflator to construct real factor prices). The term $\beta_{t,t+j}$ is a real discount factor, used to discount period $t+j$ values back to period t. The firm takes as given sequences of discount factors $\{\beta_{t,t+j}\}$ and factor prices $\{W_t\}$, $\{\tilde{P}_{It}\}$ and $\{\tilde{P}_{Lt}\}$.

In (12.2b), each of the three factors of production generates a per-period expenditure. The first term, $W_{t+j}N_{t+j}$, is wage costs. The term $0.5\phi[(K_t/K_{t-1}) - G_K]^2 K_{t-1}$ is the cost of adjusting capital, with $\phi > 0$ a positive parameter. Large costs of adjustment are captured by large values of ϕ. These costs attain a minimum around G_K, the steady-state rate of growth of the capital stock, and increase as gross investment deviates from its steady-state rate of growth. See Kiyotaki and West (1996). In (12.2c), net capital accumulation is related to gross investment, with $\delta \geq 0$ the constant depreciation rate.

In (12.2b), the net cost of land acquisition is simply the per-unit price of land multiplied by the net change in land quantity. (A negative value is of course possible, and occurs sometimes in our data.) To prevent confusion, we note that expenditures on (say) underground connections to sewers or electrical lines are understood to be part of capital K and do not result in a change in land L: 'capital' is used in the sense of national income and product accounting, and includes all fixed investment. Indeed, in the nation as a whole L_t is essentially fixed.[1]

Recall from (12.1) that the production function is 'F'. For $x = N$, K or L, let

$$F_{xt} \equiv \partial F / \partial x_t.$$

The first-order conditions are:

$$N_t\!: \; W_t = F_{Nt} = (1-\alpha)Y_t/N_t, \qquad (12.3a)$$

$$L_t\!: \; \tilde{P}_{Lt} - E_t\beta_{t,t+1}\tilde{P}_{Lt+1} = F_{Lt} = \alpha(Y_t/L_t)(1-\mu_t), \qquad (12.3b)$$
$$\mu_t \equiv K_t^{1-(1/\theta)}/[K_t^{1-(1/\theta)} + \gamma L_t^{1-(1/\theta)}],$$
$$1 - \mu_t = \gamma L_t^{1-(1/\theta)}/[K_t^{1-(1/\theta)} + \gamma L_t^{1-(1/\theta)}],$$

$$K_t\!: \; \tilde{P}_{It}\{1 + \phi[(K_t/K_{t-1}) - G_K]\} - E_t\beta_{t,t+1}\tilde{P}_{It+1}\{1 - \delta + \phi[(K_{t+1}/K_t) - G_K]G_K + 0.5\phi[(K_{t+1}/K_t) - G_K]^2\} = F_{Kt},$$
$$F_{Kt} = \alpha(Y_t/K_t)\mu_t. \qquad (12.3c)$$

The first-order condition (12.3a) simply sets the marginal product of labor equal to the real wage. As usual, the fact that the production function is Cobb–Douglas in labor means that the investment equation we derive will not depend directly on wages W_t or labor N_t, and we shall have nothing more to say about these variables.

The left-hand side of condition (12.3b) is the user cost of land, that is, the cost of acquiring a unit of land this period and selling it next period; the right-hand side is the marginal product of land. The first term in braces on the left-hand side of (12.3c) is the period t marginal cost of purchasing and installing an extra unit of capital; the second term is the expected marginal benefit of selling the undepreciated portion of that unit next period. Both terms take into account costs of adjustment. The right-hand side of (12.3c) is the marginal product of capital.

Our next step is to use (12.3b) and (12.3c) to derive a log-linear first-order condition for capital. Define the user cost of capital C_K and the user cost of land C_L as

$$C_{Kt} \equiv \tilde{P}_{It} - (1-\delta)E_t(\beta_{t,t+1}\tilde{P}_{It+1}), \tag{12.4a}$$

$$C_{Lt} \equiv \tilde{P}_{Lt} - E_t(\beta_{t,t+1}\tilde{P}_{Lt+1}). \tag{12.4b}$$

Next, rewrite (12.3c) as

$$\begin{aligned}
(K_t/K_{t-1}) - 1 \\
&= G_K - 1 + (1/\phi\tilde{P}_{It})(F_{Kt} - C_{Kt}) + \\
&+ E_t\beta_{t,t+1}(\tilde{P}_{It+1}/\tilde{P}_{It})\{[(K_{t+1}/K_t) - G_K]G_K + 0.5[(K_{t+1}/K_t) - G_K]^2\} \\
&= (G_K - 1)(1 - G_K D) \\
&+ [\phi^{-1} - \phi^{-1}(1-\delta)D][(F_{Kt}/C_{Kt}) - 1] + DG_K E_t[(K_{t+1}/K_t) - 1] + e_t,
\end{aligned}$$

$$\begin{aligned}
e_t \equiv \phi^{-1}(1-\delta)(D - E_t D_{t+1})[(F_{Kt}/C_{Kt}) - 1] \\
+ G_K E_t[(D_{t+1} - D)(\Delta K_{t+1}/K_t - G_K + 1)] \\
+ 0.5\phi E_t D_{t+1}[(K_{t+1}/K_t) - G_K]^2,
\end{aligned}$$

$$\begin{aligned}
D_{t+1} &\equiv \beta_{t,t+1}(\tilde{P}_{It+1}/\tilde{P}_{It}), \\
D &\equiv ED_{t+1}.
\end{aligned} \tag{12.5}$$

Observe that all the terms in e_t are the product of terms with mean zero, which we use as a rationalization for treating e_t as an unmodeled error term in our empirical work.

To apply a log-linear approximation to (12.5), let lower-case letters denote logarithms of the corresponding upper-case variables:

$$k_t \equiv \ln(K_t),\ y_t \equiv \ln(Y_t),\ c_{Kt} \equiv \ln(C_{Kt}),\ c_{Lt} \equiv \ln(C_{Lt}), f_{Kt} \equiv \ln(F_{Kt}). \tag{12.6}$$

Then $(K_t/K_{t-1}) - 1 \approx \Delta k_t$. Since the average value of $F_{Kt}/C_{Kt} - 1$ is zero, $F_{Kt}/C_{Kt} - 1 \approx f_{Kt} - c_{Kt}$ and (12.5) becomes

$$\begin{aligned}
\Delta k_t \approx \text{constant} + [\phi^{-1} - \phi^{-1}(1-\delta)D](f_{Kt} - c_{Kt}) \\
+ DG_K E_t \Delta k_{t+1} + e_t.
\end{aligned} \tag{12.7}$$

Finally, we solve for f_{Kt} (the log of the marginal product of capital) in terms of observables. From the first-order condition for land (12.3b) and the definition of the user cost of land (12.4b), we have $C_{Lt} = F_{Lt}$; since $F_{Lt}/F_{Kt} = \gamma(L_t/K_t)^{-1/\theta}$, we have

$$C_{Lt}/F_{Kt} = \gamma(L_t/K_t)^{-1/\theta} \Rightarrow L_t/K_t = (\gamma F_{Kt}/C_{Lt})^{\theta}. \tag{12.8}$$

Observe from (12.3b) that $\mu_t = 1/[1 + \gamma(L_t/K_t)^{1-(1/\theta)}]$. In light of (12.8), this means $\mu_t = 1/[1 + \gamma^{\theta}(F_{Kt}/C_{Lt})^{\theta-1}] \Rightarrow$

$$\begin{aligned}
F_{Kt} = \alpha(Y_t/K_t)/[1 + \gamma^{\theta}(F_{Kt}/C_{Lt})^{\theta-1}] \Rightarrow \\
f_{Kt} = \ln\alpha + y_t - k_t - \ln\{1 + \gamma^{\theta}[\exp(f_{Kt})/\exp(c_{Lt})]^{\theta-1}\}.
\end{aligned} \tag{12.9}$$

Then, taking a first-order approximation of $\ln\{1 + \gamma^{\theta}[\exp(f_{Kt})/\exp(c_{Lt})]^{\theta-1}\}$ gives

$$\begin{aligned}
f_{Kt} &\approx \text{deterministic terms} + y_t - k_t - (1-\mu)(\theta-1)(f_{Kt} - c_{Lt}) \\
&\approx \text{deterministic terms} \\
&\quad + \{1/[1 + (1-\mu)(\theta-1)]\}[y_t - k_t + (1-\mu)(\theta-1)c_{Lt}],
\end{aligned} \tag{12.10}$$

where μ is the average value of μ_t, $0 < \mu \leq 1$. In (12.10) the 'deterministic terms' include not only $\ln(\alpha)$ but also terms that result from evaluation of $\ln(\mu_t)$ at average or trend values of f_{Kt} and c_{Lt}. Let

$$\eta \equiv (1-\mu)(\theta-1). \tag{12.11}$$

The parameter η can be thought of as the elasticity of the target capital stock with respect to the user cost of land.

Substituting (12.10) and (12.11) into (12.7) yields the log-linear equation

$$\begin{aligned}
\Delta k_t &= a(k_t^* - k_t) + bE_t\Delta k_{t+1} + e_t, \\
k_t^* &\equiv y_t - (1+\eta)c_{Kt} + \eta c_{Lt} = y_t - c_{Kt} - \eta(c_{Kt} - c_{Lt}), \\
a &\equiv [1 - (1-\delta)D]/[\phi(1+\eta)],\ b \equiv DG_K,
\end{aligned} \tag{12.12}$$

where e_t has been redefined to include the approximation error, and deterministic terms have been omitted for notational simplicity. In (12.11) k_t^* is the *target* (log) capital stock (omitting the deterministic term $\ln(\alpha)$).

To interpret (12.12), first consider the case in which there are no costs of adjustment: multiply through by ϕ and then set $\phi = 0$. The first-order condition is then $k_t = k_t^* + (e_t/a)$: apart from a random shock, (log) capital equals its target in each period. Suppose further that $\gamma = 0$ so that land is absent from the production function. Then $\mu_t = \mu = 1$ and $\eta = 0$, which implies that $k_t^* = y_t - c_{Kt}$: as in the standard neoclassical investment function, target (log) capital equals the (log of the) ratio of output to the user cost of capital. When land is present ($\gamma \neq 0$), $\eta \neq 0$ and target capital also depends on the user cost of land c_{Lt}, except in the special case when $\theta = 1$ so that production is Cobb–Douglas in labor, capital and land. The sign of the response of k_t^* and thus of k_t to an increase in c_{Lt} is determined by the sign of η. Since $0 < \mu < 1$, the sign of η matches that of $\theta - 1$. When the elasticity of substitution θ is greater than one, $\partial k_t^*/\partial c_{Lt}$ is positive: increases in the user cost of land cause target capital and thus capital to increase.

When the elasticity is less than one, increases in the user cost of land cause target capital and capital to decrease.

When costs of adjustment are present ($\phi \neq 0$), the instantaneous impact of an increase in the user cost of land on k_t^* is as described in the previous paragraph. The long-run impact depends on the dynamic response of various variables to the increase. But an increase in c_{Lt} that is not associated with offsetting or compounding changes in y_t or c_{Kt} will cause k_t^* and thus k_t to increase if the elasticity of substitution θ is greater than one, and decrease if it is less.

Our empirical work relies on the partial equilibrium relationship just derived. We close this section with a brief outline of a general equilibrium relationship between land prices and business investment. The point we wish to make is that when the elasticity of substitution between capital and land is greater than one, an aggregate productivity shock that increases capital will also increase the capital–output ratio.

Write the production function as $Y_t = F(N_t, K_t, L_t, A_t)$. Assume that F is constant returns to scale in labor N_t and a composite of capital K_t and land L_t, say $Y_t = A_t G[N_t, X(K_t, L_t)]$. Then the marginal product of capital may be decomposed as

$$F_{Kt} = (Y_t/K_t) \times (X_t G_{Xt}/G_t) \times (K_t X_{Kt}/X_t)$$
$$= \text{(output–capital ratio)} \times \text{(share of capital and land in output)}$$
$$\times \text{(share of capital in combined income of capital and land)}. \quad (12.13)$$

Let us suppose that F_{Kt} is constant, as it is in a steady state of many models, including Cass–Koopmans type models and small open economy models with homogeneous goods. Let us suppose as well that $(X_t G_{Xt}/G_t)$ is constant (G is Cobb–Douglas in N_t and X_t). Then we see from (12.13) that a rise in A_t will cause a rise in K_t/Y_t if and only if a rise in A_t causes a rise in $K_t X_{Kt}/X_t$. This last condition holds when L_t is equal to the fixed supply of land and X_t takes the constant elasticity form assumed above with an elasticity of substitution $\theta > 1$. For in this case, $(K_t X_{Kt}/X_t) = 1/[1 + \gamma(L/K_t)^{1-(1/\theta)}]$. Intuitively, when $\theta > 1$ a rise in total factor productivity leads to a larger capital–output ratio because the constraint of a fixed supply of land is mitigated by a larger capital stock. On the other hand, when $\theta = 1$, so that G is Cobb–Douglas in all three factors, the capital–output ratio remains unchanged after a rise in A_t.

3. DECISION RULE

Our empirical work considers a decision rule implied by the first-order condition (12.12). We do not tie our estimation to the model we used to

rationalize (12.12). Readers uncomfortable with the series of approximations used to obtain (12.12) may prefer an alternative motivation:[2] let a representative firm minimize expected present discounted costs at a constant discount rate 'b', with per-period costs being:

$$\Delta k_t^2 + a(k_t^* - k_t)^2 - 2e_t k_t,$$

$a > 0$ a parameter, e_t a disturbance unobservable to the economist, $k_t^* \equiv y_t - c_{kt} - \eta(c_{kt} - c_{Lt})$, $\eta > -1$. Then the first-order condition to this problem is (12.12), repeated here in a rearranged form as (12.14):

$$E_t[k_t - k_{t-1} - a(k_t^* - k_t) - b(k_{t+1} - k_t) - e_t] = 0. \quad (12.14)$$

Our decision rule is a VAR in a vector of variables Z_t. One of the variables is $k_t - k_t^*$ with $k_t^* \equiv y_t - c_{kt} - \eta(c_{kt} - c_{Lt})$ for a calibrated value of η. We briefly report results for a bivariate VAR in which the second variable is Δk_t^*. But in almost all the empirical work, Z_t is (4×1) and consists of $k_t - k_t^*$, Δk_t^*, Δc_{kt} and Δc_{Lt}. (Given the linear relationship between Δk_t^*, Δy_t, Δc_{Kt} and Δc_{Lt}, all our results are unchanged if any three of these four variables are included.) Let Z_t follow a first-order VAR,

$$Z_t = \Pi Z_{t-1} + \epsilon_t, \quad (12.15)$$

which appears to be consistent with the data. Generalization to higher-order VARs is notationally complex but conceptually straightforward. Deterministic terms have been omitted for notational simplicity.

We obtain unrestricted estimates of (12.15) by OLS. We use the estimates to evaluate whether each of the variables substantially affects the other, focusing on a basic implication of our model: since the decision rule for k_t utilizes forecasts of k_t^*, $k_t - k_t^*$ will Granger-cause Δk_t^* if firms forecast k_t^* using more information than is in our VAR.

We also obtain estimates restricted to accord with (12.12) as follows. We assume that the firm sees the variables in Z_t, and that e_t is approximately orthogonal to lagged Z_ts. (This seems consistent with the previous section's model, in so far as small values for e_t imply a small correlation between e_t and observable variables.) Then (12.14) and (12.15) imply

$$E[k_t - k_{t-1} - a(k_t^* - k_t) - b(k_{t+1} - k_t)|Z_{t-1}] = 0. \quad (12.16)$$

Let $\alpha_0 \equiv (-b, -b, 0, 0)'$, $\alpha_1 \equiv (1 + a + b, 1, 0, 0)'$, $\alpha_2 = (-1, 0, 0, 0)'$. Then (12.15) imposes the restrictions implied by (12.16) if

$$\alpha_0' \Pi^2 + \alpha_1' \Pi + \alpha_2' = 0. \quad (12.17)$$

Our restricted system estimates Π subject to (12.17), with an imposed value of b (set to 0.95, in our annual data), using a technique described in the appendix to Kiyotaki and West (1996).

For both the restricted and unrestricted estimates, we transform (12.15) into a VAR in the levels of y_t, c_{kt}, c_{Lt} and k_t. We compute impulse responses of k_t to the Wold innovations (one-step-ahead forecast errors) of y_t, c_{kt}, c_{Lt} and k_t. These innovations, which in general are correlated with one another, are linear combinations of the elements of ϵ_t, the disturbance in (12.15).

To avoid confusion, we acknowledge that such innovations are not fundamental objects with simple economic labels. For example, the model of the previous section indicates that to the firm the period t surprise in y_t will be a function of period t surprises in discount factors, wages, total factor productivity and the user costs of capital and land. In the VAR, the one-step-ahead forecast errors will reflect as well information observed by the firm but not by us – that is, the difference between $E[\cdot|Z_t]$ and $E_t[\cdot]$ where '·' is given in (12.16). They will also reflect approximation error and unobservable forcing variables that are collapsed into 'e_t'. Nonetheless, we will discuss the response of capital to 'the' shock to y_t, and to c_{kt}, c_{Lt} and k_t.

4. DATA AND VARIABLE DEFINITIONS

All data are annual, running from 1961 to 1995. The starting point was dictated by the desirability of using the call rate to construct the user cost of capital. The ending point was dictated by availability of capital stock data when we first began this research in 1997. The base year for real data is 1990. We discuss in turn capital, output, user cost of capital and user cost of land. Since the first three are standard, we discuss them only briefly.

The capital stock K_t is that of non-financial corporations, obtained from sectoral balance-sheet data on the Economic Planning Agency's *Annual Report on National Accounts, 1997*. Such corporations account for most of private investment in plant and equipment. The capital stock includes both equipment and structures; a breakdown into the two types appears not to be available. Real data are available from 1969 to 1995. Using a technique similar to that described in Hayashi (1986), we used nominal data on the level of the capital stock and on nominal gross investment (the 'capital finance' and 'reconciliation' accounts) to construct the real data from 1961 to 1968. For this construction, we used the NIPA deflator for private investment in plant and equipment.

We measured output as GDP. The US investment literature often uses business output as the output variable. In our earlier work (Kiyotaki and West, 1996) we followed this tradition, using output of industry. But a small amount of experimentation suggested that results using GDP and output of industry yield very similar results. We focus here on GDP since its behavior is both better appreciated and of more widespread interest.

Our construction of the user cost of capital follows our earlier work (Kiyotaki and West, 1996), which may be consulted for details. Briefly, we have

$$C_{Kt} = \frac{P_{It}}{P_{yt}} C_{1Kt} C_{2Kt},$$
$$C_{1Kt} \equiv [(1-\tau_t Z_t)/(1-\tau_t)], C_{2Kt} \equiv 1 - \left\{ E_t\left[\frac{P_{It+1}}{P_{It}}\right]\left(\frac{1-\delta}{1+i_{at}}\right)\right\}. \quad (12.18)$$

In (12.18), P_{It} is the price index for capital goods, measured as the NIPA deflator for private investment in plant and equipment, 1990 ≐ 100; P_{yt} is the output deflator, measured as the GDP deflator, 1990 = 100 (the ratio P_{It}/P_{yt} corresponds to the real price $\tilde{P}_{It}$ used in the model in Section 2); τ_t = effective corporate tax rate, computed from statutory maximum rates for corporate, enterprise and local taxes as described in our earlier paper; z_t = present value of depreciation deductions per yen of new investment, fixed at 0.562 through the sample (0.562 is the mean value for 1961–81 for the $\{z_t\}$ series in Hayashi (1990, p. 308)); $E_t[P_{It+1}/P_{It}]$ is the fitted value of an AR(1) in (P_{It+1}/P_{It}); δ = depreciation rate, set at 0.10, which is approximately the depreciation rate implied by the balance-sheet data. Finally, $1 + i_{at}$ = nominal discount factor for the firm, computed as a weighted average of nominal return on equity (weight = 0.6) and on debt (weight = 0.4). Expected equity returns were measured as the annual average of the call rate plus a constant risk premium of 5 percent. For 1992–95, the nominal rate on debt was set to the annual average of the Bank of Japan series 'average contracted interest rates on new loans and discounts, long-term'; for 1961–91 the rate was set to the annual average of the holding yield of long-term bonds of the national telephone company NTT plus a constant risk premium of 1 percent.

The final variable to discuss is the user cost of land. Since this variable is both non-standard (in contrast to the user cost of capital) and involves some messy formulas, we discuss it in detail.

The Japanese tax system imposes both a one-time tax on land acquisition and a tax on land holding (which may vary with the amount of time the land is held). In equilibrium, the user cost probably is not well measured by the cost entailed by a sale and repurchase each period. (It may help to point out that the user cost of capital calculation does assume purchase and resale each period.) But formal modeling of an optimal decision to buy or sell would, it seems, be quite complicated, and involve data that seem not to be available, such as the length of time land is held. We assume that land is sold according to a Poisson process: there is 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 holdings.

Specifically, let P_{Lt} be the nominal land price index, τ_{pt} a tax on land acquisition, τ_{ht} a tax on land holding. Profit maximization implies that the cost of acquiring a unit of land is equal to the expected present value of the profit:

$$P_{Lt}(1+\tau_{pt}) = E_t\sum_{j=0}^{\infty}\left(\frac{1-\lambda}{1+i_{at}}\right)^j [P_{yt+j}F_{Lt+j}(1-\tau_{t+j}) - \tau_{ht+j}P_{Lt+j}] + E_t\sum_{j=1}^{\infty}\lambda(1-\lambda)^{j-1}\left(\frac{1}{1+i_{at}}\right)^j [P_{Lt+j} - \tau_{t+j}(P_{Lt+j}-P_{Lt})]. \quad (12.19)$$

In (12.19), the symbols P_{yt} (output deflator), τ_t (corporate tax rate) and i_{at} (nominal discount factor) are as defined in the discussion of the user cost of capital. We have assumed for simplicity that the j-period nominal discount factor is simply $1/(1+i_{at})^j$.

The first term on the right-hand side of this equation is the expected present discounted value of the after-tax marginal value product of land. This expectation reflects the fact that the land produces value only until the firm sells the land: with probability $1-\lambda$ the firm will own the land in period $t+1$, with probability $(1-\lambda)^2$ it will hold it as well in period $t+2$, and so on. The second term is the expected present discounted value of proceeds from selling the land after paying tax on realized capital gains. This present value also reflects the exogenous process that determines sale of the land.

We assume static expectations about the growth rate of the price of land: $E_tP_{Lt+j} = (1+i_{Lt})^jP_{Lt}$, where i_{Lt} is the nominal net expected rate of increase of nominal land price, $1+i_{Lt} = E_tP_{Lt+j}/P_{Lt+j}$, $j \geq 1$. We assume static expectations about the levels of all other variables on the right-hand side of (12.19). So, for example, $E_t[P_{yt+j}F_{Lt+j}(1-\tau_{t+j}) - \tau_{ht+j}P_{Lt+j}] = P_{yt}F_{Lt}(1-\tau_t) - \tau_{ht}P_{Lt}(1+i_{Lt})^j$. Then algebraic manipulations lead to

$$\begin{aligned}
F_{Lt} &= \frac{P_{Lt}}{P_{yt}}C_{1Lt}C_{2Lt},\\
C_{1Lt} &= \frac{1}{1-\tau_t}\\
C_{2Lt} &= C_{21Lt}(1+\tau_{pt}+\tau_{ht}C_{22Lt} - \lambda C_{23Lt}),\\
C_{21Lt} &= \left[\sum_{j=0}^{\infty}\left(\frac{1-\lambda}{1+i_{at}}\right)^j\right]^{-1} = \frac{\lambda+i_{at}}{1+i_{at}}\\
C_{22Lt} &= (1+i_{at})/[i_{at}+\lambda(1+i_{Lt}) - i_{Lt}]\\
C_{23Lt} &= [\tau_t/(\lambda+i_{at})] + [(1-\tau_t)(1+i_{Lt})]/[i_{at}+\lambda(1+i_{Lt}) - i_{Lt}].
\end{aligned} \quad (12.20)$$

The right-hand side of (12.20), which we see is equal to the marginal product of land F_{Lt}, is defined as the user cost of land C_{Lt}.[3] So

$$\begin{aligned}
C_{Lt} &= \frac{P_{Lt}}{P_{yt}}C_{1Lt}C_{2Lt}, \quad (12.21)\\
&= \frac{1}{P_{yt}} \times \text{[tax-adjusted opportunity cost of owning a unit of land for one year]}
\end{aligned}$$

It may help to indicate that, in the absence of taxes,

$$C_{Lt} = \frac{P_{Lt}}{P_{yt}}\left(\frac{\lambda+i_{at}}{1+i_{at}}\right)\{1-[\lambda(1+i_{Lt})/(i_{at}+\lambda+\lambda i_{Lt}-i_{Lt})]\}. \quad (12.22)$$

If, as well, $\lambda = 1$ (sell and repurchase every period),

$$C_{Lt} = \frac{P_{Lt}}{P_{yt}}\left(1-\frac{1+i_{Lt}}{1+i_{at}}\right). \quad (12.23)$$

Since $1+i_{Lt} = E_tP_{Lt+1}/P_{Lt}$, our measure is now a familiar one (see (12.18)). We measured the variables in C_{Lt} as follows.

The nominal land price index P_{Lt}: We tried two different indices. We focus on an index supplied by the Japan Real Estate Institute. We use annual averages of the semi-annual values of the index for the six largest cities. (Since these indices use median sale prices, it appears that the six largest cities provide a better measure of the average increase in the value of land than does the index for all urban districts.) Following Auerbach and Ando (1990), we also constructed an index from the EPA's balance-sheet data for land for the nation as a whole. To do so, we set the 1990 value of our index to 100, the 1991 value to 100×(nominal value of land in the nation as a whole in 1991)/(nominal value of land in the nation as a whole in 1990) = 100*(2231 trillion yen/2420 trillion yen) ≈ 92.2, etc. The second index showed somewhat more rapid inflation. But since both gave similar results in our regressions, we limit our discussion largely to results from the first index, presenting only a single set of results from the second.

λ: This was set to 0.10, implying the average period of time to hold a unit of land is ten years. This choice was largely arbitrary, although it was influenced by a presumption that the tax surcharge for holding land less than two or less than five years (not accounted for in our calculation above) would lead to an average holding period longer than five years.

i_{Lt}: Conceptually, this is the expected rate of increase in land prices. This was set to the annual average of the call rate, plus 2 percent. The 2 percent premium reflects a risk premium minus the ratio of imputed rent on land to the land price. (Because the realized rate of increase in land prices is very volatile and often negative, attempts to use a proxy i_{Lt} parallel to that for $E_t[P_{It+1}/P_{It}]$ (i.e., a univariate autoregression) unsuccessfully led to a number of very large positive and negative values. Also, our proxy implies a mean return lower than the historical mean. But at some dates C_{Lt} fails to be positive if i_{Lt} is set to the call rate plus 4 percent.[4] This suggests that our static expectations assumption is not very attractive, or that there are frictions that we have yet to account for, or that the historical mean is above the mean as perceived by private agents.

τ_{pt}: Set to 3.6 percent for the entire sample. This variable reflects a local tax of 4 percent of assessed value, a national registration tax of 5 percent of assessed value, and assessments that typically are around 40 percent of market value: $0.036=(0.04+0.05)\times 0.40$.

τ_{ht}: Set to 0.68 percent for the years 1961–92, 0.8 percent for 1993–95. This variable reflects a local property tax of 1.4 percent of assessed value and a city planning tax of 0.3 percent of assessed value: $0.068=(0.014+0.003)\times 0.40$. In 1993–95, there was also a national land value tax of 0.2–0.3 percent of assessed value.

5. EMPIRICAL RESULTS

We discuss in turn: trends, and calibration of η; unrestricted VARs; restricted VARs and impulse response functions; robustness.

Trends, and Calibration of η

Figure 12.1 plots the levels of our four variables: capital K_t, output Y_t, user cost of capital C_{kt} and user cost of land C_{Lt}. During our 1961–95 sample, all show trends. Capital K grew by a factor of over 12 (top panel in Figure 12.1), output Y by a factor of a little under six (second panel). The capital–output ratio (not depicted) thus rose, from about 0.5 in 1961 to about 1.1 in 1995.[5] The third panel shows that the user cost of capital C_{kt} fell; in 1995 it was less than half its 1961 value. The fall is attributable to a declining real price of capital goods (declining P_I/P_Y), as discussed in Kiyotaki and West (1996). The bottom panel in Figure 12.1 shows that the user cost of land C_{Lt} rose; in 1995 it was about 2.5 times its 1961 value. In light of the well-known recent behavior of land prices, the behavior of C_{Lt} in the last ten years of the sample suggests that a rising real land price (rising P_L/P_Y) is responsible for the rise in C_{Lt}. Figure 12.2 illustrates that this is in fact the case; net of the real land price, the user cost C_{Lt} shows no secular movement (bottom panel in Figure 12.2).

According to our model, $k_t-k_t^*=k_t-[y_t-(1+\eta)c_{kt}+\eta c_{Lt}]$ is stationary, which implies that its first difference has an unconditional mean of zero. (Reminder: η is defined in (12.11) as $\eta=(1-\mu)(\theta-1)$, with $0<\mu<1$ the mean share of capital income in income to capital and land, and $\theta>0$ the elasticity of substitution between capital and land.) One implication of stationarity of $k_t-k_t^*$ is that

$$E[\Delta k_t-\Delta y_t+(1+\eta)\Delta c_{kt}-\eta\Delta c_{Lt})=0\Rightarrow$$
$$\eta=E(\Delta k_t-\Delta y_t+\Delta c_{kt})/E(\Delta c_{Lt}-\Delta c_{kt}). \tag{12.24}$$

In addition, since the trending components of c_{kt} and c_{Lt} are real capital and land prices, $E\Delta c_{kt}=E\Delta p_{It}-E\Delta p_{Yt}$ and $E\Delta c_{Lt}=E\Delta p_{Lt}-E\Delta p_{Yt}$, which implies that

$$\eta=(E\Delta k_t-E\Delta y_t+E\Delta p_{It}-E\Delta p_{Yt})/(E\Delta p_{Lt}-E\Delta p_{It}). \tag{12.25}$$

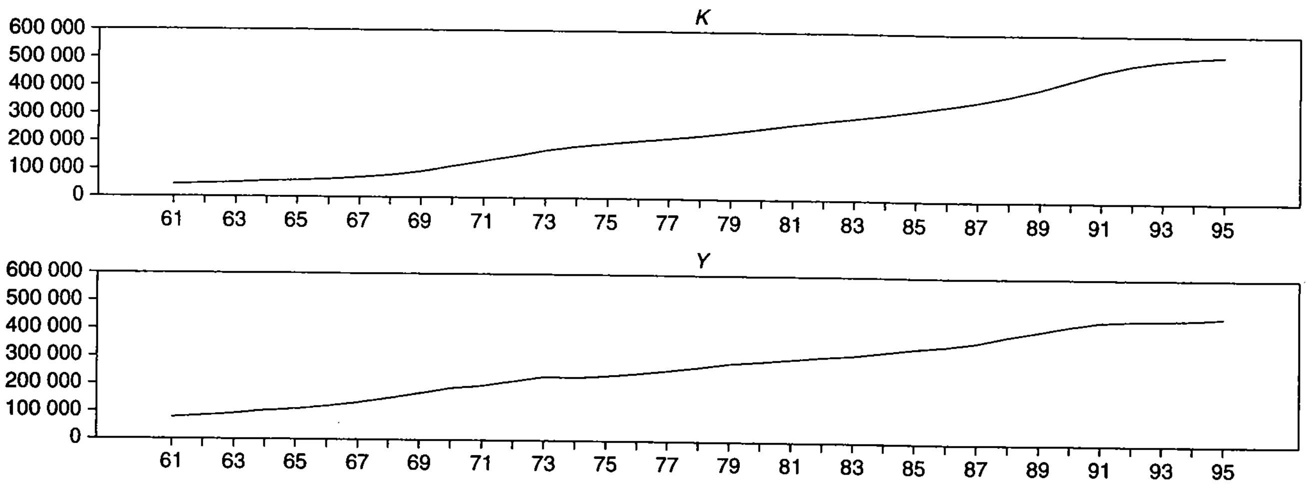
Table 12.1 presents the growth rates of capital, output, and real capital and land prices. We present results for the entire 1961–95 sample, as well as for the 1961–73 and 1974–95 sub-periods, and for both land price indices. Over the sample as a whole, the capital stock grew at an average rate of 7.7 percent a year, GDP at 5.3 percent; the real price of capital goods fell 2 percent per year. That implies that growth in $\eta(c_{kt}-c_{Lt})$ must have averaged $7.7-5.3-2.0=0.4$ percent, if $\Delta k_t-\Delta k_t^*$ is to have mean zero. For the sample as a whole, the implied value of η is about 0.04–0.05, using either of the land price indices. The means from the post-1973 period imply slightly smaller figures. The means from the 1961–73 data yield $\eta<0$, implying an elasticity of substitution $\theta<1$.

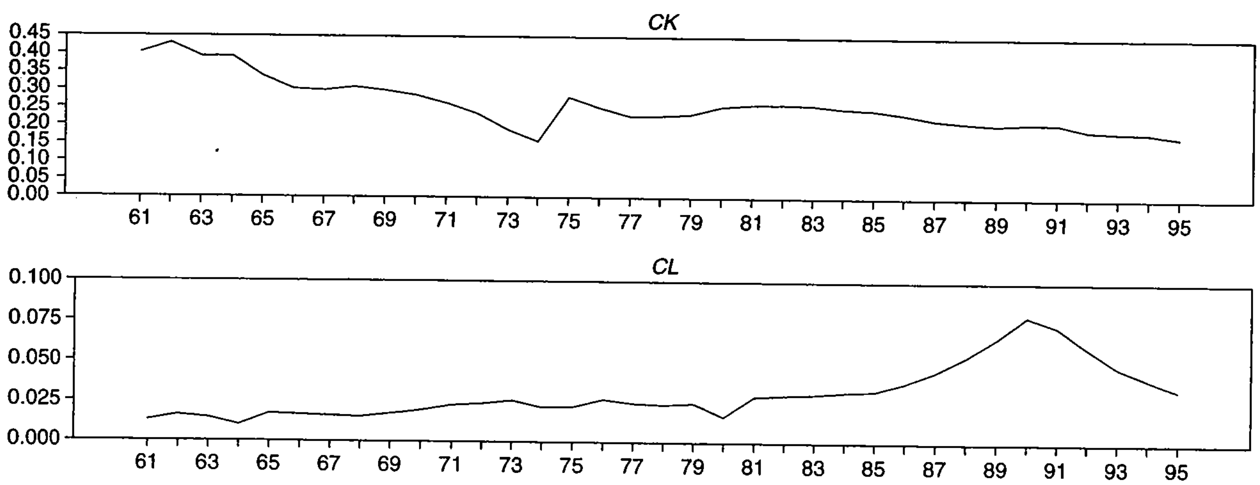
We take the figures in the table to suggest a baseline value for η of 0.05, but experiment with smaller values of $\eta\geq 0$. (We do not attempt to separately identify μ and θ.) Note 2 describes why we have a prior belief that η is non-negative.

Unrestricted VARs

Table 12.2 presents the results of least-squares regressions of first-order vector autoregressions, with $k_t^*=y_t-(1.05)c_{kt}+0.05c_{Lt}$. The table presents coefficient estimates and asymptotic standard errors, together with standard regression diagnostics. Some details are in the notes to the table.

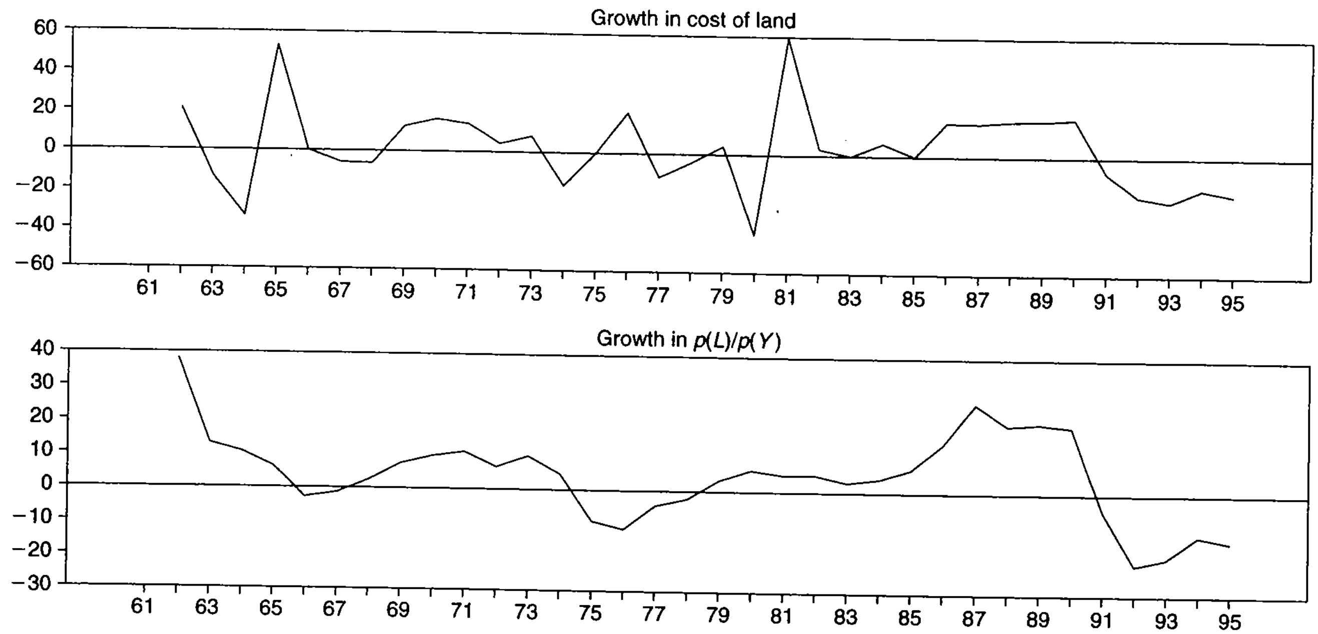
Columns (1a) and (1b) present ordinary least-squares estimates of a bivariate VAR in $(k_t-k_t^*, \Delta k_t^*)$. In this and all regressions that include both pre- and post-1973 data, we include a dummy set to one during 1974–95, as

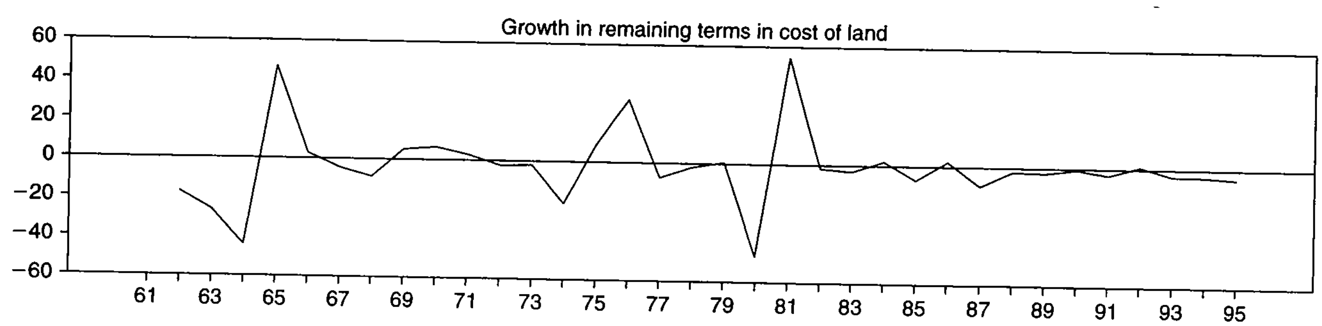




Note: *K* is the capital stock of nonfinancial corporations, *Y* is GDP; units are trillions of 1990 yen. C_K and C_L are the user cost of capital (defined in equation (12.18)) and user cost of land (defined in equation (12.21)). The natural logarithms of these four variables were used in the empirical work.

Figure 12.1





Note: The top panel plots the growth rate of the variable plotted in the bottom panel of Figure 12.1. The middle panel plots the growth rate of the real price of land. The bottom panel plots the growth rate of the remaining components of the user cost of land. See equation (12.21).

Figure 12.2

Table 12.1 Growth rates of key variables

	1961–95	1961–73	1974–95
(1) K	7.7	12.2	5.1
(2) Y	5.3	9.1	3.4
(3) P_I/P_Y	−2.0	−3.2	−1.6
(4) P_L/P_Y, P_L = average land price, 6 largest cities	4.2	9.3	1.6
(5) P_L/P_Y, P_L = balance-sheet deflator for nationwide land	7.2	13.5	4.9
(6) implied value of η, from (1)–(4)	0.053	−0.029	0.037
(7) implied value of η, from (1)–(3), (5)	0.037	−0.023	0.019

Notes:
1. Variables: K = real capital stock of non-financial corporations, Y = real GDP, P_Y = GDP deflator. The land price deflator in line (4) is the one used in most of the empirical work. The parameter η is defined in equation (12.11) in the text.
2. Let g_x denote the growth rate of a variable x. For example, g_K is 7.7 during 1961–95. Then η is calculated as: $(g_K - g_Y + g_{PI/PY})/(g_{PL/PY} - g_{PI/PY})$.

a crude means of allowing for the general slowdown in economic activity that occurred after the first OPEC shock. Column (1b) indicates that $k_t - k_t^*$ Granger-causes Δk_t^* relative to an information set consisting of lagged $k_t - k_t^*$s and Δk_t^*s, even though Δk_t^* does not Granger-cause itself. In this and the other regressions in the table, the Q- and Durbin–Watson statistics suggest that the one lag is adequate.

The remainder of our chapter relies on VARs with the four variables ($k_t - k_t^*$, Δk_t^*, Δc_{kt}, Δc_{Lt}). Columns (2a) through (2d) present least-squares regression estimates. The term $k_t - k_t^*$ continues to Granger-cause Δk_t^* relative to this expanded information set (column 2b); more generally, in the regressions for $k_t - k_t^*$, Δk_t^* and Δc_{kt} (columns 2a, 2b and 2c), $k_{t-1} - k_{t-1}^*$, Δk_{t-1}^* and Δc_{kt-1} each have at least moderate predictive power. Somewhat disappointingly, the user cost of land Δc_{Lt-1} does not enter significantly into any of these three regressions. Column (2d) indicates that none of the four lagged variables are statistically important for Δc_{Lt}.

Columns (3a) through (3d) present results when the four variable VAR is estimated using post-1973 data. The point estimates change, although, as we shall see when we present impulse response functions, they change

Table 12.2 Regression results

Regressor and summary statistic	(1a) $k_t-k_t^*$	(1b) Δk_t^*	(2a) $k_t-k_t^*$	(2b) Δk_t^*	(2c) Δc_{kt}	(2d) Δc_{Lt}	(3a) $k_t-k_t^*$	(3b) Δk_t^*	(3c) Δc_{kt}	(3d) Δc_{Lt}
	Dependent variable									
$k_{t-1}-k_{t-1}^*$	0.496 (0.146)	0.415 (0.150)	0.509 (0.145)	0.394 (0.141)	−0.368 (0.144)	0.108 (0.278)	0.387 (0.170)	0.558 (0.161)	−0.498 (0.172)	0.255 (0.350)
Δk_{t-1}^*	−0.098 (0.170)	0.074 (0.175)	−1.688 (0.950)	2.157 (0.927)	−1.894 (0.944)	1.374 (1.826)	−3.875 (1.282)	4.378 (1.217)	−4.083 (1.300)	0.655 (2.646)
Δc_{kt-1}			−1.718 (0.992)	2.258 (0.969)	−1.947 (0.986)	1.808 (1.906)	−4.027 (1.355)	4.575 (1.287)	−4.244 (1.375)	0.962 (2.797)
Δc_{Lt-1}			0.019 (0.110)	−0.008 (0.108)	0.014 (0.110)	−0.217 (0.212)	0.289 (0.170)	−0.299 (0.161)	0.299 (0.172)	−0.117 (0.350)
Constant	−82.8 (22.2)	81.2 (22.8)	−66.33 (23.33)	58.79 (22.77)	−47.37 (23.17)	11.32 (44.81)	−75.31 (24.96)	70.65 (23.69)	−59.59 (25.32)	36.87 (51.51)
Post-1973 dummy	11.0 (4.5)	−17.0 (4.6)	1.891 (6.771)	−5.038 (6.609)	−0.191 (6.727)	1.669 (13.008)				
R^2	0.493	0.325	0.519	0.422	0.254	−0.041	0.419	0.556	0.447	−0.085
s.e.	11.4	11.7	11.09	10.82	11.02	21.30	10.486	9.955	10.639	21.644
Q-statistic [p-value]			3.83 [0.87]	3.76 [0.88]	1.86 [0.98]	2.49 [0.96]	1.78 [0.88]	1.86 [0.87]	1.47 [0.92]	3.48 [0.63]

Table 12.2 (continued)

Regressor and summary statistic	Dependent variable									
	(1a)	(1b)	(2a)	(2b)	(2c)	(2d)	(3a)	(3b)	(3c)	(3d)
	$k_t - k^*_t$	Δk^*_t	$k_t - k^*_t$	Δk^*_t	Δc_{kt}	Δc_{Lt}	$k_t - k^*_t$	Δk^*_t	Δc_{kt}	Δc_{Lt}
Durbin–Watson	2.23	2.27	1.76	1.79	1.72	1.89	1.45	1.51	1.44	1.87
Sample period	1963–95 (33 obs.)		1963–95 (33 obs.)				1974–95 (22 obs.)			

Notes:
1. The table presents the results of ordinary least-squares estimates of vector autoregressions with the indicated variables. Asymptotic standard errors are in parentheses. 's.e.e.' is the degrees of freedom adjusted estimate of the standard deviation of the regression disturbance. The degrees of freedom in the *Q*-statistic are 8 in specifications 1 and 2, 5 in specification 3. The sample period that is given is for the dependent variable.
2. *k*(*t*) is the log of the capital stock, *ck*(*t*) the log of the user cost of capital, *cL*(*t*) the log of the user cost of land, *k**(*t*) the target level of capital, defined as $y(t)-(1+\eta)ck(t)+\eta cL(t)$, where *y*(*t*) is the log of output, and η is a constant set at 0.05. See text for further discussion.
3. The capital stock *k* is for non-financial corporations, output *y* is GDP, and the costs of capital and of land *ck* and *cL* were constructed as described in the text. All variables are real (1990 prices).

in such a way that the implied coefficients for a VAR in the levels of the variables are quite similar in the full sample and post-1973 estimates. The cost of land Δc_{Lt} now has some modest predictive power for $k_t - k^*_t$, Δk^*_t and Δc_{kt} (columns 3a, 3b and 3c), although Δc_{Lt} continues to be unpredictable (column 3d).

Restricted VARs and Impulse Response Functions

We next estimate VARs restricted to obey the cross-equation restrictions written out in condition (12.17). After so doing, we interpret the coefficients by transforming them to a VAR in the levels of k_t, y_t, c_{kt} and c_{Lt} and examining impulse response functions. This levels VAR has autoregressive unit roots. We focus on the impulse response of k_t to movements in the one-step-ahead forecast errors in this VAR. As is typical for Wold innovations, these errors are not orthogonal, a point that we emphasize merely to avoid confusion.

In the restricted full-sample estimates, the coefficients in the levels VAR are

$$\begin{aligned} k_t = {} & 0.879k_{t-1} + 0.518y_{t-1} - 0.397y_{t-2} - 0.122c_{kt-1} \\ & - 0.005c_{kt-2} + 0.010c_{Lt-1} - 0.004c_{Lt-2} \\ & - 10.754 - 3.233\text{dummy}_t + \hat{v}_{kt} \end{aligned} \tag{12.25a}$$

$$\begin{aligned} y_t = {} & 0.003k_{t-1} + 1.097y_{t-1} - 0.099y_{t-2} + 0.022c_{kt-1} \\ & - 0.019c_{kt-2} + 0.023c_{Lt-1} - 0.023c_{Lt-2} \\ & + 8.482 - 5.321\text{dummy}_t + \hat{v}_{yt} \end{aligned} \tag{12.25b}$$

$$\begin{aligned} c_{kt} = {} & -0.368k_{t-1} - 1.527y_{t-1} + 1.894y_{t-2} + 0.656c_{kt-1} \\ & - 0.042c_{kt-2} - 0.062c_{Lt-1} + 0.081c_{Lt-2} \\ & - 47.373 - 0.191\text{dummy}_t + \hat{v}_{ckt} \end{aligned} \tag{12.25c}$$

$$\begin{aligned} c_{Lt} = {} & 0.108k_{t-1} + 1.267y_{t-1} - 1.374y_{t-2} + 0.477c_{kt-1} \\ & - 0.364c_{kt-2} + 0.847c_{Lt-1} + 0.148c_{Lt-2} \\ & + 11.322 + 1.669\text{dummy}_t + \hat{v}_{cLt} \end{aligned} \tag{12.25d}$$

$$\hat{a} = 11.0,$$

where '*a*' is defined in (12.12) and (12.14). (Standard errors are not available.) The residuals '$\hat{v}_{\cdot t}$' are linear combinations of the residuals of the VAR in ($k - k^*$, Δk^*, Δck, ΔcL).

Equation (12.25a) indicates, as one would expect, that the impact effect on k_t of an increase in y_{t-1} is positive (0.518), that of c_{kt-1} negative (−0.122), that of c_{Lt-1} positive (0.010).

The impulse responses are plotted in Figure 12.3. The first column plots the response to a 1 percent increase in $\hat{v}_{yt}$ (the residual in equation 12.25b above), the second through fourth columns plot responses to a 1 percent increase in the residuals $\hat{v}_{ckt}$, $\hat{v}_{cLt}$ and $\hat{v}_{kt}$. The rows plot the responses of y_t (row 1), c_{kt} (row 2), c_{Lt} (row 3) and k_t (solid line) and k_t^* (shaded line) (row 4). The response of k_t^* is computed as: (response of y_t) − $(1+\eta)$ (response of c_{kt}) + η (response of c_{Lt}), with $\eta = 0.05$. The scale on all the graphs is the same; note that in column 1 the period 1 response of c_{Lt}, the period 1 and 2 responses of c_{kt} and the periods 1 through 5 responses of k_t^* have been truncated to fit in the graph. We plot ten years of responses because the new steady state has been reached within ten years.

Consider first the response to a 1 percent movement in $\hat{v}_{yt}$, which is shown in column 1. By construction the 1 percent period 0 shock to y_t is associated with zero change in the other three variables. The period 1 response of y_t is 1.097 percent > 1.0, reflecting positive autocorrelation in the growth rate of y_t. The period 1 response of c_{kt} is negative, of c_{Lt}, k_t and k_t^* are positive. (The period 1 responses may be read from the coefficients on y_{t-1} given in equation (12.25): 1.097 for y_t, −1.527 for c_{kt}, 1.267 for c_{Lt}, 0.518 for k_t.) There are essentially no further dynamics in the response of y_t, which asymptotes with an increase of 1.11 percent. The two user costs take somewhat longer to reach steady-state values, which for c_{kt} is about zero, c_{Lt} about 0.78 percent. The response of k_t^* is a linear combination of these other responses, and in the end is about 1.16 percent ($= 1.11 - (1.05) \times 0 + 0.05 \times (0.78)$). Since the long-run response of k_t is that of k_t^*, the long-run response of k_t is also about 1.16 percent.

The user cost of capital is mean reverting in response to its own shocks, in the long run (ten years) rising 0.24 percent after the initial 1 percent rise (row 2, column 2). The cost of capital shock evokes essentially no response from y_t, in either the next year or the long run (ten years). The cost of land rises by 0.477 percent, and asymptotes with a rise of 0.28 percent. In the long run, k_t^* and thus k_t fall by about 0.22 percent.

The user cost of land shows persistence in response to its own shocks, responding in the long run to a 1 percent shock with a rise of 0.87 percent (row 3, column 3). The responses of y_t and c_{Lt} are negligible. Since $\eta = 0.05$, the long-run responses of k_t and k_t^* are approximately $0.05 \times 0.87 \approx 0.05$ percent.

A shock to the capital stock causes c_{kt} to move, but evokes little response in either y_t or c_{Lt}.

It has long been noted that in investment regressions, capital responds more strongly to output than to the cost of capital (e.g. Clark, 1979). This is the case with our data: in (12.25a), the coefficient on y_{t-1} is 0.518, while that on c_{kt-1} is −0.122. The larger response has sometimes been taken to suggest the desirability of modifying the model or estimation technique. While such modifications perhaps are warranted, a stronger response to output is evidently not inconsistent with a neoclassical model: the coefficients in (12.25) are constrained to accord with condition (12.17) and thus with the model. The intuition is as follows. Column 1 of Figure 12.3 indicates that shocks to y_t tend to have persistent effects, with a 1 percent initial movement in y_t associated with a larger than 1 percent steady-state movement. Given the responses of c_{kt} and c_{Lt}, this means that k_t^* will rise substantially in the long run, which in turn implies that k_t will also rise substantially. Given costs of adjustment, k_t does not immediately leap to its new steady state. But it does rise a non-trivial amount.

On the other hand, column 2 of Figure 12.3 indicates that cost of capital shocks are mean reverting, with a 1 percent initial movement in c_{kt} associated with a distinctly less than 1 percent steady-state movement. The target capital stock k_t^* and the capital stock k_t each change relatively little in the long run, which implies an even smaller initial response.[6]

While responses to the user cost of land have not been previously analyzed to our knowledge, similar logic explains the pattern in column 3. Shocks to the user cost of land are largely permanent. But the long-run effect on k_t^* and thus on k_t is small since η is small (i.e., since the elasticity of substitution [θ] is near one and/or the share of capital income in the total return to land and capital [μ] is near one).

Robustness

Table 12.3 indicates that these results are robust to minor changes in parameter values and data. The leftmost set of entries in panel A (labeled '$\eta = 0.05$') repeats the information in Figure 12.3. One can see by comparing these results to the middle set of entries that lowering η to 0.03 does not change the results. The rightmost set of entries in panel A illustrates that our results are not sensitive to the land price index used.

Panel B indicates that when we use post-1973 data, the results are quantitatively and qualitatively unchanged. Panel C indicates that the impulse responses from the unrestricted estimates are quite similar to those from the restricted estimates that heretofore have been discussed.

Panel D gives the perhaps unsurprising result that the results change little if we set $\eta = 0$. Such a specification reduces the current model to one used in our earlier paper (Kiyotaki and West, 1996). When $\eta = 0$, the user cost of land plays the role of an information variable, which can affect capital

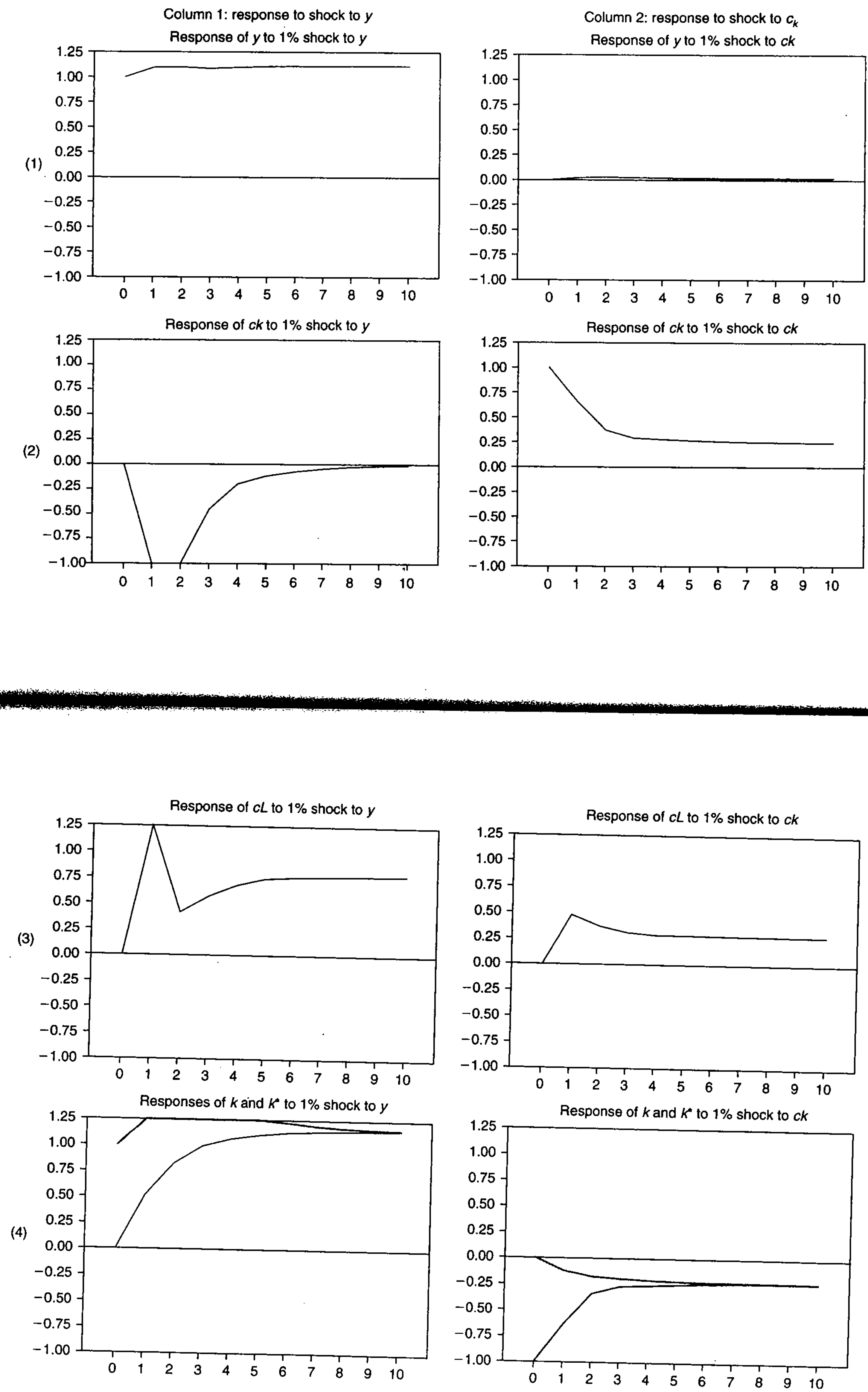
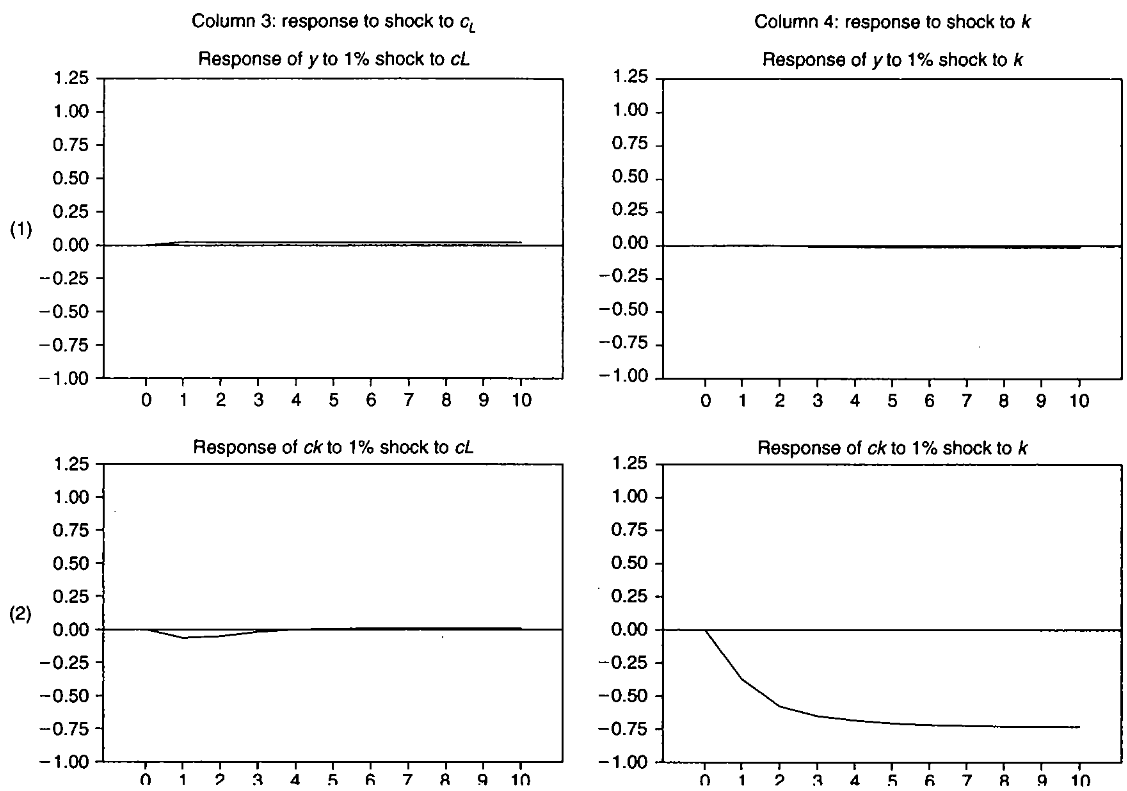
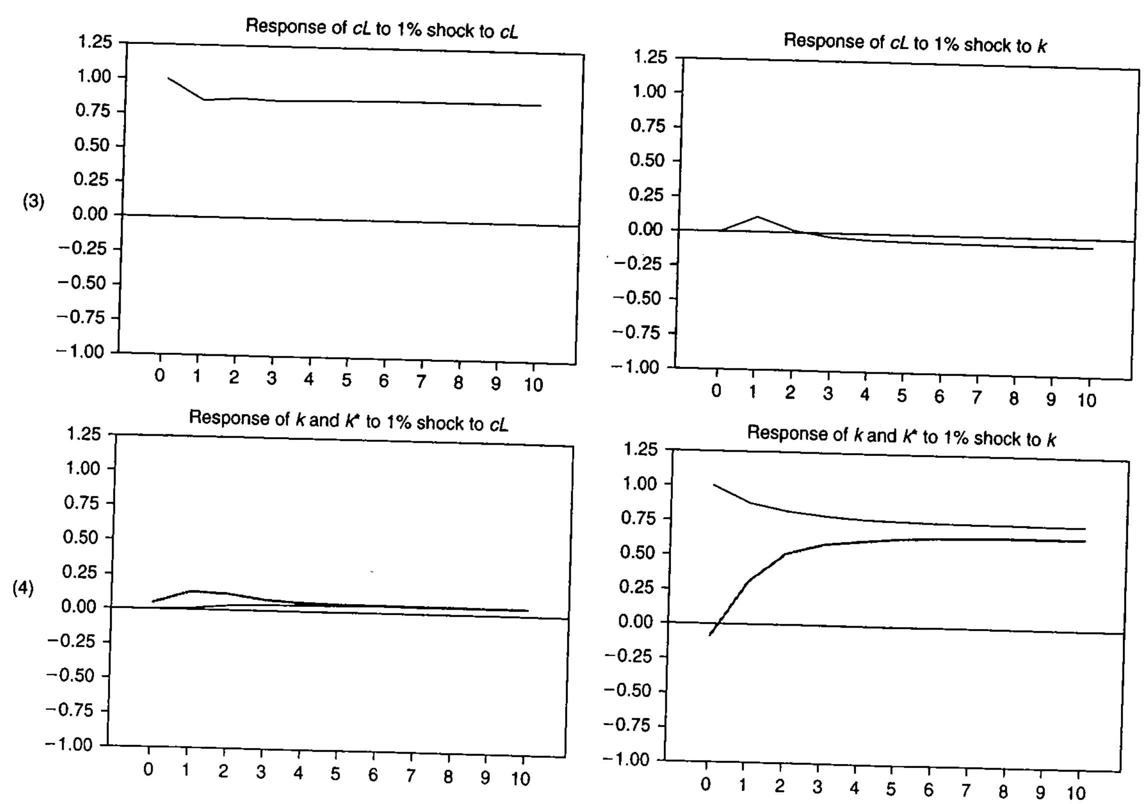

Column 1: response to shock to y
Response of y to 1% shock to y
Column 2: response to shock to c_k
Response of y to 1% shock to ck
(1)
Response of ck to 1% shock to y
Response of ck to 1% shock to ck
(2)
Response of cL to 1% shock to y
Response of cL to 1% shock to ck
(3)
Responses of k and k* to 1% shock to y
Response of k and k* to 1% shock to ck
(4)
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
0 1 2 3 4 5 6 7 8 9 10

Figure 12.3





Note: The figures plot the responses to 1% non-orthogonalized shocks, computed from the restricted VAR whose estimates are presented in equation (12.25). In the fourth row of each column, the lighter line plots the response of k^* the darker line the response of k. Columns span two pages.

Figure 12.3 (continued)

Table 12.3 Response of k *to a 1% shock, alternative specifications*

A. Full-sample estimates

Horizon	$\eta=0.05$ Shock to:				$\eta=0.03$ Shock to:				Alternative land price measure, $\eta=0.05$ Shock to:			
	y	*ck*	*cL*	*k*	*y*	*ck*	*cL*	*k*	*y*	*ck*	*cL*	*k*
1	0.52	−0.12	0.01	0.88	0.50	−0.12	0.01	0.88	0.38	−0.11	0.04	0.88
10	1.15	−0.22	0.05	0.75	1.12	−0.22	0.05	0.76	0.86	−0.24	0.09	0.71

B. Post-1973 estimates

Horizon	$\eta=0.05$ Shock to:				$\eta=0.03$ Shock to:			
	y	*ck*	*cL*	*k*	*y*	*ck*	*cL*	*k*
1	0.63	−0.05	0.00	0.95	0.61	−0.05	0.00	0.95
10	0.83	−0.04	0.02	0.95	0.84	−0.05	0.02	0.94

C. Unrestricted estimates, $\eta=0.05$

Horizon	Post-1973 sample Shock to:				Full-sample Shock to:			
	y	*ck*	*cL*	*k*	*y*	*ck*	*cL*	*k*
1	0.55	−0.04	0.02	0.95	0.55	−0.05	0.04	0.91
10	0.84	−0.05	0.03	0.91	1.09	−0.17	0.06	0.77

D. Estimates with $\eta=0$

Horizon	Post-1973 sample Shock to:				Full-sample Shock to:			
	y	*ck*	*cL*	*k*	*y*	*ck*	*cL*	*k*
1	0.57	−0.04	0.00	0.95	0.47	−0.11	0.01	0.89
10	0.84	−0.05	0.01	0.93	1.05	−0.20	0.04	0.77

Notes:

1. See notes to Table 12.2 and the text for description of the data. The parameter 'η' is defined in equation (12.11) in the text.
2. The impulses are in response to 1 percent shocks to the one-step-ahead forecast errors in VARs in (y, ck, cL, k); these shocks are not orthogonal.
3. The parameters of the VARs in (y, ck, cL, k) are computed from estimates of underlying VARs in $(k-k^*, \Delta k^*, \Delta ck, \Delta cL)$. Panels A, B and D present 'restricted' estimates, in which the underlying VAR parameters are restricted to obey equation 12.17. Panel C is based on the unrestricted estimates presented in Table 12.3. The text does not directly present the parameters for the VARs underlying the restricted estimates. But for the full-sample, restricted specification, with $\eta=0.05$, the coefficients of the VAR in (y, ck, cL, k) are given in equation (12.25) and the impulse responses are depicted in Figure 12.3.
4. In panel A, the last set of entries uses a different land price index to construct the user cost of land. This index is constructed from balance-sheet data on the nominal value of land in Japan as a whole. See text for details.

Table 12.4 Variance decomposition of k, *Choleski decomposition*

Horizon	$\eta = 0.05$ Percent of variance of k due to shocks to:				$\eta = 0$ Percent of variance of k due to shocks to:			
	y	ck	cL	k	y	ck	cL	k
1	6	12	3	78	5	10	2	83
5	16	32	12	41	16	28	7	49
10	18	36	13	33	18	32	9	41

Notes:
1. All estimates are computed from a VAR in (y, ck, cL, k), whose parameters are computed from the full-sample, restricted estimates with $\eta = 0.05$. The coefficients of the VAR in (y, ck, cL, k) are given in equation (12.25).
2. The variance decomposition is computed from the orthogonalized innovations to the VAR, with variables ordered as (y, ck, cL, k). Note that the innovations therefore are not those whose impulse responses are depicted in Figure 12.3 and presented in Table 12.3.
3. Totals may not add to 100 due to rounding.

indirectly through its ability to help forecast y_t and c_{kt} but otherwise does not affect k_t.

To be sure, land plays a slightly more important role when $\eta = 0.05$ than when $\eta = 0$. One way to illustrate this is with a variance decomposition for k_t. This is presented in Table 12.4. The decomposition is computed from orthogonalized innovations to the levels VAR (in contrast to previous tables, which used non-orthogonalized innovations). The orthogonalized innovations are computed from a Choleski decomposition, with the variables ordered y, ck, cL and k. Both decompositions look similar. But shocks to the user cost of land are more important when $\eta = 0.05$. For example, at a ten-year horizon, these shocks account for 13 percent of the variance of k_t; the corresponding figure is 9 percent when $\eta = 0$.

Our tentative conclusion is that while adding land to the production function and thus to the definition of target capital leads to sensible results, land price movements do not appear to play a particularly prominent role in explaining movements in business investment.

6. CONCLUSIONS

In Japan, business investment tends to be strong in periods when land prices are rising, and weak when land prices are falling. To explain and quantify the link between the two, we have proposed and estimated a neoclassical model. In the model, land and capital are both factors of production. Suppose the elasticity of substitution between the two is greater than one. Then anything that increases the user cost of land, such as increases in land prices, will cause a substitution into capital, and thus, all other things equal, will lead to strong business investment. The converse happens when a fall in land prices causes the user cost of land to fall.

We did not directly estimate the elasticity. But a calibration did find positive estimates of a related parameter 'η' that is positive if and only if the elasticity is greater than one. Using the calibrated value, we found estimates of the land–capital relationship that were plausible. The quantitative effect of land on capital change was, however, small. Mechanically, this appears attributable to the fact that our calibrated value of η is near zero, which is consistent with an elasticity only very slightly above one.

One priority for future research is to consider alternative measures of capital, land, and capital and land prices, which might be consistent with an elasticity distinctly greater than one. Two examples: many authors have commented on the difficulty of making sense of land prices in Japan (e.g., Auerbach and Ando, 1990) raising the possibility of problems with land price data; our intuition suggests that the effect of land prices may be more marked on structures than on equipment investment, yet our capital data and user cost are for a composite of structures and equipment. A second direction for future research involves considering the effects of regulations, in particular on land use. A final direction involves considering alternative explanations of the link between land and capital, including credit constrained models in which land serves as collateral, such as Kiyotaki and Moore (1997a, 1997b) and Ogawa et al. (1996).

NOTES

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1. This statement abstracts from creation or destruction of land by natural disasters such as earthquakes or volcanoes, and from special projects such as the bay area fill in that created the land underneath the Kansai airport in Osaka.
2. We include ourselves among those not completely comfortable with the series of approximations underlying (12.12). This is in large part because both theory and the data suggest trends that may not be well captured by our approximations. Theory: consider a non-stochastic general equilibrium version of our model, with aggregate land fixed at $L_t \equiv L$, and with the elasticity of substitution θ greater than one. Then the user cost of land C_{Lt} grows without bound but sufficiently slowly that the share of land income $(C_{Lt}L)$ in total income falls to zero, with μ_t rising to 1: as in Jones and Manuelli (1990), the fixed factor (in our case, land) asymptotically receives zero share of national income. This suggests

that it may be misleading to approximate μ_t around a constant, or perhaps even around a linear trend. Data: indeed, C_{Lt} displays an upward trend in our sample, as documented in Section 5.

An unrelated point on the general equilibrium model: if continual investment on physical capital is indispensable for sustained growth (as in most endogenous growth models), then growth eventually ceases if, as well, the elasticity of substitution is less than one. For this reason, our prior is that the elasticity is at least one.

3. Suppose we assume static expectations about the growth rate rather than level of P_{yt}. Let L denote the lag operator. Then upon multiplying both sides of (12.19) by $\{1-[(1-\lambda)/(1+i_{at})]L^{-1}\}$, we obtain an alternate expression of (12.20):

$$F_{Lt}=(P_{Lt}/P_{yt})C_{1Lt}C_{4Lt}(1+\tau_{pt}+\tau_{ht}C_{22Lt}-\lambda C_{23Lt}),$$

$$C_{4Lt}=\{(i_{at}-i_{yt}+\lambda(1+i_{yt})/(1+i_{at}),$$

where $i_{yt}=E_t(P_{yt+1}/P_{yt})-1$. This is similar though not identical to (12.20). We have not investigated the sensitivity of our results to such alternatives.

4. This was the reason we did not measure $1+i_{Lt}=E_tP_{Lt+1}/P_{Lt}$ with a univariate autoregression, as we did for the cost of capital: the fitted values were often very large, sometimes implausibly negative.
5. The ratio may seem small, in light of the stylized fact from growth theory that the capital–output ratio is about 2 or 3. But recall that the capital stock here is just that of non-financial corporations. If we add in government and household capital the ratio is about 2.5.
6. Ueda and Yoshikawa (1986) earlier pointed out that the response of capital depends on the time-series properties of the variables it is responding to.

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