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Business Fixed Investment and the Recent Business Cycle in Japan

1. Introduction

In the last decade, the Japanese economy has gone through both its strongest expansion of the last twenty years and its most severe recession of the last forty years. During this decade, business fixed investment was unusually volatile, and in a sense documented below seemed to be a dominant factor in both the recent 1986–1991 boom and the post-1991 bust. In this paper we attempt to explain the behavior of business fixed investment in Japan, with extra attention given to the 1986–1994 cycle.

We consider two approaches, one quite briefly, the other in some detail. Both approaches assume a frictionless world in which capital is accumulated to maximize a present value. The two differ in how the present value is measured. The approach presented in brief is based on Tobin’s Q, and uses stock prices to measure the relevant present value. Japanese asset prices zoomed in the late 1980s, and then collapsed. Our efforts to link asset prices and investment with a Q-model were, however, quite unsuccessful, a result consistent with a number of studies including Hayashi (1990) and Mullins and Wadwhani (1989).

Our second approach is a neoclassical, or flexible accelerator, model. Here, we compute the relevant present value ourselves, from data on output and the tax-adjusted cost of capital. Using our model, we con-
clude that business investment in Japan has responded to output and the cost of capital in a sensible way. This holds not only on average during our entire 1961–1994 sample but also in particular during the 1986–1994 period: one does not have to give pride of place to the extraordinary asset price movements to tell a coherent story about the behavior of investment.

Our formulation of the flexible accelerator model takes account of a secular increase in the capital–output ratio that occurred during our sample. Using a one-sector stochastic growth model that includes costs of adjusting capital, we show that this increase can be rationalized as a result of exogenous change in the marginal rate of transformation between investment and consumption.1 According to the model, the secular increase in the capital–output ratio will be matched by a corresponding secular fall in the relative price of investment goods. And we do find in the data that, because of a fall in the relative price of investment goods, the tax-adjusted cost of capital has fallen at roughly the same rate as the capital–output ratio has risen.

Our empirical work estimates a decision rule for capital accumulation that can be derived either from a log-linear approximation of the growth model’s first-order condition for the capital stock, or from a dynamic logarithmic version of the well-known neoclassical model in which the capital stock adjusts partially towards its target level each period. The target level is the (log of) the capital stock that equates the marginal product of capital to the cost of capital; in our Coble–Douglas specification this is the difference between the (log of) output and (the log of) the cost of capital. We use both our model’s decision rule and unrestricted autoregressions to model capital, in conjunction with unrestricted autoregressions used to model both output and the cost of capital. These estimates are consistent with our model in three ways.

First, the decision rule and the unrestricted autoregressions for the capital stock are quantitatively very similar. Second, because of convex costs of adjusting the capital stock, forward-looking firms will begin to adjust their capital stocks in advance of actual movements in the target level of capital. If firms make forecasts of movements in the target level using information not used by us, this adjustment will show up as a Granger causality from capital to the target level. And we do indeed find such causality. Third, our logarithmic model allows capital to have different elasticities with respect to output and the cost of capital.2 Because of costs of adjustment, the long- and short-run responses of capital to a shock to one of these variables will be stronger the more persistent is the shock. These responses will be quite small, for example, if there is very little persistence (lots of mean reversion), so that initial movements are directed more to output and the cost of capital. In our data, output shocks are persistent and cost of capital shocks are mean-reverting. Correspondingly, we find a large (and of course positive) elasticity of capital with respect to output, and a small (and of course negative) elasticity of capital with respect to the cost of capital.

We use the estimates of the decision rule to determine whether investment was anomalous during 1986–1991 or 1991–1994. In each of the two periods, we decompose unexpected movements in the capital stock into two components. One component is the reaction of the capital stock to surprises in output and the cost of capital; the second component is a residual surprise to the capital stock. In each period, we find that much of the unexpected movement in the capital stock is attributable to output shocks and cost of capital shocks. We conclude that given the 1986–1991 and 1991–1994 movement in output and the cost of capital, the movements in investment that occurred are consistent with historical experience.

The paper has many limitations. We emphasize two here. First, we do not attempt to explain systematically the behavior of any aggregate variable except investment: For the most part we leave uninterpreted what moves output and the cost of capital (productivity? monetary policy?). Similarly, we gloss over many aspects of the Japanese economy—the current crisis in the banking system, for example—that might require close attention if our aim were to provide a detailed analysis of the causes of the boom and bust. Second, because of space and time constraints we were not able to evaluate a model that focuses on credit constraints and balance-sheet effects (e.g., Kiyotaki and Moore, 1994, 1995); it is entirely possible that such a model would provide a more persuasive and more complete explanation of the behavior of aggregates than we provide here. We hope to address both limitations in future research.

The paper is organized as follows. Section 2 describes the behavior of some key variables. Much of the material in this section will be familiar to Japan experts. Section 3 describes the main theme of the paper, and discusses the evolution of our general equilibrium model, Sections 4 and 5 our Q and flexible accelerator models, Section 7 how we constructed the data used in our empirical work, Section 8 the results of the Q-regressions, and Section 9 the results of the flexible accelerator regressions.

1. The logic here is essentially that of Greenwood et al. (1995).
2. This property is shared by the Stock (1997) formulation of the neoclassical model, although Stock appeals to a Ruty–Dutt distinction between old and new capital rather than to the time-series properties of output and the cost of capital.
2. Behavior of Aggregate Variables

In this section, we describe the recent behavior of some key variables. Our purposes are to describe broad patterns to readers who are unfamiliar with the Japanese economy, and to introduce many of the variables that will be central to our analysis. Section 2.1 considers some basic national income and product account (NIPA) data, Section 2.2 capital stock data, and Section 2.3 asset price data. Section 2.4 summarizes. Unfortunately, because of data limitations, the frequency of the data changes from quarterly (NIPA) to annual (capital stock data) to quarterly and semiannual (asset price data); it may help to note that our subsequent analysis actually uses annual data, typically using annual averages of the higher-frequency underlying data.

Data sources are described in detail in a Data Appendix available from the authors. Briefly, the basic sources are as follows. NIPA data: the Japanese Economic Planning Agency (hereinafter, EPA) and the Bank for International Settlements; monetary and financial data; the Bank of Japan, and International Financial Statistics; capital stock and balance sheet data: the EPA. Except when otherwise stated, all data are real (1985 prices). All quarterly data are expressed at annual rates. All data are aggregate, not per capita.

2.1 NIPA DATA

Table 1 presents data on quarterly growth rates for GDP and its major components. As indicated in the means presented for 1961–1973 in column (2) of Table 1, GDP growth averaged a phenomenal 8.6% before the first OPEC shock. There is no agreed-upon date for the precise end of what has come to be known as the "rapid growth" era. But 1973 is seen as a good candidate as any. Since then, growth has averaged 3.3% [column (4) in the first row of Table 1]. A comparison of columns (5) and (4) for the other rows indicates that the slowdown in growth affected all the major components of GDP. The dates in columns (5)–(7) are troughs (1966:4) and peak (1991:2) dates chosen by the EPA.

To begin motivating our focus on business fixed investment, let us consider in more detail the last expansion and the ongoing contraction. Table 2 divides changes in GDP into various components, for the expansion of 1966:4–1991:2 and for the 15 quarters from 1991:2 to the end of our sample. To read the table, consider column (2). GDP in 1996:4 was 334.2 trillion 1985 yen, or about 3.3 trillion dollars at 100 yen/dollar. It increased by 80.5 trillion yen from 1966:4 to 1991:2 [row (2), column (2); Table 1, column (6) indicates that the corresponding compound growth rate is 4.9% per year]. GDP further increased by a paltry 5.9 trillion yen

| Table 1: GROWTH RATES AND STANDARD DEVIATIONS OF GDP AND ITS COMPONENTS. |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Private F and E             | Private Residential         | Investment                  |
| Government Spending         | Government Consumption      | Exports                     |
| Imports                     | Imports                     | Imports                     |

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The data for GDP and 1965(1) are annual, actual or real, at 1985 prices. All data for later years and all data for imports are in constant yen, at 1985 prices. Imports are annual, actual or real, at 1985 prices. All data for later years and all data for imports are in constant yen, at 1985 prices. All data for later years and all data for imports are in constant yen, at 1985 prices.
between 1991:2 and 1995:1. Columns (3)—(8) give the corresponding figures for some major components of GDP.

It may be seen that the changes in GDP went hand in hand with large changes in private plant and equipment investment. While such investment had averaged about 15% of GDP in the sample, its increase was nearly half (37.08%) of that in GDP from 1986:4 to 1991:2, and its 19.3-trillion-yen decline from 1991:2 to 1995:1 was associated with a nincrease in GDP. Complementary evidence on this combination of GDP and private plant and equipment investment is provided by the predictions of a VAR, which we briefly summarize here. Using a VAR in the arithmetic differences of the six variables listed in column (3)—(8) in Table 2, we decomposed movements in GDP and in PPI of the six variables into expected and unexpected components, for the last cycle. Unsurprisingly, we found that GDP growth from 1986:4 to 1991:2 was substantially higher than was expected in 1986:4, and that GDP growth from 1991:2 to 1995:1 was much lower than was expected in 1991:2. We also found that when we broke the GDP forecast error into errors in forecasting each of the six components in Table 2, the dominant element was the forecast error in plant and equipment investment.

We conclude that a first step in understanding the recent behavior of the Japanese economy is to understand private plant and equipment investment, and that is the focus of our paper.

2.2 CAPITAL STOCK DATA

Our capital stock data are those for nonfinancial corporations. We focus on this sector because its investment is largely congruent with that of private investment in plant and equipment. In 1993, for example, over 80% of such investment was accounted for by corporapolis, and, conversely, over 80% of total investment by nonfinancial corporations consisted of investment in plant and equipment. Our capital stock data also reflect some public and corporate residential investment (about 5% of total sectoral investment in 1993) and some plant and equipment investment by public corporations such as NTT, the telephone company (about 10% in 1993).{3}

3. That the change in inventory investment is a small part of the change in GDP is consistent with previous downturns in Japan. See West (1993). That fluctuations in plant and equipment investment have been central to the last cycle is noted, for example, in Economic Planning Agency (1994, p. 66).

4. Many small firms are included in this sector. According to the 1991 Establishment Census, Japan’s total employment of nonfinancial corporations is 42.8 million. Of this total, 25.3 million work at corporations of a single establishment, with no branch offices, of fewer than 100 employed, and only 6.5 million work at corporations whose
This capital stock includes both structures and equipment; unfortunately, these two types of capital cannot be distinguished as is conventionally done in U.S. investment studies. The corresponding output variable used in our analysis is what the EPA calls "output of industry." Here, "industry" includes, for example, production of services and residential construction; apart from statistical discrepancy, industry output = GDP = (output of government) + (output of nonprofit institutions serving households). The capital stock and output of industry are only available annually. Some details on conversion to 1985 prices are given in a footnote.1 Figure 1a plots the growth rate of capital stock, with shaded areas depicting contractions. Once again, growth rates were astounding before 1973. The effects on capital growth of the 1986–1991 boom and the 1992–1994 collapse in plant and equipment investment are apparent in the picture: capital growth was at a post-1974 high during the boom, a 1941–1994 low during the collapse. Figure 1b and c plot the levels and growth rates of output of industry and of GDP. Figure 1b indicates that industry output comprises the bulk of GDP; Figure 1c that the two move closely together but that industry output is more volatile.

Figure 1d plots the capital–output ratio. A steep upward trend is apparent. Growth in this ratio was particularly rapid in 1969–1975, but it appears that more or less steady growth has continued since then. We document below that there is a corresponding downward trend in the ratio of the deflator for private investment in plant and equipment to that of the output deflator (see Section 7 and Figure 4). These trends are not due to the particular definition of output or capital. The trend in the capital–output ratio, and in the ratio of a capital to output-goods deflator, is equally evident when (for example) capital includes inventories and fixed capital of not just the nonfinancial corporate sector but that for the whole economy, and when output is GDP (not depicted in Figure 1).

Approximate constancy of the capital–output ratio is one of the basic stylized facts of growth theory (Kaldor, 1963; Simon, 1990). Perhaps the Japanese growth in the ratio is a transitional phenomenon rationalizable in a familiar way by the Cass–Koopmans–Solow growth model. If so, experience from the United States perhaps suggests that a steady state has been reached, since the aggregate capital–output ratio was about 2.5 by the end of our sample. Our empirical work does not take a stand on whether or not this
growth is transitional, although our model in Section 4 does point out
that an indefinite continuation of such growth is not likely to be consistent with
balanced growth. Rather, we take the message of Figure 1.d to be that a good
model of investment must account for the growth in the ratio that has occurred.

2.3 PRICE AND ASSET PRICE DATA

As is well known, Japanese stock and land prices zoomed in the late
1980s, and then collapsed. Figure 2a shows the annual (1985) stock price index
and corresponds to the Toypix index along with corresponding dividend yields
multiplied by 10. The closest U.S. equivalent to the Toypix is probably the
S&P 500. Throughout this subsection, real
values are computed using the GDP deflator. The "bubble" period is
typically considered to have begun late in 1985, or towards the left end
of the next to last shaded area in the graph. A sharp peak occurred at the
end of 1988, anticipating the downturn in real activity. In the four years
from 1985 to 1993, the real value of the index increased by a factor of
about 2.5, implying an annual rate of appreciation of 23.1%. The
"bubbles" decline lost 1985's stock prices barely 15% above their 1989 value.
As may be seen, dividend-price ratios are smaller by U.S. standards: in
1985-86 they were 1.01%, and had fallen to 0.96% by 1995-96.

Figure 2b plots real, seasonally-adjusted (end of quarters 1 and 3) land prices,
measured as the average price in all urban districts. The runup began at the
end of 1986, and the peak occurred in early 1991, so that land prices
followed rather than preceded stock prices. From 19863 to 19911, the
index increased by about half, with an implied annual rate of appreciation
of about 8.4%. The 1991 value of the index is about 20% above the
19863 value. It should be noted that the comparable land-price index for
the six largest cities in Japan is more volatile, increasing by a factor of
more than 2 between 19863 and 19911, and declining more than 40%
since then.

Figure 2c plots end-of-quarter values of a safe nominal interest rate,
the call rate. (Among U.S. rates, the closest equivalent is probably the
Federal funds rate.) It also plots our measure of the business borrowing
rate. For 1992-1994, the latter is the end-of-quarter value of the Bank of
Japan series "average contracted interest rates on new loans and
discounts, long-term." For 1961-1991, the borrowing rate was set to the
corporate quarterly yield of long-term bonds of NTT, the main telephone
company, plus 1%. The risk premium of 1% corresponds to the average
spread between the series for new loans and discounts and the NTT rate,
for the period for which we had data on both series (19921 through
19931). It may be seen in Figure 2c that an inverted term structure
causes the call rate to be above the borrowing rate on occasion.

Interest rates increased during the recent 1986-1991 period of the trend is perfecty consistent with
the ongoing contraction. The increases in the call
rate after mid-1989 are commonly thought to have been part of an inten-
tional attempt by the Bank of Japan to "pin down the yen" in stock and
land prices, and to cool down an overheated economy. Similarly, the
recent declines seem to have resulted from explicit attempts by the Bank
of Japan to pin the yen down.
2.4 SUMMARY
The GDP boom of 1986–1991 and collapse of 1992–1994 went hand in hand with a boom and collapse in business investment in plant and equipment. This motivates us to focus on such investment. Since, in turn, the model we use are formulated in terms of the capital stock, we turn to the capital stock that pretty much moves one to one with such investment, the capital stock of nonfinancial corporations. Because such data are available only annually, the rest of the analysis is annual.

A ramp up and decline in stock and land prices preceded the real cycle by a year or two, suggesting the possibility of a link running from asset price and balance-sheet movements to business investment. We consider this possibility both with formal tests of Q-theory (Sections 5 and 8) and an informal examination of data patterns that are central to credit constraint models such as Kiyotaki and Moore (1994, 1995) (Section 3).

The pattern in the cost of capital is less evident, at least for 1986–1991. But whatever the pattern, the secular growth in the capital-outputs ratio suggests a secular fall in the return to capital. So we are compelled to consider the trend as well as the cyclical behavior of the cost of capital. Sections 6 and 9 investigate our version of a flexible accelerator model, in which capital accumulation depends on both output and the cost of capital.

This section digresses from the analysis in the rest of the paper to summarize some basic observations on the movement of balance sheets of nonfinancial corporations during 1961–1994. The aggregate balance-sheet data we discuss are consistent with the NIPA data on saving and investment. The data are available annually, at the end of the year. Most are available only at current prices (an exception is the capital stock). In principle, assets are valued at market rather than book value. We focus on the balance sheet of the nonfinancial incorporated business sector.4 We combine some underlying items into four types of assets [items (3.1) to (3.4) below], a liability [item (3.5)], and net worth [item (3.6)].

(3.1) capital + inventories (denoted $p_{K}$, where $p_{K} = 1$ in 1985): The sum of net fixed capital (assets) and inventories.

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(3.2) Land ($p_{L}$): Nonreproducible tangible assets, excluding improvements in land measured as such improvements are included in NIPA business fixed investment.

(3.3) Equity ($p_{E}$): Holdings of shares of other corporations.

(3.4) Monetary assets ($p_{M}$): Financial assets apart from equity, this includes, for example, money, debt, and trade credit.

(3.5) Debt ($B$): All liabilities, apart from net worth and the value of equity, this includes, for example, debt and trade credit.

(3.6) Net worth ($W$): Net worth plus the value of own equity.

Table 3a and b summarize trends and fluctuations of these balance-sheet items. These tables present the real value and growth rate of each

Table 3 BALANCE SHEETS OF NONFINANCIAL CORPORATIONS, SELECTED YEARS

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Note:
1. Data in panel (a) are billions of 1985 yen, compared by deflating the nominal data with the GDP deflator. Data are in end year.
2. The annualized growth rates in panel (b) are computed from the end of the first year to the end of the second year.

4. For other sectoral balance sheets are maintained: financial institutions, households, including unincorporated nonfinancial enterprises, nonprofit institutions serving households, and the government. Note that in contrast to the U.S. balance sheet data from the Federal Reserve System, Japan's balance sheet data are based on a sample of incorporated enterprises with the household sector.

8. For other sectoral balance sheets are maintained: financial institutions, households, including unincorporated nonfinancial enterprises, nonprofit institutions serving households, and the government. Note that in contrast to the U.S. balance sheet data from the Federal Reserve System, Japan's balance sheet data are based on a sample of incorporated enterprises with the household sector.
balance-sheet item, computed by deflating the supplied nominal values with the GDP deflator (1985=100). Here is how we characterize the dates in the tables, which do not mach the official business-cycle dates used in other parts of the paper. The period 1962–1969 is part of the rapid economic growth era of 1950s and 1960s; 1970–1973 and 1986–1990 are periods with asset price inflation; 1974–1977 and 1991–1994 are periods of slow growth, which for brevity we call recessions; 1978–1981 and 1982–1985 are periods of relatively steady growth on average.

To fix the scale of the entries in Table 3, it may help to note that the 1960 real GDP is about 399 trillion yen. So land is large relative to GDP, and is an important share—more than a quarter—of total assets. A second point worth noting is that cross-holdings of equity are an important share—about a tenth—of assets. Because land and equity are important parts of assets, net worth is sensitive to fluctuations in the prices of such assets.

The figures in Tables 3a and b show three patterns. The most important is that all six balance-sheet items tend to expand together rapidly during booms and tend to shrink (or grow more slowly) during the recessions. This is true not only for the real assets—capital+investories, land, and equity—but also for the real value of monetary assets and debts. Second, for the 33-year period 1961–1994, capital+investories, equity, and monetary assets grow at a similar rate, with debt and net worth growing at a slightly higher and land at a distinctly higher rate. Third, movements in equity, land, and net worth tend to be more volatile than those in capital+investories, monetary assets, and debt.

A natural next question would be how much of these movements are due to net accumulation of these items, and how much to the changes in asset prices relative to the GDP deflator. Net acquisitions of each balance sheet item are measured in the capital finance accounts of the sectors, as shown in Table 4. The change in the market value of an asset or liability may be written as the sum of net acquisitions and revaluation due to changing prices. This revaluation is captured in the revaluation accounts, with the identity (year-to-year change in an entry on the balance sheet) = (entry on the capital finance account) + (entry on the reconciliation account). For example, for capital+ investories K and monetary assets M,

9. It should be noted that the reliability of the data on land and equity is suspect. There is some evidence that land values are overstated, and in a way that is not particularly easy to correct (see Anido and Asch, 1995). Equity values, on the other hand, may be understated, since for normalized equity face value is used. These misstatements of land and equity may cause serious problems in constructing Tobler’s Q.

10. While the main function of the reconciliation account is to capture capital gains and losses due to changing prices, the reconciliation account of capital appears to include as well (1) the difference between historical and replacement cost of depreciation (Hayashi, 1986); (2) some measurement errors; and (3) the effects of change in the accounting system.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Outflow</th>
<th>Inflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross fixed capital formation (IC) + inventory investment</td>
<td>(K) Savings (including net capital transfers)</td>
<td>(S)</td>
</tr>
<tr>
<td>Net purchase of land</td>
<td>(T) Capital consumption</td>
<td>(D)</td>
</tr>
<tr>
<td>Savings—investment</td>
<td>(D) (Depreciation)</td>
<td>(D)</td>
</tr>
</tbody>
</table>

Financial transactions

- Net acquisition of equity (E) = Net increase in liabilities (B)
- Net acquisition of monetary assets (M) = Net issue of equity (I) + Financial surplus (F)

increase in the market value of capital+investories = net investment + reconciliation account for K,

\[ \Delta K = \Delta K - \Delta M + \Delta R + \Delta M = \Delta K - \Delta M + \Delta R + \Delta M \]

(3.7)

where \( \Delta K \) is the change in net capital+investories, \( \Delta M \) is the change in monetary assets, and \( \Delta R \) is the change in real capital gains of each entry:

\[ \Delta K = \Delta K - \Delta M + \Delta R + \Delta M \]

(3.9)

where \( \Delta K \) is the change in the real value of capital+investories, \( \Delta M \) is the change in monetary assets, and \( \Delta R \) is the change in real capital gains of each entry:

\[ \Delta K = \Delta K - \Delta M + \Delta R + \Delta M \]

(3.10)

where \( p_t \) is the expectation of the price level at date t = 1. [This expectation was computed from the fitted value of an AR(1) in the inflation rate.]

Equation (3.9) says that the change in the real value of capital+investories is equal to the sum of the real values of net capital gains and capital gains. We regard the reconciliation account as a measure of nominal capital gains, and construct real capital gains as \( RK_t / p_t \) plus a term due to inflation.

We apply this decomposition to land and equity. Concerning monetary assets in (3.10), we consider the effect of expected inflation in the second term on the right-hand side as a part of net acquisition of monetary assets; the underlying idea is that expected inflation affects nominal returns on monetary assets. Thus only unexpected inflation and the recon
The first line of the right-hand side is the real value of the net saving and issues of own equity, together with the effects of expected inflation. The second and third lines are real capital gains on capital inventories, land, and equity, and monetary assets net of debt. 1

Table 5 presents the total real value of net acquisitions and capital gains during each period. (The final period is 1991–1993 rather than 1991–1994 because of some incompatibilities introduced by data revisions made with the release of the 1994 data.) The first point to note is that real capital gains are the major factor in fluctuations of net worth of nonfinancial corporations, rather than net savings and net issue of equity. These capital gains and losses are large even when compared to annual GDP (1990 real GDP is 999 billion). During the 1986–1980 asset price inflation, real net worth increased by about 528 billion 1985 yen, of which 430 billion were capital gains and 98 trillion were net savings and net issues of equity. During 1991–1990, net worth dropped by 276 trillion, with a capital loss of 311 trillion partially offset by 31 trillion of net saving and net issues of equity. A particularity important source of real capital gains and losses is fluctuations of land and equity prices (although, as noted above, these prices may be measured poorly). This pattern also holds for the 1970–1973 asset price inflation and the 1974–1977 recession.

A second point to note is that the issue of debt is very procyclical. Debt expansion was particularly notable during the 1970–1973 and 1986–1990 asset price inflations, and contraction (or slow growth) of debt is notable during the 1974–1977 and 1991–1993 recessions. Procyclical movements in the loan supply and demand can be expected in periods of rapid economic growth and rapid inflation.
model, we include standard features such as elastic labor supply that do not play a role in the empirical work (and could, but do not, include still more features such as government and foreign sectors; see Greenwood, Hercowitz, and Kressel (1990) or Jones and Manuelli (1994)). The second aim is to motivate the regressions presented and discussed in subsequent sections. We do, however, forewarn the reader that this model is rather stylized, and we do not constrain the empirical work to fit precisely in the model.

The model is in the vein of the closed-economy one-sector Cass-Koopmans model, but with (exogenous) changes in the marginal rate of transformation between investment goods and consumption goods. The production function and basic resource constraints are

\[ Y_t = A F(K_t, H_t, N_t) = A \left( K_t \left( \frac{G_t}{H_t} \right)^{1-\delta} \right) \]

\[ Y_t = LN_t + P_t (u_t + \frac{1}{2} \frac{P_t}{K_t}) \]

\[ X_t = K_t - G_t \frac{P_t}{K_t} = \frac{I_t}{K_t} - G_t + 1 - \delta. \]

In (4.1), the aggregate output \( Y_t \) is a Cobb-Douglas function of the aggregate capital stock \( K_t \), the labor hours per worker \( H_t \), the population \( N_t \), the deterministic labor productivity level \( A_t \), and the stationary stochastic aggregate productivity level \( \Lambda_t \). In (4.2), capital accumulation proceeds as usual, with \( \delta \) the constant depreciation rate and \( I_t \) gross investment. In (4.3), output is used for per capita consumption \( \bar{c}_t \) and investment. \( P_t \) is the relative price of investment goods. It equates an exogenous marginal rate of transformation between investment and consumption goods. The adjustment cost \( (\partial/\partial X_t) \bar{c}_t \) is increasing in the deviation of capital growth from its steady-state rate \( G_t \). Basier and Crukel (1993) and Cogley and Nelson (1995) use similar adjustment costs. In (4.4), \( X_t \) is defined as the rate of capital accumulation over its steady-state gross growth rate \( G_t \) (which is solved for below). Preferences of the representative household are given by the expected discounted utility

\[ E_T \sum_{t=0}^{\infty} \beta^t w_t u_t \left( x_t - 1 + \delta \right) \]

where \( u(x) = (x^{-1} - 1)(1 - \sigma) \), \( v(1) = H^\gamma (1 + \sigma) \), and \( B_t \) is a measure of the durability of labor.

Let the aggregate productivity \( \bar{\Lambda}_t \) be strictly positive, with mean one, and follow a finite-state stationary Markov process. Let the labor productivity \( \bar{A}_t \), durability of labor \( B_t \) and population \( N_t \) grow, and let the relative price of investment goods \( P_t \) shrink, at constant rates,

\[ A_{t+1} = A_t A_t, \quad B_t = B_t \quad N_{t+1} = N_t \quad P_{t+1} = P_t \]

\[ A_{t+1} = (G_t A_t)^{1-\delta} \quad < (G_t A_t)^{1-\delta} \]

where all \( G_t = 1, l = A_t, B_t, N_t \). \( P_t \) guarantees no trend in labor hours. It may be shown that the competitive equilibrium exists. The corresponding social planner's problem maximizes the preferences of the representative household, subject to the resource constraint. The first-order conditions for labor hours and investment are given by

\[ \frac{u(\bar{c}_t) - \bar{\Lambda}_t}{\bar{c}_t} = B_t \bar{\Lambda}_t \]

\[ P_t (1 + \delta X_t) = \frac{Y_t}{H_t} \left( \frac{\partial x_t}{\partial X_t} \right) \left( 1 - 1 + \bar{\Lambda}_t \right) \]

Equation (4.8) equates the marginal product of labor in terms of utility to the marginal disutility of labor. Equation (4.9) equates the marginal cost of investment to the marginal value of an additional unit of capital. The marginal value has three terms: the marginal product of capital, the expected discounted rate of saving of remaining capital, and the expected marginal saving of adjustment costs the following period.

Let us first consider the growth implications of the model. By examining (4.1) to (4.9), we see that there is no trend in labor hours, and that one plus the growth rate of aggregate capital is given by \( G_t = G_t G_t^{1-\delta} \). Output growth at the rate \( G_t G_t^{1-\delta} \), which is lower than that of aggregate capital by a factor of \( G_t \). It follows that \( E(t) \), which is growing at the rate that \( P_t \) is shrinking, thus establishing the desired theoretical link between the two trends observed in the data. Further, define the cost of capital \( C_t \) as the opportunity cost of owning one unit of capital from date \( t \) to date \( t+1 \):

\[ C_t = \frac{P_t}{P_{t+1}} (1 - \delta) \frac{u(x_t)}{\bar{\Lambda}_t(x_t)} \]

(4.10)
Let $K^* = Y_t/C_t$. $K^*$ is the target capital stock, which, apart from a proportionality factor $d$, would obtain if there were no adjustment costs to investment. Observe that the cost of capital $C_t$ is also shrinking at rate $G_t$. So the rates of growth actual ($K$) and target ($K^*$) capital are the same.

We now show that the investment first-order condition (4.9) may be approximated in a computationally convenient fashion, as a dynamic, logarithmic version of a fixed accelerator familiar from Hall and Jorgenson (1967). Let $M_{t+1} = (E_{t+1}/P_t)(G_t)(G_{t+1}/G_t)$ be the intertemporal marginal rate of substitution in terms of investment goods. Upon manipulating (4.9), we obtain

$$X_t = \frac{\phi X_t}{P_t} \left( \frac{Y_t}{C_t} \right) + E[M_{t+1} X_{t+1} (G_t + 0.5 X_{t+1})].$$

Let $M = EM_{t+1}$ be the unconditional mean of $M_t$. Using $X_t = -G_t + 1 + (\Delta K_t/K_t)$, $C_t/P_t = 1 - (1 - \delta)E[M_{t+1}]$, and the definitions of $K_t$ and $M$, (4.11) becomes

$$\frac{\Delta K_t}{K_{t+1}} = (G_t - 1)(1 - G_t M) + [\phi^3 - \phi^2 (1 - 8M)] \frac{K_t}{K_{t+1}} + M G E_m \Delta K_{t+1} + u_t,$$

where $u_t = \phi^3 (1 - 8M) - EM_{t+1} [\ln (K_{t+1}/K_t) - 1] + GE_m \Delta M_{t+1}$. Equation (4.12) implies that the growth rate of the capital stock is a linearly increasing function of two variables: the percentage gap between the target and actual capital stocks, and the expected growth rate of the capital stock. Now take the following first-order approximation. [See Abel and Blanchard (1986) for some empirical evidence in an investment context supporting an approximation such as the one about to be used.] Note that all the terms in $u_t$ are the products of random variables that are zero in the nonstochastic steady state, and so will be small when the system is near the steady state. Next, use $\ln (K_{t+1}/K_t) - 1 = \ln (K_{t+1}/K_t) = \ln \theta - \ln k$, and throughout the paper, when upper- and lowercase are both used, the lowercase denotes a logarithm. Finally, define $\alpha = \phi^3 (1 - 8M)$ and $b = MG$. We end up with an equation used in the empirical work.

$$dK_t = \text{constant} + \frac{1}{\alpha} (K_t - k) + E P_t \Delta K_{t+1} + \epsilon_t.$$  

where $\epsilon_t$ collects approximation errors and terms assumed to be small.

5. Q-Model

Our empirical work on $Q$ is conventional. Define $Q_t$ as the ratio of the marginal value of capital to the price of capital. Given constant returns to scale, such as is assumed in the model in the previous section, the marginal value of capital [defined as the right-hand side of (4.9) in the marginal of the previous section] is equal to its average value (see Hayashi, 1982). Thus under a standard set of assumptions about stock-market behavior, $Q_t$ can be measured as Tobin’s $Q$, the ratio of the stock-market valuation of capital to the replacement cost of capital.

Apart from deterministic terms, the regressions actually run were

$$L/K_t = \gamma Q_{t-1} + \text{disturbance},$$

or $L/K_t = \gamma Q_t + \text{disturbance}$, possibly with a correction for first-order serial correlation. Here, $Q_{t-1}$ is $Q$ at the end of period $t - 1$ (beginning of period $t$).

6. Flexible Accelerator Model

In this section we derive the equations used in the main part of our empirical work. The investment first-order condition that we begin with was presented in equation (4.13) of the general equilibrium model of Section 4. But since we do not wish to tie ourselves to this model, we make a self-contained presentation here. Our dynamic, logarithmic implementation is similar in spirit though not in all detail to that of the familiar Hall-Jorgenson (1967) approach to investment as implemented by Clark (1979) and many other authors. A representative firm minimizes

$$0.5 E_m \sum_{t+i} \frac{1}{2} \left[ (K_{t+i} - k)^2 + \alpha (K_{t+i} - k)^2 + 2k_t \epsilon_t - J_t \right].$$  

where $\epsilon_t$ are the errors of our empirical work not suggested by the model; we obtain discount less from observed rates of return on financial assets rather than intertemporal marginal rates of substitution; we allow multiple rather than single shocks; we have stochastic rather than -stochastic trends.
In (6.1), $E_i$ is mathematical expectation, using data as of period $t$ assumed equivalent to linear projections, $0 \leq b < 1$ is a discount factor, $k_t$ is the log of the capital stock at the end of period $t$, $k_t'$ is the log of the target capital stock, which would obtain in a deterministic steady state, $z_t$ is a stationary cost shock observable to the firm but not the economist, and $a$ is a positive parameter that reflects the relative importance of being away from $k_t'$ and of adjustment. In (6.2), $y_t = \ln(\text{output})$ and $c_t = \ln(\text{cost of capital})$: the underlying technology is Cobb-Douglas. Inessential constants have been omitted from (6.1) and (6.2) for clarity.\(^{13}\)

Upon differentiating (6.1) with respect to $k_t$, we obtain equation (4.13), and familiar manipulations lead to

$$k_t = k_t' + \frac{1}{a} \sum_{n=0}^{\infty} (b/a)E_k k_{t+n} - \frac{1}{a} \sum_{n=0}^{\infty} (b/a)E_k k_{t+n} \cdot \cdot \cdot$$

(6.3)

whence

$$k_t - k_t' = \lambda(k_t - k_t') - \Delta k_t^* = (1 - \lambda) \frac{1}{a} \sum_{n=0}^{\infty} (b/a)E_k k_{t+n} \cdot \cdot \cdot$$

(6.4)

In (6.3), $0 < a < 1$ is the smallest root of the equation $\log(1 - a + a) = a = 0$, and we derive (6.4) from (6.3) using $\lambda = (1 - \lambda)(1 - b)$. We turn to (6.4) from (6.3) to have a decision rule in terms of a stationary variable: in our data, the percentage deviation of capital from its target value, $k_t - k_t'$, and the growth rate of target capital, $\Delta k_t^*$, arguably might be well modeled as stationary, possibly around a one-time change in mean in 1974; rapidly growing variables like $k_t$ and $k_t' - y_t$ will not.

To solve (6.4) for the implied process for $k_t - k_t'$, let $f_j$ denote a vector of variables that are useful in forecasting future $\Delta k_t^*$, including at least two of $\Delta k_t'$, $\Delta y_t$, and $\Delta c_t$—say $\Delta k_t'$ and $\Delta c_t$ for concreteness. (Giver $\Delta k_t' = \Delta y_t - \Delta c_t$ and our use of linear models, all results are identical when we use any two of $\Delta k_t'$, $\Delta y_t$, and $\Delta c_t$.) Let $Z_t = (k_t - k_t', f_t')$. Through most of the work $f_t$ contains no variables in addition to $\Delta k_t'$ and $\Delta c_t$, and $Z_t$ is $3 \times 1$. We have

$$k_t - k_t' = \lambda(k_t - k_t') - \Delta k_t^* + \frac{1}{a} \sum_{n=0}^{\infty} (b/a)E_k [\Delta k_{t+n} k_{t+n} - \Delta k_t' k_{t+n} \cdot \cdot \cdot] + \epsilon_t$$

(6.5)

\(^{13}\) Nickell (1979) also suggested a log-linear flexible accelerator model.
7.1 Q-REGRESSIONS

Gross investment [the numerator of the left-hand side of (5.1)] was computed by deflating the sectoral nominal gross investment figure by the deflator for private investment in plant and equipment. In most of the regressions reported below,

denominator of \( Q \) = nominal value of net fixed assets,

\[ (7.1a) \]

\[ = \text{own equity value + debt} \]

numerator of \( Q \) = \(-\text{(inventories + land + cross-holding of equities + monetary assets)} - r\lambda, \)

\[ (7.1b) \]

where \( r \) is the effective corporate tax rate, and \( \lambda \) is the expected present value of depreciation of past investments. Construction of \( r \) is discussed in Section 7.2; of \( \lambda \) at the end of this section. For 1961–1968, the equity value was constructed working backwards from the 1969 value, using the balance-sheet figures on net acquisitions and the Topix index. All the other items in (7.1) were obtained directly from nominal amounts on the balance sheet. In some regressions we lumped inventories with net fixed assets. In that case, (7.1a) was changed so that nominal inventories were added to net fixed assets, and (7.1b) was changed so that the value of inventories was not subtracted out.

Figure 3a depicts \( I/K \). Figures 3b and c depict \( Q \) when capital is defined as in most of this paper, to consist of net fixed assets, and next when the definition is broadened to include inventories. There is a suggestion of a downward movement in the early part of the sample, which is good news for Q-theory given the broadly parallel downward movement in \( I/K \). The bad news is that \( Q \) is almost always negative in the basic specification, reflecting a negative numerator in equation (7.1b). One possible problem is that throughout the sample, there is a misstatement of equities caused by use of book value of equity for nontraded corporations (see Section 3); Hoshi and Kashyap (1990) find that this biases QS downwards in Japanese data. Another possible problem is misstatement of the value of land (see Section 3), overstatement of which would lower the numerator of \( Q \). In our empirical work we do not, however, attempt to correct for such misstatement.

Some details on construction of the present value of future depreciation

14 The problem does, however, seem to run deeper than measurement of equity at book value than market. Hoshi and Kashyap (1990) find that a substantial fraction of firms with equity-valued at market have \( Q < 0 \), even after making a careful calculation of the market value of land.

\[ (7.3) \]
\[ C = \frac{P}{P_0} C_0 C_{\text{in}} \]  
(7.4)

\[ C_p = \frac{1 - \tau_i}{1 - \tau} \quad C_s = 1 - \frac{E[P_f_1/P_f](1 - \delta)}{1 + \delta} \]

In (7.4), \( \tau \) is the effective corporate tax rate, \( z \) is the present value of depreciation deductions per dollar of new investment; \( P_0 \) is the price of output, measured as the deflator for output of industry; 1985–1990: \( E[P_{f1}/P_f] \) is the fitted value of an AR(1) in \( P_{f1}/P_f \); \( \delta \) is the depreciation rate, set at 0.10, which is approximately the depreciation rate implied by the balance-sheet data; and \( 1 + \delta \) is the nominal discount factor for the firm. Some details on \( \tau, z, \) and \( \delta \) are given at the end of this section. It may help to note that \( C_0 \) is usually approximated as

\[ C_p = \delta \quad \text{expected inflation in } P_f + \delta \]

Figure 4a plots the level \( C = \exp(c) \) of the cost of capital. As suggested by the Figure 4b plot of \( P_0/P_f \) (the ratio of the price of investment goods to that of output), the downward trend in the cost of capital is largely attributable to a secular fall in this ratio. As indicated in Figure 4c and d, there is no trend apparent either in the tax factors in the \( C_p \) term or in the real interest-rate terms collected in \( C_s \). The latter terms do, however, have sharp cyclical effects. The spikes in \( C_s \) and hence in \( C \) during 1972–1975 are caused by violent movements in actual and thus in expected inflation: from 1972 through 1975 actual inflation in \( P_f \) was (in percent) 3.0, 12.5, 23.7, 4.9, while expected inflation was 2.6, 8.1, 14.5, 3.7. The downward trend, as well as the volatility around the time of the first OPEC shock, is also found in the cost of capital series presented in Takita, Hayashi, and Aburai (1987). Figures 4e and 5 show that the blip in \( C \) around 1974–1975 is transmitted to \( \delta \) and thus to \( \delta' = \delta - \delta \).

Some details on taxes and the nominal discount factor, which may be skipped without loss of continuity:

7.2.1 Taxes All tax rates are statutory maximums, and were obtained from various editions of the Ministry of Finance’s Schematic Explanation of Japanese Taxes. Let \( \tau_i \) be the corporate tax rate on retained earnings, \( \tau \) the enterprise tax rate, \( \tau_f \) the local tax rate. Let \( 1 + \delta \) be a safe nominal interest rate, computed as the annual average of monthly call rates. Then

\[ \tau = \tau_i + \tau_f + \tau \]

the second factor in brackets allows for the deductibility of the enterprise tax against next period’s income (see Hayashi, 1990). Because of the absence of data on the split between structures and machinery, the present value of depreciation deductions \( \tau_f \) was fixed at 0.562 for all \( \tau \); 0.562 is the 1961–1981 average of the \( \tau_f \) series given in Hayashi (1990, p. 203), who studies manufacturing firms.

This tax measure ignores a host of what we hope are minor complications. Readers familiar with the U.S. investment literature may wonder at the absence of reference to the investment tax credits; Hayashi (1990), however, states that these are of small magnitude in Japan. We also
ignore, for example, special tax treatment of dividends received by corpo-
ration, the existence of certain tax-free reserves, special capital gains
taxes on land, and periods of "special depreciation."

7.2.2 Nominal Discount Factor
We set $i_t = (1 - \omega)\text{expected net nominal return on equity from } i = 1 + \omega(1 - \sigma)\text{net nominal rate on}
debt, where $\sigma$ is the share of debt financing. We set $\omega = 0.6$, which is
roughly consistent with the average debt/equity and net-worth ratios for
nonfinancial corporations for the whole sample (see Ando and
Auerbach, 1990). The expected return on equity was assumed to be
the nominal return on safe government debt plus a constant risk pre-
mium. The annual average of call rates was used for the safe nominal
rate. The constant risk premium was set at 0.05, which is the average
annualized excess return of Topix over the call rate, using either
monthly data 1970–1995 or semiannual (March and September) data
1961–1995. The nominal rate on debt was set equal to the annual
average of the business borrowing rate described in Section 2 and
plotted in Figure 2.

A small amount of experimentation at a preliminary stage of the re-
search for this paper suggested that the results would not be sensitive to
the assumed risk premium for equity, the assumed depreciation rate,
and the use of annual averages rather than end-of-year values for inter-
est rates.

7.3 ESTIMATION TECHNIQUE FOR LIMTED
ACCURACY ERROR REGRESSIONS

In unrestricted regressions, estimates were obtained by OLS, and the
usual OLS standard errors are reported. For restricted regressions, esti-
mates of the $i_t - k$ equation were obtained with a numerical technique,
and inference conducted using a bootstrap technique. Details on both
estimation and inference are in the Appendix. With respect to estima-
tion, we merely note here:

1. We did not estimate but instead imposed an annual discount factor,
setting $\beta = 0.95$.\footnote{The growth model of Section 4 suggests computing $\beta$ from the average value of $1 - C_{t+1}$,\footnote{($C_{t+1}$ is defined in (7.45) and the growth rate of the capital stock. If we do so using the data described in the Section 7, however, we get $\beta = 1.03$.)}}
2. To obtain restricted estimates, we used a two-step procedure that un-
der conventional econometric assumptions is consistent but not effi-
cient. In a first step, we obtained consistent estimates of $\alpha$ and $A$ from
the unrestricted estimates. In a second step, we used an iterative proce-
dure to solve for $\alpha_t - v^t$ process compatible with these values and
with the unrestricted coefficients in the equations for $v_t$. Recall that $f_t$ is
the vector of variables used to forecast future $A_{t+1}$, $f_t = (A_{t+1}, \Delta c_t)'$
in our basic specification. This iterative procedure takes proper account
of the Granger causality from $k - k^t$ to $A_{t+1}$ (Without such causality,
one could of course directly compute, without iterating, a restricted $k - k^t$
process). Note that since restricted and unrestricted coefficients in
the $A_t$ and $c_t$ equations are the same, so, too, are the coefficients and
residuals in the equations for the levels of $y_t$ and $c_t$.
3. We leave unrestricted all coefficients on deterministic terms.

With respect to our bootstrap inference: 95% confidence intervals for
regression parameters and impulse responses were obtained by sorting
1000 sets of estimates from lowest to highest and dropping the smallest
and largest 25. A bootstrap $p$-value of a test of the cross-equation restric-
tions was obtained by comparing the actual value of the test statistic with
the 1000 values computed in the bootstrap. The test statistic was the
difference between the logarithms of the determinants of the variance-
covariance matrices of the restricted and unrestricted residuals.

8. Results for Q-Regressions

Table 6 presents the results of the regression (5.1). Columns (1) and (3)
report results when beginning of period $Q$ is used, for both the whole
and the post-1975 sample. Since the diagnostics reported at the foot of
the table suggested substantial serial correlation, estimates with a correc-
tion for first-order serial correlation are reported in columns 2 and 4. The
results are not encouraging. In addition to substantial serial correlation,
the coefficient on $Q$ is generally wrong-signed and is far from significant
at conventional levels in the one specification in which it is correctly
signed (column (2)). The regressions with end-of-period $Q$ (columns (5)
and (6)) and when capital is defined to include inventories (columns (7)
and (8)) are equally unsupportive.
9. Results for Flexible Accelerator Regressions

9.1 MEANS OF BASIC VARIABLES

Table 7 presents means and standard deviations of the basic variables, for the annual intervals corresponding to those presented in Table 1. The pattern for the capital stock is identical for output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986-91 period relatively strong, the 1991-94 period exceptionally weak. As indicated in Figure 4, the cost of capital fell through most of the period, especially in the early part of the sample.

The column (5) and (6) subperiods figures for this variable are heavily

Table 7 GROWTH RATES AND STANDARD DEVIATIONS OF CAPITAL STOCK AND SOME RELATED VARIABLES, SELECTED SUBPERIODS

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>k</td>
<td>8.0</td>
<td>12.7</td>
<td>5.8</td>
<td>6.7</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>(4.6)</td>
<td>(7.2)</td>
<td>(1.5)</td>
<td>(1.2)</td>
<td>(1.4)</td>
<td>(1.4)</td>
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<tr>
<td>y</td>
<td>1.9</td>
<td>1.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>(1.4)</td>
<td>(0.9)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>c</td>
<td>1.3</td>
<td>0.8</td>
<td>0.5</td>
<td>0.6</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>(1.0)</td>
<td>(0.7)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>( \rho )</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>(0.3)</td>
<td>(0.3)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>(0.2)</td>
<td>(0.2)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
<td>(0.1)</td>
</tr>
</tbody>
</table>

Notes:
1. The data are annual and real (1950 price) deflated by the private consumption deflator ("CPI") of Table 7, figure. Average log differences in 12 years, 1952-1964. The costs of capital and of labor are computed as implied by the cost function in industry and in output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986-91 period relatively strong, the 1991-94 period exceptionally weak. As indicated in Figure 4, the cost of capital fell through most of the period, especially in the early part of the sample.

2. The cost of capital in row (1) is the product of the these two ratio of output to output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986-91 period relatively strong, the 1991-94 period exceptionally weak. As indicated in Figure 4, the cost of capital fell through most of the period, especially in the early part of the sample.

3. The cost of capital in row (1) is the product of the these two ratio of output to output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986-91 period relatively strong, the 1991-94 period exceptionally weak. As indicated in Figure 4, the cost of capital fell through most of the period, especially in the early part of the sample.

4. The cost of capital in row (1) is the product of the these two ratio of output to output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986-91 period relatively strong, the 1991-94 period exceptionally weak. As indicated in Figure 4, the cost of capital fell through most of the period, especially in the early part of the sample.
influenced by the fact that the sample starts in 1973 (see Figure 4a): moving the starting date to 1975 would result in negative average growth rates. It may be seen in column (1), rows (1) and (2) that the growth rates of capital and of the target level of capital k* are quite similar over the entire sample period, despite the growing capital-to-output ratio (column (1), row (1) vs. column (1), row (5)). We note that this is consistent with the model of Section 4, and with the less structured Cob Dobbs specification of target capital in Section 6. Our empirical work does not, however, rely on the Section 4 prediction that the capital-to-output ratio will increase indefinitely. The point is that simple r-statistics such as in Table 7, plots such as Figures 4 and 5, and conventional unit-root tests (details omitted) do suggest that the unit-root specification in the cost of capital and the capital-output ratio, as well as cointegration between actual and target capital, reasonably characterize the behavior in our sample.

Rows (5) to (7) of Table 7 further decompose the growth in the cost of capital. Column (1) indicates that over the entire sample, the fall in the cost of capital is basically attributable to the fall in the relative price of new capital goods to output (line [5]). In the boom of 1986–1991, however, the fall is also attributable to tax factors (line [6], column (5)); the main event here was a series of cuts in the corporate tax rate from 43.3% in 1986 to 37.3% in 1990 and 1991. In the 1991–1994 period, falls in the relative price and in the real interest-rate term (line [7]) were both important. The latter reflects the general fall in interest rates associated with the Bank of Japan’s interest-rate cuts; see Figure 2c above.

Table 7 indicates that at least the secular movement in the capital stock is consistent with the secular movement in output and the cost of capital. To analyze cyclical dynamics, we turn to regression analysis.

9.2 REGRESSION ANALYSIS

9.2.1 Unrestricted Regressions Table 8 presents VAR estimates, obtained by OLS. As a preliminary, columns (1a) and (1b) present a very simple specification, a bivariate VAR in (k*, Δk*). The 6-statistics implied by the column (1b) figures indicate that relative to an information set consisting of past k, Δk*, and past Δk*, k, k* Granger-causes Δk* even though Δk* does not Granger-cause itself on an average, a 1% (say) excess of k over k* is associated with Δk* rising by about 0.5% the next year.

Columns (2a) through (2c) add Δc to the VAR. Column (2c) indicates that k → k* helps predict not only Δc but one of its components, Δc, with a 1% (say) excess of k over k* on average being followed with Δc falling by about –0.5% in the next year. The estimates and standard errors in column (2b) suggest that it helps to include both Δc* and Δc, as predictors of Δc; column (2c) suggests the same, a little more mildly.

Columns (3a) through (2c) add a second lag of each of the three variables k, k*, Δk*, and Δc. While individual t-statistics are small, both F-tests and t-tests on the sum of the coefficients on k, k* strongly reject the null that k → k* does not help predict Δc and Δc.* Finally, columns (4a) and (4c) present results when the sample is restricted to 1974–94. Once again, rises in k → k* anticipate rises in Δc* and falls in Δc (columns (4b) and (4c)).

In the three specifications (2)–(4), point estimates sometimes look different. We therefore began the analysis using all three. In this preliminary analysis, all three proved to yield quite similar answers to the questions we ask (see Table 10 below), indicating that from the perspective of the VAR in (y, c, l) many of the shifts in coefficients observed in Table 8 are offsetting. So for parsimony and computational simplicity we focused on the one-lag specifications in columns (2) and (4). We repeated all estimates with both samples, although for conciseness in reporting results we generally give more detailed attention to the full-sample estimates in column (2).

9.2.2 Impulse Response Functions To interpret these full-sample estimates, we solve for the restricted k → k* process using the method in the Appendix and then, using k* = y – c, transform to a unit-root VAR in (y, c, l). Apart from deterministic terms and the residual, the result is

\[
\begin{align*}
p &= 0.035(0.092) + 1.176(0.730) - 0.187(0.262) - 0.033(0.185) - 0.010(0.040) \\ &= 0.004(0.004) - 0.436(0.240) + 0.027 - 0.108 \\ &= -0.004(0.004) \\ \sigma &= -0.475(0.240) - 1.406(0.730) + 1.853(0.262) + 0.882(0.185) - 0.598(0.040) \\ &= -0.884 - 0.220 - 1.371(0.488, 0.06) - 0.264 \\ &= -0.423 - 0.220 \\ \rho &= 0.959(0.004) + 0.296(0.730) - 0.374(0.262) - 0.068(0.185) + 0.005(0.040) \\ &= 0.892(0.004) + 0.130(0.488, 0.06) - 0.135 - 0.026 - 0.146 - 0.007 - 0.003 \\ &= 0.801(0.102) \\ \alpha &= 15.17(0.012) + 0.79(0.012) \\ &= 1.15 - 0.25 - 0.146 - 0.007 - 0.003 - 0.112 \\
\end{align*}
\]

In parentheses are 95% confidence intervals, from a bootstrap. In the y and c equations, the confidence intervals on the estimates of the coefficients on k are strongly rejected that the Granger causality found in Table 8 reflects a systematic tendency for movements in k to anticipate movements in c but perhaps not p. [Asymptotic standard errors (not reported) suggest the same.] In (9.1c), the confidence intervals around \(a\) and \(k\) are large. The point estimates of these two parameters, which suggest con-
<table>
<thead>
<tr>
<th>Regressor and Dependent Variable</th>
<th>(1a)</th>
<th>(1b)</th>
<th>(1c)</th>
<th>(1d)</th>
<th>(1e)</th>
<th>(1f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k - k^*$</td>
<td>$\Delta k$</td>
<td>$\Delta^2 k$</td>
<td>$\Delta k - k^*$</td>
<td>$\Delta^2 k$</td>
<td>$\Delta k - k^*$</td>
<td>$\Delta^2 k$</td>
</tr>
<tr>
<td>$k_{t-1} - k^*_{t-1}$</td>
<td>0.428</td>
<td>0.533</td>
<td>0.452</td>
<td>0.492</td>
<td>-0.477</td>
<td>(0.160)</td>
</tr>
<tr>
<td>$k_{t-2} - k^*_{t-2}$</td>
<td>-0.003</td>
<td>0.083</td>
<td>-1.630</td>
<td>2.070</td>
<td>-1.883</td>
<td>(0.171)</td>
</tr>
<tr>
<td>$\Delta^2 k_{t-1}$</td>
<td>2.49</td>
<td>3.193</td>
<td>-3.397</td>
<td>-2.767</td>
<td>3.239</td>
<td>(1.248)</td>
</tr>
<tr>
<td>$S_{t-1}$</td>
<td>-1.570</td>
<td>2.029</td>
<td>-1.824</td>
<td>-1.973</td>
<td>2.057</td>
<td>(1.042)</td>
</tr>
<tr>
<td>$A_{t-1}$</td>
<td>1.071</td>
<td>1.114</td>
<td>-0.678</td>
<td>0.865</td>
<td>-0.758</td>
<td>(0.283)</td>
</tr>
<tr>
<td>Post-1973 dummy</td>
<td>0.183</td>
<td>-0.254</td>
<td>0.987</td>
<td>-0.128</td>
<td>0.074</td>
<td>(0.061)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.569</td>
<td>0.347</td>
<td>0.593</td>
<td>0.422</td>
<td>0.285</td>
<td>(0.058)</td>
</tr>
<tr>
<td>S.e.e.</td>
<td>0.135</td>
<td>0.139</td>
<td>0.131</td>
<td>0.129</td>
<td>0.138</td>
<td>(0.098)</td>
</tr>
<tr>
<td>Q-statistic [p-value]</td>
<td>0.92 [0.98]</td>
<td>2.88 [0.94]</td>
<td>1.22 [1.00]</td>
<td>1.16 [1.00]</td>
<td>0.80</td>
<td>(0.98)</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>2.32</td>
<td>2.40</td>
<td>1.96</td>
<td>2.02</td>
<td>1.94</td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
1. The table presents the results of ordinary least-squares estimates of the 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 disturbances. The number of degrees of freedom in the Q statistic is 8 if it is specified in 1, 5 in specification 2, and the sample period is used in the dependent variables.
2. 1) is the log of the capital stock, 2) is the log of the capital stock, 3) is the log of the capital stock, 4) is the log of the capital stock, and 5) is the log of the capital stock.
3. The capital stock is for nonfinancial corporations, the output is the output of industry, and the cost of capital is constructed as described in the text. All variables are in log differences. 

---

**Table 8 (continued)**

<table>
<thead>
<tr>
<th>(2a)</th>
<th>(2b)</th>
<th>(2c)</th>
<th>(2d)</th>
<th>(2e)</th>
<th>(2f)</th>
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</thead>
<tbody>
<tr>
<td>$k - k^*$</td>
<td>$\Delta k$</td>
<td>$\Delta^2 k$</td>
<td>$\Delta k - k^*$</td>
<td>$\Delta^2 k$</td>
<td>$\Delta k - k^*$</td>
</tr>
<tr>
<td>$k_{t-1} - k^*_{t-1}$</td>
<td>-0.997</td>
<td>1.507</td>
<td>-2.056</td>
<td>0.496</td>
<td>0.462</td>
</tr>
<tr>
<td>$k_{t-2} - k^*_{t-2}$</td>
<td>0.591</td>
<td>-1.027</td>
<td>1.500</td>
<td>(1.131)</td>
<td>(1.305)</td>
</tr>
<tr>
<td>$\Delta^2 k_{t-1}$</td>
<td>1.893</td>
<td>-1.732</td>
<td>1.761</td>
<td>(1.360)</td>
<td>(1.284)</td>
</tr>
<tr>
<td>$S_{t-1}$</td>
<td>-3.746</td>
<td>2.041</td>
<td>-1.693</td>
<td>-2.777</td>
<td>3.260</td>
</tr>
<tr>
<td>$A_{t-1}$</td>
<td>1.817</td>
<td>-1.659</td>
<td>1.667</td>
<td>(1.335)</td>
<td>(1.335)</td>
</tr>
<tr>
<td>Post-1973 dummy</td>
<td>-0.894</td>
<td>0.883</td>
<td>-0.800</td>
<td>-0.677</td>
<td>0.645</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.132</td>
<td>-0.512</td>
<td>0.080</td>
<td>(0.098)</td>
<td>(0.096)</td>
</tr>
<tr>
<td>S.e.e.</td>
<td>0.597</td>
<td>0.431</td>
<td>0.314</td>
<td>0.347</td>
<td>0.442</td>
</tr>
<tr>
<td>Q-statistic [p-value]</td>
<td>0.333</td>
<td>0.130</td>
<td>0.138</td>
<td>0.138</td>
<td>0.138</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>2.45</td>
<td>2.54</td>
<td>2.60</td>
<td>1.85</td>
<td>1.89</td>
</tr>
</tbody>
</table>

**Sample period:**
- 1964–94 (31 obs.)
- 1964–94 (31 obs.)

**Notes:**
1. The table presents the results of ordinary least-squares estimates of the 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 disturbances. The number of degrees of freedom in the Q statistic is 8 if it is specified in 1, 5 in specification 2, and the sample period is used in the dependent variables.
2. 1) is the log of the capital stock, 2) is the log of the capital stock, 3) is the log of the capital stock, 4) is the log of the capital stock, and 5) is the log of the capital stock.
3. The capital stock is for nonfinancial corporations, the output is the output of industry, and the cost of capital is constructed as described in the text. All variables are in log differences.
siderable persistence in k, directly reflect the smooth evolution of k despite some sharp movements in c and y. These estimates seem roughly comparable to estimates of some U.S. studies. In the k-equation (9.1c), the coefficients on the first lag of y and of c each are significantly different from zero at the 5% level. These coefficients indicate that, historically, a 1% rise in output has been associated with about a 0.3% rise in the next year’s capital stock, and that a corresponding increase in the cost of capital has been associated with a 0.05% fall. The larger short-run elasticity with respect to output was also found in Yoshikawa (1995).

To consider longer-term multipliers, we solve for the moving-average representation. In Figure 6, the solid line plots the first 10 of the moving-average weights (impulse responses), the dashed lines the 95% bootstrap confidence intervals. These are not responses to orthogonalized innovations, but to the actual disturbances in the (y, c, k) VAR. The top row presents responses of k, with the responses for y and c included on the next two rows. Note that the scale of the c response is different from that for k and y. Since $k - k^* = k - (y - c)$ is stationary, the long-run response of k to a given shock is equal to the difference between the long-run y and c responses. The plots stop at 10 periods because the long run is effectively reached at this horizon.

The plot in the upper left-hand corner shows that a 1% shock to y leads dynamically to monotonic increases in k that asymptote at 0.35%.

[The long run is not 1%, because this plot takes account of the reaction of all the variables in the system to the increase in y. Such a shock tends to lead to not a 1% but a 1.14% long-run increase in y (leftmost plot in the second row), and a 0.58% long-run increase in c (leftmost plot in the bottom row).] A 1% shock to c leads ultimately to a 0.07% fall in k.

What explains the stronger response (larger elasticity) of k to shocks to y than to c? As noted in the introduction, because our model has convex adjustment costs, it predicts a smaller response to shocks to c, in both the short and the long run, if there is less persistence (more mean reversion) in c. It would not make sense for a firm to rapidly cut back on k in response to a rise in c if this rise were likely to be swiftly offset with a subsequent fall. And c does appear to be less persistent than y. The figure indicates that the long-run response of c itself to a 1% shock to c is only 0.11%, in contrast to the 1.14% response of y to its own shocks.

17. Setting M equal to the mean of 1 - C0, yields $\phi = 2.2$. [See (4.6), (4.12), and (7.6).]

Although there are differences in functional forms and data frequency, this looks comparable to a value calibrated by Cogley and Nason (1990, p. 320).

18. Slight qualification: The lower end of the confidence interval on the one-step-ahead response of c to a shock to y is -3.75; for readability, the Figure 6 graph stops at -3.6.

This is the only number truncated in the graphs.
While the relevant measure of mean reversion is the multivariate one depicted in the figure, this mean reversion is also evident in the univariate c-process. The first-order autocorrelations of $dc$ and its components and of $dy$ are

$$
\begin{align*}
    & dc \quad \Delta (p_y - p) \quad dc, \quad dc, \quad dy \\
    & 1962-1994 \quad -17 \quad .26 \quad .14 \quad -22.64 \\
    & 1974-1994 \quad -38 \quad .13 \quad -45.46
\end{align*}
$$

Thus, the mean reversion observed in Figure 6 apparently is driven by mean reversion in $p_y$, the interest-rate component of the cost of capital.

In sum, then, our model rationalizes three notable characteristics of the data: the growth of the capital–output ratio, the apparently strong ability of $k - k^*$ to predict $dt^*$ and $dc$, and the signs and relative magnitudes of the elasticity of capital with respect to output and the cost of capital.

9.2.3 Decomposition of Forecast Error of the Capital Stock Table 9 presents a decomposition for the period 1986–1991, and for 1991–1994, computed from the estimates in equation (9.1). The first column in each panel repeats the Table 7 figures on realized annual growth rates. The second column presents the 1986 and 1991 forecasts from the VAR, the third column the difference between actual and forecast. These two columns do not exploit an orthogonalization. The last two columns rely on the Choleski factorization described above, in which residuals to the $y$ and $c$ equations precede that for the $k$ equation. Column (4) sums the effects of the $y$ and $c$ shocks (this sum is independent of whether $y$ or $c$ appears first in the ordering), while column (5) presents the residual $k$-shock.

Capital growth was stronger than predicted in 1986–1991, weaker in 1991–1994. But conditional on the path of output and the cost of capital, much of this behavior is easily rationalized. In both episodes, about half the surprise in capital was due to surprises in $y$ and $c$, leaving a residual surprise in $k$ to account for the other half ($\hat{\lambda} = 0.89/1.79, 1.05/1.94$) and for a smaller fraction of the actual movement.

In 1991–1994, it may look odd that the target capital $k^*$ was slightly above the predicted (−0.07), while innovations in $k^*$ led to a negative surprise in $k$ (−0.89). This seems to result from two factors. The first is that all of the good news in $k^*$ came in the last year of the three-year period: the 1991–1993 forecast error in $k^*$ in fact was negative (−0.60% (annualized)).

<table>
<thead>
<tr>
<th>Year</th>
<th>(1) Actual</th>
<th>(2) Forecast</th>
<th>(3) Total</th>
<th>(4) Due to shocks</th>
<th>(5) $y, c$ equ.</th>
<th>$k$ equ.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986–1991</td>
<td>6.47</td>
<td>6.68</td>
<td>1.79</td>
<td>0.90</td>
<td>0.89</td>
<td>0.06</td>
</tr>
<tr>
<td>1991–1994</td>
<td>2.97</td>
<td>4.92</td>
<td>-1.94</td>
<td>-0.89</td>
<td>-1.05</td>
<td>0.27</td>
</tr>
</tbody>
</table>

9.2.4 Results for Alternative Specifications Table 10 summarizes impulse responses and decompositions of the 1986–1994 forecast error, for five additional specifications: unrestricted VARs with one lag and two lags, full sample and post-1973 sample (VAR estimates for all but the two-lag, post-1973 sample are in Table 8), and the restricted one-lag VAR for the post-1973 sample. For ease of comparison, it also repeats results for the one-lag, restricted, full-sample VAR already reported in Table 6 and Table 9.

In a nutshell, the results already presented are quite robust to the variations in specification presented in the table. In panels (a) and (b), the initial response of $c$ to a shock at $y$ ranges from about 0.3% to 0.5%, and asymptotes at about 0.6 to 0.9. The initial and long-run response of a shock to $c$ is negative (apart from the initial response in the full-sample, two-lag specification) and quite small in magnitude. In panels (a) and (d), the decompositions attribute the lion’s share of the movement in $k$ to the two components of $k^*$ (again with the exception of the full-sample, two-lag VAR).

Quantitative consistency between the unrestricted and restricted estimates is also suggested by the bootstrap test of the restrictions. The p-
### Table 10: Results with Alternative Specifications

#### (a) Response of $x$ to a 1% Shock, Full-Sample Estimates

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Restricted</th>
<th>Unrestricted</th>
<th>Unrestricted, 2 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y$</td>
<td>$c$</td>
<td>$k$</td>
</tr>
<tr>
<td>2</td>
<td>.29</td>
<td>-.05</td>
<td>.95</td>
</tr>
<tr>
<td>10</td>
<td>.55</td>
<td>-.07</td>
<td>.92</td>
</tr>
</tbody>
</table>

#### (b) Response of $x$ to a 1% Shock, Post-1973-Sample Estimates

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Restricted</th>
<th>Unrestricted</th>
<th>Unrestricted, 2 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y$</td>
<td>$c$</td>
<td>$k$</td>
</tr>
<tr>
<td>2</td>
<td>.46</td>
<td>-.04</td>
<td>.95</td>
</tr>
<tr>
<td>10</td>
<td>.71</td>
<td>-.05</td>
<td>.94</td>
</tr>
</tbody>
</table>

#### (c) Decomposition of Forecast Error of $x$, Full-Sample Estimates

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Restricted</th>
<th>Unrestricted</th>
<th>Unrestricted, 2 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y + c + k$</td>
<td>$y + c + k$</td>
<td>$y + c + k$</td>
</tr>
<tr>
<td>1966–91</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
</tr>
<tr>
<td>1991–94</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
</tr>
</tbody>
</table>

#### (d) Decomposition of Forecast Error of $x$, Post-1973 Estimates

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Restricted</th>
<th>Unrestricted</th>
<th>Unrestricted, 2 lags</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$y + c + k$</td>
<td>$y + c + k$</td>
<td>$y + c + k$</td>
</tr>
<tr>
<td>1966–91</td>
<td>4.6</td>
<td>4.6</td>
<td>4.6</td>
</tr>
<tr>
<td>1991–94</td>
<td>4.9</td>
<td>4.9</td>
<td>4.9</td>
</tr>
</tbody>
</table>

### Notes
1. See notes to Table 7 and the text for description of the data.
2. All estimates are computed from vertical Vals in (a, b, c). The "restricted" estimates in (a) and (b) are computed from equation (1.1). The test does not directly perform the parameters for the Vals in (a, b, c) for the other specifications in the table, although the parameters in the underlying Vals in (a, b, c) are in the following columns in Table 7. "unrestricted" is panel (d) and (e).
3. "unrestricted, 2 lag" is panel (d) and (e). See Table 8. The "unrestricted, 2 lag" estimates in panel (d) and (e) are computed from an underlying set of equation 0-9, the Vals in (a, b, c) are in the columns (d) and (e) of Table 8 except that there is no post-1974 dummy. The "restricted" estimates in panel (d) and (e) are computed from the equation (1.1) for the Vals in (a, b, c) and the usual dummy variables.
4. The "restricted" full-sample estimates report results depicted in Figure 5(a) of Table 9(c).
value for this test was 0.656 for the whole sample, 0.737 for the post-1973 sample. 19

9.3 VARs WITH ADDITIONAL VARIABLES

We also estimated and applied three additional specifications, each of which added a fourth variable to the system. Our motivations were twofold. First, it is possible that sharper or more informative estimates might result, insofar as the additional variable helps predict $d_k$. Second, according to other investment models, a variable might help predict capital accumulation even if it does not help predict $d_k$.

The variable added was the yen-dollar real exchange rate, or real net worth of nonfinancial corporations, or real land prices. The exchange rate was chosen because of the prominence it plays in discussion of the Japanese economy, both generally and during the recent cycle (e.g., Economic Planning Agency, 1994). Net worth was chosen because of the role it plays in credit-constraint models such as Kiyotaki and Moore (1994, 1995). Land prices were chosen again because of their value as collateral in credit-constraint models (see Cigna et al. (1994) for an application to Japan), and, more generally, because of the role land price fluctuations may have played in encouraging speculative behavior (e.g., Chirinko and Schaller, 1995).

Each variable was entered as a log difference. [In the notation of Section 6, then, $f = (d_k^*, d_k^*, d_k^*, d_k^*)$ and $z = (k - k^*, d_k^*, d_k^*, d_k^*)$, where $z$ is the log of the additional variable.] We then estimated unrestricted and restricted first-order VARs for the full and the post-1973 samples. There were few differences between the two samples, so in Table 11 we report and discuss only the full-sample results, focusing on impulse responses and the 1986–1994 decomposition.

In Table 11, columns (2)–(6) of panel (a) indicate that of the three variables, only the real exchange rate has predictive power for $k - k^*$, $d_k^*$, or $d_k$ at traditional significance levels; a real exchange-rate appreciation is associated with an increase in $d_k^*$ and a fall in $k$ and $k - k^*$. (Although not reported in the table, for all three specifications the coeffi-

19 As suggested by the relative size of these two $p$-values, bootstrap confidence intervals are generally larger for the post-1973 sample. This is no doubt partly results from a smaller sample size, but may also indicate that the full-sample intercepts are a little misleading. In particular, for the one-order autocorrelation coefficient of the residual of the restricted equation for $k$, the point estimates and 95% bootstrap confidence intervals are 0.56 (0.46, 0.60) for the full sample and 0.46 (0.40, 0.57) for the post-1973 sample. Thus for the full sample there is evidence against the implied bootstrap assumption that the residuals are I(1). We take the similarity of the results for all specifications in Table 10 to indicate that this mild serial correlation has negligible economic importance.

Table 11. RESULTS WITH ADDITIONAL INFORMATION VARIABLES

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
<th>(12)</th>
<th>(13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k - k^*$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
<td>$d_k$</td>
<td>$d_k^*$</td>
</tr>
<tr>
<td>Real exh. rate</td>
<td>0.23</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Real value</td>
<td>0.23</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forecast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total S.E.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The entries in this table are impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable. The entries in the final column of each specification are the results of impulse responses to a one-standard-deviation shock on the specified variable.
clients on the remaining variables are similar to those reported in Table 8; in particular, \(k - k^*\) retains its ability to predict \(\Delta k^*\) and \(\Delta c\) in all three specifications.) For all three variables, the response of \(k\) to a shock to \(y\) is smaller in the restricted than in the unrestricted system. (In all three specifications, the long-run effect has been effectively reached by 10 periods, and shocks to \(y\) still have persistent effects on \(y\). The response to \(y\) is only 0.00 in the net-worth system (for example), because the shock to \(y\) leads to a 10-period-ahead increase in \(c\) as large as that in \(y\).) In general, however, the impulse response functions are similar to those reported in Table 10.

The panel (b) decompositions for the last cycle are not quite as consistent with previous results. The unrestricted estimates for net worth and land prices yield positive shocks to \(k\) in the 1991–1994 column (6), and the restricted estimates generally attribute a larger fraction of the movement in \(k\) to shocks to sales (column 10). That there is a discrepancy between the unrestricted and restricted impulse response functions for output means that to some degree our present value model fails to capture the dynamics of the VAR. This is perhaps supportive of the view that fluctuations in net worth, or land prices, affect capital accumulation in ways not modeled by us. It is also consistent with the argument in several papers that credit constraints have important influences on business investment in Japan. However, some of the differences between such papers and ours may be more apparent than real. In the previous section, we found a Q-model to have little explanatory power for investment. It is therefore not clear that there is a conflict between our general conclusions and those of papers that show that the addition of various variables, including ones proxying credit constraints, improve the fit of Q-models (e.g., Hoshi and Kashyap, 1990; Hoshi, Kashyap, and Scharfstein, 1991). In addition, the standard errors in panel (a) of Table 11 are large for net worth and land prices, and we have argued above that if we set the point estimates on net worth or land prices to zero—that is, omit them from the system—the present-value model seems to characterize the data well.20

While we find no direct contradiction between our results and some earlier ones, we do feel as well that the results in our and other papers are suggestive of the importance of continuing to analyze the interaction of asset prices and business investment. Other priorities for research, using the approach of our paper include use of quarterly data, analysis of the determinants of the cost of capital sufficiently detailed to allow

20. This is consistent with Brunner and Kamin’s (1995) conclusion that financial factors did not play a very prominent role in the recent period.
samples of size 21. The additional samples were ones that produced a negative estimate of $a$, a signal to us to abort the algorithm used to obtain the restricted estimates (e $0$ does not guarantee A real and stable).

REFERENCES