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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-

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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 Cobb–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 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

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[1] The logic here is essentially that of Greenwood et al. (1995).

[2] This property is shared by the Bischoff (1971) formulation of the neoclassical model, although Bischoff appeals to a putty–clay distinction between old and new capital rather than to the time-series properties of output and the cost of capital.

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 typically followed by reversions back to initial levels in 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 movement 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 will 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 digresses from the main theme of the paper, and discusses the evolution of balance-sheet variables. Section 4 describes our general equilibrium model, Sections 5 and 6 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.

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 (henceforth, 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 (3) of the first row 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 1973:4 seems as good a candidate as any. Since then, growth has averaged 3.3% [column (4) in the first row of Table 1]. A comparison of columns (3) 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 trough (1986:4) 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 1986:4–1991:2 and for the 15 quarters from 1991:2 to the end of our sample. To read the table, consider column (2). GDP in 1986:4 was 334.2 trillion 1985 yen, or about 3.3 billion dollars at 100 yen/dollar. It increased by 80.5 trillion yen from 1986:4 to 1991:2 [row (2), column (2); Table 1, column (6) indicates that the corresponding compound growth rate is 4.8% per year]. GDP further increased by a paltry 5.9 trillion yen

Table 1 GROWTH RATES AND STANDARD DEVIATIONS OF GDP AND ITS COMPONENTS, SELECTED SUBPERIODS

	(1) Share of GDP, 61:1–95:1	*(2)* 61:1–95:1	*(3)* 61:1–73:4	*(4)* 73:4–95:1	*(5)* 73:4–91:2	*(6)* 86:4–91:2	*(7)* 91:2–95:1
GDP	1.00	5.3 (4.7)	8.6 (4.8)	3.3 (3.3)	3.9 (3.1)	4.8 (2.7)	0.4 (2.4)
Private P and E	0.15	6.5 (12.5)	11.9 (15.3)	3.3 (9.3)	5.4 (8.6)	11.5 (6.4)	−6.4 (5.6)
Private residential	0.06	5.9 (19.1)	14.2 (15.5)	0.9 (19.4)	0.9 (20.2)	5.6 (16.6)	0.8 (16.0)
Inventory change	0.01	4.2 (3.2)	6.6 (3.3)	2.8 (2.2)	2.9 (2.3)	3.5 (1.6)	2.2 (1.6)
Private consumption	0.61	5.0 (4.9)	8.3 (3.8)	3.0 (4.4)	3.3 (4.7)	4.0 (3.9)	1.4 (2.3)
Government spending	0.19	4.8 (8.4)	7.5 (8.3)	3.1 (8.1)	2.6 (8.5)	1.4 (6.0)	5.7 (5.4)
Exports	0.12	9.4 (12.8)	13.5 (13.2)	7.0 (11.9)	7.9 (12.7)	9.2 (9.2)	2.6 (6.2)
Imports	0.14	7.4 (14.1)	13.0 (15.0)	4.1 (12.4)	4.4 (13.2)	12.5 (13.4)	2.9 (7.4)

The data are quarterly, real (1985 yen), seasonally adjusted and expressed at annual rates. Growth rates are computed by averaging log differences beginning with the quarter following the start date; the column (7) figure, for examples, averages log differences in the 15 quarters from 91:3 to 95:1. "Private P and E" is gross private fixed capital formation of plant and equipment; "residential" is the same for residences. The rates of growth for inventory investment are the rates of growth of the level, not the change.

Table 2 LEVEL AND CHANGE IN NIPA AGGREGATES, MOST RECENT CYCLE

	(1)	*(2)*	*(3)* Private Investment	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
	Date	GDP	Plant and Equipment	Residential	Inventories	Private Consumption	Government Cons. and Investment	Net Exports
(1)	86:4	334.2	54.7	16.5	0.5	197.8	57.0	7.6
(2)		80.5	37.0	4.8	2.9	38.7	3.8	−6.7
(3)	91:2	414.7	91.7	21.3	3.4	236.5	60.9	1.0
(4)		5.9	−19.5	0.7	−1.4	12.6	14.5	−0.9
(5)	95:1	420.7	72.2	22.0	2.0	249.1	75.4	0.1

Rows (1), (3), and (5) present the value of the indicated national income and product account components, in trillions of real, seasonally adjusted 1985 yen. Rows (2) and (4) present the change in each component, 86:4–91:2 [row (2)] and 91:2–95:1 [row (4)]. The inventory investment figure in column (5) includes inventory investment by the government. The sum of components may not add to the total because of rounding.

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 has averaged about 15% of GDP in the sample, its increase was nearly half (37.0/80.5) that of the increase in GDP from 1986:4 to 1991:2, and its 19.5-trillion-yen decline from 1991:2 to 1995:1 was associated with a minuscule increase in GDP.[3]

Complementary evidence on this comovement 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 in the six variables listed in columns (3)–(8) in Table 2, we decomposed movements in GDP and in each 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 corporations, 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).[4]

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[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 (1992). That fluctuations in plant and equipment investment have been central to the last cycle is noted in, for example, Economic Planning Agency (1994, p. 44).

[4] Many small firms are included in this sector. According to the 1991 Establishment Census of Japan, the total employment of nonfinancial corporations is 41.8 million. Of this total, 13.5 million work at corporations of a single establishment, with no branch offices, of fewer than 100 employed, and only 4.6 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.[5]

Figure 1a plots the growth rate of capital stock, with shaded areas depicting contractions.[6] 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 1961–1994 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).[7] These trends are

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stocks are publicly traded. Therefore, our study may complement panel studies of investment by publicly traded corporations.

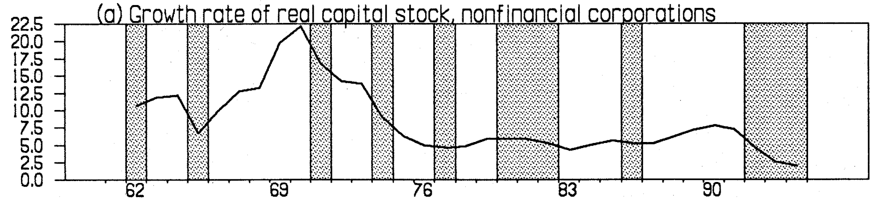
[5] The EPA provides the data in 1985 yen for 1969–1993. For 1961–1968 we constructed a real capital-stock figure from the nominal figure and the deflator for private investment in plant and equipment, and we constructed a real output series from nominal and 1980-based data by assuming that inflation rates in 1985 prices were the same as those in 1980 prices. The base year for the real 1994 capital stock and output of industry was 1990; we converted to 1985 prices by assuming real growth rates were the same in 1990 and 1985 prices.

[6] For quarterly data, we use turning points defined by the EPA [although EPA documents sometimes seem ambiguous, for example as to whether the most recent peak is 1991:1 (EPA, 1994, p. 418) or 1991:2 (EPA, 1994, p. 46)]. To define annual turning points, we looked at GDP growth in the years surrounding the EPA dates. For example, for the most recent cycle, the rate of GDP growth in 1985, 1986, and 1987 was 5.0, 2.6, and 4.1; for 1990, 1991, and 1992 the figures were 4.8, 4.2, and 1.0. This suggested a 1986 trough and a 1991 peak. After completing this paper, we found that the EPA (1996, p. 1) has defined 1993:4 to be a trough, a choice not obviously in accord with the annual growth rates of GDP plotted in Figure 1c.

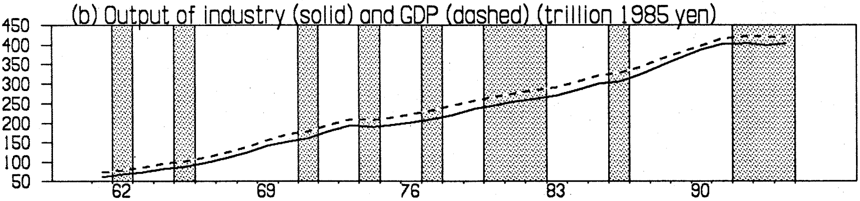
[7] Fumio Hayashi has informed us that there is some evidence that the published figure for the capital stock in 1970 is too low. When combined with reasonable measures of gross investment, this will cause overstatement of the growth of the capital stock, particularly around 1970. We have not, however, been able to construct an alternative measure.

Figure 1

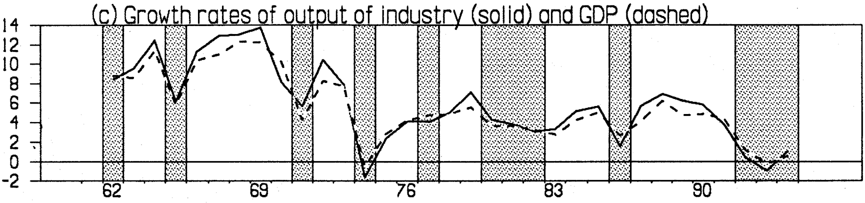
(a) Growth rate of real capital stock, nonfinancial corporations



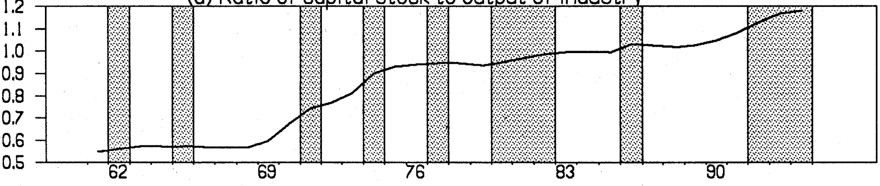
(b) Output of industry (solid) and GDP (dashed) (trillion 1985 yen)



(c) Growth rates of output of industry (solid) and GDP (dashed)



(d) Ratio of capital stock to output of industry

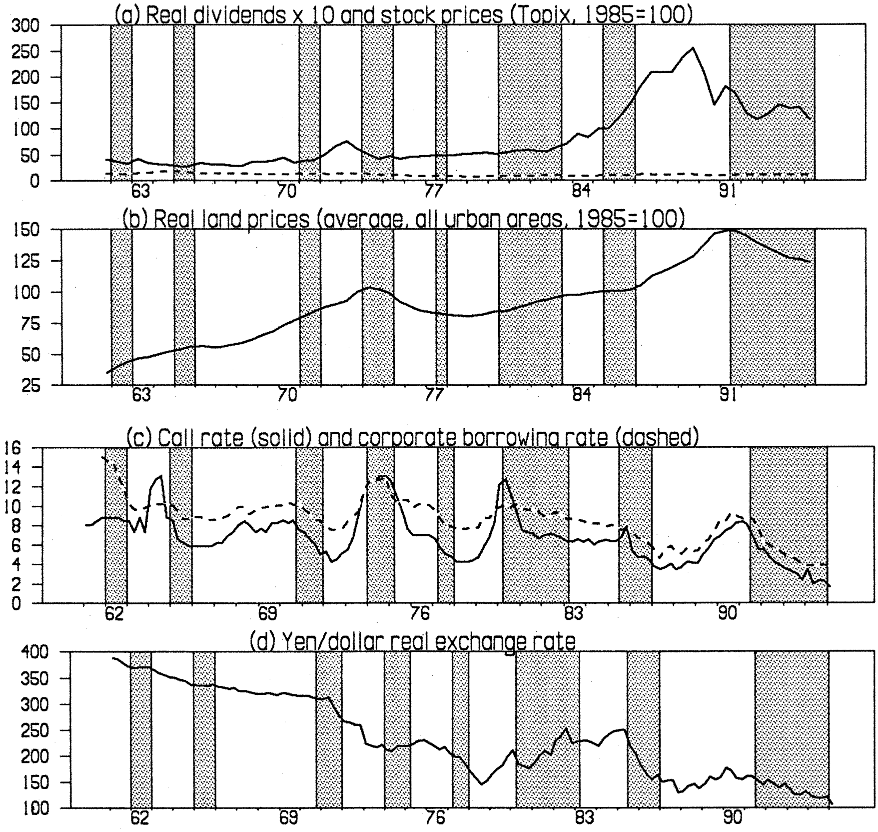


not due to the particular definition of output or capital. The trend in the capital–output ratio, and in the ratio of a capital to output-goods deflator, is equally evident when (for example) capital includes inventories and fixed capital of not just the nonfinancial corporate sector but that for the 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

Figure 2



growth is transitional, although our model in Section 4 does point out that an indefinite continuance of the trend is perfectly consistent with balanced growth. Rather, we take the message of Figure 1d 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 plots the real (1985 prices) semiannual (end of quarters 1 and 3) value of the Topix index along with corresponding dividends multiplied by 10. (The closest U.S. equivalent to the Topix is probably the S and 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 1989, anticipating the turndown in real activity. In the four years from 1985:3 to 1989:3, the real value of the index increased by a factor of about 2.5, implying an annual rate of appreciation of 23.1%. The subsequent decline left 1995:1 stock prices barely 15% above their 1985:3 value. As may be seen, dividend–price ratios are small by U.S. standards: in 1985:3 they were 1.01%, and had fallen to 0.96% by 1995:1.

Figure 2b plots real, semiannual (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 1986:3 to 1991:1, the index increased by about half, with an implied annual rate of appreciation of about 8.4%. The 1995:1 value of the index is about 20% above the 1986:3 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 1986:3 and 1991:1, 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 quarterly holding 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 (1992:1 through 1993:1). 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 expansion and fell during the ongoing contraction. The increases in the call rate after mid-1989 are commonly thought to have been part of an intentional attempt by the Bank of Japan to "pierce the bubble" 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 to spark the economy.

The final figure is that of the quarterly real yen–dollar exchange rate. The nominal rate at the end of quarter was deflated by the GDP deflators for Japan and the U.S. (1985=100). The real appreciation of the yen in the fixed rate era (1961–1971) reflects the generally higher rate of inflation in Japan.

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 models we use are formulated in terms of the capital stock, we turn to a 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 runup 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–output 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.

3. *Movements in Balance Sheets in 1961–1994*

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.[8]

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

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[8] Four other sectoral balance sheets are maintained: financial institutions; households, including unincorporated nonfinancial enterprises; nonprofit institutions serving households; general government. Note that in contrast to the U.S. balance-sheet data from the Federal Reserve System, Japan lumps unincorporated enterprises with the household sector.

(3.2) *Land* ($p_{Lt}L_t$): Nonreproducible tangible assets, excluding improvements in land insofar as such improvements are included in NIPA business fixed investment.
(3.3) *Equity* ($p_{Et}E_t$): Holdings of shares of other corporations.
(3.4) *Monetary assets* (M_t): Financial assets apart from equity; this includes, for example, money, debt, and trade credit.
(3.5) *Debt* (B_t): All liabilities, apart from net worth and the value of equity; this includes, for example, debt and trade credit.
(3.6) *Net worth* (W_t): 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

(a) Levels

	1961	*1969*	*1973*	*1977*	*1981*	*1985*	*1990*	*1994*
Capital+ inventories	63.8	137.1	242.0	258.8	320.1	358.1	474.0	538.5
Land	33.0	91.5	180.5	149.5	224.2	261.7	633.6	465.9
Equity	18.1	26.5	53.1	35.2	52.7	88.3	221.8	152.2
Monetary assets	59.8	172.8	263.6	251.6	313.5	387.5	534.6	514.1
Debts	92.7	249.0	383.5	385.2	463.6	562.5	803.7	867.7
Net worth	81.9	178.8	355.7	309.9	446.9	533.0	1060.3	802.8
Total assets	174.6	476.8	739.2	695.1	910.5	1095.5	1864.0	1670.6

(b) Growth Rates

	61–69	*69–73*	*73–77*	*77–81*	*81–85*	*85–90*	*90–94*	*61–94*
Capital+ inventories	10.0	15.3	1.7	5.5	2.8	5.8	3.2	6.7
Land	13.6	18.5	−4.6	10.7	3.9	19.3	−7.4	8.4
Equity	4.9	19.0	−9.8	10.6	13.8	20.2	−9.0	6.7
Monetary assets	14.1	11.1	−1.2	5.7	5.4	6.6	−1.0	6.7
Debts	13.1	11.4	0.1	4.7	5.0	7.4	1.9	7.0
Net worth	10.3	18.8	−3.4	9.6	4.5	14.7	−6.7	7.2
Total assets	11.8	15.7	−1.5	7.0	4.7	11.2	−2.7	7.1

Notes:
1. Units in panel (a) are trillions of 1985 yen, computed by deflating the nominal data with the GDP deflator. Data are for end of 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.

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 match 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 1990 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.[9]

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+inventories, land, and equity—but also for the real value of monetary assets and debts. Second, for the 33-year period 1961–1994, capital+inventories, 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+inventories, monetary assets, and debt.

A natural next question would be how much of these movements is due to net acquisition 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 *reconciliation* 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).[10] For example, for capital + inventories K_t' and monetary assets M_t,

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[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 Ando and Auerbach, 1990). Equity values, on the other, may be understated, since for nontraded equities face value is used. These mismeasurements of land and equity may cause serious problems in constructing Tobin'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 error, and (3) the effects of changes in the accounting system.

Table 4

Outflow		*Inflow*	
		Real Transactions	
Gross fixed capital formation + inventory investment	(IK'_t)	Savings (including net capital transfers)	(S_t)
Net purchase of land	(IT_t)	Capital consumption (depreciation)	(D_t)
Savings—investment	(DSI_t)		
		Financial transactions	
Net acquisition of equity	(IE_t)	Net increase in liabilities	(IB_t)
Net acquisition of monetary assets	(IM_t)	Net issue of equity	(IW_t)
		Financial surplus	(FS_t)

$$\begin{array}{lll} \text{increase in the market value of capital+inventories} & = \text{net investment} & + \text{reconciliation account for } K_t, \end{array} \tag{3.7}$$

$$\begin{array}{lll} p_{Kt}K'_t - p_{Kt-1}K'_{t-1} & = IK'_t - D_t & + RK'_t, \\ M_t - M_{t-1} & = IM_t & + RM_t. \end{array} \tag{3.8}$$

We can roughly decompose the change in the real value of each entry in terms of the GDP deflator as the sum of real net acquisitions plus the real capital gains of each entry:

$$\frac{p_{Kt}K'_t}{p_{yt}} - \frac{p_{Kt-1}K'_{t-1}}{p_{yt-1}} = \frac{IK'_t - D_t}{p_{yt}} + \left[\frac{RK'_t}{p_{yt}} + \left(\frac{1}{p_{yt}} - \frac{1}{p_{yt-1}}\right) p_{K_{t-1}}K'_{t-1}\right], \tag{3.9}$$

$$\frac{M_t}{p_{yt}} - \frac{M_{t-1}}{p_{yt-1}} = \frac{IM_t}{p_{yt}} + \left(\frac{1}{p^e_{yt}} - \frac{1}{p_{yt-1}}\right) M_{t-1} + \left[\frac{RM_t}{p_{yt}} + \left(\frac{1}{p_{yt}} - \frac{1}{p^e_{yt}}\right) M_{t-1}\right], \tag{3.10}$$

where p^e_{yt} is the expectation of the price level p_{yt} 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+inventories is equal to the sum of the real values of net investment and capital gains. We regard the reconciliation account RK'_t as a measure of nominal capital gains, and construct real capital gains as RK'_t/p_{yt} 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 reconciliation account figure into computation of real capital gains [the last two terms of the right-hand side of (3.10)]. We decompose similarly for debts. Then the change in the real net worth becomes

$$\frac{W_t}{p_{yt}} - \frac{W_{t-1}}{p_{yt-1}} = \frac{S_t + IW_t + FS_t - DSI_t}{p_{yt}} + \left(\frac{1}{p^e_{yt}} - \frac{1}{p_{yt-1}}\right)(M_{t-1} - B_{t-1})$$
$$+ \frac{RK'_t+RL_t+RE_t+RM_t-RB_t}{p_{yt}} + \left(\frac{1}{p_{yt}} - \frac{1}{p_{yt-1}}\right)(p_{Kt-1}K'_{t-1}+p_{Lt-1}L_{t-1}+p_{Et-1}E_{t-1})$$
$$+ \left(\frac{1}{p_{yt}} - \frac{1}{p^e_{yt}}\right)(M_{t-1} - B_{t-1}). \qquad (3.11)$$

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 debts.[11]

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 equities. These capital gains and losses are large even when compared to annual GDP (1990 real GDP=399 trillion). During the 1986–1990 asset price inflation, real net worth increased by about 528 trillion 1985 yen, of which 430 trillion were capital gains and 98 trillion were net savings and net issues of equity. During 1991–1993, net worth dropped by 274 trillion, with a capital loss of 311 trillion partially offset by 37 trillion of net saving and net issues of equity. A particularly 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 movement

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[11] In theory, the difference between saving and investment in real transactions should equal the financial surplus in financial transactions. In the data, however, they do not match because of differences in sources. So we include this gap as a part of net acquisition of net worth.

Table 5 NET ACQUISITIONS AND REAL CAPITAL GAINS OF NONFINANCIAL CORPORATIONS, SELECTED YEARS

		62–69	*70–73*	*74–77*	*78–81*	*82–85*	*86–90*	*91–93*	*62–93*
Capital+ inv.	na	108.5	89.1	75.7	83.4	85.5	146.5	94.0	682.7
	cg	−36.0	15.8	−58.9	−22.0	−47.6	−30.6	−42.6	−221.9
Land	na	14.5	27.1	5.9	1.0	4.4	36.6	3.5	96.0
	cg	43.9	62.0	−36.9	73.7	33.0	335.4	−161.6	349.5
Equity	na	4.7	3.2	1.9	2.5	1.2	12.8	−4.4	21.9
	cg	3.7	23.4	−19.8	15.0	34.4	120.7	−84.2	93.2
Monetary assets	na	108.9	107.0	−12.3	38.0	45.4	167.9	−57.9	397.0
	cg	4.4	−16.2	0.2	23.9	28.6	−20.7	15.4	35.6
Debts	na	161.2	159.4	7.4	57.0	77.7	266.2	−1.7	727.2
	cg	−5.0	−24.9	−5.7	21.4	21.2	−25.0	38.3	20.3
Net worth	na	75.5	67.0	63.8	67.8	58.9	97.6	37.0	467.6
	cg	21.0	109.9	−109.7	69.2	27.2	429.8	−311.3	236.1

Units are trillions of 1985 yen. "na" is net acquisitions, "cg" is capital gains, computed in accordance with equations (3.9), (3.10), and (3.11). See text for additional details.

of the debt and net worth of nonfinancial firms is consistent with models that emphasize the interaction between credit and investment as a possible propagation mechanism over business cycles. For example, Kiyotaki and Moore (1994) show that small temporary shocks to technology and income distributions may generate large and persistent fluctuations of aggregate output and asset prices through the interaction of collateral value, credit, and investment.

A third point is that, in terms of trend, net saving and net issues of own equity are important sources of upward movement of net worth, along with the upward trend in the relative prices of land and equity. In contrast, capital+inventories generally experiences real capital losses, because, as depicted in Figure 4, the price of capital is falling relative to the GDP deflator. A final point is that nonfinancial corporations bought land and equities net in 1986–1990 and sold equities net in 1991–1993.

4. *A Simple General Equilibrium Model*

In this section we present a simple general equilibrium model of investment. Our aims are twofold. Following Greenwood, Hercowitz, and Krusell (1995), the first is to link theoretically the upward trend in the capital–output ratio and the downward trend in the ratio of the investment-goods deflator to the output deflator, and to show that such trends in fact are consistent with balanced growth. To illustrate that these theoretical points do not require undue specialization of the 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 Krusell (1995) 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 the 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) change in the marginal rate of transformation between investment goods and consumption goods. The production function and basic resource constraints are

$$Y_t = \tilde{A}_t F(K_t, H_t N_t A_t) = \tilde{A}_t K_t^{\theta} (H_t N_t A_t)^{1-\theta}, \tag{4.1}$$

$$K_t = (1 - \delta) K_{t-1} + I_t, \tag{4.2}$$

$$Y_t = \zeta_t N_t + P_{It}\left(I_t + \frac{\phi}{2} X_t^2 K_{t-1}\right), \tag{4.3}$$

$$X_t = \frac{K_t - G_K K_{t-1}}{K_{t-1}} \equiv \frac{I_t}{K_{t-1}} - G_K + 1 - \delta. \tag{4.4}$$

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 $\tilde{A}_t$. In (4.2), capital accumulation proceeds as usual, with δ the constant depreciation rate and I_t gross investment. In (4.3), output is used for per capita consumption ζ_t and investment. P_{It} is the relative price of investment goods. It equals an exogenous marginal rate of transformation between investment and consumption goods. The adjustment cost $(\phi/2)X_t^2 K_{t-1}$ is increasing in the deviation of capital growth from its steady-state rate G_K. Baxter and Crucini (1993) and Cogley and Nason (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_K (which is solved for below).

Preferences of the representative household are given by the expected discounted utility

$$E_t \sum_{j=0}^{\infty} \beta^j N_{t+j} [u(\zeta_{t+j}) - B_{t+j} v(H_{t+j})], \tag{4.5}$$

where $u(\zeta) = (\zeta^{1-\sigma} - 1)/(1 - \sigma)$, $v(H) = H^{1+\nu}/(1 + \nu)$, and B_t is a measure of the disutility of labor.

Let the aggregate productivity $\tilde{A}_t$ be strictly positive, with mean one, and follow a finite-state stationary Markov process. Let the labor productivity A_t, disutility of labor B_t, and population N_t grow, and let the relative price of investment goods P_{It} shrink, at constant rates,

$$A_{t+1} = G_A A_t, \qquad B_{t+1} = G_B B_t, \qquad N_{t+1} = G_N N_t, \qquad P_{It+1} = P_{It}/G_{PI}, \tag{4.6}$$

$$G_B = (G_A (G_{PI})^{\theta/(1-\theta)})^{1-\sigma} < (\beta G_N)^{-1}. \tag{4.7}$$

where all $G_i \geq 1$, $i = A, B, N, PI$; (4.7) 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

$$\frac{u'(\zeta_t)(1 - \theta)Y_t}{H_t N_t} = B_t v'(H_t), \tag{4.8}$$

$$P_{It}(1 + \phi X_t) = \theta \frac{Y_t}{K_t} + E_t \left(\frac{\beta u'(\zeta_{t+1})}{u'(\zeta_t)} P_{It+1}[1 - \delta + \phi X_{t+1} (\mathrm{G_K} + 0.5\mathrm{X}_{t+1})] \right). \tag{4.9}$$

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 resale value 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 $G_K = G_A G_N G_{PI}^{1/(1-\theta)}$. Output grows at the rate $G_A G_N (G_{PI})^{1/(1-\theta)}$, which is lower than that of aggregate capital by a factor of G_{PI}. It follows that K/Y is growing at the rate that P_{It} 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 $t+1$:

$$C_t = P_{It} \left(1 - E_t \frac{P_{It+1}}{P_{It}} (1 - \delta) \frac{\beta u'(\zeta_{t+1})}{u'(\zeta_t)} \right) \tag{4.10}$$

Let $\mathrm{K}_t^* \equiv Y_t/C_t$; K_t^* is the target capital stock, which, apart from a proportionality factor θ, would obtain if there were no adjustment costs to investment. Observe that the cost of capital C_t is also shrinking at rate G_{PI}. So the rates of growth actual (K_t) and target (K_t^*) 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 flexible accelerator familiar from Hall and Jorgenson (1967). Let $M_{t+1} = (P_{It+1}/P_{It})\,[\beta u'(\zeta_{t+1})/u'(\zeta_t)]$ be the intertemporal marginal rate of substitution in terms of investment goods. Upon manipulating (4.9), we obtain

$$X_t = \frac{\phi^{-1} C_t}{P_{It}} \left(\frac{\theta Y_t}{C_t K_t} - 1 \right) + E_t[M_{t+1} X_{t+1} (G_K + 0.5 X_{t+1})]. \tag{4.11}$$

Let $M \equiv EM_t$ be the unconditional mean of M_t. Using $X_t = -G_K + 1 + (\Delta K_t/K_{t-1})$, $C_t/P_{It} = 1 - (1-\delta)E_t M_{t+1}$, and the definitions of K_t^* and M, (4.11) becomes

$$\frac{\Delta K_t}{K_{t-1}} = (G_K - 1)(1 - G_K M) + [\phi^{-1} - \phi^{-1}(1-\delta)M] \left(\frac{\theta \mathrm{K}_t^*}{K_t} - 1 \right)$$

$$+ M G_K E_t \frac{\Delta K_{t+1}}{K_t} - u_t, \tag{4.12}$$

where $-u_t \equiv \phi^{-1}(1-\delta)(M - E_t M_{t+1})\,[(\theta \mathrm{K}_t^*/K_t) - 1] + G_K E_t[(M_{t+1} - M)(\Delta K_{t+1}/K_t - G_K + 1)] + 0.5 E_t(M_{t+1} X_{t+1}^2)$. 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 $(K_t - K_{t-1})/K_{t-1} \approx \Delta \ln k_t \equiv \Delta K_t$, $(\theta \mathrm{K}_t^*/K_t) - 1 \approx \ln(\theta \mathrm{K}_t^*/K_t) \equiv \ln \theta + k_t^* - k_t$; here and throughout the paper, when upper- and lowercase are both used, the lowercase denotes a logarithm. Finally, define $\alpha \equiv \phi/[1 - (1-\delta)M]$ and $b \equiv MG_K$. We end up with an equation used in the empirical work,

$$\Delta k_t = \text{constant} + \frac{1}{\alpha}(k_t^* - k_t) + E_t b\,\Delta k_{t+1} - e_t, \tag{4.13}$$

where e_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 model 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

$$I_t/K_t = \gamma Q_{t-1} + \text{disturbance}, \tag{5.1}$$

or $I_t/K_t = \gamma Q_t$ + 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 inflexibly to that model, we make a self-contained presentation here.[12] 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

$$0.5E_t \sum_{j=0}^{\infty} b^j[(k_{t+j}^* - k_{t+j})^2 + \alpha(k_{t+j} - k_{t+j-1})^2 + 2k_{t+j}e_{t+j}], \tag{6.1}$$

$$k_t^* = y_t - c_t. \tag{6.2}$$

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[12] Among the features of our empirical work not suggested by the model: we obtain discount factors 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 deterministic trends.

In (6.1), E_t is mathematical expectation, using data as of period t, assumed equivalent to linear projections, $0 \leq b < 1$ is a discount factor, $k_t \equiv \ln K_t$ is the log of the capital stock at the end of period t, $k_t^* \equiv \ln K_t^*$ is the log of the *target* capital stock, which would obtain in a deterministic steady state, e_t is a stationary cost shock observable to the firm but not the econometrician, and α is a positive parameter that reflects the relative importance of costs of being away from K_t^* and of adjustment. In (6.2), y_t = ln(output) and c_t = ln(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

$$k_t = \lambda k_{t-1} + \frac{\lambda}{\alpha}\sum_{j=0}^{\infty}(b\lambda)^j E_t k^*_{t+j} - \frac{\lambda}{\alpha}\sum_{j=0}^{\infty}(b\lambda)^j E_t e_{t+j}, \tag{6.3}$$

whence

$$k_t - k_t^* = \lambda(k_{t-1} - k^*_{t-1}) - \Delta k_t^* + (1-\lambda)\sum_{j=0}^{\infty}(b\lambda)^j \mathrm{E}_t\, \Delta k^*_{t+j} - \frac{\lambda}{\alpha}\sum_{j=0}^{\infty}(b\lambda)^j E_t e_{t+j} \tag{6.4}$$

In (6.3), $0 < \lambda < 1$ is the smaller root of the equation $b\alpha\lambda^2 - (1 + \alpha + b\alpha)\lambda + \alpha = 0$, and we derive (6.4) from (6.3) using $\lambda/\alpha = (1 - \lambda)(1 - b\lambda)$. 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, Δk_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_t denote a vector of variables that are useful in forecasting future Δk_t^*'s, including at least two of Δk_t^*, Δy_t, and Δc_t—say Δk_t^* *and* Δc_t for concreteness. (Given $\Delta k_t^* = \Delta y_t - \Delta c_t$, and our use of linear models, all results are identical when we use any two of Δk_t^*, Δy_t, and Δc_t.) Let $Z_t = (k_t - k_t^*, f_t')'$. Through most of the work f_t contains no variables in addition to Δk_t^* and Δc_t, and Z_t is 3×1. We have

$$k_t - k_t^* = \lambda(k_{t-1} - k^*_{t-1}) - E\left[\Delta k_t^* - (1-\lambda)\sum_{j=0}^{\infty}(b\lambda)^j \Delta k^*_{t+j} \,\middle|\, Z_{t-1}, Z_{t-2}, \ldots\right] + \epsilon_{1t}, \tag{6.5}$$

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[13] Nickell (1979) also suggested a log-linear flexible accelerator model.

$\epsilon_{1t} \equiv v_{1t} - (\lambda/\alpha)\Sigma_{j=0}^{\infty}(b\lambda)^j E_t e_{t+j}$, $v_{1t} \equiv E[\Delta k_t^* - (1 - \lambda)\Sigma_{j=0}^{\infty}(b\lambda)^j \, \Delta k_{t+j}^* | Z_{t-1}, Z_{t-2}, \ldots] - E_t[\Delta k_t^* - (1 - \lambda)\Sigma_{j=0}^{\infty}(b\lambda)^j \, \Delta k_{t+j}^*]$. We assume that lagged Z_t's are part of the firm's information set, which means that v_{1t} is uncorrelated with lags of Z_t. We assume as well that e_t is also uncorrelated with these lags, and that ϵ_{1t} is serially uncorrelated. A process for Z_t consistent with (6.5) is a VAR, say

$$Z_t = \Pi Z_{t-1} + \epsilon_t. \tag{6.6}$$

Equation (6.6) assumes a VAR (1) because that is maintained in most of our empirical work. Generalization to higher-order VARs is routine.

We obtain *unrestricted* estimates of (6.6) by OLS. We obtain estimates that are *restricted* to follow the decision rule implied by (6.5) by solving for a Π consistent with (6.5). Details on the procedure are given in Section 7.3 and the Appendix. Given a set of restricted or unrestricted estimates of (6.6), most of the analysis is concerned with the coefficients and residuals in the corresponding unit root VAR in the levels of y, c, and k (and, in systems in which f_t includes a variable in addition to Δk^* and Δc, in the level of the additional variable as well). We solve for the short- and long-run elasticities of capital with respect to output and the cost of capital (also known as dynamic multipliers, or impulse response functions). We also compute the 1986 forecast of the 1991 values of k_t, k_t^*, y_t, and c_t, and similarly the 1991 forecast of the 1994 values. We then use the actual realized values to compute the surprise components, which are simply the differences between forecast and actual. We further obtain an orthogonal decomposition of the surprise components into those due to shocks to the variables in f_t, and a residual, uncorrelated, "k_t shock," as follows. To do so, we use the VAR in the levels of the variables, and apply a Choleski decomposition with the residual for k ordered last.

7. *Data and Estimation Technique for Investment Regressions*

The capital stock K_t ($k_t \equiv \ln K_t$ for the flexible accelerator) is as described in Section 2 above. Throughout this section, P_{It} refers to the deflator for private investment in plant and equipment. Because of a possible change in regime around 1974, all specifications were estimated both on the full sample and on a sample that began in 1974. The full-sample regressions always included a constant and post-1973 dummy, the post-1973 ones a constant.

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,

$$\text{denominator of } Q = \text{nominal value of net fixed assets,} \tag{7.1a}$$

$$\text{numerator of } Q = \begin{array}{l} \text{own equity value} + \text{debt} \\ -(\text{inventories} + \text{land} \\ +\text{cross-holding of equities} \\ +\text{monetary assets}) - \tau_t A_t, \end{array} \tag{7.1b}$$

where τ_t is the effective corporate tax rate, and A_t is the expected present value of depreciation of past investments. Construction of τ_t is discussed in Section 7.2; of A_t, 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 quantities 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 mismeasurement of equities caused by use of book value of equity for nontraded corporations (see Section 3); Hoshi and Kashyap (1990) find that this biases Q downwards in Japanese data.[14] Another possible problem is mismeasurement 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 mismeasurement.

Some details on construction of the present value of future deprecia-

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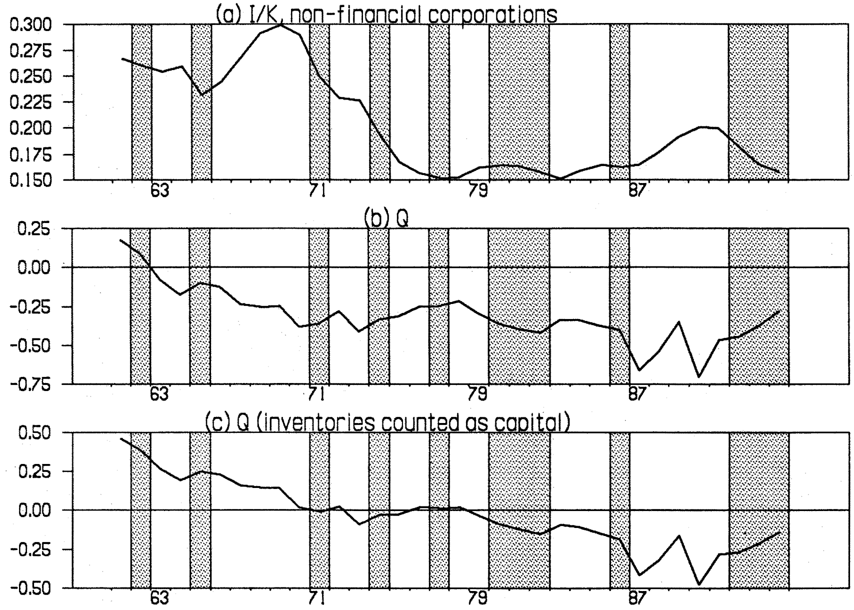
[14] The problem does, however, seem to run deeper than measurement of equity at book rather than market. Hoshi and Kashyap (1990) find that a substantial fraction of firms with equity valued at market have $Q < 0$, even after making a careful calculation of the market value of land.

Figure 3



tion deductions A_t, which may be skipped without loss of continuity: A precise definition of A_t may be found in, e.g., Hayashi (1990). For 1961–1981, we set A_t = (denominator of Q_t) × [Homma *et al.*'s (1984, Table 3-1) figure for A_t]/[Homma *et al.*'s (1984, Table 3-1) figure for net fixed assets]. (Homma *et al.* use Japanese manufacturing data.) For 1982–1994, we relied on Iwamoto (1989), who shows that under certain assumptions,

$$A_{t+1} = \frac{1 - a}{a + i_{t+1}} [aP_{It}I_t + (a + i_t)A_t], \tag{7.3}$$

where a is the percentage depreciation per year, set to 0.09, and i_t is the safe nominal interest rate, set to the fourth-quarter holding yield of the long-term bonds of NTT, the national telephone company.

7.2 DATA FOR FLEXIBLE ACCELERATOR REGRESSIONS

For y_t, we use the log of the output of industry, as described in Section 2 above. The cost of capital c_t used in the regressions is the log of a conventionally computed user cost of capital given by

$$C_t = \frac{P_{It}}{P_{yt}} C_{1t} C_{2t}, \tag{7.4}$$

$$C_{1t} \equiv \frac{1 - \tau_t z_t}{1 - \tau_t}, \qquad C_{2t} \equiv 1 - \frac{E_t[P_{I\,t+1}/P_{It}](1 - \delta)}{1 + i_{at}}.$$

In (7.4), τ_t is the effective corporate tax rate, z_t is the present value of depreciation deductions per dollar of new investment; P_{Yt} is the price of output, measured as the deflator for output of industry, 1985=100; $E_t[P_{I\,t+1}/P_{It}]$ is the fitted value of an AR(1) in $P_{I\,t+1}/P_{It}$; δ is the depreciation rate, set at 0.10, which is approximately the depreciation rate implied by the balance-sheet data; and $1 + i_{at}$ is the nominal discount factor for the firm. Some details on τ, z, and i_a are given at the end of this section. It may help to note that C_{2t} is usually approximated as[15]

$$C_{2t} \approx i_{at} - \text{expected inflation in } P_{It} + \delta.$$

Figure 4a plots the level $C_t \equiv \exp(c_t)$ of the cost of capital. As suggested by the Figure 4b plot of P_{It}/P_{Yt} (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_{1t} term or in the real interest-rate terms collected in C_{2t}. The latter terms do, however, have sharp cyclical effects. The spikes in C_{2t} and hence in C_t during 1972–1975 are caused by violent movements in actual and thus in expected inflation: from 1972 through 1975 actual inflation in P_{It} 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 Tajika, Hayashi, and Abrai (1987). Figures 4a and 5 show that the blip in C around 1974–1975 is transmitted to k^* and thus to $k^* - k$.

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 τ_c be the corporate tax rate on retained earnings, τ_g the

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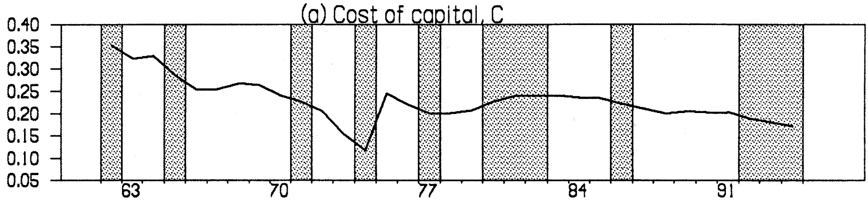
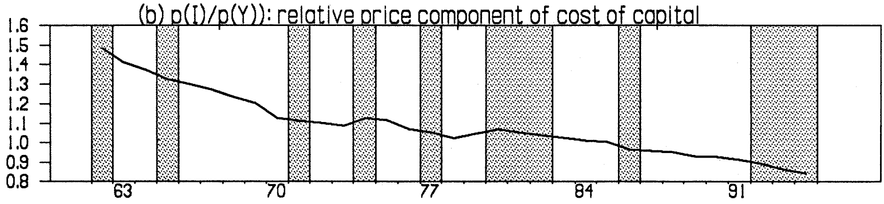
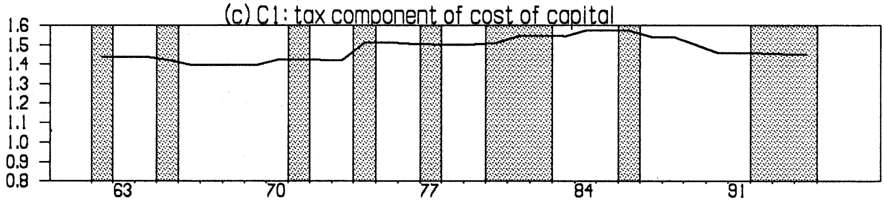
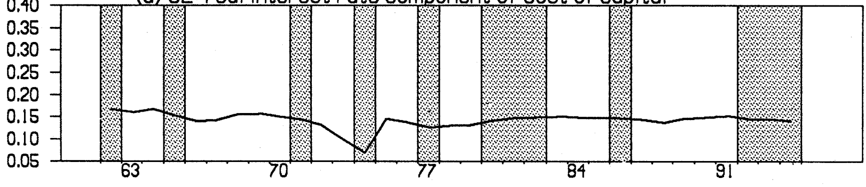
[15] A number of studies since Clark (1979) have computed expected inflation from output rather than capital-goods prices. The capital-goods inflation rate is appropriate not only in the model in Section 4, but, more generally, in "putty-putty" models in which firms are viewed as renting capital period by period at the market price of capital. See Ando et al. (1974).

Figure 4


(a) Cost of capital, C


(b) p(I)/p(Y)): relative price component of cost of capital

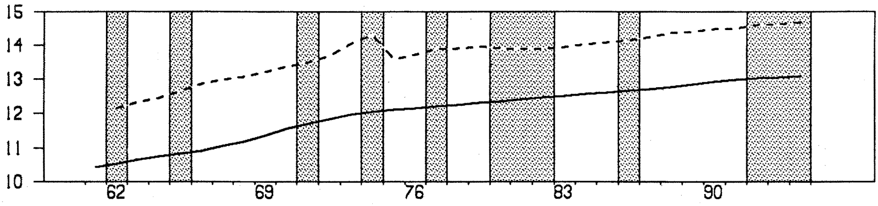

(c) C1: tax component of cost of capital


(d) C2: real interest rate component of cost of capital

enterprise tax rate, τ_1 the local tax rate. Let $1 + i_{st}$ be a safe nominal interest rate, computed as the annual average of monthly call rates. Then $\tau = [\tau_c(1 + \tau_1) + \tau_g]\ [(1 + i_{st})/(1 + i_{st} + \tau_g)]$; 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 (z_t) was fixed at 0.562 for all t; 0.562 is the 1961–1981 average of the $\{z_t\}$ series given in Hayashi (1990, p. 308), 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

Figure 5 k (SOLID), $k^* = y - c$ (DASHED)



ignore, for example, special tax treatment of dividends received by corporations, 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 $i_{at} = (1 - \omega)$(expected net nominal return on equity from t to $t + 1$) $+ \omega(1 - \tau_t)$(net nominal rate on debt), where ω 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 premium. 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 2c.

A small amount of experimentation at a preliminary stage of the research 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 interest rates.

7.3 ESTIMATION TECHNIQUE FOR FLEXIBLE ACCELERATOR REGRESSIONS

In unrestricted regressions, estimates were obtained by OLS, and the usual OLS standard errors are reported. For restricted regressions, estimates of the $k_t - k_t^*$ 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 estimation, we merely note here:

1. We did not estimate but instead imposed an annual discount factor, setting $b = 0.95$.[16]
2. To obtain restricted estimates, we used a two-step procedure that under conventional econometric assumptions is consistent but not efficient. In a first step, we obtained consistent estimates of α and λ from the unrestricted estimates. In a second step, we used an iterative procedure to solve for a $k_t - k_t^*$ process compatible with these values and with the unrestricted coefficients in the equations for f_t. [Recall that f_t is the vector of variables used to forecast future Δk_t^*'s, $f_t = (\Delta k_t^*, \Delta c_t)'$ in our basic specification.] This iterative procedure takes proper account of the Granger causality from $k - k^*$ to Δk^*. (Without such causality, one could of course directly compute, without iterating, a restricted $k - k^*$ process.) Note that since restricted and unrestricted coefficients in the Δk^* and Δc equations are the same, so, too, are the coefficients and residuals in the equations for the levels of y and c.
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 restrictions 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-1973 sample. Since the diagnostics reported at the foot of the table suggested substantial serial correlation, estimates with a correction 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.

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[16] The growth model of Section 4 suggests computing b from the average value of $1 - C_{2t}$ [C_{2t} is defined in (7.4)] and the growth rate of the capital stock. If we do so using the data described in the Section 7, however, we get $b = 1.03$.

Table 6 REGRESSION RESULTS, Q-MODEL

Regressor and Summary Statistic	*(1) 1962–94 (33 obs.)*	*(2) 1963–94 (32 obs.)*	*(3) 1974–94 (21 obs.)*	*(4) 1975–94 (20 obs.)*	*(5) 1961–94 (34 obs.)*	*(6) 1974–94 (21 obs.)*	*(7) 1962–94 (33 obs.)*	*(8) 1963–94 (32 obs.)*
Q_{t-1}	−0.008 (0.035)	0.008 (0.025)	−0.077 (0.010)	−0.024 (0.019)				
Q_t					−0.019 (0.032)	−0.067 (0.023)		
Q_{t-1} with inventories							−0.004 (0.039)	0.016 (0.029)
Constant	0.252 (0.008)	0.196 (0.036)	0.139 (0.004)	0.155 (0.010)	0.251 (0.008)	0.143 (0.008)	0.254 (0.015)	0.199 (0.032)
post-1973 dummy	−0.087 (0.016)	−0.027 (0.016)			−0.090 (0.014)		−0.087 (0.019)	−0.028 (0.016)
ρ		0.911 (0.080)		0.666 (0.161)				0.905 (0.084)
$\bar{R}^2$	0.784	0.900	0.336	0.573	0.797	0.257	0.784	0.901
S.e.e.	0.022	0.015	0.013	0.010	0.022	0.013	0.022	0.015
Q-statistic [p-value]	24.31 [0.00]	15.15 [0.03]	6.81 [0.24]	10.70 [0.03]	25.33 [0.00]	5.45 [0.36]	24.82 [0.00]	14.80 [0.04]
Durbin–Watson	0.73	1.19	1.08	0.74	0.73	0.89	0.72	1.19

Notes:

1. The table presents the results of ordinary least-squares regression estimates in columns (1), (3), (5), (6), and (7), with heteroscedasticity and autocorrelation consistent standard errors computed using four lags of the estimator suggested in Newey and West (1987). Columns (2), (4), and (8) present estimates using a Cochrane–Orcutt correction for first-order serial correlation, with the row labeled ρ presenting the resulting estimate of the first-order serial correlation coefficient. For description of summary statistics, see notes to Table 7 below.
2. In all columns, the dependent variable is the ratio of real (1985 yen) gross investment in a given year to the end-of-the-year capital stock, for nonfinancial corporations. Q is measured at the end of the year, so Q_{t-1} is beginning of period Q. "Q with inventories" combines inventories and fixed capital. All measures of Q are adjusted for taxes. See text for further details.

Given the wildly unsatisfactory nature of these results, and the more fundamental problem that Q is negative for most of our sample (see Figure 3), we decided not to attempt to refine or interpret these estimates.

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 k and for output of industry is a familiar one, with robust growth before 1973 followed by more moderate growth after 1974, and with the 1986–1991 period relatively strong, the 1991–1994 period exceptionally weak. As indicated in Figure 4, the cost of capital c fell through most of the period, especially in the early part of the sample. The column (3) and (4) subperiod figures for this variable are heavily

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

	(1) *1962–94*	*(2)* *1961–73*	*(3)* *1973–94*	*(4)* *1973–91*	*(5)* *1986–91*	*(6)* *1991–94*
(1) k	8.0	12.7	5.3	5.7	6.5	3.0
	(4.4)	(3.7)	(1.5)	(1.1)	(0.9)	(1.4)
(2) $k^* \equiv y - c$	7.9	17.2	3.0	2.5	7.2	5.9
	(16.8)	(7.9)	(18.2)	(19.7)	(4.1)	(3.2)
(3) y	5.7	9.5	3.5	4.1	5.5	0.1
	(3.8)	(2.5)	(2.4)	(2.0)	(1.1)	(1.0)
(4) c	−2.3	−7.6	0.5	1.6	−1.8	−5.8
	(16.1)	(9.3)	(18.3)	(19.7)	(3.5)	(2.5)
(5) $p_I - p_Y$	−1.8	−2.8	−1.2	−1.0	−1.2	−2.6
	(1.9)	(1.6)	(1.8)	(1.9)	(0.9)	(0.4)
(6) c_1	0.0	−0.1	0.1	0.1	−1.5	−0.1
	(1.5)	(0.9)	(1.8)	(1.9)	(1.4)	(0.1)
(7) c_2	−0.5	−4.7	1.6	2.4	0.9	−3.2
	(16.5)	(9.5)	(19.1)	(20.5)	(4.5)	(2.7)

Notes:

1. The data are annual and real (1985 yen). Growth rates are computed by averaging log differences beginning with the year following the start date; the column (6) figure, for example, averages log differences in the 3 years from 1992 to 1994. k is net fixed assets of nonfinancial corporations, y is output of industry, c is the cost of capital, constructed as described in the text and note 2 below. In columns (1) and (2), the sample periods for k and y begin in 1961 rather than 1962. Because of this, and because of rounding, rows (3) and (4) may not add to row (2). See text for further details.

2. The cost of capital in row (4) is the product of the three terms in rows (5) through (7). Row (5) is the ratio of deflator for private investment in plant and equipment to that for output of industry. Row (6) reflects tax factors. Row (7) largely reflects a nominal discount factor and expected inflation. See the text for details. Rows (5) to (7) may not add to row (4) because of rounding. See text for further details.

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 (3)]. We note that this is consistent with the model of Section 4, and with the less structured Cobb–Douglas specification of target capital in Section 6. Our empirical work does not, however, rely on the Section 4 prediction that the capital–output ratio will increase indefinitely: The point is that simple 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 whole 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 37.5% 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 ($k - k^*$, Δk^*). The t-statistics implied by the column (1b) figures indicate that relative to an information set consisting of past $k - k^*$'s and past Δk^*'s, $k - k^*$ Granger-causes Δk^* even though Δk^* does not Granger-cause itself; on 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 Δk^* 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 Δk^*_{t-1} and Δc_{t-1} as predictors of Δk^*_t; column (2c) suggests the same, a little more mildly.

Columns (3a) through (3c) 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 Δk^* 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 Δk^* 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, k) 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 $k_t - k^*_t$ process using the method in the Appendix and then, using $k^* = y - c$, transform to a unit-root VAR in (y, c, k). Apart from deterministic terms and the residual, the result is

$$y_t = \underset{(-0.054,\ 0.092)}{0.015k_{t-1}} \; \underset{(0.730,\ 1.42)}{+\,1.172y_{t-1}} \; \underset{(-0.436,\ 0.242)}{-\,0.187y_{t-2}} \; \underset{(-0.027,\ 0.105)}{+\,0.033c_{t-1}} \; \underset{(-0.084,\ 0.048)}{-\,0.018c_{t-2}}, \tag{9.1a}$$

$$c_t = \underset{(-0.884,\ -0.228)}{-\,0.477k_{t-1}} \; \underset{(-3.71,\ 1.42)}{-\,1.406y_{t-1}} \; \underset{(0.488,\ 4.06)}{+\,1.883y_{t-2}} \; \underset{(0.206,\ 0.881)}{+\,0.582c_{t-1}} \; \underset{(-0.423,\ 0.220)}{-\,0.059c_{t-2}}, \tag{9.1b}$$

$$k_t = \underset{(0.892,\ 1.012)}{0.953k_{t-1}} \; \underset{(0.040,\ 1.36)}{+\,0.294y_{t-1}} \; \underset{(-1.35,\ -0.025)}{-\,0.247y_{t-2}} \; \underset{(-0.146,\ -0.007)}{-\,0.048c_{t-1}} \; \underset{(-0.031,\ 0.112)}{+\,0.000c_{t-2}}, \tag{9.1c}$$

$$\alpha = \underset{(1.15,\ 92.3)}{15.17}, \qquad \lambda = \underset{(0.41,\ 0.92)}{0.79}. \tag{9.1d}$$

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_{t-1} suggest that the Granger causality found in Table 8 reflects a systematic tendency for movements in k to anticipate movements in c but perhaps not y. [Asymptotic standard errors (not reported) suggest the same.] In (9.1d), the confidence intervals around α and λ are large. The point estimates of these two parameters, which suggest con-

Table 8 REGRESSION RESULTS, FLEXIBLE ACCELERATOR MODEL

Regressor and Summary Statistic	*Dependent Variable*				
	(1a) $k_t - k_t^*$	*(1b)* Δk_t^*	*(2a)* $k_t - k_t^*$	*(2b)* Δk_t^*	*(2c)* Δc_t
$k_{t-1} - k_{t-1}^*$	0.428 (0.160)	0.523 (0.162)	0.452 (0.156)	0.492 (0.153)	−0.477 (0.165)
$k_{t-2} - k_{t-2}^*$					
Δk_{t-1}^*	−0.093 (0.171)	0.083 (0.174)	−1.630 (0.967)	2.070 (0.951)	−1.883 (1.021)
Δk_{t-2}^*					
Δc_{t-1}			−1.570 (0.973)	2.029 (0.957)	−1.824 (1.028)
Δc_{t-2}					
Constant	−1.071 (0.283)	1.114 (0.288)	−0.878 (0.300)	0.865 (0.296)	−0.758 (0.317)
Post-1973 dummy	0.183 (0.061)	−0.254 (0.062)	0.087 (0.084)	−0.128 (0.082)	0.074 (0.088)
$\bar{R}^2$	0.569	0.347	0.593	0.422	0.285
S.e.e.	0.135	0.139	0.131	0.129	0.138
Q-statistic [*p*-value]	1.92 [0.98]	2.88 [0.94]	1.22 [1.00]	1.16 [1.00]	0.80 [1.00]
Durbin–Watson	2.32	2.40	1.96	2.02	1.94
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 estimated of the standard deviation of the regression disturbance. The number of degrees of freedom in the *Q*-statistic is 8 in specifications 1–3, 5 in specification 4. The sample period that is given is for the dependent variable.
2. $k(t)$ is the log of the capital stock, $c(t)$ the log of the cost of capital, and $k^*(t)$ the target level of capital, defined as the difference between log of output and $c(t)$. See text for further discussion.
3. The capital stock k is for nonfinancial corporations, the output y is the output of industry, and the cost of capital c was constructed as described in the text. All variables are real (1985 prices).

Table 8 (*continued*)

(3a) $k_t - k_t^*$	*(3b)* Δk_t^*	*(3c)* Δc_t	*(4a)* $k_t - k_t^*$	*(4b)* Δk_t^*	*(4c)* Δc_t
−0.097	1.507	−2.056	0.496	0.462	−0.435
(1.164)	(1.141)	(1.209)	(0.178)	(0.175)	(0.191)
0.591	−1.027	1.550			
(1.090)	(1.068)	(1.131)			
−2.491	3.193	−3.397	−2.767	3.239	−3.001
(1.426)	(1.398)	(1.480)	(1.273)	(1.251)	(1.360)
1.893	−1.732	1.761			
(1.288)	(1.262)	(1.337)			
−1.746	2.041	−1.691	−2.777	3.260	−3.008
(1.042)	(1.021)	(1.082)	(1.305)	(1.284)	(1.395)
1.817	−1.639	1.667			
(1.303)	(1.277)	(1.353)			
−0.894	0.883	−0.800	−0.677	0.645	−0.575
(0.338)	(0.332)	(0.351)	(0.298)	(0.293)	(0.318)
0.132	−0.152	0.080			
(0.098)	(0.096)	(0.102)			
0.597	0.431	0.314	0.347	0.442	0.349
0.133	0.130	0.138	0.138	0.136	0.148
5.48	5.84	4.57	1.09	1.33	0.93
[0.71]	[0.67]	[0.80]	[0.96]	[0.93]	[0.97]
2.45	2.54	2.40	1.85	1.89	1.83
1965–94 (30 obs.)			1974–94 (21 obs.)		

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.[17] 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.[18] 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 $k - k^* \equiv k - (y - c)$ 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 0.55%. [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.

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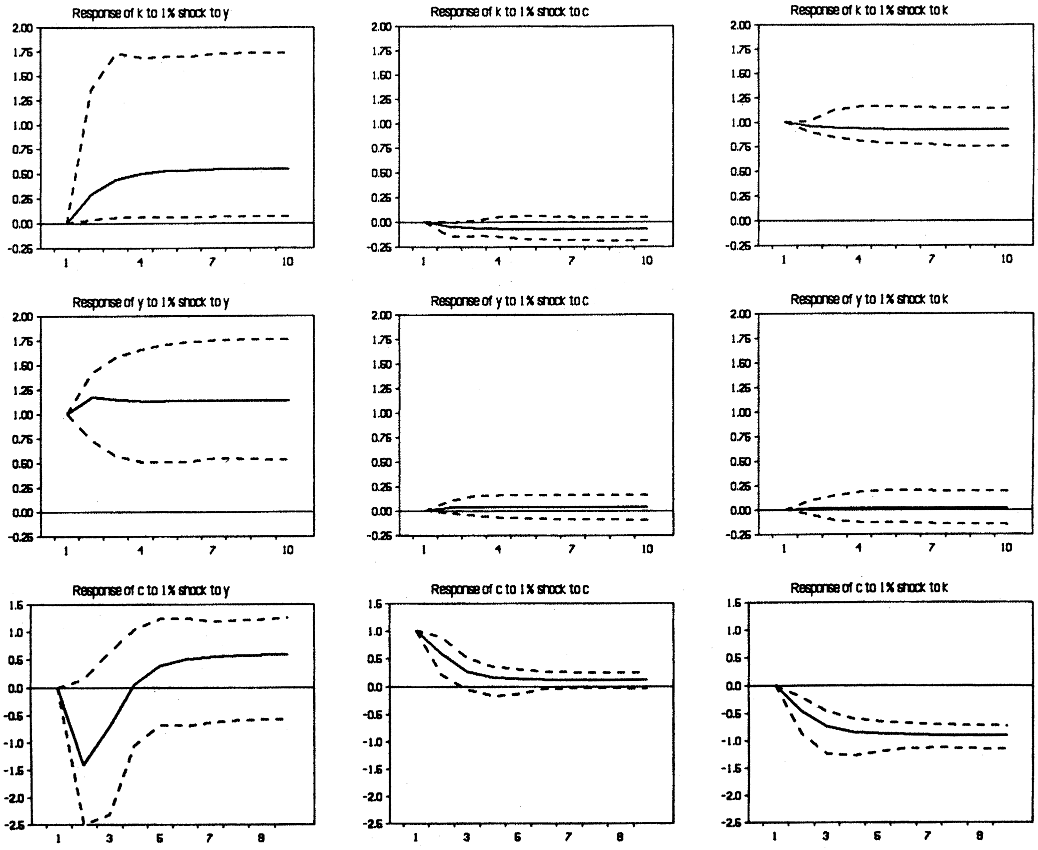
[17] Setting M equal to the mean of $1 - C_{2t}$ yields $\phi \approx 2.2$. [See (4.4), (4.12), and (7.4).] Although there are differences in functional form and data frequency, this looks comparable to a value calibrated by Cogley and Nason (1995, p. 505).

[18] Slight qualification: The lower end of the confidence interval on the one-step-ahead response of c to a shock to y is −3.71; for readability, the Figure 6 graph stops at −2.6. This is the only number truncated in the graphs.

Figure 6


Response of k to 1% shock to y
Response of k to 1% shock to c
Response of k to 1% shock to k
Response of y to 1% shock to y
Response of y to 1% shock to c
Response of y to 1% shock to k
Response of c to 1% shock to y
Response of c to 1% shock to c
Response of c to 1% shock to k
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
1
4
7
10
1
3
5
7
9

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 Δc and its components and of Δy are

	Δc	$\Delta\,(p_I - p_Y)$	Δc_1	Δc_2	Δy
1962–1994	−.17	.26	.14	−.22	.64
1974–1994	−.38	.14	.13	−.45	.46

(9.2)

Thus, the mean reversion observed in Figure 6 apparently is driven by mean reversion in c_2, 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 Δk^* and Δc, 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 ($\frac{1}{2} \approx 0.89/1.79$, $1.05/1.94$) 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^* resulted from a surprise fall in the cost of capital; the output surprise was negative. As explained above, k responds more strongly to shocks to y than to c. Second, much 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 9 DECOMPOSITION OF FORECAST ERROR OF CAPITAL STOCK

	(1) Actual	*(2)* Forecast	Surprise *(3)* Total	Surprise *(4)* Due to shock to: y, c eqns.	Surprise *(5)* Due to shock to: k eqn.
		(a) 1986–1991			
(1) k	6.47	4.68	1.79	0.90	0.89
(2) $k^* \equiv y - c$	7.23	5.97	1.27	0.84	0.43
(3) y	5.47	3.48	2.00	1.99	0.01
(4) c	−1.76	−2.49	0.73	1.15	−0.42
		(b) 1991–1994			
(1) k	2.97	4.92	−1.94	−0.89	−1.05
(2) $k^* \equiv y - c$	5.92	5.84	0.07	0.30	−0.22
(3) y	0.10	3.57	−3.47	−3.46	−0.01
(4) c	−5.82	−2.27	−3.55	−3.76	0.21

Notes:

1. See the note to Table 7 and the text for descriptions of the data. All growth rates are annualized. For example, actual growth of k for 1986–1991 was approximately 5 × 6.47%. Components may not add up to a total because of rounding.
2. The trivariate VAR whose estimates are presented in equation (9.1) was used to compute the forecasts of the levels of the indicated variables. The decomposition of the shock presented in columns (4) and (5) is obtained by performing a Choleski decomposition with the residual for k ordered last.

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 Figure 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 k to a shock to y ranges from about 0.3% to 0.5%, and asymptotes at around 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 algebraically. In panels (c) 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 k to a 1% Shock, Full-Sample Estimates

Horizon	Restricted			Unrestricted			Unrestricted, 2 lags		
	y	c	k	y	c	k	y	c	k
2	.29	−.05	.95	.50	−.03	.94	.29	.00	1.41
10	.55	−.07	.92	.80	−.08	.89	.80	−.09	.90

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

Horizon	Restricted			Unrestricted			Unrestricted, 2 lags		
	y	c	k	y	c	k	y	c	k
2	.40	−.04	.95	.51	−.03	.96	.39	−.01	1.11
10	.71	−.05	.94	.81	−.04	.94	.85	−.06	.64

(c) Decomposition of Forecast Error of k_t, Full-Sample Estimates

	Restricted				Unrestricted				Unrestricted, 2 lags			
	Forecast	Surprise			Forecast	Surprise			Forecast	Surprise		
		Total	$y + c$	k		Total	$y + c$	k		Total	$y + c$	k
1986–91	4.7	1.8	0.9	0.9	4.4	2.0	1.3	0.7	4.0	2.5	2.7	−0.2
1991–94	4.9	−1.9	−0.9	−1.0	4.8	−1.8	−1.4	−0.4	4.8	−1.8	−2.9	1.1

(d) Decomposition of Forecast Error of k_t, Post-1973 Estimates

	Restricted				Unrestricted				Unrestricted, 2 lags			
	Forecast	Surprise			Forecast	Surprise			Forecast	Surprise		
		Total	$y + c$	k		Total	$y + c$	k		Total	$y + c$	k
1986–91	4.6	1.9	1.1	0.7	4.5	1.9	1.3	0.6	4.5	1.9	1.8	.2
1991–94	4.9	−2.0	−1.3	−0.6	4.9	−1.9	−1.7	−0.3	4.5	−1.5	−1.6	.0

Notes:

1. See notes to Table 7 and the text for description of the data.
2. All estimates are computed from trivariate VARs in (y, c, k). The "restricted" estimates in panels (a) and (c) are computed from equation (9.1). The text does not directly present the parameters for the VARs in (y, c, k) for the other specifications in the table, although the parameters in the underlying VARs in $(k - k^*, \Delta k^*, \Delta c)$ are in the following columns in Table 8: "unrestricted" in panels (a) and (c), column (2); "unrestricted" in panels b and d, column (4); "unrestricted, 2 lag" in panels (a) and (c), column (3) in Table 8. The "unrestricted, 2 lags" estimates in panels (b) and (d) are computed from an underlying set of estimates whose variables are identical to that in column (3) of Table 8 except that there is no post-1974 dummy. The "restricted" estimates in panels (b) and (d) are computed by imposing the restrictions as described in the text.
3. Panels (a) and (b) present the response of k to a 1% nonorthogonalized shock to the indicated variable. See text for details. See notes to Table 9 for an explanation of panels (c) and (d).
4. The "restricted" full-sample estimates repeat results depicted in Figure 6(a) or Table 9(c).

value for this test was 0.654 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 Δk^*. Second, according to other investment models, a variable might help predict capital accumulation even if it does not help predict Δk^*.

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 Ogawa *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, $f = (\Delta k^*, \Delta c, \Delta z)'$ and $Z = (k - k^*, \Delta k^*, \Delta c, \Delta z)'$, 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)–(4) of panel (a) indicate that of the three variables, only the real exchange rate has predictive power for $k - k^*$, Δk^*, or Δc at traditional significance levels; a real exchange-rate appreciation is associated with an increase in Δk^* and a fall in c and $k - k^*$. (Although not reported in the table, in all three specifications the coeffi-

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[19] As suggested by the relative size of these two p- values, bootstrap confidence intervals are generally larger for the post-1973 sample. This no doubt partly results from a smaller sample size, but may also indicate that the full-sample intervals are a little misleading. In particular, for the first-order serial correlation coefficient of the residual to the restricted equation for k, the point estimates and 95% bootstrap confidence intervals are 0.56 (−0.40, 0.28) for the full sample and 0.46 (−0.69, 0.77) for the post-1973 sample. Thus for the full sample there is evidence against the implicit bootstrap assumption that the residuals are i.i.d. 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

(a) Regression Estimates

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Variable (z)	Coefficients on Add'l Variable			Response of k to a 1% shock								
				Horizon	Unrestricted VAR				Restricted VAR			
	$k_t - k_t^*$ eqn.	Δk_t^* eqn.	Δc_t eqn.		y	c	z	k	y	c	z	k
Real exch.	.62	−.61	.59	2	.49	−.04	.01	.94	.25	−.03	−.07	.97
rate	(.22)	(.22)	(.24)	10	.74	−.06	−.06	.91	.27	−.02	−.12	.98
Net worth	−.22	.32	.24	2	.34	−.04	.10	.94	.14	−.05	.09	.94
	(.33)	(.32)	(.37)	10	.16	−.09	.36	.88	.00	−.08	.30	.91
Real land	.80	−.63	.59	2	.42	−.02	.16	.94	.30	−.07	−.16	.93
price	(.49)	(.49)	(.53)	10	.86	−.05	.07	.91	.46	−.18	−.50	.81

(b) Decomposition of Forecast Error of k_t

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Variable (z)	Period	Unrestricted VAR				Restricted VAR			
		Forecast	Surprise			Forecast	Surprise		
			Total	Shocks to:			Total	Shocks to:	
				$y + c + z$	k			$y + c + z$	k
Real exch.	1986–91	5.0	1.7	.9	.8	5.7	.8	.2	.6
rate	1991–94	4.9	−1.9	−1.5	−.4	3.0	−2.2	−.7	−1.5
Net worth	1986–91	5.7	.8	.3	.5	5.7	.7	.0	.7
	1991–94	3.6	−.6	−1.2	.5	3.9	−1.0	−.7	−.3
Real land	1986–91	4.3	2.1	2.4	−.3	4.7	1.8	.4	1.4
prices	1991–94	4.8	−1.9	−2.4	.5	4.5	−1.6	−.3	−1.3

Notes:

1. Each set of estimates is computed from VARs in the four variables (y, c, z, k), where z = ln(real exchange rate), ln(real net worth), or ln(real land prices). The sample period is 1964–94. The unrestricted VAR is computed by transforming the OLS estimates of a VAR in ($k - k^*$, Δk^*, Δc, Δz). The restricted VAR begins with the unrestricted estimates and imposes restrictions as described in the Appendix.
2. The real exchange rate is computed as: (nominal yen/dollar exchange rate) × (U.S. GDP deflator, 1985 = 100) / (Japanese GDP deflator, 1985 = 100). The deflator for net worth is that for the capital stock; for land prices, the GDP deflator.
3. See notes to Table 9 for an explanation of panel (b); notes to Table 10 for an explanation of panel (a).

cients on the remaining variables are similar to those reported in Table 8; in particular, $k - k^*$ retains its ability to predict Δk^* and Δc 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 has effectively been 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 k-shocks [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

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[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.

explicit treatment of monetary policy, and development of models that derive the behavior of output and the cost of capital endogenously.

Appendix

Here we discuss (1) estimation of the restricted system, and (2) bootstrapping.

1 ESTIMATION OF THE RESTRICTED SYSTEM

Take the case in which $f = (\Delta k^*, \Delta c)'$; extension to larger information sets is straightforward. Recall that Z is ordered so $Z = (k - k^*, \Delta k^*, \Delta c)'$. Let $\Pi = [\pi_{ij}]$, and let $a_0 = (b\alpha, b\alpha, 0)'$, $a_1 = (-1 - \alpha - b\alpha, -\alpha, 0)'$, $a_2 = (\alpha, 0, 0)'$. Then, ignoring constants, (6.6) and (4.13) together imply $E[a_0'Z_{t+1} + a_1'Z_t + a_2'Z_{t-1} \mid Z_{t-1}, Z_{t-2}, \ldots] = 0$,

whence

$$(0, 0, 0) = a_0'\Pi^2 + a_1'\Pi + a_2' \equiv (g_1(\Pi, b, \alpha), g_2(\Pi, b, \alpha), g_3(\Pi, b, \alpha)). \quad \text{(A.1)}$$

Using an imposed value of $b = 0.95$ and the least-squares estimates of the π_{ij}'s ($i = 2,3$, $j = 1,2,3$), we solve linearly for the α that sets $g_1(\Pi, b, \alpha) = 0$. (Thus, we ignore the information on α also contained in g_2 and g_3.) We compute λ as the smaller root of the quadratic implied by $\lambda/\alpha = (1 - \lambda)(1 - b\lambda)$. To solve for the implied process for $E[k_t - k_t^* | Z_{t-1}, Z_{t-2}, \ldots]$—call it $\hat{E}(k_t - k_t^*)$—we hold α fixed and use an iterative technique to find π_{11}, π_{12}, and π_{13} that, in conjunction with the least-squares estimates of the other π_{ij}'s ($i = 2,3$, $j = 1,2,3$) and this fixed estimate of α, yield a stable matrix Π that satisfies (A.1).

For computing forecasts such as in Table 9, estimates of coefficients of deterministic terms are also required. For the Δk^* and Δc equations, the unrestricted estimates are used. For the $k - k^*$ equation, we use least-squares regressions of the time series $\{(k_t - k_t^*) - \hat{E}(k_t - k_t^*)\}$ on the deterministic terms.

2 BOOTSTRAPPING

We generated 1000 sets of samples of size 31 (inference about full-sample estimates) and 1000 of size 21 (post-1973 sample). We obtained a given one of the 1000 samples by generating data recursively, using the restricted estimates and sampling with replacement from the 3 × 1 vectors of residuals to the restricted system. The actual 1963 (full sample) or 1973 (post-1973 sample) data were used for initial conditions. Obtaining 1000 sets of estimates involved generation of 1082 samples of size 31 and 1010 samples of size 21. The additional samples were ones that produced a negative estimate of α, a signal to us to abort the algorithm used to obtain the restricted estimates ($\alpha < 0$ does not guarantee λ real and stable).

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Comment

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In their paper Kiyotaki and West (K&W) attempt to explain the dramatic behavior of investment in the recent recession in Japan. Using a conventional neoclassical model of investment as their guide, they estimate a variety of vector autoregressions (VARs), which they then use to decompose forecast errors in capital accumulation. They find that for some of their VARs a large fraction of the unexpected movement in the capital stock over the 1986–1991 and 1991–1994 periods is attributable to shocks

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