IMF WORKING PAPER

WP/89/97

INTERNATIONAL MONETARY FUND

Western Hemisphere Department

The Recent Behavior of Business Fixed Investment in the United States and the Role of Computers

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December 1, 1989

Abstract

In the 1980s, U.S. real investment in high technology equipment has grown rapidly while other components of business fixed investment have been weak. The surge in real high technology investment has been accompanied by a very sharp decline in its relative price, leading to difficult index number problems. When a previously estimated model of business fixed investment was extended to cover the period through 1988, the equation for nonresidential structures performed much as before while that for producers' durable equipment substantially underpredicted recent actual outcomes. Further disaggregation revealed that the underprediction related to the computing component.

JEL Classification Number
0233

1/ The author is grateful to Charles Adams, Krister Andersson, Barry Bosworth, David Coe, Robert Corker, Ellen Dulberger, Liam Ebrill, and Yusuke Horiguchi for helpful conversations as the research proceeded. Michael Mered provided capable research assistance.

Contents

Summary

In the current expansion of the U.S. economy, investment in high technology equipment has boomed, while other categories of business fixed investment have yet to regain their previous cyclical peaks. The high technology boom has been associated with a very rapid decline in the price of computers, as measured by new computer price indices initially introduced in 1985.

The decline in the relative price of computers leads to difficult index number problems which complicate the assessment of investment performance. For example, investment growth since 1982 appears much stronger when calculations are made using base prices for 1982 rather than 1987. This index number problem arises when a component's relative price is falling at the same time that output is growing rapidly.

When ratios of investment to output were examined to see how recent investment performance should be characterized, the assessment was clouded by these index number problems. The ratio of real gross business fixed investment to real gross national product (GNP) in 1982 prices indicated a strong performance, while the corresponding ratio in 1987 prices did not. The ratio of net investment to net national product appeared unambiguously to have declined recently, both in nominal and real terms. When a chain-weighted measure of real gross business fixed investment was examined, it was apparent that the trend increase in this ratio that had been observed up until the late 1970s came to a halt in the 1980s and may subsequently have given way to a small decrease. A broader measure of real gross investment also increased relative to output up to the end of the 1970s and appears to have declined subsequently.

Previous empirical work had estimated conventional equations explaining producers' durable equipment (PDE) investment and investment in nonresidential structures in terms of the changes in output and the cost of capital. When the data were extended to 1988, the equation for investment in nonresidential structures performed much as before, but that for PDE investment significantly underpredicted the recent surge in that category.

When PDE investment was separated into office computing and accounting machinery (OCAM) and the remainder, a stable empirical representation of the latter was found to exist, but no satisfactory equation was developed for OCAM. These results appear to indicate that investment in OCAM and in the remainder of PDE may, in fact, be heterogeneous categories which should be modeled separately.

I. Introduction

This paper reviews the recent behavior of business fixed investment in the United States, and updates and extends previous empirical work on its determinants. Section II outlines the methods used in U.S. national accounts estimates of implicit deflators for high technology equipment--the most rapidly growing component of business fixed investment in the 1980s--and discusses some problems which may arise. The third section reviews the performance of business fixed investment and discusses some puzzles which exist in answering the apparently simple question of whether recent investment behavior should be characterized as weak or strong.

An important piece of the picture is the extraordinary strength in the 1980s of real investment in high technology equipment, primarily office computing and accounting machinery, and the associated sharp decline in its relative price. The pronounced decline in the relative price of computing power leads to difficult problems of interpretation. For example, the growth of real gross business fixed investment appears much larger when calculations are made using 1982 base year prices than when 1987 prices are employed. This sensitivity to choice of base year reflects the fact that the earlier the base year, the larger the weight given to a component whose relative price is declining--in this case computers, which is also the most rapidly growing component of investment in real terms. 1/

Section III extends and updates earlier empirical work on the determinants of business fixed investment in the United States. 2/ Previously estimated equations for investment in producers' durable equipment (PDE) and nonresidential structures were re-estimated on the basis of data to the end of 1988, and incorporating the latest revisions to the data. The equation for investment in nonresidential structures performed reasonably well, but that for PDE investment substantially underpredicted the surge in investment in this category in 1987 and 1988, and failed a stability test. When PDE investment was disaggregated into office computing and accounting equipment and the remainder, it was possible to estimate an equation which tracked developments reasonably well for PDE excluding the office computing component, but not for the computing component itself. The latter outcome could be attributable to the problems of measurement mentioned earlier, or to more fundamental difficulties affecting a relatively conventional specification in a period of extremely rapid technological change. As a final test, an alternative equation was estimated employing a different price index, with mixed results.

1/ A simple numerical example of the index number problem is provided in the Appendix.

2/ The previous empirical work was presented in Evans and Kenward (1988) and Corker, Evans and Kenward (1989). The data employed in this paper are U.S. national accounts data as of mid-July 1989.

II. Deflators for Purchases of Computers

The construction of price indices for a class of commodities exhibiting high rates of quality change over time is difficult. Investment in high technology equipment in the United States is an area experiencing such change at an extraordinarily rapid pace. In 1985, the United States Bureau of Economic Analysis (BEA) introduced new deflators for computers, constructed from price indices developed by the IBM corporation in the context of a benchmark revision of U.S. national accounts data. These new deflators indicate that the relative price of computing power has declined dramatically in the 1980s. As noted in the introduction, when the relative price of an important category of output is changing rapidly, interpretation of aggregate data is complicated by the fact that aggregate growth rates may vary substantially depending on the choice of base year for calculation.

According to BEA, two broad alternative methods of index construction present themselves in the high technology area. The first is the "matched model" method. By this approach, a whole category of goods is represented by a single model, and the price change for the group over a given period is calculated as the change in the price of the representative model. One problem that may arise is that the price change of the selected model may inadequately represent price changes for the group as a whole. A second potential difficulty is that production of the representative model may be discontinued.

An alternative method of price index calculation is the "hedonic" method, which recognizes the heterogeneity of a given class of products and disaggregates them into several homogeneous characteristics. 1/ The price of the heterogeneous product is represented as a function of the implicit prices of the individual characteristics, and after econometric estimation, imputed market prices for individual characteristics can be calculated.

The employment of hedonic methods in deriving price indexes for computers focussed on computer processors, and three types of peripheral equipment, namely disk drives, printers and general purpose displays. 2/ The two fundamental characteristics of computer processors were taken to be processing speed and memory capacity; those of disk drives to be capacity and data transfer speed; those of printers to be speed, resolution and number of fonts; and those of general purpose displays to be screen capacity, resolution, the number of colors available and the number of programmable function keys.

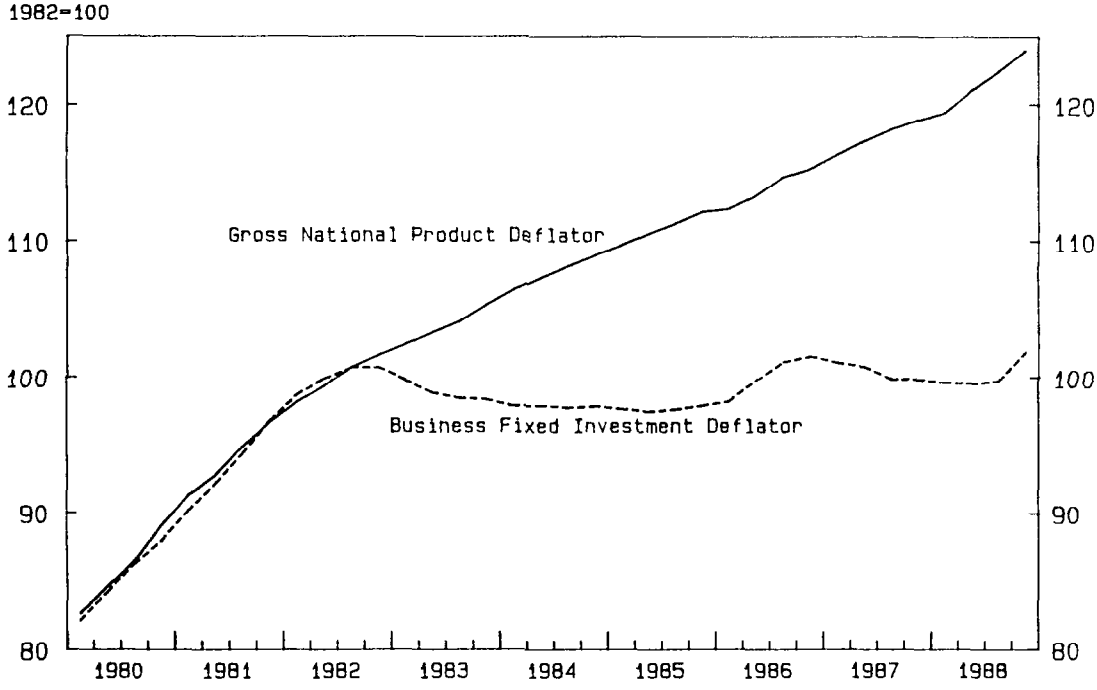
1/ See Triplett (1986).

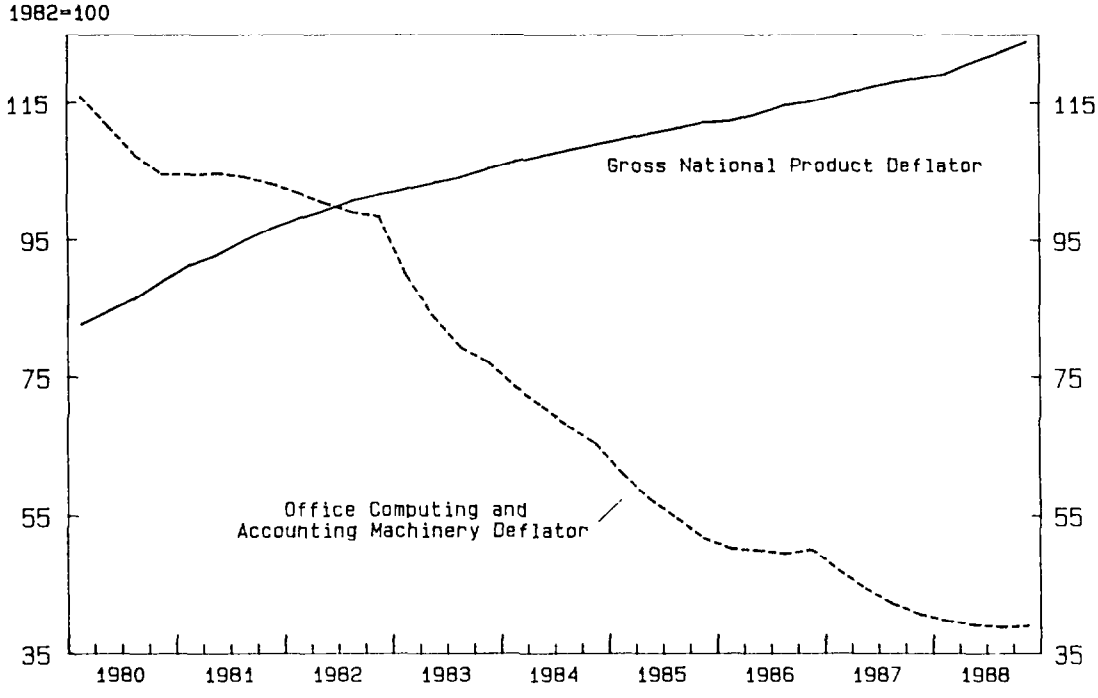
2/ For a detailed discussion, see Cole et al (1986) and Dulberger (1989). A general purpose display is an input-output device, typically comprising a key-board and a monitor.

CHART 1

UNITED STATES

IMPLICIT PRICE DEFLATORS
FOR INVESTMENT AND OUTPUT





The deflators initially constructed by BEA, based on IBM price indices, consist of composite indices for processors, disk drives, printers and displays. In these composite indices, price changes are calculated from the difference between current and base year prices for each current year model. If the model was sold in the base year, an actual base year price is used and if not, an implicit base year price is calculated from the hedonic function. For personal computers (PCs), a matched model price index was introduced in 1987, constructed using price changes of IBM PCs, supplemented by judgemental adjustments to reflect price changes for other PC models. 1/

In terms of the technical quality of the indexes under discussion, three main problem areas exist. First, only certain types of equipment and selected manufacturers are covered. Second, net prices--not transaction prices--are used, and third, information on shipments is not complete. The basic annual data for the deflators are displayed in the tabulation below.

Various Price Indexes (1982=100)

	Computers and Peripheral Equipment		Office Computing and Accounting Machinery		
	Deflator	Fixed Weight	Deflator	Fixed Weight	GNP Deflator
1982	100.0	100.0	100.0	100.0	100.0
1983	77.0	83.9	81.8	88.8	103.8
1984	64.4	70.0	69.1	78.0	107.7
1985	51.2	55.7	56.0	65.6	110.9
1986	45.2	47.9	50.0	59.7	113.9
1987	39.1	41.9	43.3	55.0	117.7
1988	...	...	39.0	...	121.7

The striking feature of the data is the extraordinary decline calculated to have taken place in the relative price of computing power since 1982 (see Chart 1). A relative price change of such magnitude can have a very substantial effect on the data (as noted earlier and illustrated in Section III). Debate has consequently developed over the appropriateness of the computer price indices now employed by BEA.

1/ Cartwright and Smith, (1988). There are two main price deflators calculated by BEA in this area. The first is that for computers and peripheral equipment, now extended to include PCs, as discussed above. The second is for office computing and accounting machinery, which combines the first with producer price indexes for selected other types of office machinery.

Denison (1989) criticized these indices, suggesting that they represent a shift in methodology from previously employed concepts. He argues in part that capital goods prices should reflect resource costs 1/ and should not attempt to adjust fully over time for quality changes. By this argument, the computer price should be represented by the resource cost of producing the computer, without any allowance for a change in computer power achievable at given resource cost. According to Denison, this is the approach historically adopted in U.S. national accounts data, with the result that much of the effect of quality change in capital goods was reflected in estimates of total factor productivity growth--derived residually from a production function--rather than in the calculated stock of capital or flow of capital services. The concept embodied in BEA's estimates of computer price deflators, according to Denison, attempts to allow for quality change fully in the price index, and thus also in measured real investment, shifting away from the previous practice.

Other critics have suggested that measures of real investment based on BEA's current methods provide a misleading picture of the productivity of capital as they do not reflect changes in utilization. 2/ Ten years ago, computing power was a scarce resource in large organizations and many computer users would organize their work schedules around the fact that computer time was more readily available at night. 3/ Today, computers are utilized less fully, because computer power is cheaper and thus less of a scarce resource.

However, this utilization argument may not call for any change to the investment series per se, or the underlying price deflator, but rather may indicate that in assessment of the data more attention should be paid to the reason behind the surge in investment in computing power. An investment surge stemming from a falling relative price for capital goods would be expected to have different implications for productivity than one taking place for other reasons. In a neoclassical world, investment should take place up to the point where marginal revenue product from an additional investment equals its marginal cost. If the price of office computing and accounting machinery (OCAM) relative to an overall output price (the GNP deflator) in 1988 was one third of its value in 1982--as BEA data indicate--then the additional physical product associated with the marginal investment in computing power in 1988 should also have been one third of its level in 1982, other things equal. 4/ That is, one would expect a relatively expensive good to be utilized more intensively than an abundant cheaper one.

1/ The notion being that given competitive markets, the price of a capital good will be driven into equality with the cost of producing it.

2/ Such an observation is made by Baily and Gordon, (1988).

3/ Either by submitting batch jobs to be run at night or by working in the office or university computer laboratory in the evening.

4/ This is not to deny that the marginal productivity of the inframarginal investment would have been higher.

While recognizing the existence of the conceptual and index number problems that arise when an important relative price is changing rapidly, BEA argues that the change in the relative price of computers is an economic reality, not an artificial result stemming from methods of calculating deflators for computers. 1/ However, recognizing the importance of the resulting index number problems--noted earlier and illustrated in Section III of this paper--BEA has provided an indication of the sensitivity of national accounts data to a change in the choice of base year, in advance of the benchmark revision of U.S. national accounts data scheduled for November 1990--at which time the data are to be rebased to 1987 prices. BEA has also noted that a difference between two alternative measures of real GNP--or a subcategory--need not be evidence that one of the measures is wrong and has indicated that it is planning to present alternative measures of real GNP in the 1990 comprehensive revision, so that the user can select the measure appropriate for a particular application. 2/

In response to the criticism that BEA's methods of measuring computer prices and output constitute a shift away from the resource-cost concept of capital, a detailed rebuttal has been provided. 3/ The BEA views its approach as consisting of three procedures, in each of which observed prices are used to establish the resource cost, and argues that its approach to measuring the output of computers is indeed consistent with a resource-cost concept of capital.

III. Recent Developments in Business Fixed Investment

This section discusses the recent behavior of business fixed investment and illustrates the index number problems associated with the drop in the price of computers.

1. The current expansion

On the basis of data calculated at 1982 prices, real business fixed investment expanded rapidly from a trough in early 1983 to a temporary peak in the fourth quarter of 1985, 35 percent above that trough. This rise primarily reflected the rapid growth of output, and to a lesser extent a decline in the cost of capital induced by falling interest rates and more generous tax provisions. Fixed investment then stagnated until mid-1987, reflecting slower output growth, the impact of oil price declines on petroleum related investment, and the withdrawal of tax concessions in the Tax Reform Act of 1986. 4/ In the period from mid-1987 to the end of 1988, real gross business fixed investment rose rapidly to

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1/ De Leeuw (1988).
2/ See Young (1989a).
3/ Young (1989b).
4/ The assessment of the roles of various factors in this paragraph reflects simulation results reported in Corker, et. al. (op. cit.).

a level 44 percent above its 1983 trough, and 22 percent above a previous peak reached in mid-1981 (panel 1 of Chart 2).

With regard to the components, real producers' durable equipment investment (1982 prices) increased by 46 percent from early 1983 to late 1985, and--after a period of stagnation in 1986 and early 1987--it surged again in late 1987 and most of 1988, reaching a level at the end of 1988 that was 71 percent above its 1983 trough and 40 percent above a previous peak in 1979 (panel 2 of Chart 2). The main engine of this robust growth was high technology equipment, 1/ which increased by 135 percent in real terms from the first quarter of 1983 to the fourth quarter of 1988. Within the high-technology category, real investment in office computing and accounting machinery (OCAM) at 1982 prices increased by 290 percent from the first quarter of 1983 to the fourth quarter of 1988, accounting for half of the rise in PDE investment. The remaining components of PDE investment have performed more sluggishly in the current expansion, rising by only 40 percent (in real terms at 1982 prices) from the beginning of 1983 to the end of 1988, at which time they remained about 5 percent below a previous peak achieved in early 1979.

Real investment in nonresidential structures (at 1982 prices) has not been robust in the current expansion, rising by 22 percent from a trough in mid-1983 to a peak at the end of 1985, and then plummeting in 1986, as the precipitous decline in world oil prices led to a curtailment of U.S. investment in petroleum drilling. By the end of 1988, real investment in structures was only 2 percent above the 1983 recession trough, and 18 percent below its 1981 peak. Excluding mining and petroleum, real investment in structures at the end of 1988 stood somewhat above the 1983 recession trough, but remained below the previous expansion peak. Real mining and petroleum structures investment at the end of 1988 was substantially below the 1983 recession trough level, and even further below the previous peak.

The story of U.S. business fixed investment in the 1980s is thus one of weak performance except as regards high technology equipment--in particular office computing machinery--which in real terms has risen at an extraordinarily rapid rate. Perhaps surprisingly, the share of nominal business fixed investment attributable to high technology equipment has remained in the neighborhood of 20 percent since 1982. Underlying the vigorous real growth in the high technology area has been the sharp decline in the associated implicit deflator, which dropped by over 30 percent from 1982 to 1988 while the overall deflator for business fixed investment remained essentially unchanged over the same period (see the discussion in Section II). 2/

1/ Which comprises the subcategories of office computing and accounting equipment, communications equipment and scientific instruments.

2/ The deflator for office computing and accounting machinery--the most important subcategory of high technology equipment--fell by 61 percent from 1982 to the end of 1988.

CHART 2

UNITED STATES

COMPONENTS OF REAL GROSS INVESTMENT

(Billions of 1982 dollars)

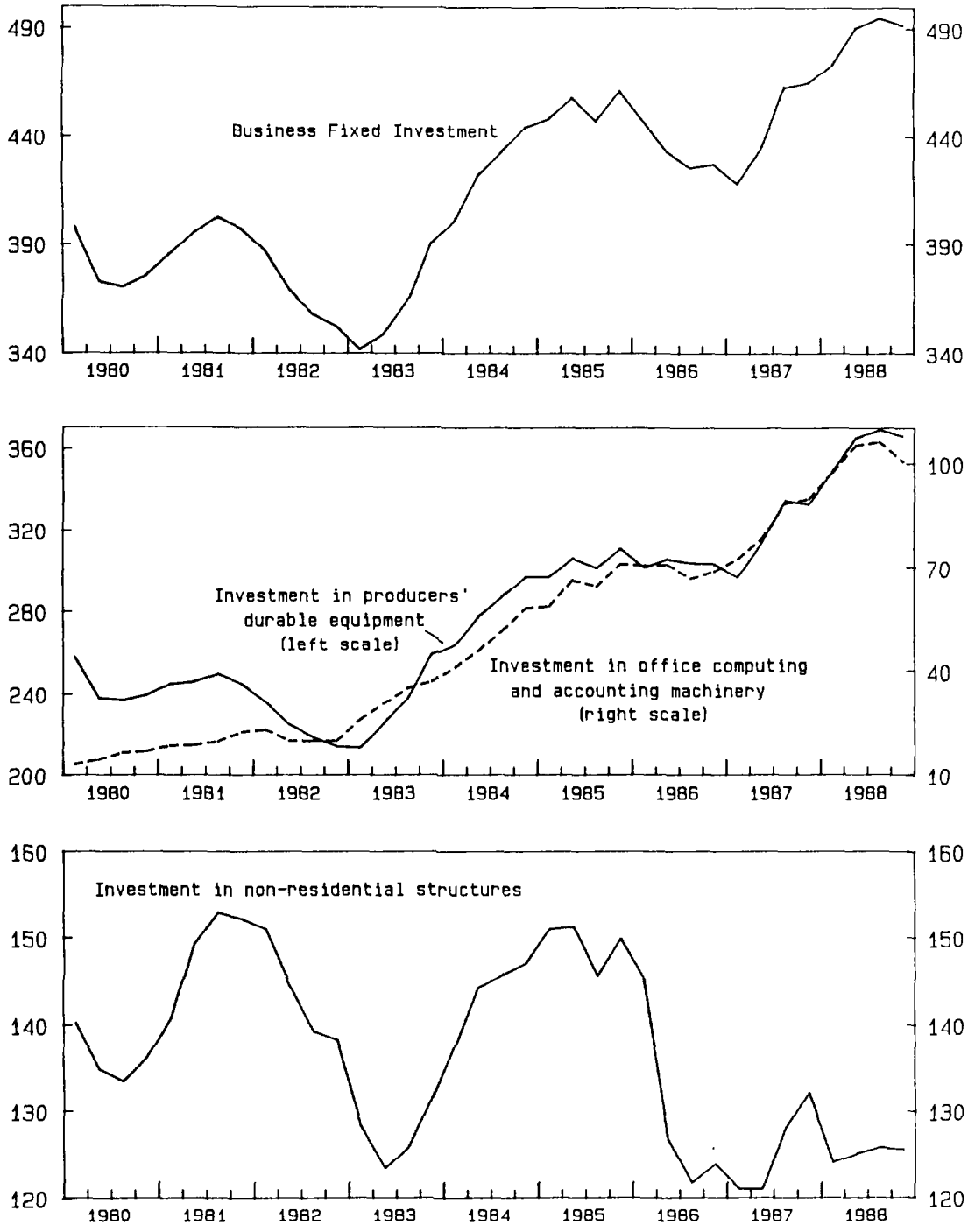
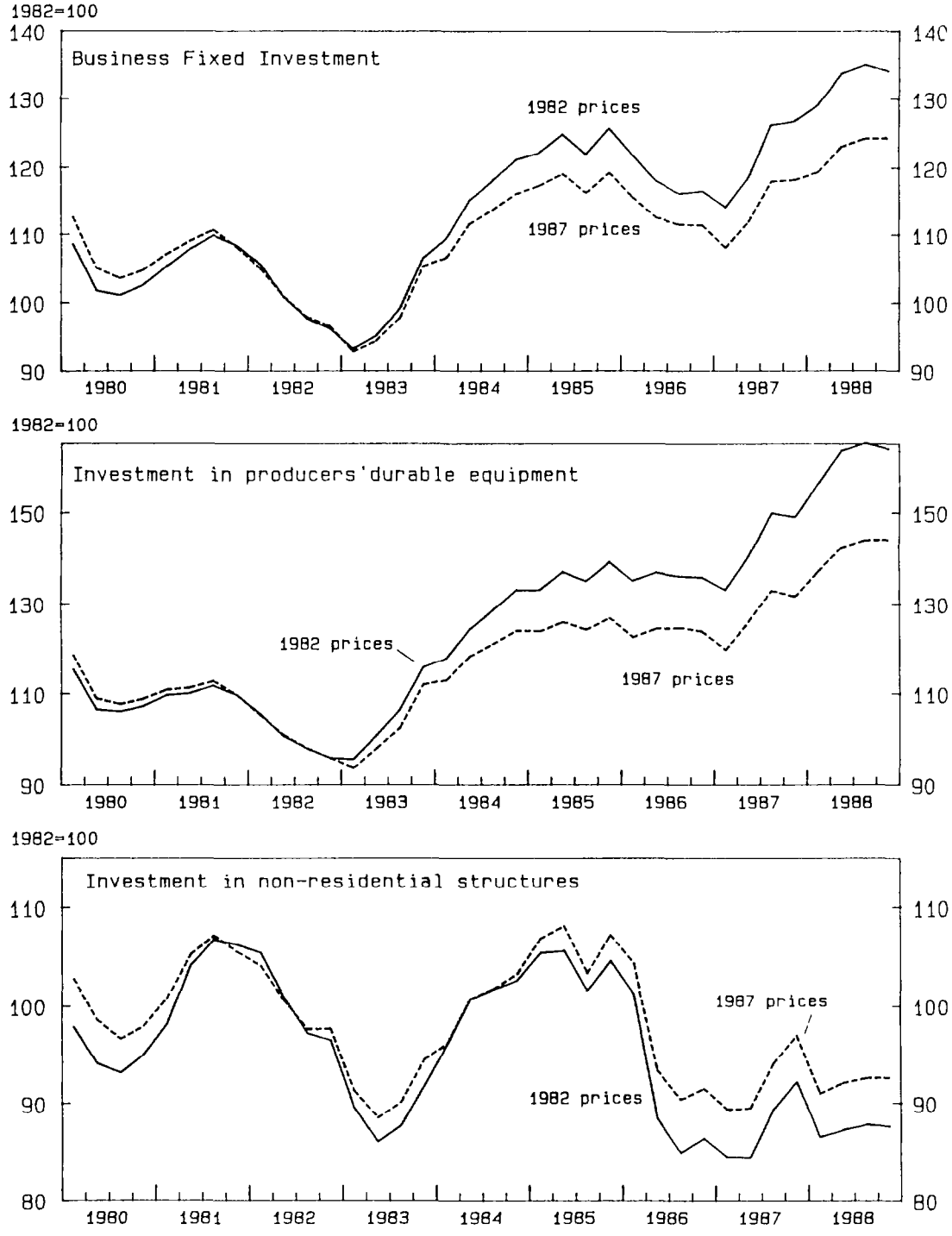


CHART 3

UNITED STATES

REAL GROSS INVESTMENT IN 1982 AND 1987 PRICES[1]



[1]The time series for gross fixed investment and its components, at 1987 prices, were derived by staff calculations as outlined in the text.

2. Investment ratios

One fundamental question which arises in examining the recent behavior of business fixed investment is whether its recent performance should be viewed as weak or strong compared to historical averages. A way of viewing the data in addressing this issue is to examine movements over time in ratios of investment to output. Table 1 shows ratios of gross fixed investment to GNP in both nominal and real terms. Relative to nominal GNP, recent movements in both total gross fixed investment and its business component seem to be broadly in line with the averages of the 1960s and 1970s. However, the nominal ratio probably obscures real capital formation, the performance of which may be made clearer by an examination of an investment/GNP ratio in real terms. Compared with real GNP (1982 prices), real gross fixed investment (and also the business component) appear recently to be somewhat above the averages of previous decades. As the table indicates, this is entirely attributable to the increased importance in real terms of investment in information processing equipment--primarily OCAM.

Table 2 provides ratios of real fixed investment to real GNP, both rebased to 1987 prices. 1/ PDE investment was separated into OCAM, communications equipment, scientific instruments, and the remainder; each category was separately rebased to 1987 prices. The rebasing has a large effect because the deflator for OCAM dropped by 60 percent from 1982 to 1988. As a result, real gross fixed investment in PDE rose by an average 4.2 percent annually from 1982 to 1988, when measured using 1982 prices, but by an average 2.2 percent when measured using 1987 prices (Chart 3). By the end of 1988, real gross business fixed investment in 1982 prices was 44 percent above the 1983 trough and 22 percent above the previous peak reached in mid-1981. The corresponding figures using 1987 based aggregates were, however, 34 percent and 12 percent, respectively--a much less robust performance. 2/

Investment in nonresidential structures was separated into mining and oil drilling and the remainder--motivated by the effect of the plunge in world oil prices in 1986--and then rebased to 1987 prices. The remaining categories of GNP--private consumption, government

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1/ As the following discussion indicates, the rebasing was quite partial, designed only to address index number problems within business fixed investment. Consequently, the calculations are subject to a margin of error, related to the importance of computers in the other components of GNP. A BEA paper which became available subsequent to the partial rebasing discussed here (Young (1989a)) presented the results of a comprehensive rebasing to 1987 for the years 1982-88. At least for that period, the partial rebasing discussed here achieved results that were essentially indistinguishable from those of the more comprehensive rebasing.

2/ A simple numerical example of this index number problem is provided in the Appendix.

consumption, inventory investment, residential construction, exports and imports, were treated as homogeneous categories and individually rebased from 1982 to 1987 prices. By means of this procedure, an estimate of real GNP at 1987 prices was obtained, incorporating the effects of the important relative price changes within business fixed investment.

In Table 2, ratios of real gross fixed investment to real GNP in 1987 prices are presented. On this basis, capital formation appears to have been no stronger in the 1980s than in previous decades. The essential reason for the difference compared with the results in the lower panel of Table 1 is the lower weight placed on investment in high technology equipment when 1987 is used as base year. Given the very rapid decline in the high technology deflator since 1982, the index number problem becomes more pronounced the further one moves from the base year. To summarize the outcome of this rebasing exercise, an important ratio to which commentators can point as indicating strong U.S. capital formation in the 1980s is the ratio of real gross fixed investment to real GNP (in 1982 prices). However, this apparent strength appears to stem at least in part from an index number problem associated with declining computer prices and is not robust to a change of the base year (Chart 4).

Table 3 provides ratios of net fixed investment to net national product in both nominal and real terms. In nominal terms, net fixed investment in the 1980s appears to be about two percentage points of NNP lower than in the 1960s and 1970s. A similar decline appears to have taken place in the ratio in real terms after increases in earlier decades (Chart 5). What to make of the fact that the net investment to output ratios are declining is not entirely clear since it appears to be related to the shortening of average service lives and increased depreciation associated with the growth of investment in high technology equipment. In a period of transition from long-lived to short-lived capital goods, net investment may decline without there necessarily being any major implication for the flow of capital services. Chart 6 presents data inter alia for the real net business sector capital stock relative to real GNP, which shows a trend increase from the 1950s to the early 1980s, and appears to have declined more recently--a similar time profile to the net investment to output ratio.

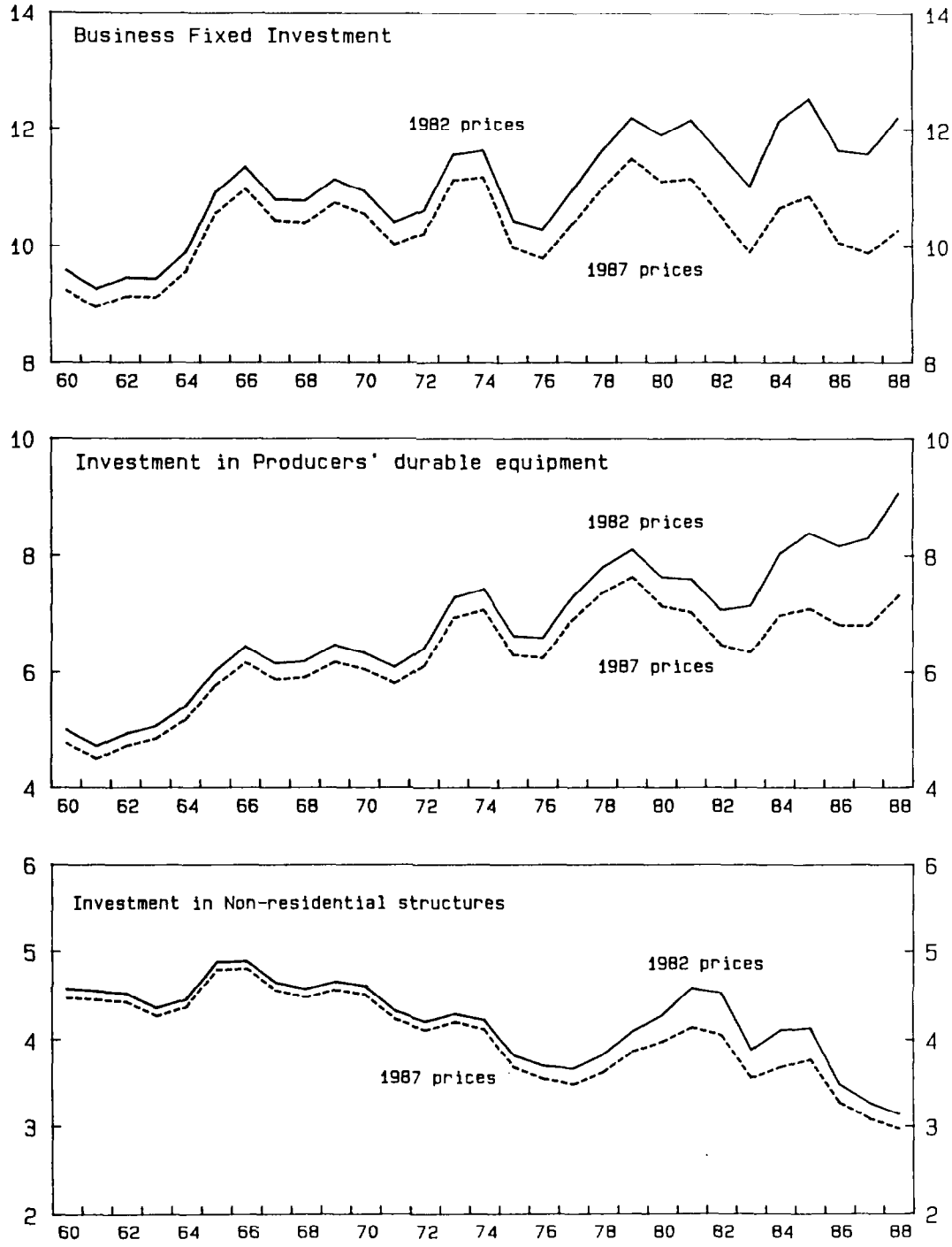
A recent paper by de Leeuw (1989) attempts to address the difficult analytical issues involved in interpretation of current investment data. The paper proposed that the preferable indicator might be a ratio of real gross fixed investment to output. A nominal ratio would be less helpful as it would not incorporate changes in the relative prices of capital goods, and a ratio of net investment to net product may also be problematic, according to de Leeuw, because of the well-known difficulties involved in measurement of depreciation and also because (as noted earlier) in a period of transition away from long-lived toward shorter-lived capital goods, the ratio of net investment to net output may decline without major economic significance. Whether the recent

CHART 4

UNITED STATES

REAL GROSS INVESTMENT RELATIVE TO REAL GNP

(percent)



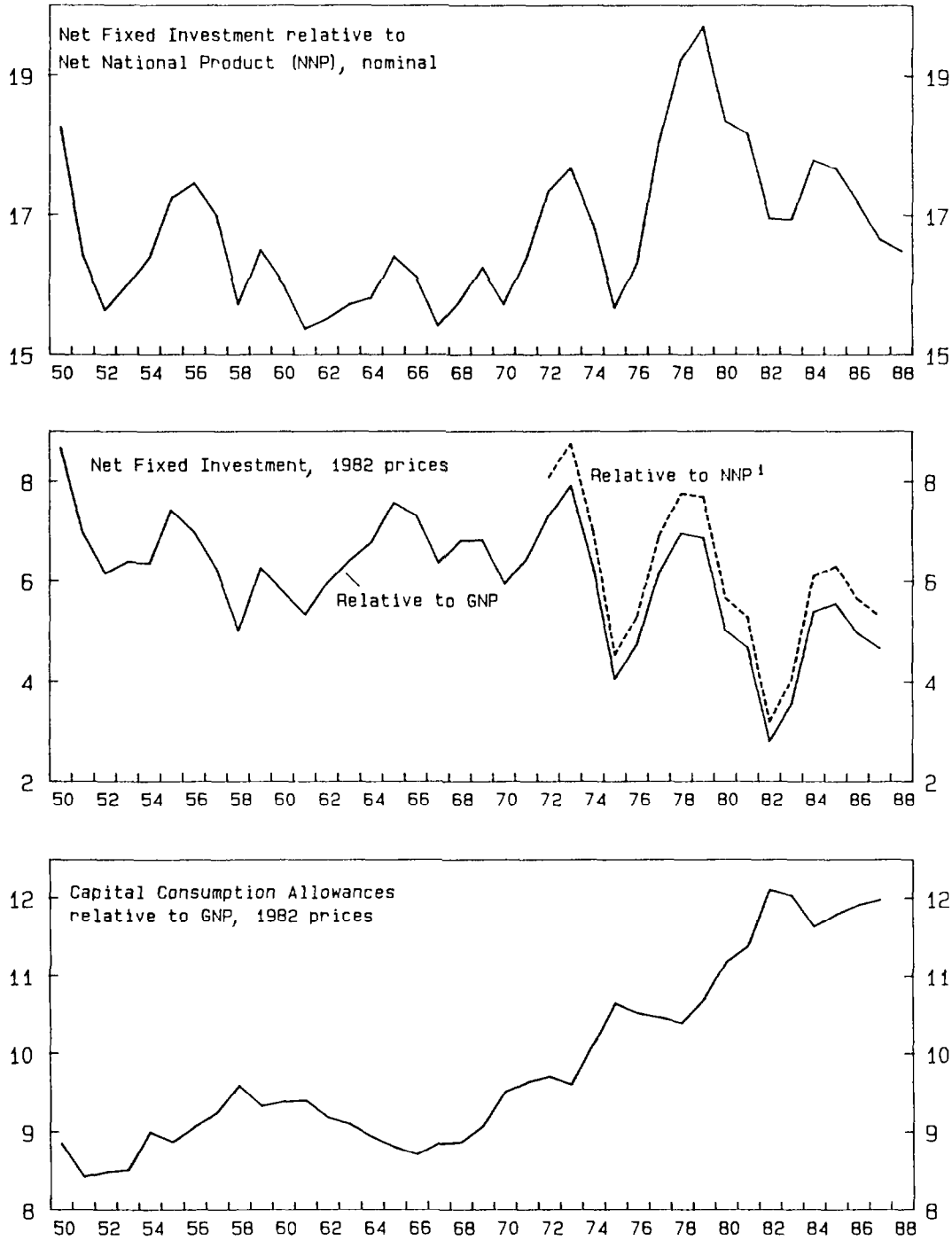
[1]The time series for real investment and real GNP at 1987 base prices were derived by staff calculations as oulined in the text.

CHART 5

UNITED STATES

NET FIXED INVESTMENT AND DEPRECIATION

(In percent)

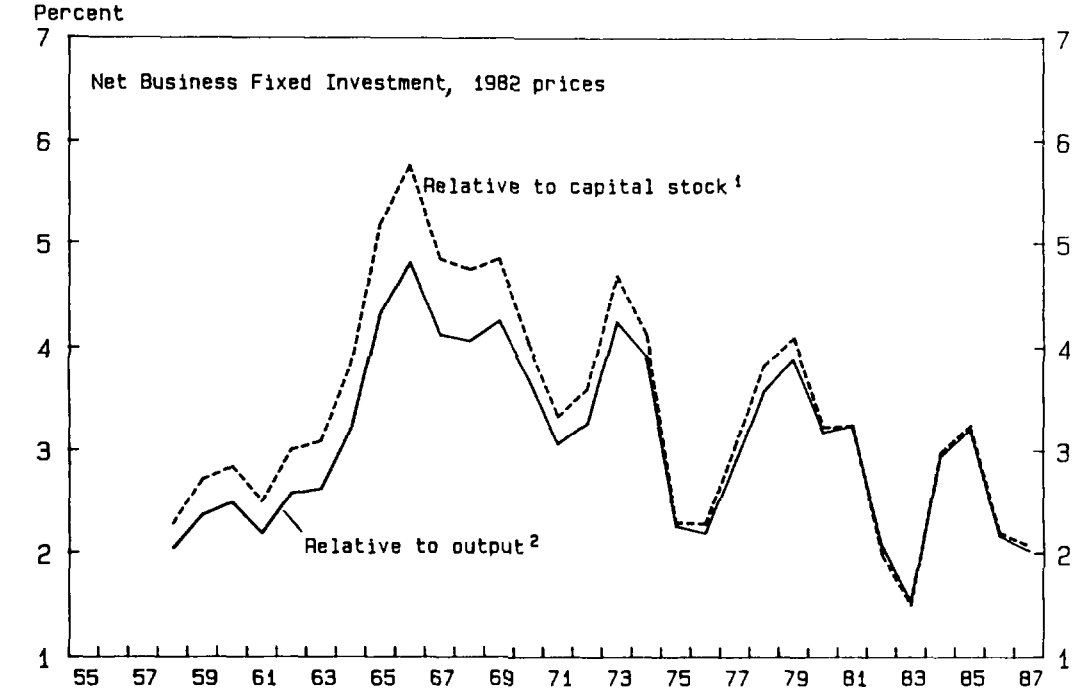


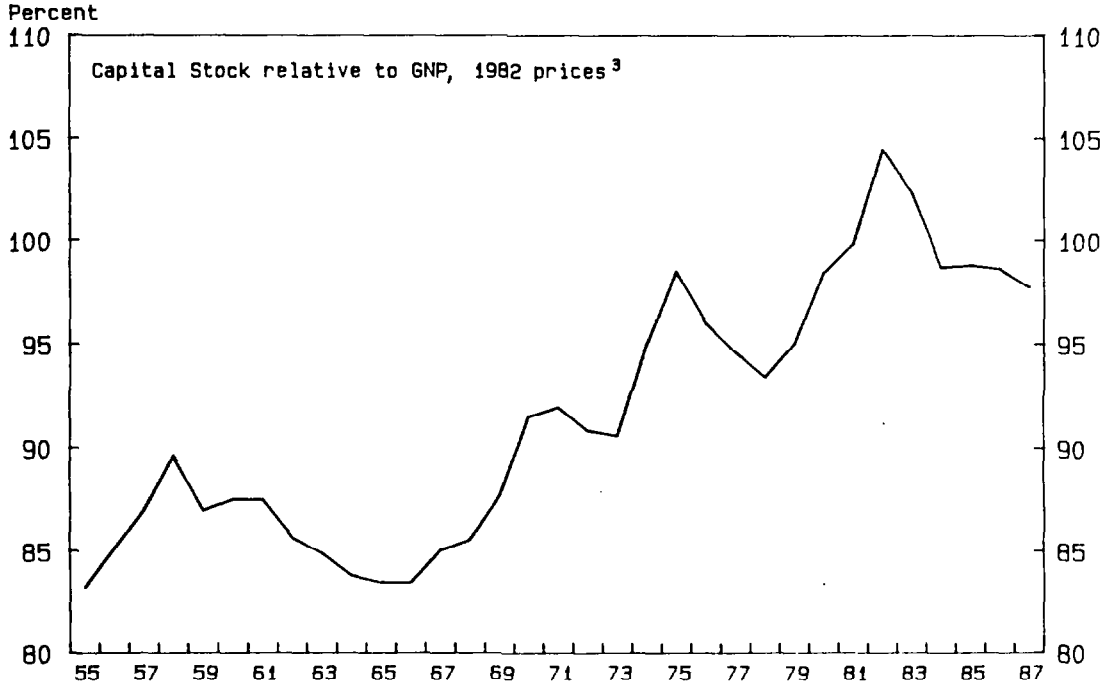
[1]Data for net national product, in 1982 prices, begin in 1972.

CHART 6

UNITED STATES

NET INVESTMENT AND THE CAPITAL/OUTPUT RATIO





[1]Net business fixed investment relative to the net business capital stock, in 1982 prices.

[2]Net business fixed investment relative to GNP, in 1982 prices.

[3]Business sector capital stock.

decline is attributable only to this adjustment in average service lives or to more fundamental factors does not appear clear.

In order to alleviate the sensitivity of the calculation to choice of base year, de Leeuw suggests that chain weights be employed. The results from such a calculation are illustrated in Chart 7. The chain-weighted ratio rises gradually over the 1950s and 1960s reaching a peak in 1979-81 and again in 1984-85. There is no obvious trend decline or increase in this ratio in the 1980s, compared with a clear trend increase in the three previous decades.

An alternative measure developed by de Leeuw examines a broadly defined measurement of real investment compared with an appropriately augmented measure of real GDP. 1/ The augmented investment series incorporates government capital formation, residential construction, investment in consumer durables, nondefense research and development spending and spending on education. This broad measure of real gross investment exhibits a trend increase from 24 percent of augmented real GDP in the early 1950s to a peak of close to 30 percent in the 1970s. In the 1980s, the previous trend increase in this ratio is no longer evident, and in fact there appears to be a modest decline (Chart 8).

To conclude this subsection, the various measurement issues complicate interpretation of data for U.S. investment, to the extent that answering the question whether capital formation should be viewed as weak or strong compared with historical trends is difficult. However, when the data are carefully re-examined, certain broad conclusions emerge.

First, an indicator which appears to suggest relatively strong capital formation in the 1980s--real gross business investment relative to real GNP in 1982 prices--shows quite a different picture when the data are rebased to 1987 prices. This result stems from the sensitivity of the calculation to choice of base year at a time when the relative price of an important component--investment in high-technology equipment--is falling sharply.

Second, when the ratio of real gross business fixed investment to output is calculated on a chain-weighted basis--a procedure which is less sensitive to choice of base year--there is no clear trend in the 1980s, in contrast to the clear rising trend in this ratio in the 1950s, 1960s and 1970s. An augmented measure of real investment, incorporating inter alia government investment, research and development and education spending shows a substantial increase relative to augmented real GDP from the early 1950s to the mid- to late-1970s; in the 1980s there are signs of modest decline.

1/ When investment is defined more broadly, the associated depreciation has to be added to output.

In sum, while interpretation is complicated, these aggregate indicators suggest that trends in U.S. capital formation may on balance have weakened in the 1980s compared with previous decades. The next section of the paper turns to estimation of equations for PDE and nonresidential structures.

IV. Empirical Analysis of the Determinants of Business Fixed Investment

In earlier research on the determinants of U.S. business fixed investment, separate equations were estimated for investment in PDE and investment in nonresidential structures using data up to the second quarter of 1987. 1/ The main explanatory variables were changes in output and the cost of capital--incorporating effects from the pretax interest rates and also changes over time in tax policy. This section updates and extends the previous empirical work, with particular attention to possible effects of the surge in real computing investment and the associated decline in its relative price.

The empirical framework relates business fixed investment to its proximate macroeconomic determinants--aggregate demand, the cost of funds, and tax factors. The specification is based on the standard neoclassical theory of capital accumulation, according to which the optimal combination of factor inputs depends on the relative prices of the inputs. If output is produced under competitive conditions and if the production function is of the Cobb-Douglas type, then the desired capital stock will be given by:

$$K^d = \alpha\ (Y/C) \tag{1}$$

where

K^d = desired capital stock

Y = output

C = real user cost of capital

α = a constant

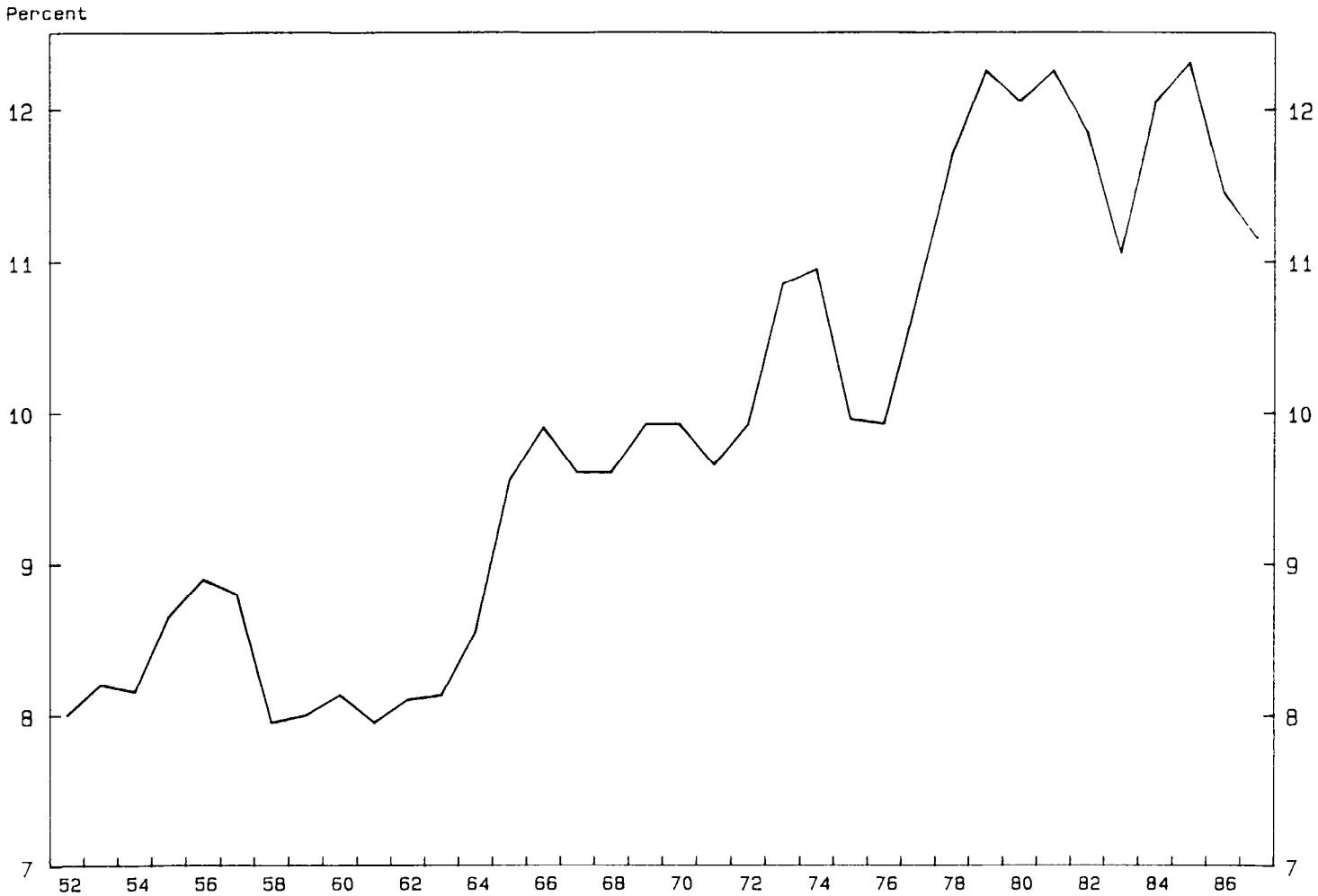
The flow of net investment is the change in the actual capital stock as it adjusts toward a new desired level. Because the actual capital stock adjusts only gradually over time, net investment will depend on current and lagged values of the desired capital stock.

1/ See Corker et al, (op. cit.). Helpful surveys can be found in Bosworth (1984 and 1985) and Chirinko (1986).

CHART 7

UNITED STATES

NON-RESIDENTIAL FIXED INVESTMENT RELATIVE TO GDP[1,2]



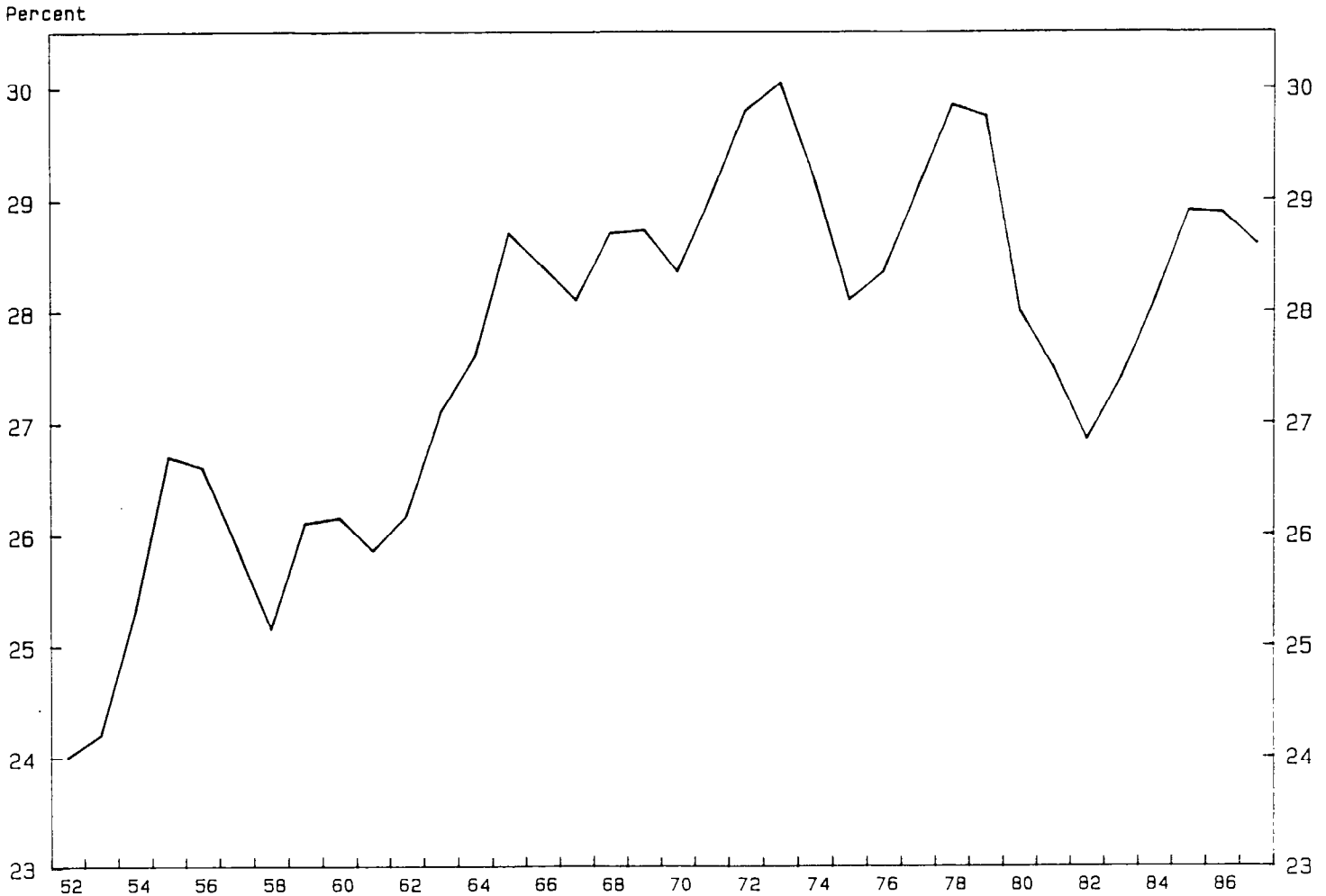
[1]Data are in 1982 prices. Investment and GDP are both calculated on a chain weighted basis.

[2]The source is the paper by de Leeuw, cited in the text.

CHART 8

UNITED STATES

AUGMENTED INVESTMENT RELATIVE TO AUGMENTED GDP[1,2]



[1]Data are in 1982 prices. Augmented investment includes government investment, spending on consumer durables, non-defense research and development, and education.

[2]The source is the paper by de Leeuw cited in the text.

Combined with the assumption that replacement investment is proportional to the lagged capital stock, this approach yields an equation for gross investment as follows:

$$Ig = \gamma\ (L)\ \Delta\ (Y/C)_t + \delta K_{t-1} \qquad (2)$$

where

γ is a polynomial in the lag operator and

δ is the rate of economic depreciation

Equations based on (2) above--pioneered by Jorgenson--are commonly used in empirical studies of investment behavior (Hall and Jorgenson, 1967). The version employed here and in previous staff work extends this approach, on the basis of the work of Bischoff (1971) and Clark (1979). When the previous equations were re-estimated on a sample that extended to the fourth quarter of 1988, the results were as shown below.

<u>Equation for investment in producers' durable equipment</u>

$$IE/Y^* = \sum_{L=0}^{14} w_L \cdot \left(\frac{Y_L - Y_{L-1}}{Y^*_L\ CE_{-L-1}} \right) + \underset{(0.7)}{7.72}\ (1/Y^*)$$

$$+ \underset{(16.4)}{0.081}\ (KE_{-1}/Y^*) - \underset{(2.2)}{0.027}.\ D1$$

w_0	= 0.0059	(4.2)	w_8	= 0.0096	(6.5)
w_1	= 0.0094	(7.7)	w_9	= 0.0078	(5.2)
w_2	= 0.0118	(9.3)	w_{10}	= 0.0059	(4.0)
w_3	= 0.0131	(9.5)	w_{11}	= 0.0041	(2.9)
w_4	= 0.0136	(9.4)	w_{12}	= 0.0024	(1.9)
w_5	= 0.0134	(9.0)	w_{13}	= 0.0011	(1.1)
w_6	= 0.0126	(8.5)	w_{14}	= 0.0002	(0.4)
w_7	= 0.0113	(7.6)	Σw_L	= 0.1221	

$\bar{R}^2 = 0.972$; DW = 2.08; $\rho = \underset{(16.8)}{0.87}$

Sample 1964(1) - 1988(4)

Equation for investment in nonresidential structures

$$IS/Y^* = \sum_{L=0}^{12} v_L \left(\frac{Y_{-L} - Y_{-L-1}}{Y^*_{-L} \; CS_{-L-1}}\right) + \underset{(2.4)}{50.3} \; (1/Y^*)$$

$$+ \underset{(3.1)}{0.025} \; (KS_{-1}/Y^*) - \underset{(4.5)}{0.00492}. \; D2$$

v_0	= 0.00125	(2.7)	v_7	= 0.00168	(3.3)
v_1	= 0.00164	(4.0)	v_8	= 0.00143	(2.8)
v_2	= 0.00190	(4.2)	v_9	= 0.00115	(2.3)
v_3	= 0.00204	(4.2)	v_{10}	= 0.00085	(1.9)
v_4	= 0.00208	(4.1)	v_{11}	= 0.00055	(1.5)
v_5	= 0.00202	(3.9)	v_{12}	= 0.00026	(1.1)
v_6	= 0.00188	(3.7)	Σv	= 0.01873	

$\bar{R}^2 = 0.961$; DW = 1.61; $\rho = \underset{(20.8)}{0.90}$

Sample: 1964(1) - 1988(4).

Notation:

IE = investment in producers' durable equipment, 1982 dollars

IS = investment in nonresidential structures, 1982 dollars

Y = GNP, 1982 dollars

Y^* = middle expansion path GNP, 1982 dollars 1/

CE = the real cost of capital for producers' durable equipment 2/

CS = the real cost of capital for nonresidential structures 2/

KE = gross stock of producers' durable equipment, 1982 dollars 2/

KS = gross stock of nonresidential structures, 1982 dollars 2/

D1 = dummy variable for credit controls in 1980:II

1/ For an explanation of this concept, see Holloway et al (1986).
2/ For further information on the definition and construction of these variables, see Corker et. al. (op. cit.).

D2 = dummy variable equal to unity from 1986:II onwards, to allow for effect of oil price plunge on investment in mining and petroleum structures

$\bar{R}^2$ is the adjusted coefficient of determination; DW is the Durbin-Watson statistic; ρ is the serial correlation coefficient, estimated by Cochrane-Orcutt, and the w_L and v_L coefficients were estimated using third degree Almon distributed lag polynomials, with the far constraint imposed; figures in parentheses are T-statistics. 1/

Both equations were reasonably well determined, with no major changes from earlier results in the estimated coefficient values. With regard to the equation for investment in nonresidential structures, one change relative to previous work should be noted. A dummy variable--equal to one from the second quarter of 1986 onward--was added to allow for the effects of the collapse in world oil prices in 1986. The estimated coefficient of this variable implied a reduction in structures' investment by about 15 percent of investment in nonresidential structures--about $18-$20 billion in 1982 prices--relative to what it would have been. 2/ The other coefficients remained broadly unchanged when the sample period was extended, and the hypothesis of coefficient stability was not rejected at the 5 percent level when a Chow/Fisher test of coefficient stability was conducted comparing sample periods ending in the second quarter of 1987 and the fourth quarter of 1988. 3/ When the within-sample performance was examined, there was no obvious tendency for the structures equation to drift off track toward the end of the sample.

The equation for producers' durable equipment (PDE), however, underpredicted actual PDE investment substantially over the last six quarters of the sample period--by an average of 1 1/2 percent on a within-sample basis. When formal Chow/Fisher tests of parameter stability were conducted, the PDE equation failed the test at both 5 percent and 1 percent levels of significance, when sample periods ending in the second quarter of 1987 and the fourth quarter of 1988 were compared. 4/

1/ Equations were estimated using the AREMOS econometric package.

2/ Investment in mining and petroleum structures dropped from an average $35 billion (1982 prices) in 1985 to an average $17 billion in the last three quarters of 1986, and had recovered only to $19 billion by 1988.

3/ Chow (1960) and Fisher (1970).

4/ An earlier version of this equation had previously passed similar tests covering earlier periods in the 1980s--a period of substantial changes in tax policy. See Corker et al. op. cit.

Reflecting these results, the out-of-sample dynamic forecast performance of the PDE equation was poor. When a version of the equation estimated to the second quarter of 1987 was used to generate a dynamic projection through the end of 1988, the equation underpredicted PDE by an average 7 1/4 percent in the four quarters of 1988, and was 6 1/2 percent below the actual value in the fourth quarter of that year.

Because of the surge in investment in high technology equipment, as discussed earlier, an obvious next step was to examine whether the source of the underprediction of total PDE might be associated with the remarkable strength of high tech investment. Producers' durable equipment investment was disaggregated into office computing and accounting machinery (OCAM) and the remainder, and separate equations were estimated. To facilitate comparison, the specification for each equation was kept similar to that of the overall PDE equation reported earlier. 1/ Within this framework, it was not possible to develop a satisfactory equation for investment in the OCAM category. Equations which performed adequately up to the early 1980s deteriorated substantially when the sample was extended. Coefficients were difficult to interpret and highly unstable over time.

1/ That is, the dependent variable in each case was real gross investment divided by middle expansion path GNP, and the independent variables were the lagged gross stock relative to middle expansion path GNP, and a distributed lag on the change in real GNP divided by the real cost of capital. To estimate the disaggregated PDE equations, quarterly series for the gross stock in each category had to be interpolated from the annual series available in BEA (1987) and the cost of capital had to be calculated for both office computing and accounting machinery and the remainder of PDE, incorporating an appropriate depreciation rate.

With regard to PDE investment excluding OCAM, more satisfactory results were developed, and an estimated equation is reported below:

$$IEEXC/Y^* = \underset{(1.5)}{101.8}\,(1/Y^*) + \underset{(1.6)}{0.036}\,.\,KIEEXC_{-1}/Y^* - \underset{(2.3)}{0.0025}\,.\,D_1$$

$$+ \sum_{L=0}^{14} u_L \,.\, \left(\frac{Y_{-L} - Y_{-L-1}}{Y^*_{-L}\ CEEXC_{-L-1}}\right)$$

u_0	=	0.054	(4.6)	u_8	=	0.082	(6.1)
u_1	=	0.082	(7.9)	u_9	=	0.067	(5.0)
u_2	=	0.100	(9.0)	u_{10}	=	0.051	(3.9)
u_3	=	0.111	(9.1)	u_{11}	=	0.036	(2.8)
u_4	=	0.115	(8.8)	u_{12}	=	0.022	(2.0)
u_5	=	0.113	(8.4)	u_{13}	=	0.011	(1.2)
u_6	=	0.106	(7.8)	u_{14}	=	0.003	(0.6)
u_7	=	0.095	(7.1)	Σu_L	=	1.0494	

$\bar{R}^2 = 0.940$; DW = 2.14; $\rho = \underset{(33.8)}{0.95}$

Sample 1964(1) - 1988(4).

Notation:

IEEXC = gross fixed PDE investment, excluding OCAM, 1982 prices;

KIEEXC = gross stock of PDE excluding OCAM, 1982 prices;

CEEXC = real cost of capital for PDE excluding OCAM

Other notation is as before, and the u_i were estimated using a third degree Almon polynomial, with the far constraint imposed. The hypothesis of stable coefficients was not rejected at the 5 percent level when Chow/Fisher stability tests were conducted comparing results from samples ending in the fourth quarter of 1985, the second quarter of 1987 and the fourth quarter of 1988.

The tentative conclusion is that the deteriorating performance of the overall PDE equation appears to reflect the inability of that equation to account for the recent surge in the component relating to OCAM. When disaggregated equations for OCAM and the remainder of PDE were estimated separately, no satisfactory empirical representation for the former category was found, while a relatively stable equation for the remaining part of PDE was estimated, with similar properties to that previously estimated for total PDE.

A final empirical test was to see whether a stable aggregate PDE equation could be developed using alternative methods of calculation of real investment and output. When an equation for total PDE investment was estimated using both chain-weighted measures of real PDE investment and also of real GNP, the results were mixed. 1/ The estimated coefficients were very similar to those previously presented in the equation for total PDE in 1982 dollars. The instability problems evident in the previous total PDE equation were mitigated but not totally eliminated. Essentially the equation would either just pass or just fail a stability test at the 5 percent level depending on precisely where the sample period was divided. When a dynamic simulation was conducted, using an equation estimated up to the second quarter of 1987 to project over the period to the end of 1988, the tendency to underpredict remained evident. In sum, a shift to chain-weighted measures of PDE investment and output with corresponding changes in the price terms does not lead to a stable PDE equation. Rather, it continued to seem necessary to disaggregate between the heterogeneous categories of OCAM and the remainder of PDE.

V. Conclusion

In the current expansion of the U.S. economy, investment in high technology equipment--primarily office computing and accounting machinery (OCAM)--has boomed, while other categories of business fixed investment have grown so weakly that they have yet to regain their previous cyclical peaks. The boom in real high technology investment has been associated with a very rapid decline in the price of computers, as indicated by sophisticated new computer price indexes initially introduced into U.S. national accounts data in 1985.

The pronounced decline in the relative price of computing power leads to difficult index number problems in assessing the performance of investment in the 1980s. For example, the growth of real gross business fixed investment since 1982 appears much stronger when calculations are made using 1982 base year prices than when 1987 base prices are employed. Similarly, the ratio of real gross business fixed investment to real GNP appears quite strong compared with historical averages when 1982 base prices are employed and significantly weaker when 1987 prices are used. This sensitivity to choice of base year reflects the fact that the earlier the base year, the larger the weight given to a component whose relative price is declining--in this case office computers, which is also the fastest growing component in real terms.

1/ The relative price terms entering the cost-of-capital formula were adjusted correspondingly.

When ratios of investment to output were examined to see how the recent behavior of capital formation should be characterized, assessment was clouded by these index number problems. However, when a chain-weighted measure of real gross business fixed investment was examined, it was apparent that the trend increase in this ratio up to the late 1970s came to a halt in the 1980s and may have given way to a small subsequent decline. A broader measure of real gross investment also increased relative to output up to the end of the 1970s and appeared to decline subsequently, and a similar time profile was displayed by the ratio of the net capital stock to output. Thus the broad conclusion suggested by a careful examination of the data is of a break in the 1980s with the trends of previous decades.

Previous empirical work had produced relatively conventional equations explaining producers' durable equipment (PDE) investment and investment in nonresidential structures in terms of an accelerator term and the cost of capital which performed reasonably well in the period to mid-1987. When the data were extended to 1988 the equation for investment in nonresidential structures performed much as before. However, that for PDE investment significantly underpredicted the recent surge in investment in this category.

When PDE investment was separated into OCAM and the remainder, a stable empirical representation of the latter was found, along lines similar to those previously used for total PDE investment. However, no satisfactory equation for OCAM was developed. The empirical results appear to indicate that investment in OCAM and the remainder of PDE are in fact heterogeneous categories which should be modeled separately. The inability to explain OCAM investment in terms of a conventional specification could stem from measurement difficulties or could suggest that a different approach may be needed for a category of investment experiencing such rapid technological and quality change.

Appendix

A Numerical Example Illustrating the Index Number Problem

Let investment consist of computers and factories. Every year, $10 is spent on computers and $90 on factories. The price of computers falls by 15 percent annually while the price of factories is constant. 1/

Consider the evolution of real magnitudes from year 1 to year 10. In year 10, real investment in computers is 4.32 (1 divided by 0.85 raised to the power 9) times higher than in year 1, while real investment in factories has remained constant.

What about total real investment? Suppose we use year 1 base prices (that is the deflators for computers and factories are set equal to unity in year 1). Then in year 1, real investment equals 100 (90+10). In year 10, real investment equals 133.2 (90+10x4.32) and the average annual growth rate of real investment has been 3.24 percent using year 1 base prices.

Now suppose we use year 10 base prices (that is deflators equal unity in year 10). Then in year 10, real investment equals 100 (90+10), while in year 1, real investment equalled 92.32 (90+2.32, with 2.32 equal to 10/4.32). The average annual growth rate of real investment has been 0.9 percent using year 10 base prices.

Thus in this example, the average growth of total real investment is 3.2 percent using year 1 prices and 0.9 percent using year 10 prices. As noted in the text, this sensitivity to choice of base year reflects the fact that the earlier the base year, the larger the weight given to a component whose relative price is dropping--in this case computers, which is also the most rapidly growing component in real terms.

1/ The reader may wish to work the example through on a calculator.

Table 1. Gross Investment Ratios

	1960s	1970s	1980-88	1985	1986	1987	1988
(In percent of nominal GNP)							
Gross fixed investment	14.5	15.6	15.4	15.7	15.3	14.9	14.8
Residential construction	4.6	5.0	4.5	4.7	5.1	5.0	4.7
Business fixed investment	9.9	10.7	10.9	11.0	10.2	9.9	10.0
Machinery and equipment	6.2	7.0	7.2	7.2	7.0	6.8	7.1
Information processing	1.1	1.6	2.2	2.4	2.3	2.2	2.3
Other	5.1	5.4	5.0	4.8	4.7	4.6	4.8
Nonresidential structures	3.7	3.7	3.7	3.8	3.3	3.1	2.9
Of which: mining and petroleum	--	0.1	0.3	0.7	0.4	0.3	0.3
(In percent of real GNP, 1982 prices)							
Gross fixed investment	15.5	16.4	16.4	17.4	16.9	16.6	17.0
Residential construction	5.3	5.3	4.5	4.8	5.2	5.1	4.8
Business fixed investment	10.3	11.1	11.9	12.5	11.6	11.6	12.2
Machinery and equipment	5.6	7.0	7.9	8.4	8.2	8.3	9.1
Information processing	0.6	1.1	2.9	3.3	3.4	3.6	4.1
Other	5.0	5.9	5.0	5.1	4.8	4.7	5.0
Nonresidential structures	4.6	4.1	3.9	4.1	3.5	3.3	3.1
Of which: mining and petroleum	0.1	0.3	0.9	1.0	0.6	0.5	0.5
Memorandum items							
Gross fixed investment excluding information processing equipment							
(in percent of nominal GNP)	13.4	14.1	13.2	13.4	13.1	12.6	12.5
(in percent of real GNP)	14.9	15.3	13.5	14.1	13.5	13.0	12.9

Table 2. More Gross Investment Ratios

(In percent of real GNP, 1987 prices) 1/

	1960s	1970s	1980-88	1985	1986	1987	1988
Gross fixed investment	15.1	15.8	15.0	15.6	15.2	14.9	15.0
Residential construction	5.2	5.2	4.5	4.8	5.2	5.0	4.8
Business fixed investment	9.9	10.6	10.5	10.9	10.1	9.9	10.3
Machinery and equipment	5.4	6.6	6.9	7.1	6.8	6.8	7.3
Information processing	0.6	1.0	1.9	2.1	2.1	2.2	2.4
Other	4.8	0.6	4.9	5.0	4.7	4.6	4.9
Nonresidential structures	4.5	3.9	3.6	3.8	3.3	3.1	3.0
Of which: mining and petroleum	0.1	0.2	0.5	0.6	0.3	0.3	0.3
Memorandum item:							
Gross fixed investment, excluding information processing equipment	14.5	14.8	13.0	13.5	13.1	12.6	12.6

1/ The methods for calculating real values at 1987 prices were outlined in the text.

Table 3. Net Investment Ratios

	1960s	1970s	1980-88	1985	1986	1987	1988
(In percent of nominal net national product)							
Net fixed investment	6.6	6.7	4.9	5.4	5.1	4.8	4.9
Residential construction	2.9	3.0	2.3 1/	2.5	3.0	3.0	...
Business fixed investment	3.7	3.7	2.6 1/	2.9	2.1	1.8	...
Plant and equipment	1.9	2.3	1.3 1/	1.6	1.3	1.2	...
Nonresidential structures	1.7	1.4	1.2 1/	1.3	0.7	0.6	...
(In percent of real net national product)							
Net fixed investment	...	7.1 2/	5.2 1/	6.3	5.6	5.3	...
Residential construction	...	3.3 2/	2.3 1/	2.7	3.1	3.0	...
Business fixed investment	...	3.7 2/	2.9 1/	3.6	2.5	2.3	...
Plant and equipment	...	2.2 2/	1.7 1/	2.3	1.9	1.9	...
Nonresidential structures	...	1.5 2/	1.2 1/	1.3	0.6	0.4	...

1/ Average 1980-87.
2/ Average 1972-79.

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