This PDF is a selection from an out-of-print volume from the National Bureau of Economic Research

Volume Title: The American Business Cycle: Continuity and Change

Volume Author/Editor: Robert J. Gordon, ed.

Volume Publisher: UMI

Volume ISBN: 0-226-30452-3

Volume URL: http://www.nber.org/books/gord86-1

Publication Date: 1986

Chapter Title: Fixed Investment in the American Business Cycle, 1919-83

Chapter Author: Robert J. Gordon, John Veitch

Chapter URL: http://www.nber.org/chapters/c10025

Chapter pages in book: (p. 267 - 358)

5 Fixed Investment in the American Business Cycle, 1919–83

Robert J. Gordon and John M. Veitch

All induction is blind, so long as the deduction of causal connections is left out of account; and all deduction is barren, so long as it does not start from observation.

John Neville Keynes 1890, 164

5.1 Introduction

The behavior of fixed investment is one of the four core topics (along with consumption, money demand, and the Phillips curve) that have dominated theoretical and empirical research in macroeconomics during the postwar era. An understanding of the sources of persistent swings in investment spending seems to be a key ingredient in any satisfactory explanation of business cycles. This paper develops a new data set and uses a new methodology to investigate the behavior of household and business fixed investment in the United States since 1919. Its results have implications for at least four partly overlapping groups of economists who have strong views about the nature of the fixed investment process and, indirectly, about the sources of business cycles.

Robert J. Gordon is professor of economics at Northwestern University. John M. Veitch is assistant professor of economics at the University of Southern California.

Gordon's research is supported by the National Science Foundation and the Sloan Foundation. Veitch acknowledges support from the Social Sciences and Humanities Research Council of Canada. We both are indebted to Ben Bernanke, Robert Chirinko, Thomas Doan, Robert Eisner, John Geweke, Fumio Hayashi, Andrew Rose, Allen Sinai, Larry Summers, Mark Watson, and members of the Northwestern University Macro-Labor workshop for helpful comments. We would also like to thank Nathan Balke for his help with the data and econometric estimation and Joan Robinson for preparing a long and complex manuscript so efficiently.

Keynesians, following the *General Theory*, regard investment behavior as containing a substantial autonomous component; investment responds to the state of business confidence and incorporates the effect of episodes of speculation and overbuilding. The instability and unpredictability of fixed investment behavior, of course, forms the basis of Keynesian support for an activist and interventionist role for government fiscal policy. A crucial and often unstated component of the Keynesian view is that these autonomous investment movements exhibit *positive serial correlation* and last long enough for government action to be effective.

In contrast, monetarists do not single out investment for special attention. Changes in aggregate private spending, consumption and investment alike, are attributed to prior fluctuations in the supply of money. Since monetarists are usually reluctant to provide detailed structural interpretations of what happens inside the black box through which the influence of money is channeled to economic activity, they are not concerned whether the primary channel runs through consumption, investment, or both. But monetarists would expect (if forced uncharacteristically to devote special attention to fixed investment behavior) to find a strong role for the money supply as a primary determinant of investment behavior.

In addition to the general approaches to macroeconomic analysis advocated by Keynesians and monetarists, two additional groups of economists have made a special effort to understand investment behavior. The "neoclassical" school, represented by the work of Jorgenson and his collaborators, emphasizes changes in the relative price or "user cost" of capital as a dominant influence, together with changes in output, on fluctuations in fixed investment. The user cost of capital is the primary channel by which both monetary policy (working through interest rates) and fiscal policy (working through investment tax incentives) influence the flow of investment spending. The final group consists of advocates of Tobin's "Q" approach, in which the influence on investment of forward-looking expectations regarding output and capital costs is captured by a single variable, Q, the ratio of the market value of capital to its reproduction cost. Since the dominant portion of fluctuations in Q is accounted for by changes in stock market prices, proponents of this approach expect econometric work to single out the stock market as an important (or dominant) factor explaining investment behavior.

Because of the long time span of data covered in the empirical portion of this paper, its results have implications for the sources of business cycles in general and of the Great Depression in particular. Keynesians view business cycles as the inevitable reflection of the instability of investment spending, which in turn justifies government intervention to reduce the amplitude of cycles. Keynesian interpretations of the Great Depression, especially Temin (1976), minimize the role of monetary factors in the first two years of the 1929–33 contraction. Monetarists reverse the roles of the government and private sector and view the basic source of business cycles as autonomous and largely unexplained fluctuations in the money supply that lead to fluctuations in private spending. A reduction in the amplitude of business cycles requires a reduction in the instability originating in government management of the money supply.

The neoclassical and *Q* approaches to the explanation of investment behavior are explicitly partial equilibrium in nature and have not been developed into broader theories of the business cycle. The neoclassical approach is compatible with some aspects of monetarism, since instability in investment can originate from government control over interest rates and investment tax incentives. But the policy implications differ from those of monetarism; to the extent that the monetarist recommendation of a constant monetary growth rate rule would increase the volatility of interest rates, then the neoclassicists would predict the consequence to be greater rather than lesser fluctuations in investment spending. The *Q* advocates have not addressed themselves to business cycle implications, but their approach creates a natural link to those (like Mishkin 1978) who emphasize the role of the 1929 stock market crash in the Great Depression.

The conflict between the Keynesian and monetarist approaches can be related to the distinction in business cycle analysis between "impulses" and "propagation mechanisms." Keynesians argue for activist monetary and fiscal policy responses to counter serially correlated investment *impulses*, while monetarists view investment as part of the *propagation mechanism* that carries the influence of autonomous money supply impulses from their origin in the government sector to their effect on private sector spending.[1] The Keynesian/monetarist debate can be translated into the modern econometric language of Granger causality and innovation accounting. Keynesians would expect to find a large role for "own innovations" in the empirical explanation of investment spending, with a relatively small role for feedback from monetary variables. An extreme Keynesian would expect investment to be exogenous in the Granger sense to prior changes in the money supply, and the same expectation would be held by neoclassicists and *Q* advocates, none of whom (to our knowledge) has ever entered the money supply directly as an explanatory variable in an empirical in-

1. Recall the famous debate of the mid-1960s set off by the attempt by Milton Friedman and David Meiselman (1963) to characterize "autonomous spending" and "the money supply," respectively, as the driving forces in the Keynesian model and their own model of income determination.

vestment equation. Monetarists, of course, would expect to find that the money supply is Granger causally prior to fixed investment.

This paper reopens the question of exogeneity in investment behavior by inquiring whether the standard approach to the estimation of "structural" investment equations leads to an overstatement of the endogeneity of investment spending. Its primary objective is to decompose fluctuations in fixed investment into three components: (*a*) feedback from policy variables and from noninvestment spending; (*b*) the propagation mechanism imparted by the investment process itself, which displays a high degree of positive serial correlation; and (*c*) "own innovations" or "shocks" in fixed investment expenditures that remain after accounting for (*a*) and (*b*). The main contributions of the paper can be divided into three categories—methodological, data creation, and empirical.

The methodological section finds that, while structural model building exercises may be useful in suggesting lists of variables that might play an explanatory role in investment equations, they generally achieve identification of structural parameters only by imposing arbitrary and unbelievable simplifying assumptions and exclusion restrictions. Consideration of real world decision making suggests that economic aggregates play "multiple roles" in investment behavior, which implies that the observed coefficients on explanatory variables in equations describing investment behavior represent a convolution of numerous structural parameters that cannot be separately identified. As a result it is possible only to estimate reduced forms.

The estimation methodology suggested here is the same as that proposed in a previous paper on inflation (Gordon and King 1982). It starts with guidance from traditional structural models on the choice and form of explanatory variables to be included. Then estimation is carried out in a format similar to that of the unconstrained "Simsian" vector autoregression (VAR) models. Explanatory variables are typically entered with unconstrained lags of the same length, and the list of explanatory variables typically includes a mixture of those suggested by several structural models, together with those that may not be suggested by any structural model but might in principle play a role through real wealth effects, credit constraints, or expectation formation (e.g., the real money supply). The approach differs from the usual VAR model building exercise by focusing mainly on equations for the variable of primary interest (inflation in Gordon and King and investment expenditures in this paper) rather than by giving "equal time" to all the variables in the model. It is less "atheoretical" than most VAR research, because structural models retain a usefulness in suggesting lists of candidate variables to be included in reduced-form equations and the form in which those variables should be entered (in this paper, for instance, stock market prices enter in the form of Tobin's Q variable), even if the underlying structural parameters cannot be identified.

The second contribution is the use of a new set of quarterly data for major expenditure categories of GNP extending back to 1919. The data file also contains quarterly data back to 1919 for other variables that have been suggested as explanatory "candidates" in investment equations. These include the capital stock, interest rates, the cost of capital including tax incentive effects, a proxy for Tobin's Q, and the real money supply.

Equipped with its hybrid methodology and its extended data set, the paper then proceeds to empirical estimation. The empirical section differs from the usual research on investment that typically attempts to measure response parameters within the context of a single structural theory, for example, neoclassical or Q. Instead, our skepticism that structural parameters can be estimated leads us to estimate reduced-form equations. These include explanatory variables suggested by several theories and can be used to decompose the variance of investment within particular historical periods among the contribution of lagged values of explanatory variables (output, interest rates, money, Q), the contribution of lagged investment, and "own innovations" to investment. The analysis of shocks to investment links this paper to the debate between Temin (1976), Thomas Mayer (1980), and others on the role of an autonomous shock to consumption in 1930, and to papers in this volume by Hall on shifts in the consumption function and by Blanchard and Watson on "shocks in general." Our extended data set also allows us to investigate changes in investment behavior between the interwar and postwar periods.

The discussion begins (section 5.2) with a review of the central issues that lead to our choice of a reduced-form rather than a structural approach. This is not a full-blown survey of the literature, but rather a selective analysis of problems with structural estimation that have emerged over the past twenty years. Then section 5.3 introduces the data set and describes the behavior of the major variables in each of the fourteen business cycles since 1919, as well as over longer subperiods. Section 5.4 presents the estimated equations for four categories of investment (producers' durable equipment, nonresidential and residential structures, and consumer durables expenditures), and section 5.5 offers a study of multivariate causality and exogeneity, innovation accounting, and a historical decomposition of the sources of investment spending. Section 5.6 summarizes the main results and implications.

5.2 Pitfalls in Structural Estimation of Investment Equations

Most of the investment literature is concerned solely with business investment. This orientation reflects the influence of Keynes's *General Theory*, especially its preoccupation with the state of business confidence as a determinant of investment plans. However, business investment constitutes less than half of total private investment in the United States economy. Consumer expenditures on durable goods have been larger than producers' durable equipment expenditures since 1920, and residential structures expenditures have exceeded those on nonresidential investment in at least half the years since 1929.

One might expect household investment behavior to respond to different variables than does business investment. For instance, if a substantial proportion of consumers are credit constrained, then episodes of "credit crunches" are liable to produce a greater response in the investment outlays of consumers than of businessmen.[2] A systematic exploration of household investment behavior may need to explore factors that matter in household decision making; for example, it may be disposable income that matters for households but total GNP for businessmen, and the various tax incentive terms conventionally included in measures of the user cost of capital may matter for businessmen but not for households. Here we begin with a critique of the more familiar literature on business investment and subsequently apply our analysis to the determinants of household investment.

Chirinko's (1983a) systematic review of assumptions and results distinguishes four classes of econometric models describing business investment behavior—Jorgenson's neoclassical approach, Tobin's Q, the "general forward-looking" approach based on explicit modeling of expectations, and Feldstein's "return-over-cost" and "effective tax rate" models. Because they have accounted for the vast majority of empirical studies completed to date, we concentrate only on the neoclassical and Q frameworks for investment research. Extended surveys are presented by Eisner and Strotz (1963), Jorgenson (1971), Helliwell (1976), and Chirinko (1983a), whereas here we treat only a few selected issues that lead to our skepticism that traditional structural parameters can be identified.

5.2.1 The Neoclassical Paradigm

As of the mid-1970s, the neoclassical paradigm was so dominant (at least outside New Haven) that Helliwell's (1976) survey makes no mention of any other framework. Before the mid-1960s, investment equations had been dominated by the accelerator approach and had

2. The quantitative importance of the credit crunch phenomenon is explored in the paper by Eckstein and Sinai in this volume (chap. 1).

added interest rates, profits, or other variables as determinants of investment without explicit constraints based on optimizing behavior. The studies initiated by Jorgenson and collaborators, particularly Jorgenson (1963, 1967), Hall and Jorgenson (1967, 1971), and Jorgenson and Stephenson (1967, 1969), are distinguished by their derivation of the desired capital/output ratio from specific assumptions about behavior and about the form of the production function. The centerpiece in the determination of the desired capital stock is the expected real rental price of capital services, which is equated with the expected marginal product of capital. If factors are paid their marginal products and the production function is of the Cobb-Douglas form, the desired capital stock at a given point in time (K_t^d) is a linear function of expected output (X_t^e) divided by the expected real price of capital services (C_t^e/P_t^e):

$$K_t^d = \frac{\gamma P_t^e X_t^e}{C_t^e}, \tag{1}$$

where γ is the income share of capital in output. Decision and delivery lags make actual net investment a distributed lag on past changes in the desired capital stock:

$$I_t^N = \sum_{j=0}^{J} \alpha_j \Delta K_{t-j}^d. \tag{2}$$

When the expected variables (P^e, X^e, and C^e) are replaced by current actual values (an unjustified assumption discussed below), and when the demand for replacement capital is represented by a fixed geometric depreciation factor (δ) times the lagged capital stock (K_{t-1}), the neoclassical investment model becomes:

$$I_t = \alpha_0 + \sum_{j=0}^{J} \beta_j \Delta(PX/C)_{t-j} + \delta K_{t-1} + \epsilon_t. \tag{3}$$

Equation (3) embodies a number of strong assumptions and restrictions, and a large "counterrevolution" literature has developed to explore the consequences of loosening them. The "pure" Jorgensonian neoclassical approach assumes a "putty/putty" technology without adjustment costs; the capital stock can be adjusted instantly, transformed, bought, or sold as needed to bring a firm's actual capital stock into line with its desired capital stock. As long as expectations are assumed to be static, the only justification for the lag distribution included in (3) is the technological gestation lag. Another interpretation is that investment expenditures involve adjustment costs. Without adjustment costs or gestation lags, the Jorgenson model is subject to the criticism that whenever a gap exists between K_t^d and K_t, the rate of investment will be infinitely large and the gap will be eliminated instantaneously. However, with either of these assumptions "tacked on," the Jorgensonian K_t^d is not derived from a complete cost minimization problem and is probably not optimal.[3]

Another peculiarity of the approach is apparent in equation (1), which allows the desired capital stock to be a function only of the relative price of capital rather than the relative price of all inputs. Yellen (1980) has shown that (1) can be derived only by assuming that real wages are inversely related to C/P and respond fully and instantaneously to any changes in C/P. As a result, all factor price changes must be assumed to leave the profitability of the firm unaffected, even in the short run. Thus the neoclassical approach leaves no room for theories that predict a profit squeeze, investment slump, and growth slowdown following a period of excessive real wage growth (see Malinvaud 1982).

However, even if one were to accept the formulation in (1) with the single relative price variable, the measurement of capital's user cost is fraught with ambiguity. As shown recently in Auerbach's (1983) survey, taxes and inflation may not change the cost of capital in the same way for all firms, leaving the feasibility of aggregation an open question. Simple formulas for C/P are also elusive when markets are incomplete and when managers use financial leverage and dividend policy to influence market perceptions.

The empirical "counterrevolution" begins with Eisner and Nadiri (1968), an article that takes particular exception to the multiplicative specification in (3) that forces both the short-run and long-run responses to X and C/P to be identical. Eisner and Nadiri find that the elasticities with respect to output are considerably higher than those with respect to relative prices, and Bischoff (1971) finds that lags are shorter on output than on relative prices. Chirinko and Eisner (1983) find in experiments with the Data Resources, Incorporated (DRI) and MIT–Penn–Social Science Research Council (MPS) econometric models that splitting apart the X and C/P variables can cause the implicit relative price elasticity to fall by more than half, and together with minor redefinitions of the C/P variable can cause a reduction in that elasticity by a factor of four. However, even by loosening restrictions in this way they find that response coefficients to changes in the investment tax credit in six models still vary by a factor of four (or a factor of about two for the four most extensively used models—Chase, DRI, MPS, and Wharton).

5.2.2 Expectations and Identification

An even more serious problem in equations (1) through (3) is the cavalier treatment of expectations, which are included in (1) but as-

3. This paragraph reflects an oral history provided to us by Fumio Hayashi.

sumed to be static in the transition from (1) to (3). In Helliwell's words, "This important issue has been dealt with principally by the handy assumption that the future will be like the present" (1976, 15). At best, expectations of future output are allowed to depend on a distributed lag of past values of output, but generally lagged values of other variables that might be relevant for expectations formation (e.g., the money supply) have been excluded as an identification restriction. Since investment is a forward looking activity, not only must the X and C/P variables be represented by expectations that in principle should depend on an information set containing past values of all relevant macroeconomic aggregates, but also the functional parameters entering the investment model should depend on the same general information set.

This point can be illustrated in a generalization of a simple model set forth recently by Andrew Abel and Olivier Blanchard (1983) that falls into the class of "general forward looking models." In place of (1) we allow the desired capital stock to depend on a sequence of expected future sales, with a discount factor σ; unlike Abel and Blanchard, we also allow the desired capital stock to depend on the sequence of expected future rental rates (C/P):[4]

$$(4) \qquad K^d_{t+n} = \alpha(1 - \sigma) \sum_{i=0}^{\infty} \sigma^i E\{F[X_{t+n+i}, (C/P)_{t+n+i}] | \Omega_t\}.$$

Here t is the time an investment order is placed for delivery at $t + n$, with n the length of the delivery or gestation lag. The parameter α is the steady-state ratio of capital to output, and Ω_t is the information set relevant at time t to the formation of expectations about all future variables. The relevant information set might, for instance, include past values of output, the interest rate, and the money supply.

It has been an almost universal practice in the empirical literature to express the depreciation rate of capital as a fixed exponential constant. In contrast Eisner (1972), Feldstein and Foot (1971), and Feldstein and Rothschild (1974) have argued that the timing of replacement investment is an economic decision and is motivated by economic considerations. In particular, fixed proportions in building or machine construction create an enormous incentive for net investment and replacement investment to be considered as part of the same economic decision making process.[5] Accordingly we replace the fixed replace-

4. Even if a project is financed by issuing a long-term bond on the day of its completion, time periods after the date of completion are relevant both for the taxation of earnings and for any capital gains that may accrue.

5. Students of United States twentieth-century architecture know that there was virtually no central city office building construction between 1930 and 1955; that is, there was *neither* any expansion in the number of square feet *nor* any replacement of old buildings, both for the same set of reasons.

ment rate in the Abel/Blanchard model by an expected rate (θ) that depends on the information set:

$$(5) \qquad K_{t+n} = [1 - E(\theta|\Omega_t)]K_{t+n-1} + I_{t+n},$$

where I_{t+n} represents investment expenditures made at time $t + n$ (strictly speaking this should be an expectation—see note 6 below).

Investment orders depend on the gap between desired and actual capital that is expected to occur at time $t + n$ and the present expectation of the fraction of the capital stock that will be replaced at that time. Although the fraction of the gap to be closed is decided at time t and is not an expected value, today's decision regarding the fraction depends on the expected cost of adjustment during the period of the gestation lag, for example, expected interest rates on short-term construction loans, r_t:[6]

$$(6) \qquad 0_t = \lambda[E(r_{t+1}|\Omega_t)][K^d_{t+n} - K_{t+n-1}] + E(\theta|\Omega_t)K_{t+n-1} + \xi_t,$$

where ξ_t is a disturbance term.

Finally, actual investment expenditures (I_t) are a sum of past orders, with a distributed lag indicating that projects have heterogeneous gestation lags:

$$(7) \qquad I_t = \sum_{j=0}^{n} \omega_j(\Omega_t)0_{t-j}.$$

Here in (7) for completeness we allow the ω_j coefficients to depend on the information set, thus introducing the possibility that orders may be canceled before delivery or that the gestation lag is influenced by the evolution of the economy between time periods $t - j$ and t.[7] Thus it appears that the Abel/Blanchard assumption that $\sum_{j=0}^{n} \omega_j = 1$ is unrealistically restrictive.

It is obvious from inspection of equations (4) through (7) that in principle it is not possible to identify structural coefficients on current and lagged economic aggregates in an aggregate investment equation, because any of those aggregates could be playing double, triple, or even more complex roles as ingredients in the information sets Ω_t. The reduced form involves complicated convolutions of the variables en-

6. To be consistent with the rest of the formulation, the term "K_{t+n-1}" in equation (6) should be an expectation, not an actual value. This approximation is adopted to simplify the reduced-form equation in (8) below.

7. As an example, airlines that ordered the Boeing 757 and 767 aircraft in 1978 reacted to the previously unexpected period of poor profits that occurred during 1980–82 both by canceling part or all of their orders and by "stretching out" the delivery period. American Airlines initially ordered both the 757 and the 767, but it canceled its entire order for 757 aircraft. United Airlines has stretched the delivery dates on half of its 767 order by up to five years and has finally canceled that half.

tering the information set, which appears in five places in the reduced form:

$$(8) \quad I_t = \sum_{j=0}^{n} \omega_j(\Omega_t)\{\lambda[E[r_{t+1}|\Omega_t)][\alpha(1 - \sigma)$$
$$\sum_{i=0}^{\infty} \sigma^i E(F[X_{t+n+i}, (C/P)_{t+n+i}]|\Omega_t) - (1 - E(\theta|\Omega_{t-j-1}))K_{t+n-j-2}$$
$$- I_{t+n-j-1}] + E(\theta|\Omega_{t-j})K_{t+n-j-1} + \xi_{t-j}\}.$$

The research by Abel and Blanchard (1983) provides a good example of the arbitrary assumptions and simplifications needed to achieve identification in a model like equations (4) through (7). Their problems occur despite a much simpler framework that differs by (*a*) excluding the rental price from any appearance, even in determining the desired capital stock; (*b*) allowing expectations based on an information set only with regard to the sequence of expected future output; (*c*) allowing only past values of sales to be included in that information set; and (*d*) assuming fixed values of all other parameters. Further, Abel and Blanchard have two additional types of data not available in this historical study of aggregate expenditures: (*e*) separate data on orders and expenditures and (*f*) sectoral data that allow a distinction between aggregate and sectoral sales. Despite these differences, Abel and Blanchard achieve identification of a structural model only by assuming arbitrary fixed values of several parameters, and they find no conclusive evidence for preferring the resulting structural model to the corresponding reduced form.[8]

In our application to a set of aggregate data, the more general model in equations (4) through (7) does not appear to allow the identification of structural parameters. For instance, consider the role of interest rates and stock prices. Both seem to be relevant information for economic agents forming expectations about future output, not to mention future interest rates and stock prices (both components of the Jorgensonian rental price). Yet how is the estimated coefficient on a lagged interest rate variable to be disentangled to allow identification of separate roles that this variable plays in forming expectations in different places in the model in affecting the desired capital stock, in affecting the desired rate of replacement of old capital, and in affecting the desired rate of closing the gap between desired and actual capital?

8. "For the information set containing also aggregate sales, the structural model performed poorly, being unable to explain the relation—or the lack of relation—between investment in a sector and aggregate sales. . . . The model . . . is clearly not structural; some of its maintained assumptions . . . are rejected by the data. Some of the additional assumptions made in estimation . . . are rejected for some of the sectors. Nor are the econometric results overwhelmingly supportive" (Abel and Blanchard 1983, 44).

5.2.3 The Q Approach

The expectations quagmire is inherent in the neoclassical approach, with its identification of key parameters requiring ad hoc exclusion restrictions in the set of variables allowed into the information set influencing expectations. The "pure" Q approach differs from the usual investment accelerator by explaining investment activity on the basis of deviations from portfolio balance, and by assuming from the start that there is no "time to build," that is, that there are no gestation lags, so that $I_t = 0_t$. Net investment activity takes place when marginal Q, the ratio of the increase in the value of the firm from acquiring an additional unit of capital to its marginal purchase cost, exceeds unity. Numerous authors, including Abel (1979) and Hayashi (1982), have derived Q investment functions in the following form that adds lags to allow for delivery or gestation lags:[9]

$$\frac{I_t}{K_t} = \psi_0 + \sum_{s=0}^{S} \mu_s(Q_{t-s} - 1) + e_t. \tag{9}$$

The theoretical derivation involves "marginal Q," which is forward looking and hence unobservable. Actual estimation of (9) involves replacing marginal Q with average Q, the ratio of the market value of firms to the replacement cost of their assets. (Hayashi 1982 has shown that actual and marginal Q are equal under specified assumptions but does not test whether these assumptions are empirically supported.) If (9) is estimated for data on net investment, then the constant term ψ_0 should be zero, since net investment should be zero in the steady state when Q is unity. When data on gross investment are used, then the constant term implicitly measures the depreciation rate. At a Q ratio of unity, the firm should just replace its old capital but should not buy any new capital. More generally, the constant term ψ_0 reflects the mean value of any omitted variables.

Much of the discussion of possible problems in the Q approach relates to measurement errors in either the numerator (market value) or the denominator (replacement cost) of the Q ratio. For instance, firms may not pay attention to every quarterly movement in securities prices, given the possibility of excess volatility in financial markets (Shiller 1981). In addition Hall (1977) and Chirinko (1983b) have emphasized the likelihood of errors owing to the indirect measurement of the value of stocks and bonds and to the fact that the value of a firm's shares depends on everything owned by the corporations—not just their physical capital but also intangible capital, natural resources, goodwill, mo-

9. Hall (1977, 88) shows that with a geometric delivery lag, only the current value of Q enters. In the basic analysis of Abel and Hayashi, only current Q enters, and gestation lags are a special case.

nopoly position, and firm specific human capital. The denominator of the Q ratio is likely to be measured with error because of the absence of a complete inventory of the capital actually in place and the need for approximations that may ignore premature retirements (owing, for instance, to changes in energy prices), and because of mismeasurement of the replacement price of capital owing to inadequate adjustment for quality change.

To date empirical results with the Q model have been disappointing. It does not perform as well in the 1970s as other alternatives (Clark 1979) and yields a relatively low R^2 even when carefully adjusted for tax effects (Summers 1981).[10] One possible problem is illustrated by the increases in energy prices after the two oil shocks of the 1980s. These were followed by a sharp decline in the stock market and in measured average Q, but not by a marked decline in investment. This might reflect a production relation in which capital and energy are substitutes, so that a higher relative price of energy induces new capital investment.

Similarly, an episode of "wage push" that increases the share of labor semipermanently could well reduce the Q ratio for a long time by depressing the numerator much faster than the denominator can adjust. Recall that the denominator is the replacement cost of capital, measured as today's capital goods price index times a perpetual inventory measure of the real capital stock. If the inflation rate is larger than the retirement rate, the denominator of the Q ratio can grow while the numerator is falling. A decline in the stock market can occur when higher prices of labor or energy eliminate the profit earned by old plants, but nevertheless firms may keep operating these plants as long as they contribute more to cash flow than to variable cost (recent examples include dinosaur steel plants recently closed by United States Steel or the Boeing 707s finally grounded by TWA four years after the second oil shock.)

Even if Q could somehow be measured accurately, with a correct measure of capital actually in place used to calculate the denominator of the Q ratio, empirical tests of the theory would run aground on a basic asymmetry in adjustment costs and gestation lags that seems to have been ignored. An increase in Q above unity should induce positive net investment limited only by the size of adjustment costs and delivery lags, but a decrease in Q below unity induces negative net investment subject to a quite different set of adjustment costs. Firms may not retire capital until its cash flow falls to its variable cost, and there may be a

10. The poor postsample performance of the Q approach is illustrated by Clark (1979, 93). Since his article was written, a national accounts revision has substantially raised the level of actual investment for the later 1970s, thus implying an even poorer performance of the Q approach.

long transition period that brings with it the danger of bankruptcy before this variable cost point is actually reached. Firms with little profit making potential and with a near zero value on the stock market may nonetheless have sufficient residual goodwill or monopoly power to be able to keep themselves afloat by issuing debt, as has been so evident in the airline industry. An implication is that a revival of industry fortunes (owing, for instance, to a decline in energy prices) may cause stock prices to soar without setting off an investment boom, as firms concentrate on paying off debt and restructuring their balance sheets.

Such portfolio arrangements can create considerable looseness between stock market movements and investment decisions. The same looseness may occur in part because the evaluation of a company's future formed by firm management differs from that formed by the market. In graduate school we were first exposed to Paul Samuelson's joke that "the stock market has predicted nine out of the last five recessions," and we also have heard much from Modigliani and Cohn (1979) and others about irrationality in market valuations. So it seems no wonder that management should be as skeptical of the market's verdict in making valuations as we economists have been. In a recent survey of six hundred companies, *Business Week* found that 60% of executives responding felt that the "real value" of their company was underestimated by the stock market.[11]

Our criticism of the Q theory has been based on asymmetric adjustment costs and possible irrationality or differences in opinion in market valuations. It is related to the critique by Bosworth (1975), which stresses that firms will pay little attention to Q because the stock market fluctuates excessively whereas investment projects take time to plan and construct. Bosworth's argument is criticized by Fischer and Merton (1984), who deny that managers would ignore the stock market even when granting Bosworth the extreme assumptions that (*a*) there occurs a completely exogenous and irrational decline in the stock market (with an accompanying increase in the expected return on the stock market from 15% to 20%) while (*b*) firm managers' assessments are "completely unaffected by such animal spirits and they know with certainty the true objective probabilities" (that the expected equilibrium real return is 15%; p. 39). Even in such a situation, Fischer and Merton argue, the stockmarket would influence investment, since rational managers would use retained earnings to purchase their own or other firms' shares. Similarly, they would be reluctant to finance new investments by issuing equity at the depressed stock market prices.

No doubt some firms are influenced by such considerations, but others may forge ahead with new investment projects, for at least two

11. See "Companies Feel Underrated by Street," *Business Week*, 20 February 1984, 14.

reasons. First, animal spirits may influence the stock and bond markets differently. The 1973–75 episode of collapsing stock market was accompanied by negative short-term ex post real interest rates and by long-term real bond rates that were relatively low, judged either in terms of the high contemporaneous inflation rate of 1974–75 or by the average inflation rate of the period 1974–81 viewed retrospectively. Thus firms may simply have switched from equity to debt issue. Fischer and Merton would contend that rational managers should have borrowed short term to buy back their shares instead of planning new investment projects, but their view seems to ignore the potentially large costs of postponing investment projects.

Managers face a trade-off between the uncertain capital gains to be made on purchase and subsequent resale of their own shares or those of other firms and the less uncertain losses that would be incurred if (given long lead times and gestation lags) new capacity were not constructed *now* in anticipation of the next period of prosperity and high capacity utilization. The planning and implementation of investment in new plant and equipment may be an ongoing bureaucratic process involving high costs of delay or postponement.

Surely the real world is characterized by both responses, with some firms responding to a stock market slump that they believe is temporary by choosing the buy-back route while others engage in friendly or hostile takeover bids and still others continue with previously planned investment projects. Fischer and Merton may argue correctly that the stock market must make *some* difference to investment expenditures, while we put forth the compatible argument that the stock market may be used as just *one piece of information*, in addition to the traditional factors (expected output, rental prices, etc.). If this is a correct interpretation, then the Q model, by including only the single Q variable, as in equation (9), incorporates arbitrary exclusion restrictions just as does the neoclassical paradigm. When we incorporate looser restrictions into both approaches, they melt together into a generalized reduced form in which output, interest rates, stock prices, the money supply, tax rates, and other variables enter a model like equations (4) through (7) in multiple roles, influencing desired capital, expectations, desired adjustment speeds, and replacement rates.

5.2.4 Household Investment

Household investment is durable goods and residential structures has received much less attention than business investment in equipment and structures.[12] This neglect cannot be justified by the share of household fixed investment in GNP, since this share has been at least as large

12. There are exceptions, however, particularly for residential housing. See deLeeuw (1971), Feldstein (1981), and Polinsky (1977).

as that of business investment throughout the period 1919–83 and has become relatively larger in the past two decades. Perhaps it is the perception that household investment is passive rather than a driving force in business cycles that has kept it in the background. Expenditures on consumer durables and residential structures, rather than being treated on a par with business investment, enter into macroeconomic model building mainly as a channel of transmission of monetary policy episodes of disintermediation and credit controls.

There are many parallels between the models used for consumer expenditure and those used to explain business investment. Both the simple Keynesian consumption/income relation and Friedman's permanent income hypothesis are close analogues to certain variants of the accelerator hypothesis of business investment behavior. Lagged or expected GNP is replaced as an explanatory variable by lagged or expected disposable income in moving from business to consumer investment, but the mechanism remains the same. More recent attempts at modeling the consumer's decision, such as Bernanke (1982), treat optimal durable goods investment within the framework of intertemporal utility maximization under uncertainty. The resulting model closely parallels the "business investment in the presence of adjustment costs" literature that originated with Lucas (1967). All models like Bernanke's either implicitly or explicitly require consumers to form expectations of future values of relevant variables, leading to the same complications (delivery lags, replacement timing) that occur for business investment above in equation (8). As is the case in (8), the estimated coefficients of the relevant time series variables are underidentified convolutions of many structural parameters.

5.2.5 Relation to Other Critiques

Christopher Sims (1980a) presented a critique of traditional econometric models and urged the profession to shift from structural estimation to his atheoretical VARs. In a sense the preceding critique of structural investment equations represents a special case of Sims's more general critique. Both place particular emphasis on the fact that any set of lagged variables may in principle influence expectations of a variable, and that thus there is little justification for many of the exclusion restrictions that are incorporated in traditional econometric models. For instance, there is ample evidence that it is suboptimal to form expectations of real output using only a univariate autoregression, as in most empirical implementations of the neoclassical investment model and in such recent papers as Abel and Blanchard (1983).[13] In

13. Unrealistically restrictive assumptions regarding the set of variables admissible into the information set pervade theoretical papers, not just empirical tests. In a related

contrast, our own recent work (Gordon 1983b) shows that nominal GNP growth is associated with past changes in interest rates, the monetary base, and the money multiplier, with different weights in each postwar decade. And in another paper (Gordon 1982) we showed that, for a given nominal GNP change, real output depends among other things on its own lagged value, lagged inflation, lagged changes in real energy prices, and variables to capture the effects of government price control programs.

Despite the preceding critique of traditional investment equations and its similarity to Sims's general critique, there is no need to go as far as Sims in endorsing completely atheoretical VAR models. Consideration of a reduced-form equation like (8), together with the long list of candidate variables that might influence expectations, suggests that degrees of freedom are likely to be exhausted even in a relatively large data set like that used in this paper. VAR models estimated to date usually involve short lists of aggregate variables without including individual categories of expenditure—for example, investment—or special variables that might be important for a particular category.

Gordon and King (1982) recommend an econometric approach that combines the VAR approach with the estimation of reduced-form equations suggested by traditional theory. Both the reduced-form and VAR approaches can be viewed as selecting different methods of allocating zero restrictions in the face of scarce degrees of freedom. As with any trade-off in economics, the best way to allocate these restrictions depends on an assessment of benefits and costs. The VAR technique, in which every variable is included on the right-hand side of every equation with lag distributions of equal length, is a useful tool for checking traditional specifications and determining, for instance, whether stock prices or the money supply "belong" in an investment equation. To repeat a phrase frequently used in oral discussions by Sims, Shiller, and others, the VAR technique is an efficient way to conduct "exploratory data analysis."

But reduced-form econometrics must be guided by prior structural analysis. Excessive pursuit of symmetry in the VAR approach can lead an investigator to omit particular variables that may matter for one equation but not others, for example, variables to measure the effect

---

paper John Taylor (1983) derives a model of investment with gestation lags that shares with equations (4) and (6) the feature that current investment orders depend on expectations of both future output and capital costs. Taylor is not concerned with the identification issues under discussion here, but he does choose to simplify his model, as do Abel and Blanchard, by making expectations of future output depend only on past output, and in addition he makes future capital cost depend only on future and past output. By omitting the multiple roles for past financial variables in determining expectations of all future variables, Taylor thus introduces prior simplifying restrictions that have no empirical justification.

of the wartime price controls in a study of inflation or the investment tax credit in a study of investment behavior. Gordon and King (1982; and in more detail King 1983) have concluded that specifications used in some VAR applications have been cavalier about detrending and have tended to yield estimates that mix secular and cyclical effects and can result in biased coefficients.

The general Simsian critique, and our particular critique of the investment literature, seems to point to estimation of highly unrestricted and unconstrained specifications. Both appear to move in the opposite direction from econometric work set in motion by the Lucas (1976) critique, which has embarked on the task of estimating parameters "at deep levels of choice—for example, parameters of utility and production functions—that remain invariant in the face of changes in policy rules. As yet this line of research, represented, for instance, by Hansen and Singleton (1982), has not yet provided convincing time series characterizations of the major macroeconomic variables that might be compared with traditional explanations. Further, applications of the Hansen/Singleton methodology appear to achieve "identification via an 'incredible' disturbance assumption," according to a recent critique by Peter Garber and Robert King (1983).

5.2.6 The Hybrid Methodology: Blending Structure with VAR Reduced Forms

The central role of investment fluctuations in business cycles has spawned an enormous number of papers that estimate structural investment equations in which unconvincing simplifications and exclusion restrictions have been introduced to achieve identification. Often the focus is on persuading the reader that the author's favorite explanatory variable is statistically significant, or that some other author's favorite variable is insignificant. Our skepticism regarding the multiple roles played by aggregate time series variables, and our doubt that any proxy for Tobin's Q can adequately summarize all the influences on investment appropriations and expenditures, leads us to estimate reduced-form equations. Our point of departure is a list of "candidate" explanatory variables that has been suggested in previous theoretical research. Our basic emphasis is on determining which variables play an important role in the investment process and how much of the variance of investment remains to be attributed to "innovations."

The methodological approach adopted here is similar to that previously applied to the econometric explanation of inflation behavior. This line of research has proved fruitful in developing an inflation equation that over the postwar period appears to remain relatively stable and that, when estimated for the period before 1981, seems able to track reasonably well the sharp disinflation that has occurred since then.[14] Insights of previous structural models are used to develop the list of explanatory variables and to emerge with a specification that introduces a few more constraints than typically appear in "pure" VAR models. The equation can be used to test for the exogeneity of particular sets of lagged variables in the inflation process, for temporal stability, and for biases in one set of coefficients that result from the omission of another variable. They can be used to identify significant shifts in sets of lagged coefficients between one period and another. However, what has been lost in the inflation equation literature, and cannot be regained, is the ability to use particular coefficients to identify specific aspects of the behavior of labor markets as opposed to product markets.[15]

The specification of the investment equation in this paper begins with the lagged dependent variable. Just as we are interested in "inflation inertia," we are interested in "investment inertia." The serial correlation properties of the investment process, which result at least in part from aggregation over heterogeneous projects having different gestation lags, are part of the basic "propagation mechanism" by which random shocks in the demand for investment goods are translated into business cycles displaying persistence in the deviation of output from trend. Most previous econometric work on investment, whether based on a neoclassical specification like equation (3) or a Q specification like (9), has omitted the lagged dependent variable. If the "true" investment process exhibits a high degree of positive serial correlation, then estimated coefficients are likely to be biased when the lagged dependent variable is omitted. Although we exhibit evidence of the effects of this misspecification below, the nature of the bias can be illustrated in the following simple model. Imagine that the true model of investment spending (I_t) involves both an accelerator effect on the lagged change in output (ΔX_{t-1}) and dependence on the lagged dependent variable (I_{t-1}):

$$I_t = \beta \Delta X_{t-1} + \rho I_{t-1} + e_t, \tag{10}$$

while the misspecified regression that is actually estimated is:

$$I_t = b \Delta X_{t-1} + u_t. \tag{11}$$

By the usual analysis of specification error in the case of a left-out variable, we can write the expectation of the estimated accelerator coefficient as:

$$E(\hat{b}) = \beta + \gamma \rho, \tag{12}$$

14. An assessment of the 1981–83 "disinflation experiment" using the DRI model and a reduced-form approach is presented in papers by Eckstein (1983) and Gordon (1983a, 1984b). A detailed quantitative review of the performance of my equation in postsample dynamic simulations is provided by Perry (1983).

15. See Gordon (1977) and Sims's comments in the printed discussion of that paper.

where γ is the coefficient of the "auxiliary" regression of lagged investment on the lagged change in output. Since investment is *part* of output, there is a presumption that γ is positive, although a precise expression for γ requires a more complete specification of the time series process generating noninvestment output. A full analysis of this problem would also need to take account of the fact that most empirical accelerator equations include a set of current and several lagged ΔX terms. It is sufficient here to note simply that tests of the accelerator hypothesis may yield biased coefficients, as in (12), and that the error term in (11) is quite likely to exhibit serial correlation, since it is related to the "true" error term e_t as follows:

$$(13) \qquad u_t = e_t + \rho[(1 - \gamma)I_{t-1} + \gamma I_{t-2} - \gamma \Delta N_{t-1}],$$

where N is noninvestment output.

The list of regressors for our investment equations, in addition to the lagged dependent variable, begins with the two central variables in the neoclassical approach, the change in output and in the real price of capital services (C/P). Tobin's Q is included as well, in combination with the neoclassical variables rather than alone as in equation (9). Because changes in the money stock may be relevant for the formation of expectations and/or as a proxy for the effect of credit rationing, these are included as well. The most important variables that are omitted are the prices of other inputs besides capital, for example, the real wage and real energy prices. This omission is justified by the need to control the scale of this empirical investigation, which tends to grow with the square of the explanatory variables considered as candidates.

The empirical equations share with the VAR approach the use of unconstrained and relatively short lag distributions and the inclusion of the same number of lags for each explanatory variable, including the lagged dependent variable. In our initial research, as in much other recent VAR research, lag distributions were limited to four quarters. Later we adjusted the lag length to eight quarters for the postwar period, in light of the evidence that the coefficient on the price of capital services for the postwar period is sensitive to an extension of lag length. Contemporaneous values of variables are excluded from the estimated regressions. Subsequently we examine correlations among contemporaneous orthogonalized innovations in a VAR model containing equations for investment and for each of our final set of explanatory variables. At that stage we carry out several "innovation accounting" exercises for two alternative choices of the ordering of contemporaneous errors in the VAR system. As shown by Gordon and King (1982, 212–14), such choices amount to decisions about admitting current variables into the estimating equations.

The specification of the investment equations in this paper differs from most applications of the VAR technique in its correction for heteroskedasticity and in its attention to the form of variables. All real expenditure series are normalized by "natural real GNP" (X^N). The money supply is expressed in *real* terms, since it is entered into an equation for *real* investment expenditures, and it is also normalized by X^N. Our empirical tests also examine shifts in coefficients over time. The precise values of the individual lag coefficients are of no particular interest. Instead, we emphasize exclusion tests on the contribution of all lags of a given right-hand variable, running these tests for both the interwar and the postwar periods. This technique allows us to determine whether the relative contribution of different sets of variables has changed over time. There is no analogy in the paper to the usual search for significant coefficients, since positive and negative results in the exclusion tests are equally interesting.

5.3 Data and Descriptive Statistics

5.3.1 Development of the Basic Variables

This paper investigates the historical behavior of four categories of fixed investment: producers' durable equipment (*PDE*), nonresidential structures (*NRS*), residential structures (*RS*), and consumer durables expenditures (*CD*). Whereas in the previous literature some of these categories have been analyzed with different theories in separate papers, here they all seem amenable to analysis within the same reduced-form methodology. Our inclusion of consumer durables expenditures as part of "investment" creates an overlap in coverage with Hall's paper in this volume (chap. 4).

Quarterly data on the four investment categories for 1947–83 come from the national income and product accounts. Investment and real GNP data for 1919–41 are created by the Chow and Lin (1971) method of interpolation from a variety of sources, as described in the appendix to this chapter. We have been careful to interpolate each component of real GNP on the basis of separate data sources, in order to avoid a spurious correlation between dependent and explanatory variables in this study. The Chow/Lin method is an iterative procedure in which a regression is run to explain a data series available only annually (e.g., real GNP), using as explanatory variables the annual average of one or more series available monthly (e.g., industrial production and real retail sales). In this example the coefficients from the regression are used to create monthly (or in our case quarterly) values for real GNP.

Some investigators have carried out historical studies with raw monthly data rather than interpolated data. Examples include Bernanke (1983b), Sims (1980b), and the papers in this volume by Bernanke and Powell (chap. 10) and Blinder and Holtz-Eakin (chap. 3). This makes sense when comparable monthly data are available for both the interwar and the postwar periods. However, investigators of postwar investment behavior have uniformly used national accounts quarterly data, not monthly data on the industrial production of producer durables and on square feet of nonresidential construction. To achieve comparability in a study of investment, interpolated quarterly data for the interwar period are preferable. Further, to use the raw monthly data would involve discarding the information available in the annual averages for components of real GNP. It seems clear from the literature that the previous absence of quarterly investment expenditure data for the interwar period has caused investigators to limit themselves to the postwar period, and we hope that the availability of the new data set will spur further historical research on investment and other components of real GNP.

All expenditure series, real GNP, the real capital stock, and the real money supply are deflated by the "natural real GNP" (X^N) series, whose the creation is described in Gordon (1984a, appendix C). The basic procedure is to establish a constant "natural rate of unemployment" for the portion of the labor force not engaged as self-employed farmers and proprietors—this natural rate is arbitrarily set equal to the rate estimated for 1954 in a study of inflation dynamics covering the period 1954–80. Then, adjusting for the shrinking share of self-employed proprietors (who are not counted among the unemployed), the corresponding total natural unemployment rate series is used to establish the level of X^N in selected benchmark years (1901, 1912, 1923, 1929, 1949, and 1954). Since actual and natural unemployment are not equal in the benchmark years, an assumed "Okun's law" coefficient of 2.0 was used in calculating X^N for those years, and the values for intervening years were interpolated using logarithms. The deflation by X^N is introduced to avoid heteroskedasticity—the level of X^N rises from $229 billion in 1919 to $1,667 billion in 1983. Use of the X^N series is superior to detrending in a study of business cycles, since detrending for a period like 1929–41 yields an unrealistically low estimate of "normal" conditions.

In addition to data on investment expenditures, this study has developed five other series as possible explanatory variables. All are from original sources, and only the capital stock is interpolated. The others are available monthly.

1. *Capital stock*. This is available as an annual series from the Commerce Department capital stock study for both producers' durable equipment and nonresidential structures. Four concepts are available, gross and net, in current and constant dollars. In this study the net real stock is interpolated quarterly (as described in the appendix). It is used and subsequently rejected as an explanatory variable, and the

net real stock times the current investment price deflator is used as an estimate of the replacement cost of capital for construction of the "Q proxy" described below.

2. *Real money supply and real monetary base.* The "high powered money" series is from Friedman and Schwartz (1970), divided by the interpolated GNP deflator and linked to the corresponding postwar series. The M1 series has been created by Benjamin Friedman back to 1915 on a basis that is consistent with the current (early 1980s) definition.

3. *"Average Q."* First a "Q proxy" series is calculated as an index number, with 1972:2 = 1.0, since the numerator and denominator are in different units. The numerator is the Standard and Poor's 500 stock price index, and the denominator is the replacement-cost net capital stock index described above. This quarterly series is used to interpolate Summers's annual average "conventional Q" series (1981, table 3, col. 1) for the period 1931–79. Data for 1919–30 and 1980–83 are obtained by linking "Q proxy" to the interpolated Summers series in 1931 and 1980.

4. *Real interest rate.* The expected inflation rate used to calculate the real interest rate is typically computed as the predicted value from a simple time series regression including lagged inflation and a few other lagged variables. Invariably this leads to a predicted series in which the main weight is carried by the first lag on inflation, and the result is a highly volatile estimate of the expected inflation rate and the corresponding expected real interest rate relevant for investment decisions. In this study the volatile series produced by this procedure is ignored, and in its place we use a twelve-quarter "rectangular" weighted average of past inflation. Even this arbitrary approximation is flawed, however, because it gives unreasonable values in periods for the first few years after both World War I and World War II. As Gordon has argued previously (1973), rational agents would have treated wars and immediate postwar periods as special episodes, in light of a long history of wartime inflation and postwar deflation. Since there was no trend in prices over the century before World War I, an expected inflation rate of zero is imposed for the interval 1919–24, and the twelve-quarter average is introduced beginning in 1925:1. After World War II the same procedure is used for 1947–49, except that the constant value is set equal to 2.6%, the value of the twelve-quarter average in 1950:1. This series on expected inflation is subtracted from the Baa rate, to reflect the presumed relevance of a less than highest grade interest rate for the average investment decision.

5. *The real price of capital services* (C/P). Standard formulas, shown in the appendix, are used to calculate the real price of capital services from a variety of data sources. The before-tax real borrowing rate is taken to be the real Baa rate, from series 4 above. This facilitates

comparisons of the effects of the full C/P variable as contrasted with that of the real Baa rate, one of the major components of C/P. The depreciation rate included in the estimate of C/P is that which is yielded by an iterative search for the rate that makes the quarterly interpolated capital stock series in (1) above consistent with the published annual capital stock series and our new interpolated quarterly investment series. Tax rates are obtained from published sources, as described in the appendix.

5.3.2 Fixed Investment in Recessions, 1920–82

Descriptive statistics on the variables used in this paper are provided in tables 5.1, 5.2, and 5.3. The first of these calculates the percentage decline in three ratios to X^N over the thirteen recessions in our sample period, five in the interwar period and eight in the postwar period. NBER reference cycles are used throughout, and this creates an inconsistency between the cycle dating procedure actually used (see the chronology paper by Moore and Zarnowitz in this volume, appendix A) and the "growth cycle" concept that would be more relevant given our deflation of real variables by X^N.

Column 1 of table 5.1 shows the percentage decline in the "output ratio" X/X^N, ranging from 40.2% in 1929–33 to only 2.7% in 1960–61. The next three columns exhibit recession declines in the ratio of three different investment magnitudes to X^N—all four types of expenditure, the two "business" types ($PDE + NRS$), and the two "household" types ($RS + CD$), respectively. Leaving aside the mammoth numbers for 1929–33, the largest absolute declines in total investment were in the recessions of 1920–21, 1937–38, and 1973–75, in that order.

The remaining columns of table 5.1 establish the importance of fixed investment behavior as a contributing factor in business cycles. Shown for each cycle is the percentage of the total decline in the X/X^N ratio accounted for by the decline in the ratio of total investment to X^N. While these percentages are quite small for the first two postwar recessions, in other recessions they range from 30% to 78%, with the recessions in which investment played the largest role ranked as 1920–21, 1960–61, and 1980. Interestingly, the relative contribution of investment to the Great Contraction of 1929–33 was less than in all five of the postwar recessions between 1957–58 and 1980. There seems to be no systematic difference between the interwar and postwar recessions in the division of the investment decline betweeen the two business types and the two household types. The two business types accounted for a larger contribution in eight of the thirteen recessions, and the two household types did so in the remainder.

The three right-hand columns display an elasticity concept, measured as the percentage change in the ratios shown in columns 5 through 7

Table 5.1 **Peak-to-Trough Decline in Percentage Ratios to Natural Real GNP: Thirteen Business Cycles, 1920–82**

	Percentage Decline				Share of Total			Elasticities		
Cycle	Real GNP (1)	Four *I* Types (2)	*PDE* + *NRS* (3)	*CD* + *RS* (4)	Four *I* Types (5)	*PDE* + *NRS* (6)	*CD* + *RS* (7)	Four *I* Types (8)	*PDE* + *NRS* (9)	*CD* + *RS* (10)
Interwar										
1920:1 to 1921:2	9.0	7.0	3.3	3.7	77.8	36.7	41.1	3.4	3.4	3.4
1923:1 to 1924:3	4.1	2.1	0.9	1.2	51.2	22.0	29.2	2.1	1.6	2.6
1926:4 to 1927:4	5.5	1.7	1.1	0.6	30.9	20.0	10.9	1.3	1.6	1.0
1929:3 to 1933:1	40.2	16.6	9.4	7.2	41.3	23.4	17.9	1.8	2.0	1.6
1937:2 to 1938:2	11.9	6.5	4.2	2.3	54.6	35.3	19.3	3.0	3.7	2.3
Postwar										
1948:4 to 1949:4	5.3	1.0	2.1	−1.1	18.8	39.8	−21.0	0.8	3.6	−1.7
1953:2 to 1954:2	7.2	0.9	0.6	0.3	12.7	7.8	4.9	0.6	0.8	0.4
1957:3 to 1958:2	5.0	2.3	1.4	0.9	45.8	29.0	16.8	2.2	2.9	1.6
1960:2 to 1961:1	2.7	1.7	0.6	1.1	61.4	20.6	40.8	3.0	2.2	3.7
1969:4 to 1970:4	4.2	1.8	1.1	0.7	43.1	25.2	17.9	1.9	2.2	1.6
1973:4 to 1975:1	8.5	4.7	2.0	2.7	55.2	23.4	31.8	2.2	2.0	2.4
1980:1 to 1980:3	3.6	2.1	0.8	1.3	59.2	22.2	37.0	2.4	1.9	2.9
1981:3 to 1982:4	6.3	2.1	1.4	0.7	34.0	22.8	11.2	1.5	2.0	1.0

divided by the average value of each ratio in the peak quarter of each cycle. An elasticity of unity would indicate that the decline in investment was proportional to its peak-quarter share, that is, that the percentage responses of investment and noninvestment were equal. An elasticity above unity indicates that the contribution of investment to the decline in real GNP was larger than its peak-quarter share in real GNP, and that the contribution of noninvestment must have been smaller. For all four types of investment (col. 8), the elasticities range from 0.6 to 3.7. The elasticity for the Great Contraction is a middle-ranked 1.8, less than in the 1920–21, 1923–24, and 1937–38 interwar recessions and in all five of the recessions between 1957–58 and 1980. At least one example with a low elasticity can be easily explained, the 1953–54 recession in which the dominant depressing influence on real GNP was the post-Korea decline in defense spending. And the relatively high elasticity of household investment in 1980 may reflect the influence of the Carter credit controls.

5.3.3 Means and Standard Deviations

Table 5.2 displays means and standard deviations of the variables used in this paper over thirteen complete trough-to-trough business cycles between 1919 and 1982 and one incomplete cycle between 1938 and 1941. Also shown are averages for the entire interwar period and postwar period. Each cell shows the mean, with the associated standard deviation displayed immediately below in parentheses. The first column shows that on average the X/X^N ratio was considerably higher in the postwar period than the interwar period, and of this 10.3 percentage point difference, 5.2 points are accounted for by the four investment types taken together. Also evident is the much higher standard deviation of the X/X^N and the total real investment series during the interwar period over individual cycles. The regression equations in the subsequent tables of results cover several business cycles in each subsample period, and this implies that regression coefficients depend not just on the quarter-to-quarter variance of the investment series, but also on changes in means across cycles.

In this light it is interesting to note the high means for both types of structures investment that reflect the construction boom of the 1920s, which plays a large role in some nonmonetary explanations of the Great Depresson (see Gordon and Wilcox 1981) and in our analysis below in section 5.5. The ratios to X^N of nonresidential structures were higher in the 1921, 1924, and 1927 cycles than in any postwar cycle. The mean for the 1924 cycle was highest for residential construction, followed by 1949 and a tie between 1921 and 1954. The ratios to X^N of producers' durable equipment and consumer durables show quite a different pattern, with all three of the highest ratios achieved during the period 1971–82.

Table 5.2 Means and Standard Deviations of Basic Variables

	Percentage Ratio to Natural Real GNP									
Cycle Beginning in Trough[a]	Real GNP (1)	Four *I* Types (2)	*PDE* (3)	*NRS* (4)	*RS* (5)	*CD* (6)	Real M1 (7)	Service Price *C/P* (8)	*Q* (9)	Real Corporate Baa Rate (10)
Interwar										
(*1919–41*)	89.8	17.2	4.1	4.4	3.3	5.4	28.0	14.9	147	6.6
	(12.5)[c]	(6.2)	(1.4)	(2.4)	(1.6)	(1.3)	(3.3)	(0.4)	(48)	(3.8)
1919:1	96.4	19.1	5.7	3.1	4.4	6.0	28.7	15.0	104	7.8
	(4.2)	(3.1)	(1.1)	(0.5)	(0.7)	(1.3)	(2.0)	(0.4)	(14)	(0.6)
1921:2	99.1	22.0	4.8	6.5	4.6	6.1	28.5	15.1	115	7.3
	(6.1)	(3.3)	(0.9)	(1.3)	(0.5)	(0.8)	(0.9)	(0.3)	(10)	(0.6)
1924:3	103.4	25.5	5.3	8.0	5.4	6.9	28.7	12.5	156	4.8
	(1.9)	(1.3)	(0.3)	(9.5)	(0.5)	(0.5)	(0.7)	(0.8)	(19)	(0.8)
1927:4	87.8	16.6	3.7	4.9	2.9	5.2	25.5	16.9	186	9.1
	(13.8)	(6.7)	(1.6)	(2.1)	(1.7)	(1.4)	(1.2)	(0.5)	(71)	(4.6)
1933:1	75.8	10.8	2.9	2.1	1.4	4.3	26.1	14.8	153	6.2
	(6.7)	(2.7)	(0.9)	(0.6)	(0.4)	(0.8)	(2.7)	(0.5)	(40)	(5.4)
1938:2[b]	87.0	14.5	3.7	2.8	2.8	5.2	32.6	14.0	133	4.2
	(7.3)	(2.3)	(0.7)	(0.7)	(0.5)	(0.6)	(3.2)	(0.9)	(17)	(0.9)

(*continued*)

Table 5.2 (continued)

Cycle Beginning in Trough[a]	Percentage Ratio to Natural Real GNP: Real GNP (1)	Four *I* Types (2)	*PDE* (3)	*NRS* (4)	*RS* (5)	*CD* (6)	Real M1 (7)	Service Price *C/P* (8)	*Q* (9)	Real Corporate Baa Rate (10)
Postwar										
(*1947–82*)	100.1	22.4	6.3	3.9	4.2	8.0	26.0	15.8	91	3.1
	(3.4)	(1.8)	(0.9)	(0.5)	(0.8)	(1.1)	(9.0)	(2.7)	(24)	(2.1)
1947:1	99.5	21.5	6.4	4.0	4.5	6.7	43.9	11.2	84	0.8
	(1.4)	(0.8)	(0.6)	(0.2)	(0.5)	(0.4)	(2.5)	(0.6)	(12)	(0.1)
1949:4	103.6	21.6	5.7	3.9	4.8	7.1	37.3	13.1	67	0.7
	(2.6)	(1.7)	(0.4)	(0.1)	(0.7)	(0.7)	(1.8)	(0.9)	(2)	(0.6)
1954:2	100.7	21.6	5.5	4.2	4.6	7.3	32.2	15.3	85	1.9
	(2.3)	(1.3)	(0.4)	(0.2)	(0.5)	(0.5)	(1.9)	(0.6)	(6)	(0.1)
1958:2	98.4	20.2	4.9	4.0	4.5	6.8	28.2	16.4	102	2.7
	(1.8)	(0.9)	(0.3)	(0.2)	(0.4)	(0.3)	(0.9)	(0.5)	(6)	(0.6)
1961:1	101.9	22.4	6.1	4.3	4.2	7.8	24.2	16.0	124	3.6
	(2.5)	(1.5)	(0.8)	(0.3)	(0.5)	(0.8)	(1.6)	(1.0)	(12)	(0.4)
1970:4	100.2	24.4	7.0	3.7	4.5	9.2	20.0	16.3	95	3.6
	(2.5)	(1.9)	(0.6)	(0.3)	(0.8)	(0.6)	(1.0)	(0.4)	(12)	(0.2)
1975:1	98.0	23.7	7.3	3.1	3.7	9.6	16.3	16.4	70	3.2
	(2.0)	(1.5)	(0.7)	(0.2)	(0.5)	(0.6)	(0.8)	(0.2)	(4)	(1.2)
1980:3	94.3	22.2	7.5	3.3	2.5	8.8	13.9	22.5	63	7.6
	(2.5)	(1.0)	(0.5)	(0.1)	(0.4)	(0.3)	(0.3)	(1.3)	(3)	(1.0)

[a]Statistics cover quarters from first quarter after trough to next trough.

[b]Through 1941:3 only.

[c]Standard deviations in parentheses.

Another difference between the two structures types and the two equipment types concerns the difference between the interwar and postwar standard deviations. The standard deviations of nonresidential and residential structures fell from 2.4 to 0.5 and 1.6 to 0.8 points, respectively. The standard deviations of producer and consumer durables fell much less, from 1.4 to 0.9 and 1.3 to 1.1, respectively. While nonresidential structures had by far the highest standard deviation in the interwar years, consumer durables had the highest standard deviation in the postwar years.

Additional insight into the behavior of investment spending is provided by figures 5.1 and 5.2. The former displays real GNP (X), total investment (I), and noninvestment GNP (N), each expressed as a ratio to X^N. Here we note the contrast between the volatility of I in the 1920–21 recession and subsequent recovery, and its relative stability during 1923–29. Evident throughout the interwar period is the high positive covariance between I and N; this covariance appears to occur at annual and lower frequencies and is not an artifact of our interpolation procedure. The postwar period is dominated by the large bulge in N during the Korean War, though there is a less pronounced hump in I in 1972–74. Also evident is the downward drift in both X and N relative to I after 1966. The robust health of the I/X^N ratio in the second half of the 1970s suggests the possibility that our average Q variable may perform poorly, in light of its collapse after 1973.

Figure 5.2 exhibits each of the four categories of investment, also expressed as a ratio to X^N. The investment boom of the 1920s and the unusual share of boom contributed by nonresidential structures are clearly visible. The 1930s are characterized by a simultaneous collapse in all four categories, as well as by a milder slump of consumer durables spending. By 1939–40, the two equipment categories had each recovered to within a percentage point of the 1926–29 average, but residential structures had recovered only to about half of the 1926–29 level, and nonresidential structures to less than one-third. Postwar business cycles exhibit a continuing shift from structures to equipment, together with a general tendency for booms in residential structures to lead booms in *PDE*, with consumer durables in between. Cycles in nonresidential structures do not coincide with those in the other four categories, with the appearance of a process involving much longer lags.

Table 5.2 exhibits the means and standard deviations of the major explanatory variables—the real money stock expressed as a ratio to X^N, the price of capital services, average Q, and the real Baa rate. The behavior of these variables is illustrated in figure 5.3, where each is expressed as an index with 1919:1 = 1.0. The most stable variable in both the interwar and postwar periods was real M1, the variation of

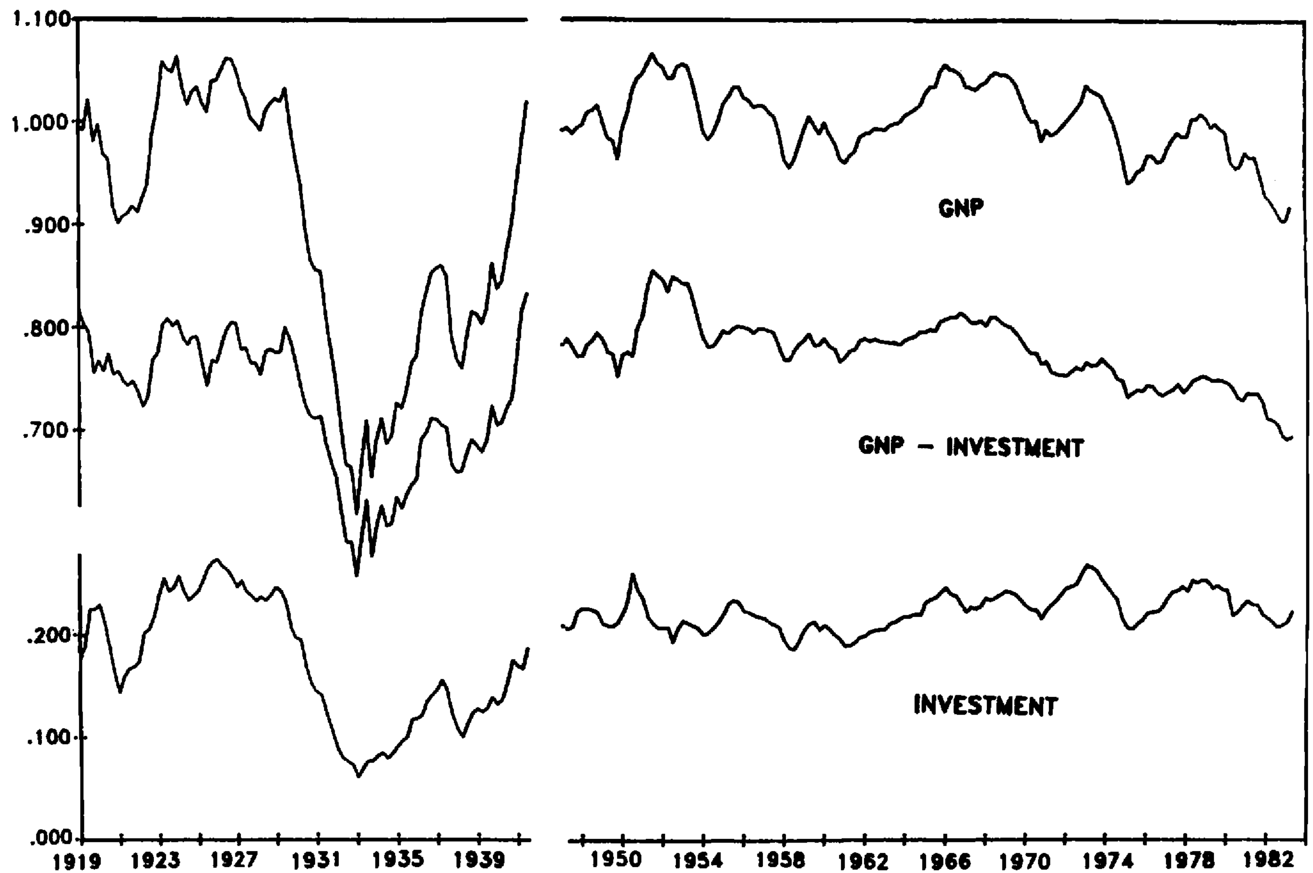

Fig. 5.1 Gross national product and its components.

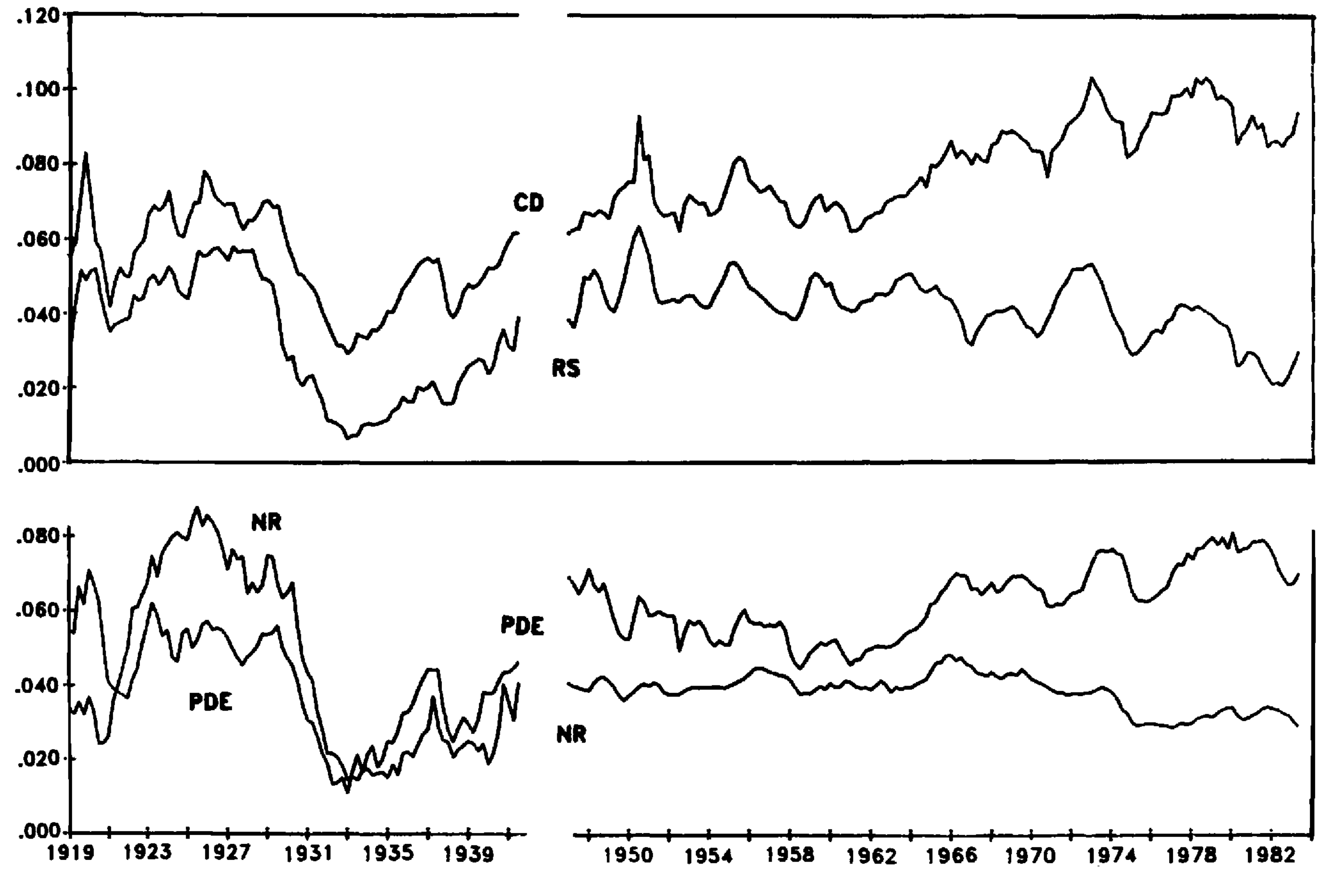

Fig. 5.2 Components of investment.

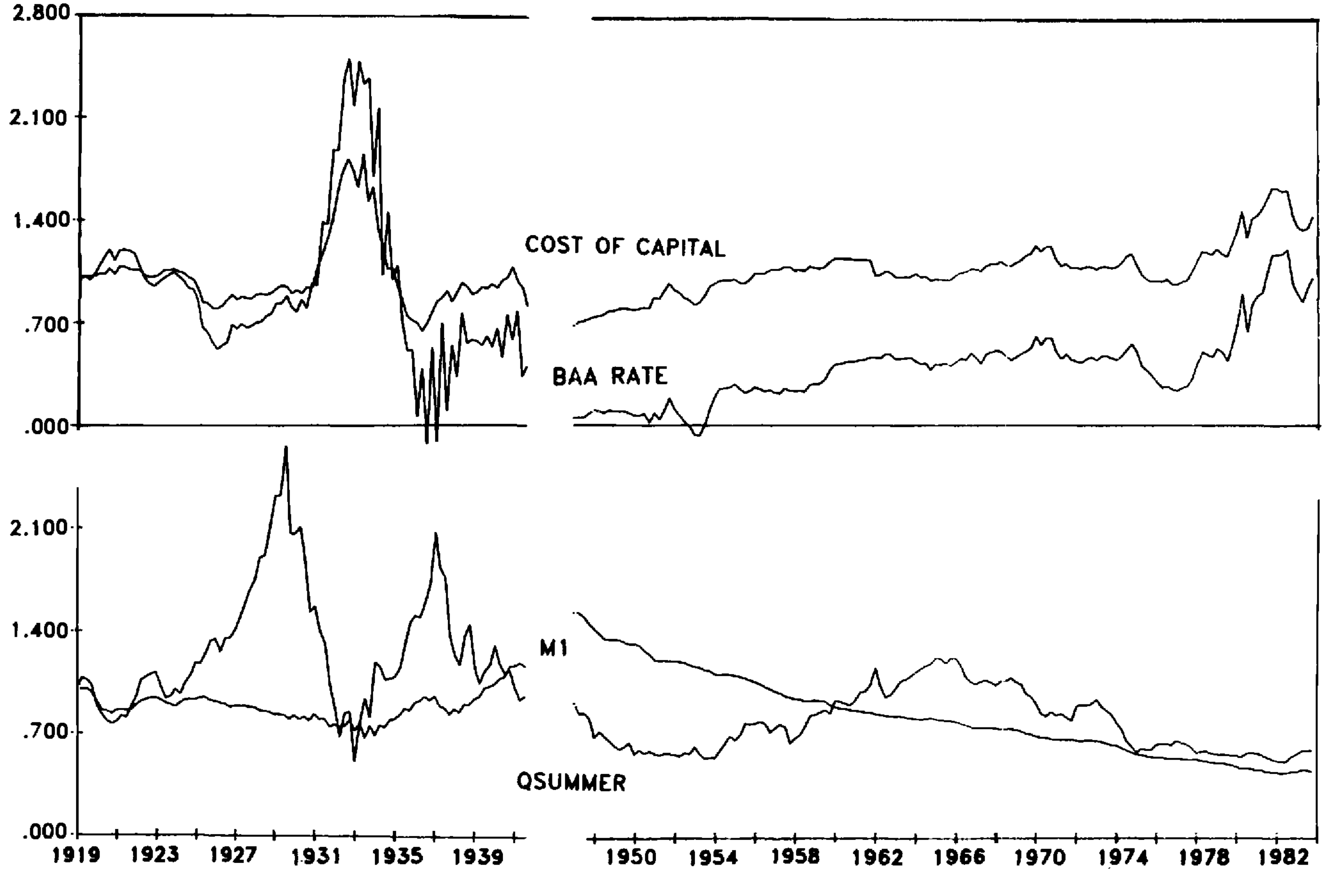

Fig. 5.3 Normalized monetary and financial variables.

which consists of a slight uptrend at the end of the 1930s and a consistent downtrend during the postwar period. The standard deviation of real M1 is smaller than that of total investment within most interwar cycles and is about the same order of magnitude during postwar cycles.

The capital service price has a small standard deviation and little drift. It exhibits two major humps, in response to high real interest rates in 1930–34 and 1980–83. The smaller degree of volatility in the capital service price than in the real interest rate reflects the dominant role in the former variable of a fixed depreciation rate. Both the service price and the real interest rate exhibit minima in 1936–37, 1952–53, and 1975–77, reflecting price increases that are subtracted from the nominal Baa rate. The average Q variable (expressed as a percentage in table 5.2) has a much higher mean in the interwar period than in the postwar. The standard deviation of Q averaged over the interwar period was double that in the postwar, and the average for individual cycles in the interwar period was more than four times higher than the average for individual postwar cycles.

The regression analysis in the next part of the paper compares the differing relative contributions of lagged investment and lagged GNP in explaining current investment. As a preliminary, we present a decomposition of variance of the ratios to X^N of real GNP (X), real investment (I), and real noninvestment GNP (N). A familiar formula linking the variances of these three variables is:

$$\text{var}(X) = \text{var}(I) + \text{var}(N) + 2\text{cov}(I,N). \tag{14}$$

The top half of table 5.3 presents a decomposition of variance as in (12) for the interwar and postwar periods, and for the two halves of the postwar. The bottom half of the table exhibits a parallel decomposition for the four components of total investment.

The enormous decline in the variance of all components in the postwar period is immediately apparent. There is no decline, however, in the ratio var(I)/var(X), which is slightly higher in 1947–65 and 1947–83 than in 1919–41. The most interesting contrast between the interwar and postwar periods is in the covariance term. The positive covariance between I and N contributes almost half of the total variance of real GNP in 1919–41, whereas it contributes a negligible fraction in 1947–65 and is actually negative in the postwar period taken as a whole. One may conjecture that whereas the interwar period was dominated by the cyclical behavior of private spending, much of the variance of noninvestment in the postwar period was contributed by government spending. The negative covariance of I and N in the postwar period may suggest that investment was "crowded out" by major increases in government spending.

The bottom half of the table shows that about two-thirds of the total variance of investment in the interwar period was contributed by the

Table 5.3 **Decomposition of Variance: Real GNP, Investment, and Noninvestment, Percentage Ratios to Natural Real GNP**

	1919:1 to 1941:3	1947:1 to 1965:4	1966:1 to 1983:4	1947:1 to 1983:4
Total real GNP				
Variance (*X*)	157.4	7.3	15.8	12.0
Variance (*I*)	38.9	2.0	2.2	3.2
Variance (*N*)	45.7	4.9	10.6	11.2
2 covariance (*I*, *N*)	72.8	0.4	3.0	−2.4
Variance (*I*)/variance (*X*)	0.25	0.27	0.14	0.27
Variance (*N*)/variance (*X*)	0.29	0.67	0.67	0.93
Four types of investment				
Variance (*I*)	38.9	2.0	2.2	3.2
Variance (*PDE*)	2.0	0.4	0.3	0.9
Variance (*RS*)	2.7	0.3	0.6	0.6
Variance (*NRS*)	5.7	0.1	0.3	0.2
Variance (*CD*)	1.6	0.4	0.4	1.4
Residual covariance terms	26.9	0.8	0.6	0.1

covariance term, that is, a shock common to all investment types rather than to only one. In the two halves of the postwar period the covariance terms contribute less than half, and they contribute virtually nothing for the postwar period taken as a whole. The largest "own variance" in the full postwar period is for consumer durables, but the smaller value of this term for the two separate halves of the postwar period indicates the dominance of a trend effect. Nonresidential structures shifted from contributing the largest own variance in the interwar period to the smallest in the postwar period.

5.4 Regression Equations Explaining Total Investment Expenditures

5.4.1 Will the Real Accelerator Please Stand Up?

The starting point of our hybrid methodology is to determine the specification for a reduced-form investment equation that seems "reasonable" a priori. Our goal is then to use the estimated reduced-form equations to suggest "data coherent" ways of moving to more structural models and interpretations. In arriving at such interpretations, we recognize the conventional wisdom that many structural models may imply the same reduced form. However, there is a similar problem with structural models. Quite dissimilar "structural" models may result when the same general economic phenomenon is interpreted by different authors.

For example, a starting point in many studies of investment behavior, and an ending point in some, is the accelerator hypothesis. In its simplest form, dating back to Clark (1917), it explains the level of real investment as a function of the change in real GNP. But this apparently straightforward idea does not imply a single "structural" specification. The change in real GNP may enter only as a current value or as a combination of current and lagged values. Or the investigation may start from the "flexible accelerator" hypothesis, in which investment depends on the current level of output and one lagged value of the capital stock. Or one might adopt a more general dynamic specification, as in table 5.4 below, that allows several lagged values of investment to enter as well as current and lagged changes in output. Since the coefficient on lagged investment turns out to be roughly unity, this last alternative amounts to a regression explaining the *change* of investment spending, in which case the accelerator hypothesis would call for the output variable to enter as a *second* difference. A rational expectations approach to the accelerator, as in Abel and Blanchard (1983), would imply a reduced form in which levels of *expected* future output appear, rather than lagged values. These expectations may be functions of many variables in addition to lagged output. An extreme version of the expectational approach to investment behavior might lead to the conclusion that investment is a random walk, parallel to Hall's (1978) interpretation of consumption as a random walk.

All these models are merely alternative formulations of a single underlying structure, the accelerator mechanism. However, each model results in a different specification for the appropriate reduced-form equation. This proliferation of structural models is also a problem with the other mechanisms that are claimed to be important for explaining investment, for example, the Q approach. To avoid losing sight of our objectives by examining a multitude of different formulations, we choose to set up "straw man" reduced forms that are relatively unrestricted and allow alternative explanatory variables suggested by alternative theories to enter on equal terms.

5.4.2 Contribution of the Accelerator and the Cost of Capital

We begin by examining reduced-form regressions for each of the four individual categories of total investment: consumer durables, residential structures, producers' durable equipment, and nonresidential structures. We begin at a disaggregated level and subsequently study the consequences of alternative aggregation schemes. In table 5.4 and later tables, the full sample period of available quarterly data is divided into 1919–41 and 1947–83. In preliminary work a break was allowed in the middle of the postwar period at 1965, but Chow tests rejected the hypothesis of a structural change for most equations, and so here the postwar period is treated as a single entity. There are insufficient degrees of freedom available to test for a structural break within the interwar period at 1929. Chow tests indicate a decisive break in structure at World War II.[16]

Our reduced-form equations omit the lagged capital stock (K_{t-1}) term, which appears in (3), for two reasons. First, an identity links the lagged capital stock and lagged investment, precluding an investment equation containing several lagged values of investment from also including several lagged values of the capital stock. Second, although a single lagged value of the capital stock may appear, preliminary tests indicated statistical insignificance in every sample period.

Tables 5.4 and 5.5 are each arranged in two sections, corresponding to the two sample periods (interwar and postwar). Each cell in the tables contains results for each of the four categories of investment spending in the following format: the first line of each section gives the sum of coefficients with its significance level, and the second line exhibits the significance level for an F-test on the exclusion of all lags of that explanatory variable. A blank on the second line indicates that the .10 level of statistical significance was not attained.

The first line for each investment type in tables 5.4 and 5.5 presents the regression results for what might be termed a "naive accelerator/cost of capital" specification of the investment equation. The log level of investment spending (I/X^N) is regressed on eight lagged first differences of real noninvestment GNP, $\Delta N/X^N$, and eight lagged values of first differences of the appropriate real cost of capital series ($\Delta C/P$). In the regressions involving household investment in table 5.5, real personal disposable income, $\Delta Y^D/X^N$, replaces real GNP, and eight lags of the first difference of the real Baa interest rate are used as a proxy for the price of investment. In line 1 both the $\bar{R}^2$ and Durbin-Watson statistic are very low for all categories over all periods, indicating a poor fit and serially correlated errors. The "accelerator" variable passes the exclusion test only for producers' durable equipment in the interwar period and for residential structures in the postwar. An even poorer showing is exhibited by the "cost of capital," which passes the exclusion test only for postwar residential structures.

Line 2 in each block is identical to line 1, except that four lags of the dependent variable are included as additional regressors. The results from these regressions further weaken the case for the accelerator and the price of investment. For all categories and all sample periods the lagged dependent variables terms enter significantly at the .01 level.

16. Recall that quantitative controls during World War II preclude a meaningful analysis of investment behavior during that period. Further, some of the series used for our data interpolation are not available after 1941; thus our data series have not been created for the 1942–46 interval.

Both the accelerator and the price of investment become insignificant for most types and sample periods. While the accelerator variable has explanatory power for postwar producer durables, and for consumer durables in both periods, the sums of the coefficients are insignificantly different from zero in every equation. Overall this formulation of the two traditionally dominant explanations of investment behavior fares poorly in both the interwar and the postwar periods.

5.4.3 Contribution of Q and Real M1

Since the sum of coefficients on lagged investment in line 2 of each block is close to unity, the equation amounts to an explanation of the behavior of the first difference of investment. To be consistent with the first difference format, in line 3 the accelerator is expressed as the first difference of the first difference of real noninvestment GNP, $\Delta\Delta N/X^N$, and the remaining explanatory variables are entered as lagged values of their first differences. Noninvestment GNP and the cost of capital or interest rate terms enter with eight lags, while the remaining explanatory variables enter with four lags. Our measure for Tobin's average Q has no significant explanatory power, except for postwar nonresidential structures, and as often as not enters with the wrong sign. The change in C/P continues to be insignificant in the exclusion tests, although the sum of coefficients is significantly negative for the two durables categories in the postwar period.

Previous research by King (1983) and Sims (1983) has emphasized a distinction between the role of inside and outside money as a determinant of real output. In the work of King this distinction is implemented by entering the two multiplicative components of M1, the money multiplier and monetary base ($M1/P = m(B/P)$), separately in VAR models for total output. We can investigate the same issue here and inquire whether the effect of monetary changes on investment occurs through the multiplier, the base, or a mixture of the two. The first difference specification for the explanatory variables suggests that we should split the change in M1 into the level of the multiplier times the first difference in the base ($m\Delta B/P$), and the level of the base times the first difference in the multiplier ($B/P\Delta m$). Both components enter significantly into the equations for producer and consumer durables, interwar and postwar. The change in the money multiplier has moderate explanatory power for both structures categories in the postwar period, as well as for nonresidential structures in the interwar period.

5.4.4 Other Specifications

The final reduced-form specification appears in line 3 or 4 of each block. The specification in line 4 differs from that in line 3 only in

Table 5.4 **Equations for Business Investment: Interwar and Postwar Sample Periods**

	Explanatory Lagged Variables									
	I (1)	Δ*N* (2)	ΔΔ*N* (3)	Δ*C*/*P* (4)	Δ*Q* (5)	*m*Δ*B*/*P* (6)	*B*/*P*Δ*m* (7)	$\bar{R}^2$ (8)	SEE (9)	DW (10)
1921:2 to 1941:3										
Producer durables										
1.		.95*** *		.16				.08	1.26	.181
2.	.96*** ***	−.06		−.09				.93	0.34	
3.	.92*** ***		−.03	.14**	.01**	.36*** ***	.57*** ***	.96	0.28	
4.	.93*** ***		−.14 *		.01*	.27*** ***	.34*** ***	.95	0.29	
Nonresidential structures										
1.		.56		.09				−.19	2.70	.048
2.	.98*** ***	.09		−.07				.96	0.51	
3.	.93*** ***		.30	.17	−.00	.12	.82**	.96	0.48	
4.	.95*** ***		.19		−.00	.05	.46**	.96	0.47	

1949:2 to 1983:4										
Producer durables										
1.		.07		−.25				−.11	1.03	.057
2.	.98***	.08		−.27***				.95	0.21	
	***	***								
3.	1.00***		.51***	−.22**	.02	.39**	.55***	.96	0.19	
	***		***			**	***			
Nonresidential structures										
1.		.30**		−.30*				−.02	0.486	.066
2.	.97***	.01		−.04				.96		
	***									
3.	.98***		.02	−.01	.01***	.06	.20***	.97	0.085	
	***				***		*			

Note: Numbers shown in each cell are sums of coefficients, and asterisks next to these numbers indicate significance levels of the sums (* for .10, ** for .05, and *** for .01). Asterisks below the numbers indicate with the same notation the joint significance of all lags in an exclusion test. All equations include, in addition to the listed variables, a constant term. Durbin-Watson statistics are now shown for equations containing lagged dependent variables.

Table 5.5 **Equations for Household Investment: Interwar and Postwar Sample Periods**

	Explanatory Lagged Variables									
	I (1)	ΔY^D (2)	$\Delta\Delta Y^D$ (3)	Δr (4)	ΔQ (5)	$m\Delta B/P$ (6)	$B/P\Delta m$ (7)	$\bar{R}^2$ (8)	SEE (9)	DW (10)
1921:2 to 1941:3										
Consumer durables										
1.		.64***		.12				.08	1.22	.102
2.	.97*** ***	.04 **		−.09 *				.95	0.28	
3.	.94*** ***		.00	.08 *	.002	.23** *	.46** *	.96	0.26	
4.	.96*** ***		.07		.002	.21** *	.34** *	.95	0.28	
Residential structures										
1.		.48*		.21				−.16	1.79	.072
2.	.98*** ***	−.00		−.08				.96	0.31	
3.	.98*** ***		−.11	−.06	−.12**	.11	.33	.97	0.31	
4.	.96*** ***		−.21	.05		.15	.34	.96	0.31	

1949:2 to 1983:4										
Consumer durables										
1.		.91*		.17				−.06	1.18	.098
2.	.97*** ***	−.13 **		−.31				.92	0.33	
3.	.95*** ***		.56	−.46**	−.00	.86*** **	1.27*** ***	.93	0.30	
4.	.96*** ***		.60* *	−.47**		.83*** ***	1.23*** ***	.93	0.30	
Residential structures										
1.		.84*** ***		−2.24*** ***				.22	0.72	.231
2.	.94*** ***	−.08 *		−.20*				.95	0.18	
3.	.93*** ***		−.03	−.22*	−.004 *	.02	.22 ***	.96	0.16	
4.	.92*** ***		−.05	.22*		−.05	.12 ***	.96	0.16	

Note: See note to table 5.4.

excluding variables that are significant but have the wrong signs. Both the accelerator and the price of investment are included along with average *Q* and the monetary variables. The accelerator variable is significant only for postwar producers' durable equipment. We experimented with alternative specifications of the final reduced form in order to check the robustness of our results. In these tests the cost of capital term in the business investment equations was replaced by the real Baa rate, but this rate was never significant and as often as not carried the wrong sign.

A variant of the "expectational accelerator" was also estimated by a two-stage procedure. Time series models for noninvestment GNP and personal disposable income were estimated and used to generate *k*-step ahead forecasts. Eight leads of these forecasts, in various transformations, were used as explanatory variables but were always insignificant, often with the wrong sign, for all but postwar producers' durable equipment. This set of results implies that the significant monetary variables in tables 5.4 and 5.5 enter *directly* into the determination of investment spending, rather than *indirectly* through an effect on expectations of future output.

5.4.5 Summary of Disaggregated Results

Perhaps the most surprising result of these initial reduced-form estimates is the small explanatory role accorded conventional variables and the large role given to unconventional variables like the real money supply. The poor showing of the interest rate and cost of capital, combined with the singular importance of average *Q* for nonresidential structures, leads one to suspect that the financing decision is an important determinant of investment expenditures. The broad role played by the money multiplier may indicate that credit rationing, rather than interest rate changes, is the primary constraint in the financing decision. This view is consistent with that expressed in Roosa (1951) as to the dominant channel through which monetary policy affects the economy.

The similarities in the behavior of the two structures and the two durable goods categories suggest that aggregation by asset type rather than by decision maker is preferable. This approach to disaggregation would also be in accord with Tobin's asset approach, insofar as durable goods are normally shorter lived than structures. However, this approach is at odds with the conventional structural approach to investment. With its focus on the investment decision, the traditional approach has always aggregated by decision maker (i.e., household vs. business) rather than by character of the asset (i.e., structures vs. equipment).

5.4.6 Aggregation Schemes

Table 5.6 displays our basic equation for two alternative aggregation schemes, household/business and durables/structures. The household/business aggregation scheme is not particularly successful. In the interwar period both categories appear to be autonomous, with only lagged "own values" passing the exclusion test (as well as the money multiplier in the business equation). Both real monetary variables become highly significant for the two categories in the postwar period. The only difference in behavior between household and business investment appears in the postwar period, when business investment exhibits a strong accelerator effect. If we were to ignore real balance effects, as does most of the literature, then aggregation by decision maker would result in a pair of highly autonomous investment series in the interwar period. Stated another way, this aggregation scheme would indicate that the decision maker does not respond to relevant economic variables.

Aggregation by the asset character of investment leads to more illuminating results. Durable equipment and structures exhibit marked differences in behavior in both sample periods. Structures investment for 1919–41 is quite autonomous, but durables expenditures exhibit sensitivity to interest rates (with the wrong sign) and to real monetary variables. More important is the finding that real money balances are highly significant in explaining both investment categories in the postwar period. Durable goods are sensitive to the accelerator and interest rates (with the correct sign), whereas structures depend significantly on the average Q variable. This result may indicate the importance of the different financing methods that are used for equipment and structures. One might think of short-lived assets as financed to a large extent by internally generated funds, that is, retained earnings and disposable income, while investment in structures may depend heavily on conditions in the bond and security markets.

Using the alternative aggregation criterion of asset durability produces the most sensible results in table 5.6. Investment behavior is found to differ between short- and long-lived assets in a way that is statistically significant. The accelerator and the Baa rate are both important for investment in durables, while structures (dominated by the nonresidential category) respond to average Q. These results provide evidence supporting the importance of financial conditions for investment decisions. What is surprising is the way the conventional investment literature, with its emphasis on the business investment decision, has overemphasized disaggregation by decision maker and has glossed over the importance of the asset characteristics of investment and the role of real monetary variables.

Table 5.6 Equations for Alternative Aggregation Schemes: Interwar and Postwar Sample Periods

	Explanatory Lagged Variables									
	I (1)	$\Delta\Delta N$ (2)	$\Delta\Delta Y^D$ (3)	Δr (4)	$\Delta C/P$ (5)	ΔQ (6)	$m\Delta B/P$ (7)	$B/P\Delta m$ (8)	$\bar{R}^2$ (9)	SEE (10)
1921:3 to 1941:3										
Household	.96*** ***		−.18	.07		−.01	0.27*	0.75**	.98	.442
Business	.95*** ***	.26			.23	.01	0.41	1.11** *	.97	.647
Durables	.91*** ***	−.22		.32** **		.01	0.48*** ***	1.07*** ***	.97	.430
Structures	.94*** ***	.43		.14		−.01	0.27	1.36**	.97	.754
1949:1 to 1983:4										
Household	.86*** ***		.31	−.77***		−.02 *	1.16*** ***	1.96*** ***	.89	.399
Business	1.01*** ***	.46** ***			−.24**	.03** ***	0.45 ***	0.74***	.94	.222
Durables	.98*** ***	.81** ***		−.97*** **		.02	1.67*** ***	2.23*** ***	.96	.401
Structures	.97*** ***	−.16		−.24		.01 ***	0.16 ***	0.60*** ***	.97	.198

Note: See note to table 5.4.

5.5 Investment in a Vector Autoregression Model

5.5.1 Correlations among Contemporaneous Innovations

The equations estimated in tables 5.4 to 5.6 investigate the feedback from the various lagged explanatory variables to components of investment, but they say nothing about the relationships among contemporaneous innovations in the variables, or about the feedback from investment to the explanatory variables. These issues can be addressed by analyzing a vector autoregression (VAR) system that contains the primary variables of interest. We economize on space by restricting attention to a VAR model containing six variables—real investment in structures (*ISTR*), real investment in durable goods (*IDG*), real non-investment GNP (*N*), the real money base (*B*/*P*), the M1 money multiplier (*m*), and the real Baa interest rate (*r*). For the interwar period the interest rate variable in table 5.6 has the incorrect (positive) sign in the equations for both *ISTR* and *IDG*, leading us to choose a five-variable system omitting the interest rate for 1920–41.

All variables (except *m* and *r*) are once again expressed as ratios to natural real GNP (X^N). To maintain the symmetry required for the VAR system, all variables are expressed as first differences, in contrast to tables 5.4 to 5.6, where investment is expressed as a ratio, output as a second difference, and the other variables as first differences. Extra degrees of freedom allow the inclusion of eight lags on all variables in the postwar period, as opposed to four lags in the interwar period.

Columns in table 5.7 correspond to each of the six variables in the VAR system. A slash (/) divides the interwar result from the postwar result in both the top and bottom sections of the table. The dashes (—) indicate the exclusion of the interest rate in the interwar model. The top section shows correlations among contemporaneous innovations. There is a uniformly high correlation between the two components of investment, *ISTR* and *IDG*. Another similarity between the interwar and postwar periods is the positive correlation between the money multiplier (*m*) and both *ISTR* and *IDG*, the negative correlation between *IDG* and the monetary base (*B*/*P*), and the high negative correlation between the base and the multiplier. Perhaps the most important difference between the interwar and postwar periods is the sharp decline in the correlation of durable goods investment (*IDG*) with non-investment GNP (*N*). This is similar to the decomposition of variance in table 5.3 above and may indicate that *N* in the interwar period is dominated by a common impulse to private spending that also influenced *IDG*, whereas in the postwar period *N* was more affected by defense expenditures in the Korea and Vietnam periods that had no impact or even a negative impact on *IDG*.

Table 5.7 **Correlation Coefficients and Exogeneity Tests in Basic VAR Models (Interwar/Postwar)**

	Δ*ISTR* (1)	Δ*IDG* (2)	Δ*N* (3)	Δ*B/P* (4)	Δ*m* (5)	Δ*r* (6)
Correlations						
Δ*IDG*	.35/ .35					
Δ*N*	−.04/ .09	.51/ .04				
Δ*B/P*	.09/ .18	−.17/−.17	−.29/ .17			
Δ*m*	.19/ .25	.24/ .28	.30/−.07			
Δ*r*	—/−.26	—/−.15	—/−.00	−.54/−.39	—/−.21	
				—/−.30		
Exogeneity Test						
Δ*ISTR*	/	/	*/	/	/**	—/
Δ*IDG*	/**	**/***	/***	***/**	**/**	—/*
Δ*N*	/	/	/*	**/***	/	—/***
Δ*B/P*	/	/	/	***/***	***/**	—/
Δ*m*	/*	/	/	/**	*/***	—/
Δ*r*	—/	—/	—/	—/	—/*	—/

Note: Asterisks designate significance levels of .10 (*), .05 (**), and .01 (***). Blanks indicate that the interest rate is excluded from the model for the interwar period.

The correlations of the base and the multiplier with noninvestment GNP change signs in the postwar period. This is suggestive of a change in the behavior of monetary policy between the two periods. Another "structural" shift is suggested by the change of the coefficient of the interest rate on *IDG* from positive (shown in table 5.6 but not table 5.7) to negative. This should be interpreted in conjunction with the sharp decline in the correlation of *N* and *IDG* in the postwar period. These facts may indicate that durable goods expenditures in the interwar tended to be more constrained by income or retained earnings, whereas in the postwar period the availability and price of credit was relatively more important.

5.5.2 Multivariate Exogeneity Tests

The bottom section of table 5.7 displays significance levels for the contribution of each explanatory variable in each equation. Explanatory variables are represented by the six columns, and dependent variables by the six lines. Asterisks denote the same significance levels as in tables 5.4 to 5.6 and are calculated from *F*-ratios on the joint exclusion of all lags of a particular variable. Often such tables reveal a highly significant set of diagonal elements, reflecting highly significant lagged dependent variables in the VAR equations. This occurs here only for *IDG*, *B/P*, and *m*. The insignificance of the other diagonal elements may reflect the fact that all variables in the model are expressed as first differences.

Investment in structures appears to be relatively exogenous in both periods, with modest feedback from noninvestment GNP in the interwar and the money multiplier in the postwar. Durable goods investment exhibits substantial feedback from several variables in either period or both, and in this sense is much less "autonomous" than investment in structures. The pattern of monetary influences on *IDG* and *N* differs. While *IDG* reflects significant feedback from the base and the multiplier in both periods, *N* reflects feedback from the base in both periods, the interest rate in the postwar period, and the multiplier in neither. A notable feature of the pattern of exogeneity is the independence of the money multiplier and the interest rate from almost all the other variables. In the postwar period the interest rate is totally independent of all the remaining variables, feeding into only *IDG* and *N*. The channel of influence from the interest rate to investment, if any, appears to be indirect, running through noninvestment GNP, with only a weak direct effect in the postwar period. The pattern of these exogeneity results may suggest the existence of two impulse sources in the business cycle, one financial (interest rates and money multiplier) and the other real (investment in structures), whose effects interact through the propagation mechanism represented here by the remaining variables.

5.5.3 Innovation Accounting

VAR modeling techniques are often criticized for the ambiguity inherent in the a priori ordering of the variables necessary to carry out the usual "innovation accounting" exercise. However, the allocation of the variance of the investment categories between "own" innovations and innovations in other explanatory variables is of interest in any investigation of the role played by investment in business cycles. As with our choice of aggregation schemes, we allow our earlier empirical results to suggest "appropriate" orderings of the variables. The equations estimated in table 5.6 suggest that investment in structures is quite autonomous, a result reinforced by the exogeneity tests of table 5.7. Our basic model, as it appears in the top half of table 5.8, places structures (*ISTR*) first in the ordering, followed by investment in durables (*IDG*). Gestation lags in both types of investment make it plausible that at least one quarter is required before investment spending can be influenced by changes in noninvestment real GNP (*N*), the real base (*B*/*P*), the multiplier (*m*), or interest rate (*r*). Although our empirical results cast doubt on other ordering schemes, a priori notions about the importance of autonomous government spending in the postwar period might suggest an ordering with noninvestment real GNP first, followed by investment in structures, then durables. Results for this ordering appear in the bottom half of table 5.8. The interest rate

Table 5.8 **Innovation Accounting at Sixteen-Quarter Forecast Horizon in Two VAR Models (Interwar/Postwar)**

Dependent Variable	Δ*ISTR* (1)	Δ*IDG* (2)	Δ*N* (3)	Δ*B*/*P* (4)	Δ*m* (5)	Δ*r* (6)
Δ*ISTR*	76.8/58.0	4.4/ 4.2	7.7/ 5.6	3.3/ 2.8	7.8/22.5	—/ 7.0
Δ*IDG*	13.2/15.8	44.4/45.4	10.0/ 8.1	8.3/ 5.2	24.1/11.7	—/13.7
Δ*N*	7.8/10.0	20.9/ 3.3	47.6/56.6	10.5/ 6.7	13.2/10.4	—/13.0
Δ*B*/*P*	6.7/ 4.8	4.9/ 7.3	11.7/ 7.1	63.0/68.6	13.7/ 8.3	—/ 3.9
Δ*m*	13.2/ 7.4	8.6/ 5.4	13.5/ 6.5	24.7/20.5	40.0/49.4	—/10.8
Δ*r*	—/10.3	—/ 7.1	—/ 2.2	—/ 7.4	—/11.0	—/62.0

Dependent Variable	Δ*N* (1)	Δ*ISTR* (2)	Δ*IDG* (3)	Δ*B*/*P* (4)	Δ*m* (5)	Δ*r* (6)
Δ*N*	64.8/57.5	7.7/ 9.1	3.8/ 3.3	10.5/ 6.7	13.2/10.4	—/13.0
Δ*ISTR*	5.3/ 6.6	76.9/57.1	6.7/ 4.1	3.3/ 2.8	7.8/22.5	—/ 7.0
Δ*IDG*	19.6/ 8.8	13.7/15.0	34.3/45.5	8.3/ 5.2	24.1/11.7	—/13.7
Δ*B*/*P*	13.5/ 7.8	7.0/ 4.1	2.8/ 7.4	63.0/68.6	13.7/ 8.3	—/ 3.9
Δ*m*	16.1/ 6.5	13.8/ 7.4	5.4/ 5.4	24.7/20.5	40.0/49.4	—/10.8
Δ*r*	—/ 2.1	—/10.5	—/ 7.0	—/11.0	—/ 7.4	—/62.0

Note: As in table 5.7, dashes indicate that the interest rate is excluded from the model for the interwar period.

is placed last in both orderings, since the theory of efficient markets suggests an instantaneous response to innovations in other variables. *B/P* and *m* are intermediate variables but are capable of moving quickly, particularly if the Federal Reserve is operating to stabilize the interest rate.

In the ordering with structures first, the own innovation of structures accounts for most its variance at the sixteen-quarter forecast horizon in both sample periods. This own contribution is not altered in the slightest by placing *N* first in the ordering. Structures appear to be virtually autonomous, with a highly significant influence only from the money multiplier in the postwar period. *ISTR* acounts for more than 10% of the variance of *IDG* in both periods, *N* and *r* in the postwar, and *m* in the interwar. In an alternative version of the model in which the variables are expressed in levels (not shown in table 5.8), the role of *ISTR* is substantially greater, accounting for at least one-third of the variance of almost all the other variables in both periods.

Innovations in *IDG* account for more of the variance of *N* than vice versa in the interwar period, which might be interpreted as indicating that the multiplier was a stronger influence than the accelerator during that interval. Investment in durables displays substantial feedback both from investment in structures and from the money multiplier in both periods. That the money multiplier has a larger effect on the three categories of spending (*ISTR*, *IDG*, and *N*) than the two other financial variables (*B/P* and *r*) may indicate that the collapse of the banking system in 1929–33 and disintermediation in the postwar period were important channels of influence, proxied by the money multiplier, of the financial system on real expenditures. As mentioned above, the ordering in the bottom of table 5.8 that places *N* first does not change these results significantly, and this seems to support our argument for the exogeneity of investment in structures.

5.5.4 Historical Decomposition of Variance in Both Investment Types

A more revealing display of the implications of the VAR model is contained in the historical decomposition of each series in the system over each of the sample periods. The ordering used in arriving at these decompositions was that of our basic VAR model that places the explanatory variables in the order shown in the top half of table 5.8 (*ISTR*, *IDG*, *N*, *B/P*, *m*, and *r*). To limit the number of diagrams, we present only the decomposition of the two categories of investment—interwar structures in figure 5.4 and durable goods in figure 5.5, followed by postwar structures in figure 5.6 and durable goods in figure 5.7.

The top frame in each diagram compares the actual time path of investment with a "projection" that summarizes the net effect of the constant terms in all of the equations. The contribution of each of the other variables in the system then appears below. These contributions refer not just to the lagged values times the estimated coefficients in the *IDG* equation alone, but rather to the contributions of the innovations in each variable to investment behavior, taking account of *all* channels of feedback working through the six-equation model (recall that interest rates are excluded in the interwar period).

The predominant role of own innovations in the structures investment (*ISTR*) process is evident in figure 5.4. There is a high plateau in the own innovations series in 1926–27, a gradual downward movement in 1928–29, and a sharp plunge beginning in 1929:3, before the fourth-quarter stock market debacle. Equally interesting is that the own in-

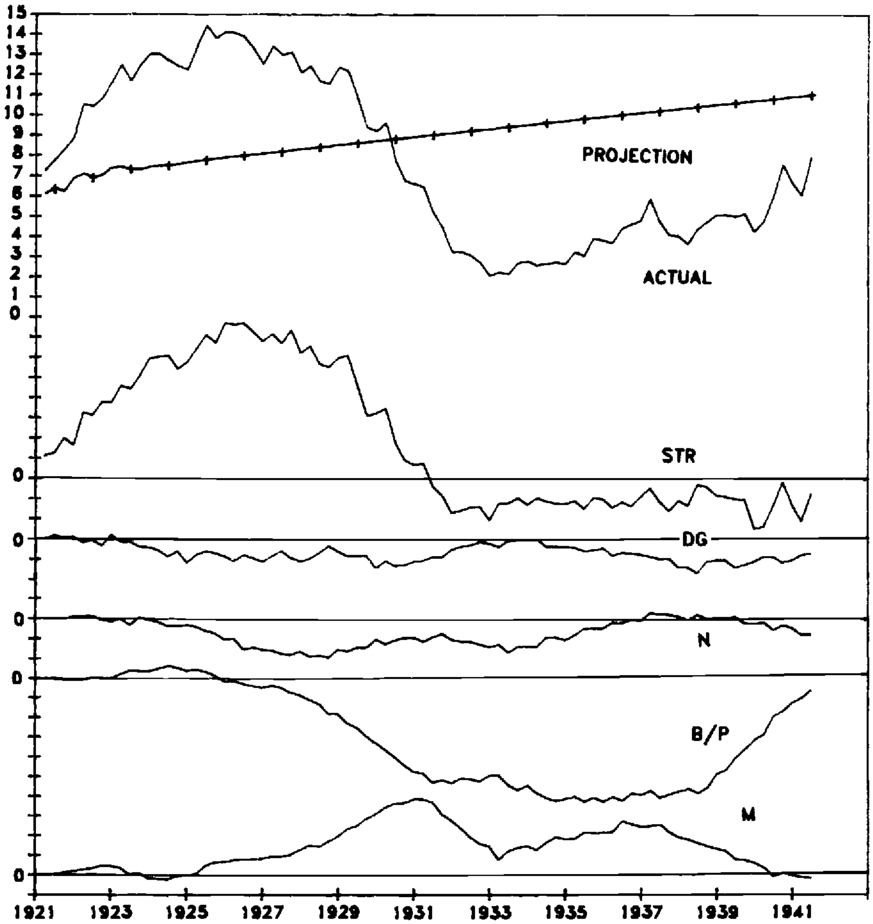

Fig. 5.4 Decomposition of structures, 1921–41.

novation series remains negative throughout 1931–41, supporting the interpretation of "overbuilding" in the 1920s that required a long period of subsequent adjustment in the 1930s.

Two other variables display interesting patterns in figure 5.4. The real monetary base (*B*/*P*) makes a major negative contribution in 1927–31 and a positive contribution in 1938–41. The latter episode is easy to understand in light of the large inflow of gold to the United States during this period. However, the decline in the contribution in *B*/*P* in 1927–31 may seem puzzling, since nominal *B* varied little in the Great Contraction of 1929–33, while the price level (*P*) declined substantially. The behavior of the *B*/*P* contribution can be explained in terms of the "projection" for *B*/*P* (not shown), which displays a sharp upward trend during the entire period 1920–41 in response to the doubling of *B*/*P* between 1920 and 1941. The actual value of *B*/*P* is below this "projection" continuously from 1920 to 1938 and then above it from 1939 to 1941. Thus the VAR historical decomposition algorithm interprets the slow increase in the real base in 1927–31 as being an actual decline relative to trend, and this is reflected in the contribution of base innovations to structures investment in figure 5.4. The other variable making an important contribution is the money multiplier, which exhibits a sharp decline during the period of monetary contraction and bank failures between 1931 and 1933, as well as after the increase in reserve requirements in 1936–37. The role of the multiplier makes our analysis compatible with the emphasis on the financial crisis in Bernanke (1983b).

Figure 5.5 shows the interwar historical decomposition of innovations to equipment investment. Compared with figure 5.4 for interwar structures, the own innovations in *IDG* are relatively less important and the innovations in the monetary base and money multiplier are more important. To some extent the innovations in the base and multiplier are offsetting, and this reflects in part the upward trend of the base and downward trend of the multiplier in the interwar period. However, we recall from tables 5.4 to 5.6 that both the base and the multiplier have consistently positive coefficients in the interwar regression equations for expenditures on durables.

Figures 5.6 and 5.7 decompose the variance of *ISTR* and *IDG* for the postwar years. Note that in these figures the scale is compressed horizontally and expanded vertically, since the ratio of investment to natural output varied over so much smaller a range in the postwar period. Figure 5.6 for postwar structures shares with the interwar figure 5.4 a predominant role for own innovations. However, figure 5.7 for durables is quite different from the other historical decompositions. Structures innovations play a much more important role in explaining postwar durables expenditure fluctuations than the own innovations in

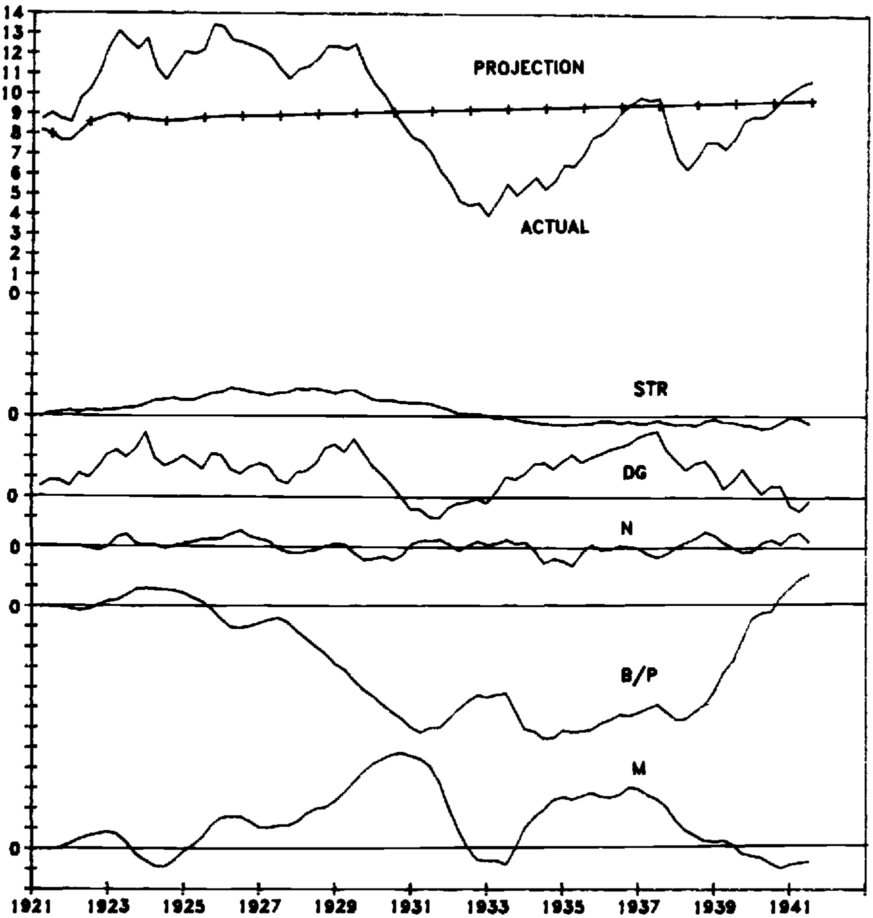

Fig. 5.5 Decomposition of equipment, 1921–41.

durables. Further, there is a substantial role for real interest rate innovations in figure 5.7, supporting the highly significant negative coefficients on the real interest rate variable in tables 5.4 to 5.6. The effect of high real interest rates in 1981–83 in reducing investment expenditures is particularly noticeable.

Thus any conclusion in this paper that investment contains a large autonomous component must refer mainly to structures, whereas durable equipment investment displays substantial feedback both from structures investment and from financial variables. It does not seem surprising that there should be feedback from structures investment to equipment investment, since the two activities are complementary. Construction of a new factory, office building, or shopping center re-

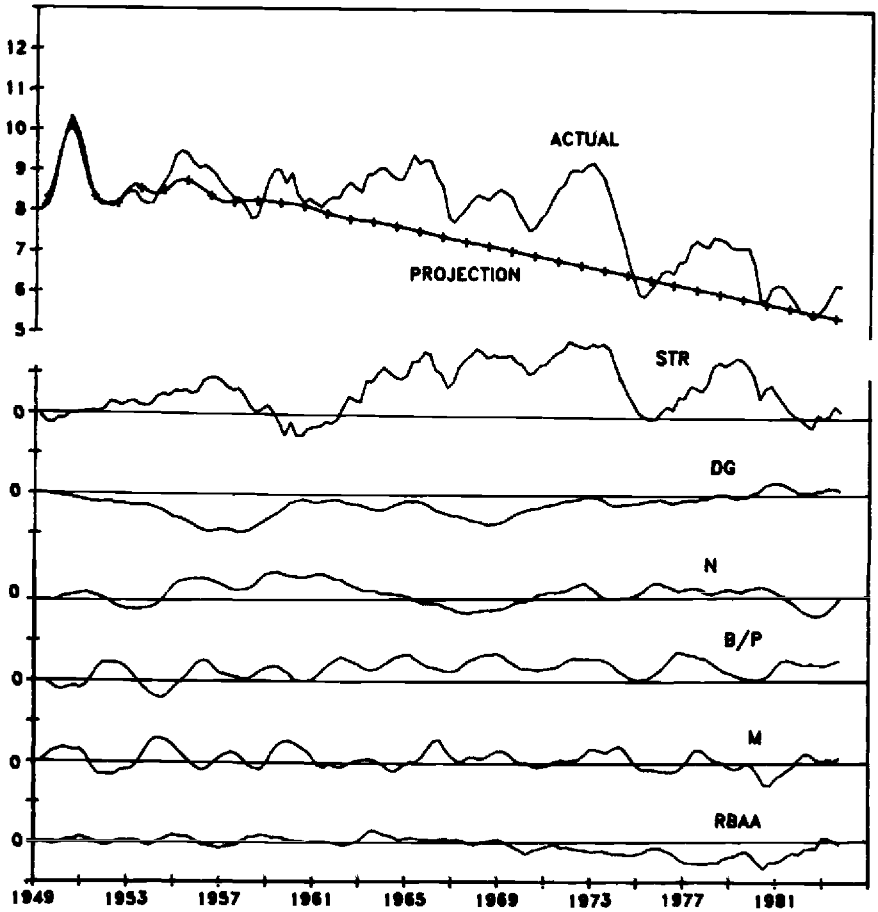

Fig. 5.6 Decomposition of structures, 1949–83.

quires investment in equipment, just as residential construction stimulates investment in furniture, appliances, and other components of consumer durables expenditures.

5.5.5 The Temin "Autonomous Shift" in 1930

An important part of Temin's (1976) interpretation of the first stage of the Great Contraction of 1929–33 is an autonomous shift in consumption in 1930, which he identified by estimating an annual consumption function. Our purpose here is not to review the controversy stirred up by Temin's result (see Mayer 1980), but rather to reexamine his hypothesis using the more definitive microscope provided by our quarterly data set. Table 5.9 exhibits quarter-by-quarter residuals from

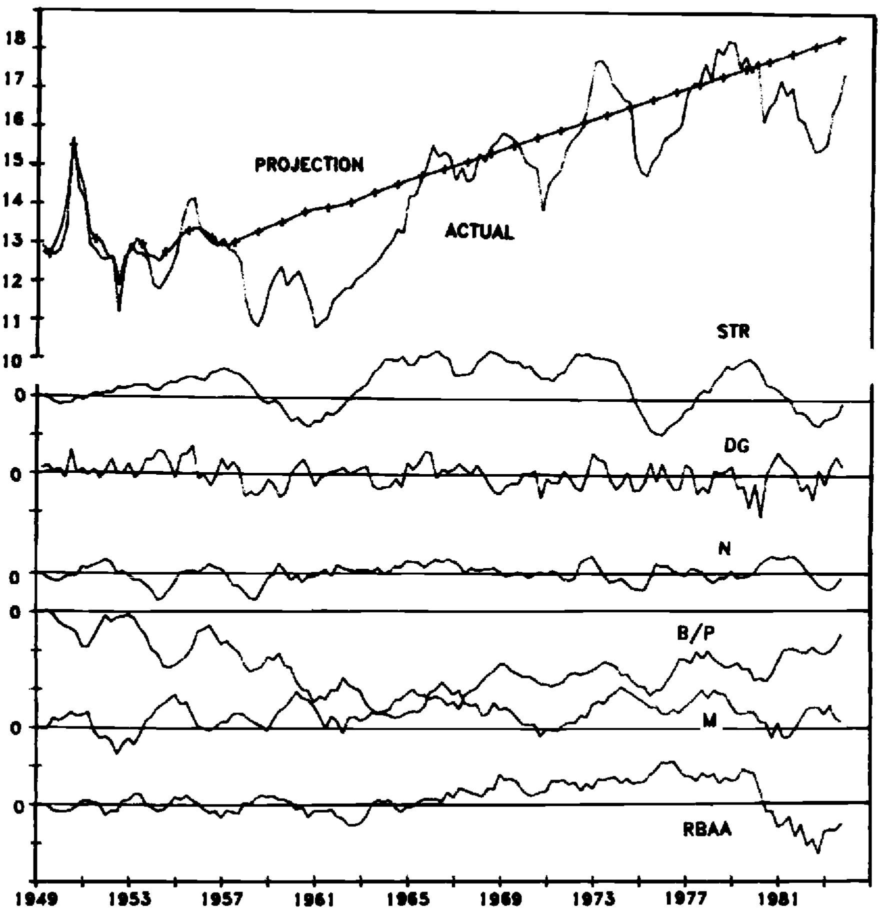

Fig. 5.7 Decomposition of equipment, 1949–83.

our interwar VAR models for the sixteen quarters covering 1929–32. Asterisks are used to mark off residuals greater in size than 1.0 times the standard error of estimate (see note to table 5.9).

The five variables of the model are the first differences of, respectively, investment in structures (*ISTR*), investment in durables (*IDG*), noninvestment real GNP (*N*), the real monetary base (*B/P*), and the money multiplier. All variables (except *m*) are expressed as percentage ratios to natural real GNP, and beneath the residuals the table shows the level of these ratios in 1929:2, ranging from 5.6% for the monetary base to 77.6% for noninvestment real GNP. Here we treat the behavior of noninvestment real GNP as representing "consumption," actually nondurable consumption, since in 1929 nondurable consumption made

Table 5.9 Residuals ("Innovations") in Interwar VAR Model: 1929:1 to 1932:4

Cycle	Δ*ISTR* (1)	Δ*IDG* (2)	Δ*N* (3)	Δ*B/P* (4)	Δ*m* (5)
1929:1	0.77*	0.05	1.10	−0.38*	0.12*
1929:2	0.10	−0.29	−0.89	−0.10	−0.04
1929:3	−1.29**	0.41	3.10**	−0.08	0.02
1929:4	−1.20**	−1.11**	−1.07	−0.21	−0.03
1930:1	−0.14	−0.13	−1.45	−0.08	0.04
1930:2	−0.03	−0.48	−1.35	−0.11	0.02
1930:3	−1.17**	−0.36	−0.11	−0.22	−0.05
1930:4	−0.12	−0.19	−0.55	−0.01	0.01
1931:1	−0.21	−0.46	0.81	0.34*	−0.07
1931:2	−0.21	0.04	1.27	−0.14	−0.09*
1931:3	−0.54	−0.45	−2.01*	0.40*	−0.21**
1931:4	0.10	0.09	−0.65	0.04	−0.09*
1932:1	−0.69	0.32	0.10	0.21	−0.04
1932:2	0.08	0.10	−0.35	0.07	−0.01
1932:3	0.63	0.15	−1.42	−0.35*	0.06
1932:4	0.34	0.02	0.67	0.29	0.03
Level in 1929:2	12.2	12.2	77.6	5.6	4.4
Cumulative residuals					
1929–30	−3.08	−2.10	−1.22	−1.19	0.17
1931–32	−0.46	−0.23	−1.58	0.86	−0.42
Cumulative residuals as percentage of 1929:2 level					
1929–30	−25.2	−17.2	−1.6	−20.5	3.9
1931–32	−3.8	−1.9	−2.0	14.8	−9.5

Note: Asterisks are used to denote residuals as follows: (*) indicates between 1.0 and 1.5 times the sample period standard error, and (**) indicates more than 1.5 times the standard error.

up 85.2% of *N*, and it accounted for 74.6% of the decline in *N* from 1929 to 1930.

The emphasis in this paper on autonomous movements in investment, particularly structures investment, is supported in table 5.9. There were three large negative innovations in 1929–30 to *ISTR*, including one in 1929:3, one quarter before the business downturn and stock market crash. There was a large negative innovation in *IDG* in 1929:4. The cumulative residuals of *ISTR* and *IDG* in 1929–30 amount, respectively, to −25.2% and −17.2% of their *levels* in 1929:2. In contrast, the only large *N* residual for 1929–30 is *positive* in 1929:3. The cumulative *N* residuals in 1929–30 amount to only −1.6% of its level in 1929:2. Thus we find no evidence that negative residuals for nondurables consumption played a key role in the initial stages of the Great Contraction.

Two other interesting results are evident in table 5.9. First, there are substantial negative innovations in the real monetary base beginning as early as 1929:1 and cumulating to −20.5% of the 1929:2 level in 1929–30. Second, the largest cumulative negative residuals in the period 1931–32 are contributed by the money multiplier, supporting a role for bank failures and the credit contraction in aggravating the contraction. Especially interesting is the large negative multiplier innovation in 1931:3, the quarter when the Fed tightened its policy following Britain's departure from the gold standard.

Overall, these results are consistent with our interpretation of two sources of the business cycle, real and financial, with the negative innovations in real investment playing a dominant role in 1929–30, and with the nature of the negative financial innovations shifting from a contribution of the monetary base in 1929–30 to one by the money multiplier in 1931–32.

5.6 Summary and Conclusion

5.6.1 Methodology and Data Description

Most of the tests of "structural" investment equations that have been carried out in the literature embody what Sims (1980a) calls "incredible" exclusion restrictions. The literature on the neoclassical investment paradigm embodies prior assumptions about the form of the production function. In its putty/putty version it neglects expectations entirely, and in its putty/clay version it fails to allow time series aggregate variables to play multiple roles in the formation of expectations in different phases of the investment process. As a result, coefficients on variables like lagged output and interest rates cannot be interpreted in the structural way that has been typical in the literature.

The Tobin Q theory starts from a plausible point of departure but then takes itself too seriously, allowing *only* Q to influence investment. There seems to be no reason the single Q variable, whether or not it is measured with error, should embody all influences of other variables on the investment process. Our discussion emphasizes in particular the role of asymmetric adjustment costs, as well as the trade-off firms face between costly alternatives when the stock market gives one set of signals and output or other variables give a conflicting set.

We conclude that the difficulties of structural equation building are irremediable. As a substitute we carry out a hybrid methodology, in which theory is used to suggest sets of variables and their form but empirical estimation is carried out by estimating equations in the symmetric VAR format, with all explanatory variables entering the investment equation and with the dependent variable included with the same number of lags. Our hybrid approach thus combines insights from structural models with the unconstrained approach to testing and data exploration that typifies investigations using VAR models.

Our first empirical task is to establish the importance of fixed investment in historical business cycles. Using procedures described in the appendix, we have created a new set of quarterly data on major expenditure components of GNP extending back to 1919:1. We include four types of real investment expenditures in our study—producers' durable equipment, nonresidential structures, residential structures, and consumer durables expenditures. The decline in the sum of these four components (*I*) contributes between one-third and one-half of the decline in real GNP in recessions, even though the share of *I* in GNP at the typical business cycle peak is about one-quarter. Total investment actually was relatively more important in postwar recessions between 1957 and 1980 than it was during the Great Contraction of 1929–33.

A decomposition of variance allows a description of the relation between investment (*I*) and noninvestment real GNP (*N*) in major episodes. The interwar years were characterized by a high own variance of investment, particularly in 1919–29, and after 1929 by a high covariance between *I* and *N*. The own variance of *N* was more important in the postwar period and was dominated by the Korean War episode. Of the four components of investment, the own variance of nonresidential structures was the largest in the interwar period, while the own variance of consumer durables expenditures was largest in the postwar period.

5.6.2 Implications for Four Schools of Thought

Keynesians, monetarists, neoclassicists, and *Q* advocates all have an interest in the results of this investigation. Members of each group will be disappointed with our results if they are seeking support of "monocausal" or "one factor" hypotheses of investment behavior. Yet ironically the empirical findings offer some solace to each group, because they provide substantial support for an eclectic view of investment that blends elements of each approach while providing evidence against opponents of each who insist on some alternative monocausal explanation.

Keynesians view investment behavior as containing a substantial autonomous component. Our empirical investment equations summarized in table 5.6, together with the historical decompositions in figures 5.4 to 5.7, support the view that autonomous innovations in *structures* investment are an important driving force in the business cycle. In table 5.8 the effect of innovations in structures investment on durable equipment expenditures, as well as on noninvestment GNP, is greater than the reverse feedback from equipment and noninvestment GNP innovations to structures investment, in both the interwar and the postwar periods. The boom in structures investment between 1923 and 1929, the subsequent slump in the 1930s, and the smaller negative innovations in the early 1960s and boom in 1971–73 all can be viewed mainly as autonomous events rather than as a passive reaction to other economic variables.

While monetarists would doubtless be unhappy with a view that treats major swings in structures investment as autonomous, they nevertheless have the consolation of learning that the response of both structures and equipment investment to the real money supply is significantly greater than to the "traditional" variables in investment equations, the accelerator (output change), the user cost of capital, and Q. The effect of money, split here between the real monetary base and the M1 money multiplier, is substantial in both the interwar and the postwar periods. The regression results in table 5.6 find a strong impact of both the base and multiplier on equipment investment in the interwar period, and on both structures and equipment investment in the postwar. The historical decompositions in figures 5.4 to 5.7 indicate that base innovations had an important impact on both structures and equipment investment, as well as on noninvestment GNP, in the interwar period, whereas the multiplier played a role in both the interwar and the postwar periods.

It seems ironic that this study of investment behavior provides more support for the general views of the economy represented by Keynesians and monetarists than it does for the views of specialists in the investment process, the neoclassicists and Q advocates. In tables 5.4 and 5.5 the user cost of capital for businesses and the real interest rate for households are insignificant or have the wrong signs in every equation for the interwar years. The equations for consumer and producer durables spending exhibit a significant and correctly signed (negative) sum of coefficients for the postwar period, but in every postwar equation the user cost or interest rate variable fails an "exclusion test" on the joint significance of all lagged values in the explanation of investment spending. The verdict on the Q approach is even more negative. In the aggregated regression equations of table 5.6, the Q variable passes the exclusion test only in one equation, for postwar structures investment. This appears in table 5.4 to be attributable to the nonresidential component of structures investment. Such results pose a new task for Q theorists, that is, to determine what factors would make investment in structures more responsive to Q than investment in producers' durable equipment.

Our empirical work casts doubt on the importance of the accelerator hypothesis of investment behavior that has been supported by some past work, for example, Clark (1979). The simple device of including four lags on the dependent variable in equations explaining total I eliminates the significant explanatory contribution of lagged values of real GNP, except in the equipment equations for the postwar period. However, we find that it is possible to obtain significant sums of coefficients for an accelerator effect in a postwar durable equipment equation only when real GNP is entered as a second rather than a first difference. These findings support our basic interpretation that there is a sharp difference between the behavior of structures and equipment investment, with the former behaving mainly in an autonomous fashion, whereas the latter reflects feedback both from investment in structures and from financial and monetary variables.

5.6.3 Deeper Issues and Unsettled Questions for Future Research

In a recent paper Blanchard (1981, 154) reached the conclusion that "the multiplier is dead and the accelerator alive." This paper reaches the opposite conclusion, particularly for the structures component of investment. The accelerator mechanism, interpreted as the feedback from autonomous movements in noninvestment GNP to investment in structures, seems to be considerably weaker than the multiplier mechanism, interpreted in the elementary textbook fashion as the effect on total GNP of autonomous movements of investment, particularly the structures component. Although there is a substantial effect of monetary and financial variables on investment, nevertheless there are major and persistent movements in investment that occur in both the interwar and the postwar periods that cannot be explained by prior changes in output, money, stock prices, or interest rates.

That we label major movements in structures investment "autonomous" does not mean we leave them unexplained. Rather, this basic interpretation of the paper treats structures investment as exogenous *with respect to the explanatory variables included in our statistical analysis*. This does not rule out other explanations, and in fact we can offer three complementary explanations of the behavior of structures investment in the interwar period. First, the residential structures boom of the 1920s and subsequent slump of the 1930s can be explained in part by demographic factors that lie outside the scope of this paper. While the rapid population growth of 1900–1920, together with the postponement of construction during World War I and the 1920–21 recession, may provide a partial explanation of the intensity of the

1920s residential construction boom, the restrictive immigration law of 1924 and subsequent deceleration in population growth may help to account for the decline in residential construction after 1926.

Hickman (1973) has documented both the effect of the decline in population growth on the desired housing stock and also the extent of overbuilding in the mid-1920s. Hickman's work treats the rate of population growth as endogenous, with the rate of household formation responding to the growth rate of income, and he is able to decompose the observed decline in the rate of population growth between the early 1920s and mid-1930s into two components—that due to the effect of declining income, and a remaining exogenous decline due primarily to the decline in immigration. To isolate the effect of the exogenous component of the decline in household formation, Hickman calculated two dynamic simulations of his model, one in which standardized households are assumed to increase steadily at the 1924–25 rate of growth and another in which income and other economic variables are identical but in which standardized households follow their actual declining path after 1925. The impact of the actual demographic slump gradually becomes more important as the 1930s progress, accounting for a decline in housing starts between the two simulations of 28.3% for 1933 and 39.1% for 1940. His result is consistent with our figure 5.4 above, in which the own innovation in structures investment is negative throughout the 1930s.

A second factor, more relevant for investment in structures than in equipment, is the element of speculation. The Florida land boom of the 1920s, the stock market "bubble" of 1928–29, and earlier investment excesses like the "South Seas Bubble" of the early eighteenth century all have some similarity to the construction boom of the 1920s. For six years (1923–28) real residential construction achieved a level more than double the average of the entire decade before World War I, and in four successive years (1924–27) the ratio of real residential construction investment to GNP reached by far its highest level of the twentieth century. Hickman estimates that even with a continuation of population growth at the 1924–25 rate rather than a post-1925 decline, housing starts would have fallen by 35% between 1925 and 1930 (as a ratio to natural real GNP, real residential investment actually fell by 57%).

Nor is the phenomenon of overbuilding confined to the interwar period. Figure 5.6 shows that the postwar own innovation to structures investment peaked in 1972–73. Several years later contemporary accounts recognized the phenomenon of overbuilding: "In Chicago, new apartment construction has just about ceased. In Atlanta, where there is at least a three-year supply of unsold condominiums overhanging the market, mortgage companies are auctioning off high-rise units to the public at two-thirds their original asking price. . . . The current problems stem fromm overbuilding in the early 1970s" ("The Great High-Rise Bust," *Newsweek*, 30 August 1976, 5).

The third factor that may be an important explanation behind the apparently "autonomous" structures investment boom of the 1920s and slump of the 1930s is the "Schumpeterian" bunching of innovations. This hypothesis is developed by R. A. Gordon (1951), who argued that the buoyancy of both residential and nonresidential construction in the 1920s reflected in large part the influence of the automobile in expanding the boundaries of urban areas:

> Between 1923 and 1929 the growing *use* of automobiles and trucks had a more important impact on total investment and employment than did the expansion of motor vehicle output. Motor vehicle registrations in 1929 were about 75 percent greater than in 1923 and nearly three times the number in 1920. . . . large scale investment was necessary for roads and bridges, oil wells, pipe lines, garages and service stations, and tire and automobile supply stores, as well as for oil refining and tire manufacture. In addition, the automobile accelerated the trends toward urbanization and "suburbanization," stimulating thereby residential and commercial building.

Other industries were also involved in the bunching of investment opportunities in the 1920s. Among these were electric power—well over half the installation of electric generating capacity during 1902–40 occurred during the decade of the 1920s. Other important new industries were radio, telephone, and chemicals.

The results in this paper support the view that there are two basic impulses in the business cycle, real and financial. The real impulse appears in our statistical evidence as an autonomous innovation to investment in structures. This concluding section has suggested three factors that may underlie the cycle in structures investment. We choose to emphasize this element of investment behavior here because it has received relatively little attention in recent research, however familiar it may seem to experts on the earlier literature on business cycles. The financial impulse works through the effect on investment of changes in the monetary base and money multiplier, as well as the real interest rate for postwar investment in durable equipment. In these results the money multiplier may be acting as a proxy for such phenomena as the banking contraction of 1929–33 and the episodes of credit crunches and disintermediation in the postwar years.

Many avenues for future research are opened up by these results. Past studies of structures investment need to be reviewed for problems of identification and simultaneity that may have led to a misleading emphasis on the investment accelerator, rather than autonomous movements, as the driving force behind structures investment. Our inability to find a strong influence of the stock market (working through our Q variable) on investment, except for postwar nonresidential structures, needs to be reconciled with the recent findings of Fischer and Merton (1984), who find a stronger connection between economic activity and prior movements in the stock market. Finally, we hope that our new quarterly interwar data on components of expenditures will stimulate further research into the interrelations of real and financial variables during the Great Depression.

Appendix

General Description

This appendix investigates the behavior of investment in the United States economy over both the interwar (1919–41) and the postwar (1947–1983) periods. Annual nominal and real expenditures and deflator series are available as far back as 1929 using *Survey of Current Business* supplements (hereafter *SCB*). Before 1929, however, one must resort to a number of sources to collect annual data that can be matched up to the 1929 Commerce Department figures. Swanson and Williamson (1971) contains nominal series for all the major national account categories for the period 1919 to 1928, which have been adjusted from Kuznets's figures to conform to the *SCB* definitions. These annual nominal series are used here for all the national accounts categories except for investment in structures and foreign trade. The desired division of investment into residential and nonresidential structures uses figures from Grebler, Blank, and Winnick (1956) and adjusts nominal GNP accordingly. Net exports are broken down into the two nominal components, exports and imports, using index available in the *Statistical History of the United States*, which are then linked to the 1929 *SCB* values.

This provides us with a complete set of annual nominal national income accounts. The next task is to find implicit deflators for these nominal series. Our starting point is the set of *SCB* implicit deflators for all the national income categories for the period 1929 to 1941. Annual figures for the GNP deflator, 1919–28, are obtained by linking Kuznets's GNP deflator to the *SCB* 1929 implicit GNP deflator. Since both current and constant dollar index are available for exports and imports, it is possible to construct implicit deflators for both series from 1919 to 1928 that can be matched to the *SCB* 1929 deflators. For the remaining categories, such as consumption and investment, deflators are not available for the period 1919–28. To obtain figures for this period, our interpolation program is run over the available annual price series, 1929–41, to produce quarterly figures. The final regression is used to "back forecast" the quarterly values over the period 1919–28. These quarterly values are then averaged to yield annual price series for 1919–28. With the complete set of price deflators it is possible to convert the nominal national accounts into real series covering the full period 1919–41. The real annual national account series are interpolated to arrive at a complete set of real quarterly accounts and a corresponding set of deflators.

An interpolation procedure following that of Chow and Lin (1971) is used in converting the annual series to quarterly observations. A more complicated procedure, such as that suggested by Litterman (1981), is deemed too costly compared with the possible gain in accuracy. The procedure itself is fairly simple. Since our annual series are annual averages of quarterly variables, the procedure we use is that termed "distribution" by Chow and Lin. In what follows upper-case letters represent annual series, and lower-case letters represent the associated quarterly series. To each annual series to be interpolated (Y_{it}) is associated a number of quarterly series (x_{it}) that a priori information suggests move within the year the way quarterly observations on the annual dependent variable would. These quarterly explanatory variables are annualized (X_{it}), and a regression against the annual dependent variable is run:

$$Y_{it} = X_{it}\beta + U_t. \tag{A1}$$

It is assumed in each interpolation that the *quarterly* errors follow an AR(1) process, which induces a complicated covariance structure on the annual error, U_t. The first autocorrelation of U_t, ρ_A, is related to the quarterly autocorrelation coefficient, ρ_Q, by the nonlinear formula:

$$\rho_A = \frac{\rho_Q^7 + 2\rho_Q^6 + 3\rho_Q^5 + 4\rho_Q^4 + 3\rho_Q^3 + 2\rho_Q^2 + \rho_Q}{2\rho_Q^3 + 4\rho_Q^2 + 6\rho_Q^2 + 4}. \tag{A2}$$

Estimating ρ_A as the first autocorrelation of the residuals from the regression in ($A1$), we can obtain an estimate of ρ_Q by solving ($A2$), and this is used in an iterative GLS procedure to obtain estimates of β and ρ_Q. The final estimates from this procedure are then used to generate quarterly observations for the dependent variable as:

$$\hat{y}_{it} = x_{it}\hat{\beta} + \hat{\rho}_Q\hat{u}_{t-1}. \tag{A3}$$

The assumption of $AR(1)$ errors in the quarterly equation overcomes the artificial choppiness induced if u_t is assumed to be white noise.

This procedure is used to derive the quarterly series for the implicit deflators and real series of the national accounts as well as Summers's *Q* and some components of the cost of capital.

Sources of Annual Interwar and Postwar Quarterly Variables

1. GNP
   1919–28 (annual): Implicit deflator constructed from a nominal and a real GNP series available on NBER tape, dataset 08A Income

Table 5.A.1

Annual National Account Category	Time Period Interpolated	Independent Series in Interpolation
1. GNP (*Q*)		
Deflator—*QD*	Derived as residual	
Real GNP—*Q*	1919:1, 1941:4	*C T IIPTT DPTSLS*
2. Consumer durables (*CDG*)		
Deflator—*PDCDG*	1929:1, 1941:4	*C T CPINF*
Real—*QCDG*	1919:1, 1941:4	*C T IIPDCG*
3. Consumer Nondurables and services (*CNDSV*)		
Deflator—*PDCNDSV*	1929:1, 1941:4	*C T CPI*
Real—*QCNDSV*	1919:1, 1941:4	*C T IIPNDCG DPTSLS*
4. Investment, producers' durable equipment (*IPDE*)		
Deflator—*PDIPDE*	1929:1, 1941:4	*C T WPI CPWGE*
Real—*QIPDE*	1919:1, 1941:4	*C T IIPPG*
5. Investment, residential structures (*IRSTR*)		
Deflator—*PDIRSTR*	1929:1, 1941:4	*C T WPI CPWGE*
Real—*QIRSTR*	1919:1, 1941:4	*C T CONSTR QRSTR*
6. Investment, nonresidential structures (*NRSTR*)		
Deflator—*PDINRSTR*	1929:1, 1941:4	*C T WPI CPWGE*
Real—*QINRSTR*	1919:1, 1941:4	*C T CONSTR QNRSTR*
7. Investment, change in inventories (*IBINV*)		
Real—*QIBINV*	Derived as residual	
8. Government purchases (*G*)		
Deflator—*PDG*	1929:1, 1941:4	*C T CPWGE*
Real—*QG*	1919:1, 1941:4	*C T*
9. Exports (*X*)		
Deflator—*PDX*	1919:1, 1941:4	*C T WPI*
Real—*QX*	1919:1, 1941:4	*C T QXPROXY*
Imports (*M*)		
Deflator—*PDM*	1919:1, 1941:4	*C T WPI*
Real—*QM*	1919:1, 1941:4	*C T QMPROXY*

and Employment. Nominal GNP taken from Swanson and Williamson (1971, table B-1), adjusted for the use of the investment in structures series taken from Grebler, Blank, and Winnick (1956).
1919–41 (quarterly): The quarterly series for the GNP deflator was calculated by adding up the real and nominal interpolated account categories, except inventories, and dividing the nominal sum by the real sum.
1929–41 (annual); 1947–83 (quarterly): Nominal GNP series from *SCB* table 1.1. Implicit deflator from *SCB* table 7.1. All references to *SCB* figures are updated through June 1984.

2. Consumer Durables Expenditures
1919–28 (annual): Nominal expenditures from Swanson and Williamson (1971, table B-2). Implicit deflator constructed from interpolation.
1929–41 (annual); 1947–83 (quarterly): Nominal series from *SCB* table 1.1, deflator from *SCB* table 7.1.
3. Consumer Nondurables and Services
1919–28 (annual): Implicit deflator constructed from interpolation. Nominal series is the sum of consumer semidurables, perishables, and services from Swanson and Williamson (1971, table B-2).
1929–41 (annual); 1947–83 (quarterly): Nominal and real series are the sum of consumer durables and services from *SCB* tables 1.1 and 1.2 with the implicit deflator defined as the ratio of the nominal sum to the real sum.
4. Investment in Producers' Durable Equipment
1919–28 (annual): Implicit price deflator from interpolation, nominal series from Swanson and Williamson (1971, table B-3).
1929–41 (annual); 1947–83 (quarterly): Nominal and real series are the sum of the corresponding residential and nonresidential investment in producers' durable equipment from *SCB* tables 1.1 and 1.2. Implicit deflator is the ratio of the nominal sum to the real sum.
5. Investment in Residential Structures
1919–28 (annual): Implicit deflator from interpolation. Nominal series taken from Grebler, Blank, and Winnick (1956, table K-4, col. 4), does not include residential investment in farm structures.
1929–41 (annual); 1947–83 (quarterly): Nominal series for residential construction, nonfarm taken from *SCB* table 1.1, implicit deflator taken from *SCB* table 7.1.
6. Investment in Nonresidential Structures
1919–28 (annual): Implicit deflator from interpolation. Nominal series from Grebler, Blank, and Winnick (1956, table K-4, col. 5), includes farm investment in structures.
1929–41 (annual); 1947–83 (quarterly): Real and nominal series are the sum of nonresidential and residential farm investment in struc-

tures, *SCB* tables 1.1 and 1.2. Implicit deflator is arrived at by dividing the nominal sum by the real sum.

7. Change in Business Inventories
1919–41 (quarterly): Both real and nominal series were arrived at as residuals by subtracting from total real (nominal) GNP the real (nominal) sum of all other account categories.
1947–83 (quarterly): Both real and nominal series taken from *SCB* tables 1.1 and 1.2.
8. Government Purchases of Goods and Services
1919–28 (annual): Price deflator from the interpolation, nominal purchases from Swanson and Williamson (1971, table B-1).
1929–41 (annual); 1947–83 (quarterly): Deflator from *SCB* table 7.1 and nominal series from *SCB* table 1.1.
9. Exports
1919–28 (annual): Real and nominal series constructed by matching constant and current dollar index from the *Statistical History of the United States*, series U21 and U22, to the *SCB* export series in 1929. The deflator was then defined as the ratio for the real and nominal series.
1929–41 (annual); 1947–83 (quarterly): Deflator from *SCB* table 7.1 and nominal series from *SCB* table 1.1.
10. Imports
1919–28 (annual): Real and nominal series constructed by matching constant and current dollar index from the *Statistical History*, series U33 and U34, to the *SCB* import series in 1929. The deflator is then defined as the ratio of the real and nominal series.
1929–41 (annual); 1947–83 (quarterly): Deflator from *SCB* table 7.1 and nominal series from *SCB* table 1.1.
11. Capital Stock, Equipment and Structures
1925–83 (annual): Nominal and real series for the two types of capital stock, equipment and structures, was taken from various issues of *SCB*. Nominal and real series for the capital stock of consumer durables was taken from Musgrave (1979). To utilize the information available from our associated quarterly investment series in constructing each quarterly capital stock series, we followed the iterative procedure: (*a*) the annual series provide a beginning and ending value for the capital stock; (*b*) assuming a fixed exponential rate of depreciation, the quarterly series must satisfy $K_t = I_t + (1 - \delta)K_{t-1}$. The procedure uses the starting value of the capital stock and the associated quarterly I_t series, iterating on δ until the value of the quarterly capital stock at the end of the period is "close" to the specified ending value. Below we present the estimated annual depreciation rate for each type of capital stock in each of the subperiods.

Nonresidential structures	1919–41	$\hat{\ } = 6.396$
	1947–83	$= 6.036$
Consumer durable goods	1919–41	$\hat{\delta} = 20.40$
	1947–83	$= 20.63$
Producers' durable equipment	1919–41	$\hat{\delta} = 14.88$
	1947–61	$= 13.80$
	1962–83	$= 14.96$

Rental Price of Capital Services

The rental price of capital services, for equipment and for structures, was constructed using for equipment:

$$C_E = \frac{P_E(\delta_E + r)(1 - RITC_E - DUM \cdot Z_E \cdot TAX \cdot RITC_E - Z_E \cdot TAX)}{(1 - TAX)}$$

and for structures:

$$C_S = \frac{P_S(\delta_S + r)(1 - RITC_S - Z_S \cdot TAX)}{(1 - TAX)} .$$

A composite cost of capital series was constructed by weighting each of C_E and C_S by their share in the sum of the capital stock of equipment and structures. Individual components of the cost of capital services are:

δ_E = Depreciation rate of the net stock of producers' durable equipment estimated iteratively as explained above.

δ_S = Depreciation rate of the net stock of nonresidential structure estimated iteratively as above.

DUM = Dummy variable, set equal to 1.0 for the duration of the Long amendment to the Revenue Act of 1962 and set equal to zero in all other periods.

P_E = Implicit deflator for investment in producers' durable equipment, as explained above.

P_I = Implicit deflator for investment in nonresidential structures, as explained above.

$RITC_E$ = Rate of investment tax credit on equipment investment, from Jorgenson and Sullivan (1981).

$RITC_S$ = Rate of investment tax credit on nonresidential structures investment, from Jorgenson and Sullivan (1981).

TAX = Highest marginal tax rate on corporate income from Tax Foundation (1979).

r = Discount rate, which is calculated as the Moody's Baa corporate bond yield minus the expected rate of inflation. The construction of the expected inflation rate is discussed in the text.

Z_E = Present value of one dollar's worth of depreciation on equipment. Figures for 1947–83 are from Jorgenson and Sullivan (1981), while figures for 1919–41 are calculated using straight-line depreciation, average asset life for the period from Jorgenson and Sullivan and the Baa corporate bond rate.

Z_S = Present value of one dollar's worth of depreciation on nonresidential structures. Figures for 1947–83 are from Jorgenson and Sullivan (1981), while figures for 1919–41 are calculated using straight-line depreciation, average asset life for the period from Jorgenson and Sullivan, and the Baa corporate bond rate.

Sources of Interwar Quarterly Variables

The data utilized in this section were made available, in part, by the Inter-University Consortium for Political and Social Research. The data for macroeconomic time series were originally collected by the National Bureau of Economic Research.

C = Constant term used in the regression.

CONSTR = Index of total construction, s.a. Monthly observations from NBER tape, dataset 02A Construction: data originally collected for *Engineering News-Record Yearbook.*

CPI = Consumer price index, all items, s.a.

CPINF = Consumer price index, less food, s.a. Monthly observations for both taken from NBER tape, datasest 04A Prices: data originally collected by the Bureau of Labor Statistics.

CPWGE = Index of composite wages, s.a. Monthly observations from NBER tape, dataset 08A Income and Employment: data originally collected by the Federal Reserve Board and the Federal Reserve Bank of New York.

DPTSLS = Physical volume of department store sales, s.a. Monthly observations taken from NBER tape, dataset 06A Distribution of Commodities: data originally collected by the Federal Reserve Board.

IIPTT = Index of industrial production, total, s.a.

IIPDCG = Index of industrial production, durable consumer goods, s.a.

IIPNDCG = Index of industrial production, durable consumer goods, s.a.

IIPPG = Index of industrial production, producers' goods, s.a. Monthly observations on the four variables above taken from NBER tape, dataset 01A Production of Commodities: data originally collected by the Federal Reserve Board and the Federal Reserve Bank of New York.

QNRSTR = Real value of contracts for industrial buildings, s.a. Quarterly observations arrived at by deflating the value of contracts for industrial buildings (from NBER tape, dataset 02B Construction: data originally collected by the Federal Reserve Board) by the interpolated deflator for nonresidential structures.

QRSTR = Real value of residential construction contracts, s.a. Quarterly observations arrived at by deflating value of residential contracts (from NBER tape, dataset 02B Construction: data originally collected by *Engineering News-Record*) by the interpolated deflator for residential structures.

QMPROXY = Constructed variable for real imports, s.a. A quarterly nominal series on imports, which did not match the *SCB* definition, was deflated by the interpolated *WPI*. The nominal import series was taken from NBER tape, dataset 07A Foreign Trade: data originally appeared in the *Monthly Summary of Foreign Commerce*, various issues.

QXPROXY = Constructed variable for real exports, s.a. A quarterly nominal series on exports, which did not match the *SCB* definition, was deflated by the interpolated *WPI*. The nominal export series was taken from NBER tape, dataset 07A Foreign Trade: data originally appeared in the *Monthly Summary of Foreign Commerce*, various issues.

RBAA = Yield on corporate bonds, Moody's Baa rating. Monthly observations originally collected by Moody's Investors Service, taken from Federal Reserve Board and various issues of the *Federal Reserve Bulletin*.

RHCPBD = Yield on corporate bonds, highest rating. Monthly observations from NBER tape, dataset 13A Interest Rates: data originally collected by the United States Department of Commerce.

STKPRCE = Index of all common stock prices, New York Stock Exchange. Monthly observations from NBER tape, dataset 11A Security Markets: data originally collected by Standard and Poor's.

T = Trend term appearing in the regression.

WPI = Wholesale price index, all items, s.a. Monthly observations taken from NBER tape, dataset 04A Prices: data originally collected by Babson Statistical Organization.

Comment John Geweke

In their paper Gordon and Veitch have made a commendable and intellectually honest effort to compare the relationship between fixed investment and other important macroeconomic variables during the interwar period and in two postwar periods. Their strongest empirical finding is a sharp difference between the interwar and postwar periods, fixed investment being more nearly autonomous before the war than after. By contrast, there is little evidence of shifts since World War II. In common with many other researchers, they conclude that measurable variants of Tobin's Q have little explanatory power in an equation for aggregate fixed investment. In contrast with some other empirical work using aggregate data, they find no evidence for an accelerator, at least a limited role for a cost of capital variable in the postwar era, and substantial feedback from the monetary base, the monetary multiplier, or both, to fixed investment.

In reaching these conclusions the authors employ an econometric model with many fewer prior constraints than are typically found in the empirical aggregate investment literature. They point out that a reduced-form equation for aggregate investment, like their (8), is hopelessly underidentified without restrictions for which there are no sound theoretical arguments. While I find this argument persuasive, I think there is a more fundamental criticism of the use of "representative agent" models to achieve identification of parameters estimated from aggregate data, to which I shall return. The authors abandon the conventional approach in favor of a methodology described as a combination of the vector autoregression (VAR) approach with the estimation of reduced-form equations suggested by traditional theory. Experience suggests that evaluation of the paper's empirical results is likely to be overshadowed by an effort to delineate economic interpretations that are admissible from those that are inadmissible on the basis of this "hybrid" methodology. It may therefore be useful to provide an interpretation of this methodology complementary to the authors'.

Prior considerations—from economic theory or at any rate from professional common sense—are used at two points in the formulation of the model. The first is in the choice of the variables that will appear; short of the most blatant data mining imaginable, this use of "theory" is indispensable. The second use of prior considerations is the (identifying) restriction that the relevant structural econometric model is block recursive, in the classical sense, with the investment equation

John Geweke is professor of economics at Duke University.

Financial support from the National Science Foundation and the Sloan Foundation is gratefully acknowledged.

being the sole occupant of its block. The position of the investment block within the system determines which contemporaneous variables appear on the right-hand side of this equation. The authors argue, very much in the spirit of Herman Wold, that the investment equation comes first, with no contemporaneous variables on the right-hand side. Given the restriction to block causal chain models, that further restriction seems quite reasonable, but table 5.8 suggests the decision does matter. The assertion that a causal chain model of this form is structural is necessary for the interpretations of the estimates made throughout the latter part of the paper: without it, for example, the coefficients on output have no direct bearing on the accelerator hypothesis, and coefficients on the cost of capital cannot be associated with the supply of capital.

The hypothesis that the relevant structural model involves a specified list of variables in a specified causal chain is structure of a minimal sort. Whether one calls the model theoretical or atheoretical is a matter of taste; "minimally structural" seems more precise. What is much more important is to delineate the kinds of conceptual experiments that can be conducted and the kinds of hypotheses that can be tested in the context of such a model. The vector of disturbances for each block of equations is identified, and so one can ask about the effects on endogenous variables of certain kinds of variation in these disturbances. (We seem to learn most about such systems when examining the effects of very artificial movements in the disturbances, such as one-time shocks [Sims 1980a] or sine and cosine waves [Geweke 1983].) This point is a rather simple one; confusion usually arises if the notion that the ordering of the variables in the system is merely a normalization is paired with subsequent reference to a disturbance as a shock to a particular variable. The latter interpretation presumes a causal chain structure. The true assumptions and legitimate applications of the VAR models in this paper, and in the earlier work of Sims, are the same. The preeminent hypothesis that can be tested using this methodology is that of no structural change in one or more blocks from one regime to another. The methodology employed here is therefore one approach well suited to the theme of the conference.

Nothing else in the model is identified. As the authors have pointed out, what appears on the right-hand side is a confounding of determinants of desired capital stock, gestation lags, and variables that enter through the information set employed in the formation of expectations. It is precisely in this sense that the investment equation is a reduced form. This fact must be employed carefully in interpreting the empirical findings in the paper. The presence of money and capital costs in the postwar investment equation and the absence of output effects when the investment block appears first rather than second are interesting food for thought. But the joint insignificance of coefficients on output in the investment equation is only circumstantial evidence that the accelerator is dead: the accelerator could simply be hiding behind an expectations mechanism and a monetary authority that tightens credit during booms. "Missing and presumed dead" might be a better appellation. Certainly either is preferred to "dead on arrival" in an arbitrarily overidentified ambulance.

I would like to return now to the predicament described in the first part of the paper, which provided the justification for applying a minimally structural model to aggregate data. The authors develop a model in which gross investment is a function of the expected price of capital services, expected output, decision lags, delivery lags, gestation lags, the current capital stock, the price of all other inputs, and (certainly not least) the variables upon which expectations are conditioned. They conclude that these functional relationships cannot be disentangled from an estimable equation without some heroic and entirely unjustified assumptions about each relationship. The model they set forth is not a "deep parameter" model, in that it is not derived from engineering technology and the preference functions of firm managers, but that is probably beside the point. I suspect that any deep parameter model would have been more prone to the identification problems posed. Their argument persuasively illustrates the incredibility of common overidentifying restrictions on investment equations. That alone should make us skeptical of reported estimates and their interpretation. In this sense, no more is needed. However, greater megatonnage could have been brought to bear in the attack; the stronger attack would in turn suggest some approaches complementary to the estimation of minimally structural aggregate models.

Observe first of all that the problems cited in section 5.2 are not peculiar to macroeconomic models or aggregate data. They exist even for a single firm producing a single homogeneous output from capital alone in a stationary stochastic state. Even for such a firm, the assumptions made would most likely be inappropriate and unrealistic in a model intended to be genuinely structural in an interesting variety of circumstances. Much capital is in fact indivisible, and most investment is in fact irreversible: log linear production functions may be reasonable, but smooth delivery and gestation lags are not. Key investment decisions typically revolve around "whether, when, and how much" rather than taking the form of smooth adjustment to changing output and prices. Economies and diseconomies of scale are critical in deciding whether to enter new markets. These inconvenient facts are not cited by way of attacking the method of analysis per se: smooth problems are tractable and have closed-form solutions, whereas realistic ones generally do not. But if one is really trying to obtain reliable estimates of technological parameters invariant under some kinds of policy changes, this sort of objection is very much to the point. In formal terms, if a true technology involving lumpy capital and irreversible decisions is projected onto a smooth adjustment space, then we should not expect that projection to remain undisturbed when nontechnological dimensions of the environment are changed. Investment models with closed-form solutions could not be applied seriously to firms accounting for the majority of business fixed investment in the United States. This observation is supported by the dearth of such applications in the literature, especially at the deep parameter level.

The argument is even stronger when applied to investment in consumer durables and owner-occupied residential structures. Competitive pressures may assure optimization and a homogeneous technology in long-run industrial equilibrium, but the assumption that households maximize homogeneous utility functions is much weaker.

Even if these problems were surmounted, industry by industry, the problem of aggregation would remain. Necessary conditions for the existence of capital aggregates and aggregate production functions have been known for a long time (see the surveys by Fisher 1969 and Muellbauer 1975). American Telephone and Telegraph, as newly constituted, can produce long distance telephone service with capital alone—as the next AT&T "strike" will remind us—and that precludes the existence of capital aggregates (Fisher 1969, 558). In the art of macroeconometric modeling it may be wise, for many purposes, to sweep the aggregation problem under the rug. In explaining quarterly investment, however, it is difficult to conclude that the problem is anything but central. To take one example, consider the response of business fixed investment, as defined in the national accounts, to alternative, fully specified paths for monetary policy. Because of very great differences in gestation lags and provisions for cancellation of orders in different industries, this response must be presumed to depend to a large degree on the distribution of orders and states of completion of projects across industries. To the extent that these distributions, and other relevant factors, cannot be inferred from aggregate data alone, we should observe very different behavior of fixed investment in different business cycles. This the authors have documented, most vividly in their table 5.1.

To focus on the capital aggregation problem is, perhaps, to beat a dead horse in polite company. In a quarterly macroeconometric model of investment, however, it is difficult to conclude that the problem is anything but central. We would expect the aggregation issue to pose larger problems in modeling changes in levels of capital stocks, defined broadly as "immobile factors of production," than in any other kind of macroeconomic modeling. To the extent that aggregation is the *dominant* difficulty in short-run macroeconometric modeling—and I am not arguing here that this is necessarily the case—we should expect that efforts to nail down tightly "structural" relationships with aggregate data and to elucidate common behavior across business cycles will be more futile for the investment sector than for any other. In any event, the aggregation argument implies that there cannot exist structural representative agent models of investment demand over the business cycle. The frustrations of various empirical investigators cited in this paper, and the poor performance of investment models generally, probably are deeply rooted.

Considerations of these kinds ought to receive more weight in modeling investment demand. They provide an argument against the application of optimizing models that is complementary to the one in the present paper in the case of aggregate data, and they suggest that even if the numerous identification problems could somehow be solved, models would still be unstable and predict poorly from one business cycle to the next. They suggest that "deep parameter" models are a waste of intellectual energy if the goal is to provide better predictions of the behavior of aggregate time series and that they will not prove structural if the representative firm assumption is taken literally.

On the positive side, there emerges a more productive agenda for future research. The modeling of short-run investment demand ought to proceed at a level at which the conditions for capital aggregation are more plausible, or at which the aggregation problem reasonably appears to be second order. At this level it might also be possible to use engineering and institutional considerations to produce credible models of the technology and identifying restrictions that would sort out the multiple roles of variables. Realistic models are not likely to be of the linear quadratic variety with closed-form solutions, but the advance of computing technology is rapidly removing this constraint. Such a model with predictive power significantly beyond mechanical extrapolation would be a very important advance. Aggregate fixed investment would, in this approach, be attacked sector by sector. In the interim, minimally structural approachs like the one taken here are useful in organizing statistical information and developing stylized facts of aggregate behavior. Acceptance of either the authors' identification argument or the aggregation argument advanced here implies that the minimally structural approach dominates representative agent models with arbitrary identifying restrictions.

Comment Christopher A. Sims

Gordon and Veitch approach the analysis of investment in the business cycle in a style that, as they point out, is close to that employed by

Christopher A. Sims is professor of economics at the University of Minnesota.

Gordon and others in analyzing inflation using price equations and wage equations. The data are treated carefully, with the complexities of their dynamics drawn out and discussed in some detail. Interpretations are explored both for the regularities persistent enough to affect equation parameters and for the special episodes that show up as residuals. But the interpretation is largely informal, with no attempt to construct an explicit mapping from the empirical estimated parameters to a set of "deeper" parameters.

I share Gordon and Veitch's skepticism toward empirical studies that interpret data under a narrow set of ad hoc maintained hypotheses. The combination of careful statistical treatment of the data with informal interpretation of the statistical models is far more useful than the reverse—elaborate formal interpretation of models that do not fit or that have not seriously confronted the data in all their complexity. Once one moves away from a style of research in which a single overidentified model is treated as a maintained hypothesis, results are likely to emerge in the form of degrees of plausibility for various classes of interpretations, and expressing such results formally will often, maybe even usually, be impractical.

Nonetheless, informality in discussion of scientific research is only an occasional practical necessity, not a virtue in itself. It carries with it some pitfalls of its own. Interpretation of a statistical model, that is, translation of the numerical properties of the data into conclusions about the way people behave, necessarily involves making assumptions. Formal modeling makes these assumptions explicit. While it may seem at times that in economics formality carried to enough of an extreme gives professional license to make explicitly ridiculous assumptions, informal interpretation of models may allow assumptions to remain hidden.

Gordon and Veitch find implications in their results for Keynesian theory, monetarist theory, "neoclassical" theory, and Q theory. They also interpret some of their results as casting light on the relative strength of the multiplier and the accelerator. All of this is done without explicit fitting of models embodying these theories or explicitly identifying multiplier and accelerator with parameters in fitted statistical models. I think it is worthwhile to examine more closely how these implications are arrived at, not because I think most of them are wrong, but because in the long run those that are correct will carry more weight if the assumptions they are based on are more explicit.

The authors point out that the "theories" in conventional theoretical discussions often are empty, having no implications for data without auxiliary assumptions that their proponents leave implicit or indeterminate. This does make it frustrating to try to use formal models in interpreting data. The econometrician is forced to make explicit the assumptions that give business cycle theories content, and especially if he does this clearly in a context where he treats more than one theory as retaining plausibility, he is likely to be accused of not formulating the theories "correctly." In fact, these implicit assumptions often exist in many versions, with each "monetarist," "Keynesian," or "*Q* theorist" having his own.

Nonetheless I think more formal modeling would have been possible and helpful in this paper and would not necessarily have compromised realistic assessment of the data. One can construct formal models exemplifying various theories and discuss how far they are, in what dimensions, from fitting the data. Even where it is not practical to generate formal models that fit well, the qualitative character of such models may be important in guiding our interpretations.

Old-Fashioned Keynesian Theory

The old-fashioned Keynesian theory is implicit in much of Gordon and Veitch's discussion, as, for example, when they cite the size of feedbacks found in a VAR model as relevant to the size of multiplier (for feedback from investment) effects. Keynesian theory emphasizes that investment is volatile and that consumption responds to it, via the multiplier, so that investment fluctuations engender larger income fluctuations. Accelerator theory in its original forms emphasizes the response of investment to the rate of growth of income without, usually, much emphasis on the notion that noninvestment expenditure has substantial volatility. Multiplier theory is usually presented with a dynamic component—the idea of rounds of expenditure propagating across sectors, with "leakages." Accelerator theory has been presented with various dynamic appendages to its basic notion that there is an instantaneous equilibrium relation between the rate of growth of income and the level of the capital stock.

Multiplier theory by itself, combining an assertion about where unpredictable variation arises with a description of how it propagates, is a theory with content. It gains policy relevance if one makes the further identifying assumption that deliberately induced changes in government expenditure or taxation will propagate in consumption with the same dynamics as do the volatile shifts in investment expenditure. It can be made testable by identifying the notion of "volatility" in investment with the notion that investment should have substantial unpredictable variance. Then unpredicted disturbances to investment should be followed with some delay by increases in consumption, probably larger than the increase in investment itself.

Samuelson's classic multiplier/accelerator paper showed how an accelerator, with an arbitrary delay introduced into it, could strongly affect the dynamics of a multiplier model. His model was not stochastic, and he did not argue for a relocation of the source of volatility. One might take a pure Keynesian multiplier/accelerator to be one in which volatility in investment is the main generator of the business cycle, with propagation through both multiplier and accelerator dynamics. I know of no example of anyone's arguing strongly for the opposite, a model in which shifts in consumption behavior are the main source of volatility, with multiplier/accelerator dynamics still generating the cycle. Such a model is clearly a logical possibility, however. More generally, both consumer and investor behavior might be independent sources of volatility.

If we estimate reduced-form regressions of consumption and investment on lagged investment and lagged consumption, that is, a two-by-two VAR, we might then interpret the consumption regression as reflecting consumer behavior, with its residual representing shifts in such behavior and the investment equation as correspondingly representing investor behavior. Multiplier dynamics and accelerator dynamics could then be read off from the MAR (moving average response) representation of the VAR.

In this framework, the size and pattern of the MAR responses are important to the interpretation. If the multiplier mechanism is at work, any shock, whether in consumption residuals, investment residuals, or both, should lead to a sustained rise in consumption, probably larger than the rise in investment, if it leads to a sustained rise in investment. It is therefore regrettable that, in giving us neither the VAR coefficients nor plots of the MARs, Gordon and Veitch choose not to present the information that would allow us to assess whether shocks really get "multiplied," and if so by what multiplier. They give us only statistical significance on blocks of coefficients and variance-explained accounting. Neither tells us what we need to know to find the point estimates of the dynamic multiplier.

The identifying assumptions we are using to distinguish consumption disturbances from investment disturbances here rely on delays in responses. If the two sorts of disturbances are distinct and responses are delayed, we ought also to expect the VAR residuals to show little correlation. (We are relying for identification of ideas close to those put forth years ago by Herman Wold, as I pointed out in Sims 1981). Investment and noninvestment innovations do not show small correlation in all of the periods and categories Gordon and Veitch explore, and in fact the strongest feedbacks occur precisely when contemporaneous correlations are strongest.

When identifying "multiplier" and "accelerator" with MAR feedbacks, the notion that reduced-form residuals (innovations) in the two equations can be identified with shifts in consumption and investment behavior is critical. Gordon and Veitch do not make the connection between this point and their choice of aggregation scheme—household versus business or durable goods versus structures. They focus on equation parameters as the basis for choice. But the degree of orthogonality of the disturbances is at least equally important. It is hard to see a priori why there should be distinct durable goods and structures shocks to household behavior, with delays in propagation of the shock from one category to the other. The Keynesian notion that business decisions may change for reasons not much related to consumer behavior, and that the results propagate into consumer decisions with a delay, may be wrong, but at least it is supported by a plausible story—consumers are credit constrained, or for other reasons they react directly to income flows with a transactions lag. If Gordon and Veitch mean for us to take seriously the idea that household durable goods consumption is subject to shocks distinct from household nondurable goods consumption, and that these propagate with a delay into nondurable consumption, a simple model showing how the notion works would have been helpful.

The Expectational Accelerator

Gordon and Veitch point out that expectational accelerator models are likely to be consistent with a variety of dynamic behavior patterns and hence to be underidentified. Such models do nonetheless provide a possible framework for interpreting results like those in this paper. In such a model, multiplier effects might still be read off from MAR response patterns, but the idea that shocks to investment and consumption equations separately represent consumption and investment behavioral disturbances no longer holds. If shocks to consumption behavior are persistent, small disturbances in it might generate large changes in expected future output, hence large, and undelayed, changes in investment. Investment innovations might be a better index of shifts in consumption behavior than consumption innovations.

Here is a simple example of a multiplier/expectational accelerator model:

$$C(t) = a + bY(t - 1) + u(t) \tag{1}$$

$$K_t = c(1 - h) \sum_{i=0}^{\infty} h^i E_t[Y(t + i)] + v_t \tag{2}$$

$$Y(t) = C(t) + K(t) - K(t - 1). \tag{3}$$

Equation (1) is the consumption function and (2) is the expectational accelerator. In (2) it is asserted that the current capital stock is kept at a fixed ratio to an exponentially weighted average of future output levels. For some ranges of its parameter values, the system has stationary solutions. Assuming, say, $b = .94$, $c = 3.33$, and $h = .90$, that at t investors know the values of current and past K and C, and that u and v are each serially uncorrelated yields as autoregressive representation

(4) $$C(t) = .94\, C(t - 1) + .94\, I(t - 1) + u(t)$$

(5) $$K(t) = 4.37\, C(t - 1) - .28\, K(t - 1) - 4.37\, K(t - 2) + e_I(t),$$

where e_I is a linear combination of the original u and v. (Note that, though the operator applied to K in [5] is not invertible, the system as a whole is stable. Also note that to derive [4] and [5] we assume that self-perpetuating exponential explosions in the capital stock are known by investors not to be sustainable.)

Gordon and Veitch give us the analog of (5) in isolation. But in the system (4) and (5), (5) cannot be interpreted in isolation. If we were to treat (5) as an "accelerator equation" describing the response of capital stock to consumption, in attempting to use it to generate a distributed lag determining K from current and past C we would find it implied explosive behavior for K. The usual trick for measuring "long-run response" of K to C (dividing the coefficient on lagged C by one minus the sum of coefficients on lagged Ks) produces a negative number. Furthermore, though the coefficients in (4) and (5) are invariant to the variances of the disturbances in (1) through (3), the explanatory power of each variable, and hence significance tests for blocks of variables, is sensitive to those variances.

The moving average representation implied by (4) and (5), with the variance of u about twice that of the "investment schedule" disturbance v, gives the following variance decomposition at the sixteen-quarter horizon, with I first in the orthogonalization:

	Explained by	
% Variance in	I	C
I	92.8	7.2
C	91.3	8.7

Investment appears as driving variation in consumption in the model, even though consumption schedule disturbances are larger. It does so because an innovation in the consumption schedule generates an expectation of sustained higher income and is therefore accompanied by an immediate expansion of investment. In fact, the proportion of variance in investment explained by consumption innovations is lowest when *either* investment or consumption shocks have relatively large variance. Investment innovations tend to pick up the dominant source of disturbance to the system. When the two underlying shocks have about equal variance, the proportion of variance in investment explained by consumption shocks rises to about 15%.

Using the kind of interpretation Gordon and Veitch apply at some points in their paper, this model seems to show a strong multiplier and little accelerator. It is a model Keynesian in spirit—volatile investment, driven by shifts in expectations, has large multiplier effects on consumption—but it has an accelerator mechanism as an important part of its transmission dynamics, and the consumption schedule in it is more volatile than the investment schedule.

Cost of Capital Models

None of the foregoing models includes prices of any kind as an explicit variable. They do not deny, however, that prices exist and are likely to be correlated with real business cycle fluctuations. Multiplier theory asserts that disturbances in investment expenditure propagate into other components of GNP. It is quite consistent with this theory that an investment disturbance should be associated with an interest rate disturbance, either through financial market reactions or through the reaction of investment to policy or foreign sector shifts. Thus multiplier theory does not deny the possible explanatory power of financial variables in a regression model of investment and noninvestment spending. It does, however, suggest that if such financial variables are included in the model its interpretation will become much more complicated.

In all their reported results, except for a few regressions of investment on lagged investment and noninvestment, financial variables are mixed in with real variables in a single system. This makes interpretation of the results in the light of "real theories" like the multiplier/accelerator difficult. Multiplier/accelerator theory does not say anything about how much predictive power price and financial variables should have. It does suggest likely patterns for the joint behavior of investment and noninvestment MAR response paths even when prices are in the model, but these are not discussed by Gordon and Veitch.

Gordon and Veitch interpret neoclassical and Q theory as predicting that cost of capital variables should have a lot of predictive value for investment. They also point out that these theories are partial equilibrium theories and really make no statement about how data should behave. My view is that the question of how much predictive power such variables have (and whether high cost of capital is predictive of lower or higher investment) is interesting and important. It affects the interpretation and plausibility for many theoretical approaches to business cycles. However, it is not reasonable to think of the relative predictive powers of such variables and lagged noninvestment as relating to a horse race between accelerator, Q, and neoclassical theories. It is an interesting race, but these are not the horses performing—in fact, these are not even horses.

Monetarist Theory

The comments of the preceding section apply here as well. That monetary variables should have predictive value is not at all inconsistent with multiplier/accelerator theory. The difference is that monetarist theory, unlike Q and neoclassical investment theories, is seriously put forward as a complete theory with implications for data, at least by some of its proponents. That is, monetarists argue not only that there is an equilibrium relation between money and real activity, but that disturbances to monetary variables propagate into real variables with a delay, are not explainable as systematic reaction to the real variables themselves, and account for much of the observed business cycle.

Monetarist theory is therefore confirmed in Gordon and Veitch's finding that monetary aggregates have substantial explanatory power for investment. On the other hand, as I pointed out in the *American Economic Review* paper Gordon and Veitch cite (Sims 1983), this confirmation is analogous to confirming the existence of an exploitable trade-off between inflation and unemployment by regressing unemployment on inflation: even in a model where monetary policy is totally ineffective, a policy authority aiming at stabilizing the price level would generate a path for money aggregates that would have great predictive value for real variables. And this result applies both to the money stock itself and to the base.

Conclusion

Gordon and Veitch have cleanly displayed the empirical regularities that are the focus of their discussion. They have isolated some interesting phenomena and given sensible interpretations of at least some of them. Multiplier and monetarist theories each show some degree of consistency with the data. Financial variables show substantial predictive power for investment. Investment contains a lot of unpredictable variation. For reasons they have laid out themselves, they have had difficulty connecting these results to much of the conventional "theory of investment," but this reflects defects in that theory.

The criticisms in this comment arise from holding the authors to an idealized standard. We have little in the way of formal theory capable of making predictions about observed data on investment and other aggregate variables, particularly when some of the variables are price variables. If Gordon and Veitch had gone some way toward providing such theories, even if only simple models whose quantitative properties could be compared with the data, their paper would have been better.

I think they would have in this case been led to give us a more detailed look at their regression and VAR data analysis. But good models in this area will involve at least some elements of modeling dynamic optimization under uncertainty, and such models, even apparently simple ones, are challenging to solve and understand. It will probably take many economists, working over some years, to develop practically fruitful ways of combining sophisticated, honest data analysis with stochastic theory.

Reply Robert J. Gordon and John M. Veitch

Christopher Sims has contributed a constructive set of comments. We agree with his characterization of our paper as achieving a clean display of interesting empirical regularities, as well as with his criticism that, holding us to an "idealized standard," he would have preferred that some part had been devoted to developing simple models whose qualitative properties could have been compared with the data. Sims contributes one example that he calls a "multiplier/expectational accelerator model" and discusses its implications for the decomposition of variance in a hypothetical two-variable VAR model that includes only consumption and investment. A related criticism is that our paper estimates only equations for investment rather than equations for both investment and consumption.

In urging us to carry out a parallel study of consumption and investment, Sims can be interpreted as making a suggestion for future research rather than a serious criticism of the present paper. In focusing on the four components of investment (which include consumer durables expenditures), we were attempting to limit the scope of a long and ambitious paper that was primarily intended to provide an empirical contrast between existing postwar quarterly data and our newly created set of quarterly expenditures data for the interwar period. To have carried out a serious study of consumer expenditures on nondurable goods and services would have poached on the turf of Robert Hall, who has contributed a paper on that subject to this volume (chap. 4). The systems properties of small VAR models for the whole economy, including not only consumption expenditures but also the nature of policy feedbacks from expenditures to government spending and the money supply (alluded to by Sims in his section "Monetarist Theory"), could be usefully studied in a sequel to this paper.

The purpose of this rejoinder is to provide some quantitative evidence to clothe the bare bones of Sims's conjectures regarding the implications for multiplier/accelerator theory of a small two-by-two VAR model containing equations only for aggregate investment and consumption. Before proceeding with the exercise we must demur that limiting a VAR model to just investment and consumption, without any separate role for monetary variables, is inconsistent with the findings in our paper that monetary shocks were important in both the interwar and the postwar periods.

In what follows we shall maintain definitions that are consistent with those in our paper, including consumer durables expenditures in "investment" and treating "consumption" as including only consumer expenditures on nondurable goods and services. In the interpretation that Sims suggests, evidence in support of the multiplier mechanism would be based on an inspection of the MAR (moving average response) representation of the VAR model. We should expect to find a sustained rise in consumption, probably larger than the rise in investment, following any shock to consumption residuals or investment residuals.

The results, shown in table C5.1, provide a partial confirmation of Sims's conjectures for the interwar but not for the postwar period. In the interwar two-by-two VAR model, a shock to either consumption or investment generates a sustained response of consumption, confirming the multiplier mechanism, but also a response of investment. However, in contrast to Sims's prediction, the response of consumption is in no case appreciably larger than that of investment. Behavior in the

Table C5.1 **Moving Average Responses in Two-by-Two Investment Consumption Model**

	Investment Innovation		Consumption Innovation	
Quarters after Shock	Interwar	Postwar	Interwar	Postwar
Investment response				
4	1.55	0.71	0.89	0.08
8	1.31	0.29	1.12	−0.04
12	0.92	0.10	0.99	−0.06
16	0.65	0.06	0.80	−0.05
Consumption response				
4	0.31	0.18	1.15	0.22
8	0.72	0.05	1.07	0.17
12	0.76	−0.05	0.98	0.11
16	0.67	−0.07	0.85	0.08

Innovation Accounting at Sixteen-Quarter Horizon (Interwar/Postwar)

	Investment	Consumption
Investment	79/98	45/26
Consumption	21/2	55/74

postwar period is completely different, with very small responses except for the response of investment to its own innovations. A possible reason for the difference between the interwar and postwar responses involves the omitted monetary variables, which in the Great Depression acted to amplify expenditure shocks but, at least in the second half of the postwar period, acted to counteract expenditure shocks.

The bottom section of table C5.1 displays the decomposition of variance ("innovation accounting") for the two-by-two model in the same format as table 5.8 in the paper. Here we see that, as in the larger models discussed in the paper, the investment innovation accounts for most of the variance of investment and a substantial fraction of the variance of consumption, 45% in the interwar and 26% in the postwar period. Sims may doubt the relevance of this result in light of his multiplier/expectational accelerator model that makes investment appear to be driving consumption when in fact consumption disturbances are the dominant source of variance. But we in turn may doubt the relevance of his model, in which investment is free to jump instantaneously within the current quarter in response to a consumption shock (allowing the investment innovation to "mask" the consumption shock), in contrast to the real world, in which there are substantial gestation lags in the investment process.

Finally, Sims is skeptical of our preference for aggregating the four categories of investment along the structures/equipment dimension rather than along the household/business dimension. We have examined the pattern of orthogonality of the disturbances in a four-variable VAR model containing only the four components of investment. These results are displayed in table C5.2, which is in the same format as the bottom part of table 5.7 in the paper. The results are mixed. In addition to the significant diagonal elements, we find examples of strong feedback from consumer durables (*CD*) to producers' durable equipment (*PDE*) in the postwar period and from residential structures (*RS*) to nonresidential structures (*NRS*) in the interwar period. These confirm the structures/equipment pattern of aggregation. But there are other elements that support the household/business pattern of aggregation, including feedback from *RS* to *DG* in the postwar period and *DG* to

Table C5.2 **Exogeneity Tests**

	DG	*PDE*	*RS*	*NRS*
DG	***/***	/	/***	/
PDE	/***	***/***	/***	*/
RS	**/		***/***	/*
NRS	***/		***/	***/***

RS in the interwar, and weak feedback from *NRS* to *PDE* in the interwar. The ambiguity of these results may suggest that investment should be studied either with all four categories lumped together or with each studied separately, with little justification for either two-way aggregation scheme.

Discussion Summary

Allen Sinai suggested that the bulk of the analysis was at too aggregated a level, and this comment led the authors to devote much more attention in the final version to the four components of investment and to alternative aggregation schemes. Sinai also found the role played by real balances interesting. Robert Eisner felt that the analysis confused output expectations with a fixed distributed lag on past output. He argued that such an expectational proxy was inadequate because the weights on past output were likely to change over time. Olivier Blanchard felt that the structural interpretation, given the results, was too strong and would be valid only if investment were independent of contemporaneous variables. Robert Hall believed that more structural information on the investment process would be interesting but that identification of the structure would require that additional exogenous variables be found. He noted how hard it was to find such variables.

Mark Watson questioned the use of interpolated data in the prewar and not the postwar period. He noted that the interpolated series were essentially conditional expectations of the actual interpolated variables and that consequently the second moments of the data were not the same as the second moments of the conditional expectations. However, he observed that explicit corrections could be made in the estimation procedure.

John Veitch reported that to check the consistency between the prewar and postwar samples, he and Gordon had also used data for the postwar period interpolated in the same manner as the prewar data and found that the results (not reported in the conference version of the paper) were not sensitive to this change. In regard to the issue of contemporaneous correlations, Veitch suggested that the accounting conventions of the Bureau of Economic Analysis made it much more likely that investment in structures might be contemporaneously uncorrelated with other variables. As an example, he noted that current housing starts inevitably appear in the income accounts as residential investment for future quarters.

References

Abel, Andrew B. 1979. *Investment and the value of capital.* New York: Garland.

Abel, Andrew B., and Olivier Blanchard. 1983. Investment and sales: An empirical study. Paper presented at National Bureau of Economic Research Macro Conference, July.

Auerbach, Alan J. 1983. Taxation, corporate financial policy, and the cost of capital. *Journal of Economic Literature* 21 (September): 905–40.

Bernanke, Ben S. 1982. Adjustment costs, durables, and aggregate consumption. Working Paper 1038, National Bureau of Economic Research.

———. 1983a. Nonmonetary effects of the financial crisis in the propagation of the Great Depression. *American Economic Review* 73 (June): 257–76.

———. 1983b. An equilibrium model of industrial employment, hours, and earnings, 1923–1939. Working Papers in Economics E-83-19, Hoover Institution.

Bischoff, Charles W. 1971. The effect of alternative lag distributions. In *Tax incentives and capital Spending*, ed. Gary Fromm, 61–130. Washington, D.C.: Brookings Institution.

Blanchard, Olivier J. 1981. What is left of the multiplier accelerator? *American Economic Review* 71 (May): 150–54.

Bosworth, Barry. 1975. The stock market and the economy. *Brookings Papers on Economic Activity* 6(2): 257–300.

Chirinko, Robert S. 1983a. Investment and tax policy: A survey of existing models and empirical results with applications to the high-technology sector. Report for the National Science Foundation, Division of Policy Research and Analysis.

———. 1983b. Investment, Tobin's *Q*, and multiple capital inputs. Paper presented to the Econometric Society winter meetings, December.

Chirinko, Robert S., and Robert Eisner. 1983. Tax policy and investment in major U.S. econometric models. *Journal of Public Economics* 20 (March): 139–66.

Chow, Gregory C., and An-loh Lin. 1971. Best linear unbiased interpolation distribution and extrapolation of time series by related series. *Review of Economics and Statistics* 53 (November): 372–76.

Clark, J. Maurice. 1917. Business acceleration and the law of demand: A technical factor in business cycles. *Journal of Political Economy* 25 (March): 217–35.

Clark, Peter K. 1979. Investment in the 1970s: Theory, performance, and prediction. *Brookings Papers on Economic Activity* 10(1): 73–124.

deLeeuw, Frank. 1971. The demand for housing: A review of cross-section evidence. *Review of Economics and Statistics* 53 (February): 1–10.

Eckstein, Otto. 1983. Disinflation. In *Inflation: Prospects and remedies*, ed. W. D. Nordhaus. Alternatives for the 1980s, no. 10. Washington, D.C.: Center for National Policy.

Eisner, Robert. 1972. Components of capital expenditures: Replacement and modernization versus expansion. *Review of Economics and Statistics* 54 (August): 297–305.

Eisner, Robert, and M. I. Nadiri. 1968. Investment behavior and neoclassical theory: A comment. *Review of Economics and Statistics* 50 (August): 369–82.

Eisner, Robert, and Robert H. Strotz. 1963. Determinants of business investment. In *Impacts of monetary policy*, ed. Commission on Money and Credit, 60–337. Englewood Cliffs, N.J.: Prentice-Hall.

Feldstein, Martin S. 1981. The distribution of the U.S. capital stock between residential and industrial uses. *Economic Inquiry* 19 (January): 26–37.

Feldstein, Martin S., and David K. Foot. 1971. The other half of gross investment: Replacement and modernization expenditures. *Review of Economics and Statistics* 53 (February): 49–58.

Feldstein, Martin S., and Michael Rothschild. 1974. Towards an economic theory of replacement investment. *Econometrica* 42 (May): 393–424.

Fischer, Stanley, and Robert C. Merton. 1984. Macroeconomics and finance: The role of the stock market. Working Paper 1291, National Bureau of Economic Research.

Fisher, F. M. 1969. The existence of aggregate production functions. *Econometrica* 37:553–77.

Friedman, Milton, and David Meiselman. 1963. The relative stability of monetary velocity and the investment multiplier in the United States, 1897–1958, In *Stabilization policies*, ed. Commission on Money and Credit. Englewood Cliffs, N.J.: Prentice-Hall.

Friedman, Milton, and Anna J. Schwartz. 1963. *A monetary history of the United States*, 1867–1960. Princeton: Princeton University Press.

———. 1970. *Monetary statistics of the United States: Estimates, sources, and methods*. New York: Columbia University Press.

Garber, Peter M., and Robert G. King. 1983. Deep structural excavation? A critique of Euler equation methods, Technical Paper 31, National Bureau of Economic Research.

Geweke, J. F. 1983. The superneutrality of money in the United States: An interpretation of the evidence. Working Paper, Duke University.

Gordon, Robert A. 1951. Cyclical experience in the interwar period: The investment boom of the twenties. In *Conference on Business Cycles*, 163–214. New York: National Bureau of Economic Research.

Gordon, Robert J. 1973. Interest rates and prices in the long run: A comment. *Journal of Money, Credit, and Banking* 5 (February): 460–63.

———. 1977. Can the inflation of the 1970s be explained? *Brookings Papers on Economic Activity* 8(1): 253–77.

———. 1982. Price inertia and policy ineffectiveness in the United States, 1890–1980. *Journal of Political Economy* 90 (December): 1087–1117.

———. 1983a. "Credibility" vs. "Mainstream": Two views of the inflation process. In *Inflation: Prospects and remedies*, ed. W. D. Nordhaus, 25–34. Alternatives for the 1980s, no. 10. Washington, D.C.: Center for National Policy.

———. 1983b. The conduct of domestic monetary policy. Working Paper 1221, National Bureau of Economic Research.

———. 1984a. *Macroeconomics*. 3d ed. Boston: Little, Brown.

———. 1984b. Inflation in the recovery. Paper presented to a meeting of academic consultants with the Board of Governors of the Federal Reserve System, May.

Gordon, Robert J., and Stephen R. King. 1982. The output cost of disinflation in traditional and vector autoregressive models. *Brookings Papers on Economic Activity* 13(1): 205–42.

Gordon, Robert J., and James A. Wilcox. 1981. Monetarist interpretations of the Great Depression: Evaluation and critique. In *The Great Depression revisited*, ed. Karl Brunner, 49–107. Boston: Martinus Nijhoff.

Grebler, Leo, David M. Blank, and Louis Winnick. 1956. *Capital formation in residential real estate: Trends and prospects*. Princeton: Princeton University Press.

Hall, Robert E. 1977. Investment, interest rates, and the effects of stabilization policies. *Brookings Papers on Economic Activity* 8(1): 61–103.

———. 1978. Stochastic implications of the life cycle–permanent income hypothesis: Theory and evidence. *Journal of Political Economy* 86:971–88.

Hall, Robert E., and Dale W. Jorgenson. 1967. Tax policy and investment behavior. *American Economic Review* 57 (June): 391–414.

———. 1971. Application of the theory of optimum capital accumulation. In *Tax incentives and capital spending*, ed. G. Fromm, 9–60. Washington, D.C.: Brookings Institution.

Hansen, Lars P., and Kenneth J. Singleton. 1982. Generalized instrumental variables estimation of nonlinear rational expectations models. *Econometrica* 50 (September): 1269–86.

Hayashi, Fumio. 1982. Tobin's marginal *q* and average *q*. *Econometrica* 50 (January): 213–24.

Helliwell, John F. 1976. Aggregate investment equations: A survey of issues. In *Aggregate investment: Selected issues*, ed. J. Helliwell, 13–53. London: Penguin Education.

Hickman, Bert G. 1973. What became of the building cycle? In *Nations and households in economic growth: Essays in honor of Moses Abramovitz*, ed. Paul David and Melvin Reder. New York: Academic Press.

Jorgenson, Dale W. 1963. Capital theory and investment behavior. *American Economic Review* 53 (May): 247–59.

———. 1967. The theory of investment behavior. In *Determinants of investment behaviour*, ed. R. Ferber, 129–55. Universities–National Bureau Conference Series no. 18. New York: Columbia University Press.

———. 1971. Econometric studies of investment behavior: A survey. *Journal of Economic Literature* 9 (December): 1111–47.

Jorgenson, Dale W., and James A. Stephenson. 1967. The time structure of investment behavior in U.S. manufacturing, 1947–1960. *Review of Economics and Statistics* 49 (February): 16–27.

———. 1969. Issues in the development of the neoclassical theory of investment behavior. *Review of Economics and Statistics* 51 (August): 346–53.

Jorgenson, Dale W., and Martin Sullivan. 1981. Inflation and corporate capital recovery. In *Depreciation, inflation, and the taxation of income from capital*, ed. Charles R. Hulten, 171–237. Washington, D.C.: Urban Institute Press.

Keynes, John Neville. 1890. *The scope and method of political economy*. London: Macmillan.

King, Stephen R. 1983. Macroeconomic activity and the real rate of interest. Ph.D. diss., Northwestern University.

Litterman, Robert A. 1981. A random walk, Markov model for the interpolation of time series. Working Paper 190, Federal Reserve Bank of Minneapolis.

Lucas, Robert E., Jr. 1967. Adjustent costs and the theory of supply. *Journal of Political Economy* 75 (August): 321–34.

———. 1976. Econometric policy evaluation: A critique. In *The Phillips curve and labor markets*, ed. Karl Brunner and Allan Meltzer, 19–46. Carnegie-Rochester Conference Series on Public Policy 1. Amsterdam: North-Holland.

Malinvaud, Edmond. 1982. Wages and unemployment. *Economic Journal* 92 (March): 1–12.

Mayer, Thomas. 1980. Consumption in the Great Depression. *Journal of Political Economy* 86 (January): 139–45.

Mishkin, Frederic S. 1978. The household balance sheet and the Great Depression. *Journal of Economic History* 38:918–37.

Modigliani, Franco, and Richard A. Cohn. 1979. Inflation, rational valuation and the market. *Financial Analysts Journal* (March/April), 3–23.

Muellbauer, J. 1975. Aggregation, income distribution and consumer demand. *Review of Economic Studies* 42 525–43.

Musgrave, John C. 1979. Durable goods owned by consumers in the United States, 1925–77. *Survey of Current Business* 59 (March): 17–25.

Perry, George L. 1983. What have we learned about disinflation? *Brookings Papers on Economic Activity* 14(2): 587–602.

Polinsky, A. Mitchell. 1977. The demand for housing: A study in specification and grouping, *Econometrica* 45 (March): 447–61.

Roosa, Robert. 1951. Interest rates and the central bank. In *Money, trade, and economic Growth: Essays in Honor of John H. Williams*, 270–95. New York: Macmillan.

Samuelson, Paul. 1939. A synthesis of the principle of acceleration and the multiplier. *Journal of Political Economy* 47 (December): 786–97.

Shiller, Robert. 1981. Do stock prices move too much to be justified by subsequent changes in dividends? *American Economic Review* 71(3): 421–36.

Sims, Christopher A. 1980a. Macroeconomics and reality. *Econometrica* 48 (January): 1–48.

———. 1980b. Comparison of interwar and postwar business cycles: Monetarism reconsidered. *American Economic Review, Papers and Proceedings* 70(2): 250–57.

———. 1981. An autoregression index model for the U.S., 1948–1975. In *Large-scale macro-econometric models*, ed. J. Kmenta and J. B. Ramsey. Amsterdam: North-Holland.

———. 1982. Policy analysis with econometric models. *Brookings Papers on Economic Activity* 13(1): 107–64.

———. 1983. Is there a monetary business cycle? *American Economic Review* 73 (May): 228–33.

Summers, Lawrence H. 1981. Taxation and corporate investment: A *q*-theory approach. *Brookings Papers on Economic Activity* 12(1): 67–127.

Swanson, J., and S. Williamson. 1971. Estimates of national product and income for the U.S. economy, 1919–41. Working Paper 71–32, Department of Economics, University of Iowa.

Tax Foundation. 1979. *Facts and figures on government finance*. Washington, D.C.: Tax Foundation.

Taylor, John. 1983. Optimal stabilization rules in a stochastic model of investment with gestation lags. Working Paper 1225, National Bureau of Economic Research.

Temin, Peter. 1976. *Did monetary forces cause the Great Depression?* New York: Norton.

U.S. Bureau of the Census. 1965. *The statistical history of the United States from colonial times to the present.* Stamford, Conn.: Fairfield.

U.S. Department of Commerce. 1981. *The national income and product accounts of the U.S., 1929–76.* Supplement to the *Survey of Current Business*, September.

Wilcox, James A. 1983. Disaggregating data using related series. *Journal of Business and Economic Statistics* (July), 187–91.

Yellen, Janet, 1980. Jorgensonian investment theory: The case of the missing wage rate. Working Paper, University of California at Berkeley.