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Interest Rates and Investment Spending: Some Empirical Evidence for Postwar U.S. Producer Equipment, 1947–1980*

This paper explores the dynamic effect of interest rates on investment spending utilizing vector autoregressions. Nominal interest rate innovations have a strong and persistent effect on investment, overshadowing "animal spirit" or own-investment innovations and GNP innovations. This result is robust to different ordering of the contemporary innovations. By imposing cross-equation restrictions, we test the Fama-Litterman-Weiss hypothesis that nominal yields affect investment since they provide information on future GNP. This hypothesis cannot be rejected at high significant levels. The strong and persistent nominal interest rate effect on investment is eliminated when we include a rational expectations predictor of future GNP in the VAR system. The results therefore support the accelerator model of investment.

I. Introduction

The empirical evidence on the effect of interest rates on aggregate investment behavior is ambiguous. The early neoclassical models of investment (e.g., Hall and Jorgenson 1967; Jorgenson and Stephenson 1967) and the putty clay extensions (e.g., Bischoff 1969, 1971) imposed various nonlinear restrictions on demand shifters and the user cost of capital. Some studies use the nominal interest rate in constructing user cost whereas others use a proxy for the real rate. Given these restrictions and different definitions of user cost of capital, it is difficult to distinguish the interest rate effect, nominal or real, from other effects on investment behavior. Moreover, some writers (e.g., Eisner and Nadiri 1968; Eisner 1978; Clark 1979) concluded that interest rates are not empirically relevant. The latter authors' empirical findings point to the accelerator effect to be the most critical determinant of investment spending.

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Two empirical studies that formally incorporated investment behavior with an adjustment cost mechanism and rational expectations were contradictory (Blanco 1978; Bernanke 1983*a*). Both these studies again imposed strong identifying restrictions on their econometric models.

A further set of studies based on adjustments costs—the Tobin q models—do not separate out interest rate from output effects (e.g., von Furstenberg 1977; Summers 1980). An exception to this is the work of Abel and Blanchard (1983) who decomposed q into output and interest rate effects. However, their study concludes that current q explains only a fraction of investment behavior. While most of the empirical models above are derived from partial equilibrium analysis, the only consistent empirical general equilibrium model of investment behavior (Kydland and Prescott 1982) that we know of has been rejected by the data (Altug 1984).

Because of all these conflicting results, how interest rates affect investment behavior remains inconclusive although this is an important question in macroeconomic modeling and the theory of the business cycle.

The traditional literature on investment suggests that investment responds to the real rate of return—the marginal efficiency of capital schedule. Nominal interest rates and inflation may additionally affect investment behavior through tax distortions or liquidity effects.

While the above effects are theoretically uncontroversial, there is a question whether it is the long-term rate or short-term rate that matters. The usual view, through the cost of adjustment mechanism, is that the long-term rate is important. When the marginal cost of investment rises, firms are rewarded for superior forecasting. This allows the firm to spread its investment spending more optimally over time, thus minimizing costs. Therefore the cost of adjustment mechanism is directly responsible for the relevance of long-term rates (e.g., Lucas 1967; Gould 1968). All empirical literature to date has used long-term yields.

However, as Hall (1977) and Lawrence and Siow's (1985) time-to-build model have pointed out, it is the short-term rate that is relevant when there is no cost of adjustment mechanism and there is free entry into the industry. When the marginal cost of investment goods is perfectly elastic, superior forecasting about demand conditions beyond the gestation period of the investment project is irrelevant for market equilibrium. Abstracting from the problems of reversibility, only short rates matter. Thus the choice between short-term and long-term rates is an open question.

Recently, a new strand of literature has emphasized the predictive content of nominal interest rates. That is, changes in nominal rates today reflect agents' forecasts of GNP tomorrow (Litterman and Weiss 1985). This argument was first put forward in a seminal paper by Fama

(1981) in which he claimed that the negative relationship between stock prices and inflation was essentially characterizing the demand for money. Applying the Fama-Litterman-Weiss argument to the theory of investment, then higher nominal interest rates would be inversely related with new investment expenditure decisions, despite the fact that real interest rates remained constant. Firms using the forward-looking nature of nominal rates would, on observing an increase in nominal rates, infer a slowdown in their sector's future demand and hence capital spending. Thus nominal rates would play a key role in determining the path of investment (see Lawrence and Siow [1985] for an explicit derivation of this result).

It is therefore of importance in empirical work to distinguish between direct incentive effects of interest rate movements and indirect effects due to the predictive power of interest rates as forward-looking prices.

Objectives

It is our purpose to test for the presence of a real-rate effect on investment spending as well as on the predictive power of nominal rates in forecasting GNP. One reservation of the study is that our real rate of interest abstracts from tax distortion (see Feldstein [1982] on the importance of those distortions, in particular, the impact of anticipated inflation on the after-tax real rate of return). We will also test the Hall hypothesis that it is short-term interest rates and not long-term rates that have the most significant impact on investment spending. The methodology utilized is to estimate restricted and unrestricted vector autoregressions (VARs). While we regard VARs as a methodology for summarizing the dynamic nature of the data, we are not oblivious to several of its shortcomings. For example, we cannot throw much light on contemporaneous exogeneity. However, the test results that we do present are valid independent of our assumptions of contemporaneous causality.[1]

The main motivation for using VARs is that most studies claim to be estimating "structural" investment equations. Such equations are suspicious unless strong assumptions are made: (*a*) there is no aggregation problem with different types of capital. This is particularly important in a world where each capital project has a different gestation lag; (*b*) the irreversibility of investment is ignored; and (*c*) the processes driving investment, such as GNP or interest rates, are exogenous. Even if the model is correct, the data may reject the model because of other "false restrictions" needed to estimate the structural model.[2]

1. We have also reestimated the equations altering the ordering of the contemporaneous innovations. The resulting dynamic elasticities are insensitive to the ordering.

2. In other words much of the estimation is carried out in equations which are not regression equations, since the error term is not orthoganal to the right-hand-side vari-

The empirical findings are that short-term real interest rates have a direct but *small* effect on our postwar quarterly product equipment spending. Short-term nominal rates, on the other hand, have a profound and persistent effect on measured investment, due to the fact that nominal rates are forward-looking with predictive power in explaining future anticipated GNP. Once we control for anticipated GNP, the impact of nominal rates—in terms of magnitude and persistence—is significantly damped. Thus the Fama-Litterman-Weiss hypothesis of nominal rates as good predictors of GNP is not rejected.

We also find that short-term interest rates have far greater predictive power than long-term rates in explaining the path of post–World War II product equipment spending. This is consistent with the Hall hypothesis of perfectly elastic investment supply of inputs and free entry of new firms into the capital industry.

As expected, there are also strong feedback effects between output and investment. By simulation of the nonlinear restricted VARs, the nominal rate has an extremely powerful and persistent effect on producer equipment. This persistence would be particularly difficult to find or explain with single-equation models.

Section II discusses the empirical methodology. The empirical results are presented in Section III and, finally, a discussion of the results is presented in Section IV.

II. Empirical Methodology

There are three major obstacles in directly estimating any structural investment model on aggregate data. The first problem is due to aggregation. In any realistic economy there are many types of capital with different times to build, adjustment costs, and demand parameters. Therefore, measured aggregate investment consists of the aggregation of these different types of capital investment. While aggregate investment will in general be driven by distributed lags of forecasts of demand shifters and interest rates, the weights of these distributed lags are a "convolution of the distributional weights for value put in place for each type of capital and the distributional weight of each type of capital in the total capital stock" (Taylor 1982 p. 61). It is impossible to separate the contribution of the two distributions with one set of data. The second problem is due to the irreversibility of investment. As Sargent (1980) and Bernanke (1983*b*) showed, closed-form investment equations cannot be derived when irreversibility is taken seriously. The third problem, which confounds all studies of investment, is that of

ables. As we will show using Granger-causality tests, this assumption is unjustified on empirical grounds.

the endogeneity of the processes driving investment. Surely GNP and nominal interest rates are not exogenous with respect to aggregate investment. However, all the studies we know ignore the endogeneity problem in their empirical work. Given these problems, we are not willing to impose "incredible identifying restrictions" (Sims 1980 p. 2) to obtain structural estimates of an investment model. We suspect that few economists believe in the structural investment models estimated to date because of these false restrictions.

Our approach, then, is to estimate vector autoregressions (VARs). At the aggregate level, we use VARs only to measure the relevance of various factors that affect investment. In particular, we want to test for the direct effect of short-term real interest rates on investment. The nonneutral effects of nominal interest rate and inflation on investment, as well as the effect on predicted GNP on investment behavior, will also be investigated. Finally, we will make strong assumptions about contemporaneous causality and show the responses of investment to interest rates, output, and inflation innovations. While we acknowledge that the responses may be difficult to interpret structurally, the responses are useful for summarizing the data. The tests on the real rates are valid independent of our assumptions on contemporaneous causality. Good descriptions of the methodology are in Sims (1980) and Litterman and Weiss (1984).

We now use an example to show how we test our restrictions. The discussion borrows from Litterman and Weiss (1985). Consider the following model where investment depends on the real rate of interest and predicted GNP:[3]

$$\pi_t = \sum_{j=1}^{2} a_{1j}\pi_{t-j} + \sum_{j=1}^{2} a_{2j}i_{t-j} + \sum_{j=1}^{2} a_{3j}Y_{t-j} + \sum_{j=1}^{2} a_{4j}I_{t-j} + \varepsilon_{1t}$$

$$i_t = \sum_{j=1}^{2} b_{1j}\pi_{t-j} + \sum_{j=1}^{2} b_{2j}i_{t-j} + \sum_{j=1}^{2} b_{3j}Y_{t-j} + \sum_{j=1}^{2} b_{4j}I_{t-j} + \varepsilon_{2t}$$

$$Y_t = \sum_{j=1}^{2} c_{1j}\pi_{t-j} + \sum_{j=1}^{2} c_{2j}i_{t-j} + \sum_{j=1}^{2} c_{3j}Y_{t-j} + \sum_{j=1}^{2} c_{4j}I_{t-j} + \varepsilon_{3t}$$

$$I_t = \sum_{j=1}^{2} d_{1j}r_{t-j} + \sum_{j=1}^{2} d_{2j}Y^e_{t-j} + \sum_{j=1}^{2} d_{4j}I_{t-j} + \varepsilon_{4t} \qquad (1)$$

$$r_{t-j} = i_{t-j} - E_{t-j}\pi_{t-j}$$

$$Y^e_{t-j} \equiv E_{t-j}Y_{t+1-j} \, ,$$

3. In the actual estimation we will use longer lag structures. The example here is used for simplicity of exposition.

where

π_t: inflation rate between t and $t + 1$;
i_t: one period nominal interest rate prevailing at t;
Y_t: real GNP;
I_t: real *measured* investment;
r_t: real rate of interest between t and $t + 1$;
E_t: conditional expectations operator based on information at t;
Y_t^e: anticipated GNP at $t + 1$ based on information at t.

Our definition of the real rate of interest is derived from the standard Fisher equation. A shortcoming in this specification is that we ignore taxes, inflationary tax distortions, and depreciation. We use the short-term real rate because in the empirical work (to be described in the next section) long-term nominal rates do not Granger cause investment in the presence of short-term rates. In the restricted VAR we will also use predicted GNP instead of actual GNP. This specification is used to capture the forward-looking behavior of investment spending.

We should mention the rationale for estimating *measured* investment on lags of anticipated output. If capital were produced instantaneously (in one period), then we would find that the coefficients on all lags of anticipated GNP would be zero. However, investment takes time to build, and thus measured investment at time t is capturing not only newly determined projects but spending determined from previous periods. Hence the justification for including lags of anticipated GNP. The distinction between determined projects and measured investment is made clear in Taylor (1982) and Lawrence and Siow (1985). We can thus state that investment put in place reflects agents' decisions based on previous and current forecasts of demand conditions prevailing in each sector of the economy.

From the first and third equations in (1), $E_{t-j}\pi_{t-j}$ and Y_{t-j}^e can be written as

$$
\begin{aligned}
E_{t-j}\pi_{t-j} &= \sum_{k=1}^{2} a_{1k}\pi_{t-j-k} + \sum_{k=1}^{2} a_{2k}i_{t-j-k+1} \\
&+ \sum_{k=1}^{2} a_{3k}Y_{t-j-k+1} + \sum_{k=1}^{2} a_{4k}I_{t-j-k+1}, \quad \text{for all } j \\
Y_{t-j}^e &= \sum_{k=1}^{2} c_{1k}\pi_{t-j-k} + \sum_{k=1}^{2} c_{2k}i_{t-j-k+1} \\
&+ \sum_{k=1}^{2} c_{3k}Y_{t+1-j-k} + \sum_{k=1}^{2} c_{4k}I_{t+1-j-k}, \quad \text{for all } j.
\end{aligned}
\tag{2}
$$

Equations (1) and (2) are combined to derive the restricted vector autoregression:

$$
\begin{aligned}
\pi_t &= \sum_{j=1}^{2} a_{1j}\pi_{t-j} + \sum_{j=1}^{2} a_{2j}i_{t-j} + \sum_{j=1}^{2} a_{3j}Y_{t-j} + \sum_{j=1}^{2} a_{4j}I_{t-j} + \varepsilon_{1t} \\
i_t &= \sum_{j=1}^{2} b_{1j}\pi_{t-j} + \sum_{j=1}^{2} b_{2j}i_{t-j} + \sum_{j=1}^{2} b_{3j}Y_{t}-j + \sum_{j=1}^{2} b_{4j}I_{t-j} + \varepsilon_{2t} \\
Y_t &= \sum_{j=1}^{2} c_{1j}\pi_{t-j} + \sum_{j=1}^{2} c_{2j}i_{t-j} + \sum_{j=1}^{2} c_{3j}Y_{t-j} + \sum_{j=1}^{2} c_{4j}I_{t-j} + \varepsilon_{3t} \\
I_t &= \sum_{j=1}^{2} d_{1j}\left[\left(i_{t-j} - \sum_{k=1}^{2} a_{1k}\pi_{t-j-k} - \sum_{k=1}^{2} a_{2k}i_{t+1-j-k}\right.\right. \\
&\quad \left.\left. - \sum_{k=1}^{2} a_{3k}Y_{t+1-j-k} - \sum_{k=1}^{2} a_{4k}I_{t+1-j-k}\right)\right] \\
&\quad + \sum_{j=1}^{2} d_{3j}\left[\left(\sum_{k=1}^{2} c_{1k}\pi_{t-j-k} + \sum_{k=1}^{2} c_{2k}i_{t+1-j-k}\right.\right. \\
&\quad \left.\left. + \sum_{k=1}^{2} c_{3k}Y_{t+1-j-k} + \sum_{k=1}^{2} c_{4k}I_{t+1-j-k}\right)\right] + \sum_{j=1}^{2} d_{4j}I_{t-j} + \varepsilon_{4t}
\end{aligned}
\tag{3}
$$

All the unobserved variables in (1) have been replaced by observable variables in (3). Nominal interest rates and inflation are allowed to affect investment directly only through the real rate. Nominal interest rates may also affect investment indirectly as a predictor of future Y_t. Equation (3) also has different lag lengths in different equations. In testing the restricted VAR system, we will compare it with an unrestricted system of the same lag lengths as that of (3). In the unrestricted model, the π_t, i_t, and Y_t equations are the same as (3). I_t is an unrestricted linear function of i_{t-j}, π_{t-j}, Y_{t-j}, and I_{t-j}, $j = 1$ to 3. The restricted system has 14 overidentifying restrictions.

All hypotheses are tested using the likelihood ratio statistic formed by taking

$$(T - dfc)\log\left(\frac{\det \Sigma^{c}}{\det \Sigma^{u}}\right),$$

where T is the number of observations in each equation; dfc is a degrees of freedom correction equal to the total number of parameters of the unrestricted system divided by the number of equations; Σ^{c} is the covariance matrix of residuals in the constrained system; and Σ^{u} is the covariance matrix of residuals in the unrestricted system. Under the null hypothesis, the statistic is assumed to be distributed χ^2 with dfc

degrees of freedom. This model likelihood test radio was used by Sims (1980).

We use seasonally adjusted (with the exception of interest rates) quarterly data from 1947 to 1980; π_t is the rate of inflation between t and $t + 1$, and is derived from the GNP deflator; i_t is the average three-month Treasury bill rate expressed as a quarterly rate. This is our measure for short-term nominal rates. The long-term rate, i_t^L, is measured by the 30-year-average treasury bond rate; Y_t is real GNP; and I_t is measured real-producer equipment. The data have all been collected from the Citibank Data Base. Product equipment is used to measure investment rather than total investment, which includes equipment, structures, and inventory so as to minimize the aggregation problem.

III. Empirical Results

The first problem is to test whether long-term rates or short-term rates belong in the investment equation. We ran a simple ordinary least squares regression of I_t on a constant, linear time trend, and four lags each of π_t, Y_t, I_t, and i_t^L. The probability of obtaining an F-statistic for the null hypothesis that the coefficients of four lagged values of i_t are jointly zero was .04. The probability of the equivalent F-statistic for the coefficients of the four lagged values of i_t^L was .36. Thus the evidence favors using only short-term rates in the investment equation. We cannot therefore reject the hypothesis that short-term rather than long-term rates matter for producer equipment.[4]

Next we consider a fourth-order VAR system with π_t, i_t, Y_t, and I_t. There are two reasons for estimating an unrestricted system. First, we can throw some light on the exogeneity assumptions used in many investment studies. Second, we use this unrestricted system as a benchmark to compare to our restricted systems derived from economic theory.[5] All the VARs include a constant and a time trend.

Table 1 summarizes causality tests based on the estimated VAR. The causality test statistic is an F-ratio for the null hypothesis that the coefficients of the four lagged value for each of the variables being tested are jointly equal to zero. An important result from table 1 is that I_t Granger causes Y_t at a marginal significance level of .002. This "causality" rejects the exogeneity assumption on Y_t used by many researchers when estimating structural investment models. Another re-

4. Because of space restrictions we do not report the individual regression coefficients here. The reader should also be cautious in interpreting this result, since we do not consider contemporaneous correlations.

5. We cannot use more than four lags of each variable due to restrictions imposed by the data. As shown in Section II, a fourth-order unrestricted VAR system will lead to a seventh-order restricted system when the investment equation only includes anticipated real rates of return (see Litterman and Weiss 1985).

TABLE 1 Causality Tests for Variables in Unrestricted VAR*

	Dependent Variables			
Regressors	Y_t	I_t	π_t	i_t
Y_t		$.35 \times 10^{-2}$	.09	.85
I_t	$.20 \times 10^{-2}$		.32	.50
π_t	.67	.63		.70
i_t	$.10 \times 10^{-3}$	$.40 \times 10^{-3}$	.62	

* The causality test statistic is an F-ratio for the null hypothesis that coefficients of four lagged values of each of the regressors are jointly equal to zero. A constant (linear time trend), four lagged values of the dependent variable, and all other regressors are also included in the regressions. Each entry gives the marginal significance level. The marginal significance level is the probability of obtaining an F-ratio at least as large as the test statistic under the null hypothesis.

sult is that i_t "causes" Y_t even after we controlled for I_t, implying that i_t helps predict Y_t. This predictive power makes it necessary to separate the predictive effect of nominal rates on investment versus the discounting effects.

Before we saw the estimated covariance matrix of the residuals of the unrestricted VAR, we intended to triangularize the system with the order π_t, i_t, Y_t to I_t. This order means that a π_t innovation is assumed to disturb all other variables instantly, whereas an I_t innovation is only allowed to affect I_t instantly. Table 2 summarizes the estimated covariance matrix of the residuals of the unrestricted VAR. An important result of the covariance matrix is the positive correlation between I_t and i_t. This positive correlation means that we cannot follow our original triangularization, with i_t innovations instantly disturbing I_t but not vice versa. A positive correlation could mean that the investment function has shifted instead of the savings function. Moreover, we cannot attribute the positive correlation to investment responding to a π_t innovation which is also correlated with i_t because the π_t, I_t correlation is small. Therefore we decided to use the order Y_t, I_t, π_t to i_t in triangularizing our VAR systems for the rest of this paper (see n. 2).

Table 3 shows the moving-average responses of I_t to an orthogonalized one-standard-deviation shock to the residuals of each equation in the VAR system. The responses are expressed as fractions

TABLE 2 Covariance Matrix of Residuals of Unrestricted VAR System

	Dependent Variables			
Regressors	Y_t	I_t	π_t	i_t
Y_t	5.81×10^{-3}	5.52×10^{-4}	2.86×10^{-3}	2.83×10^{-3}
I_t	.47*	2.33×10^{-4}	4.74×10^{-4}	6.20×10^{-4}
π_t	.08	.07	2.07×10^{-1}	-3.20×10^{-3}
i_t	.29	.32	$-.06$	1.59×10^{-2}

* Entries below diagonal are correlations.

TABLE 3 Responses of I_t to Innovations to the Unrestricted VAR System*

	Innovations in			
Quarters	Y_t	I_t	π_t	i_t
1	.474	.880		
2	.566 (.087)†	.445 (.075)	.154 (.081)	−.133 (.078)
3	.585 (.094)	.419 (.106)	.167 (.093)	−.307 (.101)
4	.554 (.113)	.202 (.122)	.130 (.086)	−.495 (.121)
5	.366 (.098)	.110 (.118)	.145 (.109)	−.831 (.137)
6	.218 (.110)	.008 (.134)	.119 (.123)	−1.16 (.132)
7	.104 (.118)	−.028 (.166)	.128 (.140)	−1.31 (.156)
8	.027 (.131)	−.036 (.192)	.159 (.164)	−1.41 (.193)
9	−.016 (.157)	−.074 (.210)	.199 (.176)	−1.49 (.225)
10	−.42 (.208)	−.112 (.244)	.210 (.180)	−1.47 (.286)
13	−.089 (.200)	−.191 (.284)	.275 (.183)	−1.04 (.341)
17	−.035 (.176)	−.228 (.308)	.123 (.130)	−.341 (.424)

* An innovation by variable j is a positive one standard deviation shock of the orthogonalized innovation in variable j in the first quarter. The responses are expressed as fractions of one standard deviation of the residual from the I_t equation in the unrestricted VAR system.

† The numbers in parentheses are standard errors.

of a standard deviation of the residual in the I_t equation. The point estimates and standard errors of the moving-average responses are derived by Monte Carlo simulations of the estimated autoregressive parameters.[6] The simulations are conditional on the estimated covariance matrix of the residuals. The Y_t innovations have the expected effect on I_t. The peak effect is at the 3-quarters mark. The i_t innovations are much more powerful, beginning later and persisting over 3 years. The magnitude of the effect is also bigger than that of the output innovation. Inflation innovations are positive, although it is small and of short duration. An interesting result is that I_t innovation on itself does not persist beyond 1 year, and the magnitude of the effect is smaller than that of output or interest rate innovations. In fact, the own-response of I_t is less persistent than the own-response of all other variables in the VAR system. The small response to own-innovations is evidence against "animal spirits" theories of investment.

Table 4 summarizes the moving-average responses of Y_t to orthogonalized innovations in the variables in the VAR system. An I_t innovation results in an unusual pattern of negative Y_t responses (although estimated coefficients are not statistically different from zero). This negative response is further evidence that independent investment innovations are not very important. The negative effect of i_t innovations on Y_t is similar to the effect on I_t. Again π_t is unimportant.

The moving-average responses of π_t and i_t to innovations in the variables in the VAR system are not presented. We simply note here that Y_t, I_t, and i_t innovations have no effect on π_t. The Y_t and I_t innova-

6. For further details, see Kloek and Van Dijk (1978).

TABLE 4 Responses of Y_t to Innovations to the Unrestricted VAR System

	Innovations in			
Quarters	Y_t	I_t	π_t	i_t
1	1.00			
2	.938 (.090)	−.213 (.081)	.055 (.078)	−.175 (.078)
3	.875 (.113)	−.261 (.131)	.107 (.091)	−.556 (.111)
4	.716 (.156)	−.522 (.170)	.092 (.125)	−.750 (.137)
5	.513 (.166)	−.383 (.186)	.024 (.152)	−1.03 (.177)
9	.167 (.255)	−.291 (.319)	−.134 (.247)	−1.62 (.312)
10	.109 (.237)	−.272 (.299)	−.121 (.250)	−1.64 (.347)
13	.117 (.307)	−.382 (.457)	−.093 (.242)	−1.26 (.435)
17	.085 (.254)	−.370 (.468)	−.073 (.191)	−.651 (.536)

tions have small positive effects on i_t. But the effects all damp out in less than 1 year. The i_t innovations on itself are persistent over 1 year.

In summary, the unrestricted VAR shows the investment response to both short-term interest rates and output innovations. Inflation innovations are not important. The exogeneity assumptions on processes driving investment used by many researchers when estimating structural investment models are rejected. These misspecifications have surely contributed to the conflicting results of the "structural" studies of price effects on investment behavior.

Investment Theory and Restricted VARs

All theoretical models suggest that investment should be inversely related to the real rate of return and positively related to anticipated GNP. The former is the marginal efficiency of investment schedule, while the latter reflects the accelerator effect. We estimate four restricted VAR models. In all the models, the inflation, output, and interest rate equations are specified exactly the same as in the unrestricted VAR system, each depending on four lags of inflation, output, interest rates, and investment. The investment equation, aside from the constant and trend, is restricted in the following ways:

Model A: Four lags of the real rate, r_t; output, Y_t; and investment, I_t.
Model B: Four lags of the real rate, r_t; anticipated output, Y^e_t; and investment, I_t.
Model C: Four lags of anticipated output, Y^e_t, and investment, I_t.
Model D: Four lags of i_t, π_t, I_t, and Y^e_t.

The real rate and anticipated output are both defined with rational expectations as illustrated in section II. In all three cases, A, B, and C, the alternative model is the unrestricted VAR model where π_t, i_t, and Y_t equations are the same as the restricted models. Following Litterman and Weiss (1985), we allow the unrestricted I_t equation to have the same lag length as the restricted equation. Because of the assumption of rational expectations, the I_t equation has seven lags of i_t, π_t, Y_t, and I_t in the four restricted models.

Model A states that the direct nominal interest rate and inflation channel is through the real rate of interest. However, this does not rule out indirect nominal rate and inflation effects through lagged output or investment in this simultaneous equation setup, which obviously allows feedback. Model B suggests that investment decisions are based on future demand conditions and real interest rates. This is captured by including lags of anticipated GNP rather than GNP itself. Model C is a typical accelerator-effect model in which only predicted GNP matters. It thus implicitly states that the nominal rate effect on investment is simply due to its predictive power of GNP. Model C is nested in model B. Finally, model D suggests that the nominal rate directly affects investment over and above its predictive power on demand shifters (future anticipated GNP) and allows for the possibility of direct non-neutrality through i_t or π_t. Model C is also nested in model D.

Empirical Results: Restricted versus Unrestricted VARs

The test statistic for model A has a marginal significance level of 0.046 ($\chi^2 = 33$ with 21 degrees of freedom). Lagged real rates and lagged output are insufficient to explain investment behavior.[7] Model B has a marginal significance level of .27 ($\chi^2 = 24$ with 21 degrees of freedom). Thus the restrictions imposed on model B cannot be rejected by the data. Since the difference between models A and B is whether to include lags of Y_t or Y_t^e, the result certainly supports economic intuition that investment behavior is forward-looking. Table 5 plots the contemporaneous correlations and covariance matrix of the residuals. This should be compared to the correlations of the unrestricted version in table 2. The two sets of correlations are very similar. The dynamics of the restricted model are shown in tables 5–9. The standard errors in parentheses are calculated using Monte Carlo simulations. Comparison of tables 3 and 6 show that when the model is restricted to incorporate a forward-looking GNP term, the impact of an i_t innovation on investment declines in magnitude while that of output increases. This is what one would expect, since part of the predictive power of i_t is now captured by the feedback effect on output.

Model C includes the forward-looking anticipated GNP lags but excludes a real rate of return effect. Thus nominal rates and inflation can only affect investment indirectly by changing agents' forecasts of GNP. Model C has a marginal significance level of 0.07 ($\chi^2 = 31$ with 21 degrees of freedom). Treating model C as the null hypothesis and

7. The reader should note that this result is independent of causal ordering (i.e., our choice of triangularization).

TABLE 5 Covariance Matrix of Residuals Model B

Regressors	Dependent Variables Y_t	I_t	π_t	i_t
Y_t	6.02×10^{-3}	6.42×10^{-4}	1.83×10^{-3}	3.05×10^{-3}
I_t	.53	2.47×10^{-4}	1.53×10^{-4}	7.57×10^{-4}
π_t	.05	.02	2.15×10^{-1}	-4.39×10^{-3}
i_t	.30	.38	−.07	1.62×10^{-2}

TABLE 6 Responses of I_t to Innovations of Model B

Quarters	Innovations in Y_t	I_t	π_t	i_t
1	.526			
2	.706 (.080)	.543 (.085)	.210 (.087)	−.145 (.060)
3	.903 (.126)	.527 (.135)	.209 (.108)	−.296 (.086)
4	.778 (.167)	.309 (.145)	.221 (.121)	−.414 (.121)
5	.602 (.172)	.146 (.147)	.215 (.134)	−.602 (.146)
6	.413 (.183)	.080 (.177)	.282 (.132)	−.860 (.172)
7	.268 (.181)	−.109 (.176)	.122 (.152)	−.979 (.201)
8	.146 (.202)	−.082 (.219)	.125 (.162)	−1.05 (.239)
9	.058 (.214)	−.173 (.233)	.068 (.172)	−1.14 (.270)
10	−.010 (.244)	−.213 (.244)	.064 (.187)	−1.17 (.284)
13	−.128 (.374)	−.217 (.297)	.126 (.207)	−.994 (.328)
17	−.145 (.229)	−.195 (.291)	.074 (.152)	−.548 (.314)

TABLE 7 Responses of Y_t to Innovations to Model B

Quarters	Innovations in Y_t	I_t	π_t	i_t
1	1.00			
2	.982 (.103)	−.156 (.086)	.207 (.080)	−.204 (.078)
3	.948 (.149)	−.218 (.140)	.204 (.100)	−.517 (.136)
4	.641 (.182)	−.500 (.152)	.229 (.138)	−.693 (.144)
5	.436 (.213)	−.406 (.163)	.161 (.174)	−.941 (.155)
9	.014 (.289)	−.295 (.263)	.080 (.233)	−1.60 (.307)
10	−.024 (.313)	−.254 (.298)	.174 (.253)	−1.65 (.335)
13	−.103 (.350)	−.251 (.366)	.222 (.260)	−1.37 (.409)
17	−.146 (.298)	−.262 (.353)	.139 (.200)	−.834 (.465)

model B as the alternative, the test statistic has a marginal significance level of 0.98 ($\chi^2 = 6.7$ with 17 degrees of freedom). Table 10 plots out the simulated impact of innovations in i_t, π_t, Y_t, and I_t under the restrictions imposed by model C. The nested hypothesis test suggests that I_t can be explained by lagged anticipated GNP and investment without any direct real rate effect. We can thus infer from our statistical tests that real rates are of a second order of magnitude relative to forecasts

TABLE 8 **Responses of π_t to Innovations to Model B**

	Innovations in			
Quarters	Y_t	I_t	π_t	i_t
1	.051	−.007	.999	
2	.205 (.088)	−.067 (.086)	.274 (.082)	.070 (.076)
3	.083 (.087)	.163 (.085)	.296 (.084)	.038 (.076)
4	.076 (.092)	.021 (.101)	.161 (.082)	.009 (.076)
5	.126 (.083)	.017 (.092)	−.126 (.089)	.055 (.081)
9	.039 (.062)	−.072 (.077)	−.019 (.055)	−.111 (.072)
13	−.026 (.059)	−.018 (.056)	.024 (.050)	−.175 (.071)
17	.003 (.045)	−.020 (.056)	.012 (.038)	−.120 (.077)

TABLE 9 **Responses of i_t to Innovations to Model B**

	Innovations in			
Quarters	Y_t	I_t	π_t	i_t
1	.308	.253	−.088	.913
2	.467 (.087)	.369 (.077)	.011 (.094)	1.06 (.073)
3	.496 (.151)	.210 (.129)	.069 (.134)	.500 (.130)
4	.418 (.162)	.064 (.175)	.127 (.125)	.445 (.145)
5	.380 (.175)	.141 (.164)	.010 (.141)	.613 (.164)
9	.164 (.132)	.070 (.154)	−.065 (.105)	−.116 (.192)
13	.036 (.122)	.009 (.139)	−.036 (.105)	−.420 (.209)
17	−.038 (.147)	−.050 (.127)	.048 (.087)	−.364 (.213)

TABLE 10 **Responses of I_t to Innovations to Model C**

	Innovations in			
Quarters	Y_t	I_t	π_t	i_t
1	.480	.877		
2	.696 (.086)	.508 (.098)	.059 (.036)	−.071 (.091)
3	.880 (.115)	.488 (.104)	.109 (.058)	−.250 (.158)
4	.788 (.127)	.268 (.133)	.117 (.072)	−.401 (.181)
5	.637 (.138)	.067 (.146)	.145 (.091)	−.574 (.176)
6	.445 (.162)	−.021 (.175)	.140 (.104)	−.814 (.185)
7	.274 (.186)	−.139 (.199)	.136 (.119)	−1.00 (.217)
8	.146 (.212)	−.162 (.224)	.138 (.142)	−1.11 (.236)
9	.058 (.230)	−.171 (.245)	.129 (.162)	−1.20 (.280)
13	−.041 (.225)	−.179 (.270)	.179 (.213)	−1.01 (.239)
17	−.061 (.235)	−.186 (.293)	.139 (.173)	−.576 (.190)

of GNP in predicting investment. This does not mean that there is no dynamic real rate impact. A comparison of the fourth column of tables 6 and 10 throws some light as to the exclusion of the real rate lags. A unit standard deviation increase in i_t in the first quarter causes investment to decline significantly by .145 standard deviations in the second quarter, when the real rate is included. When it is excluded, this figure falls by half and is not significantly different from zero. Again in the third quarter investment declines by .3 standard deviations when the real rate is included (model B) and is significant in model C. But as time moves forward, the impact of i_t on I_{t+j} becomes strikingly similar in both models.

We also tested the nested hypothesis of model D against model C, in order to ascertain whether or not nominal interest rates would lose all significance once we included lags of anticipated GNP. This is confirmed by the data with a marginal significance level of .233 (χ^2 = 12.5 with 17 degrees of freedom). In the presence of anticipated GNP, nominal rates lose their predictive power.

The data would thus suggest that the real cost of capital abstracting from tax distortions is marginally important in explaining future investment in the very short run. After about 2 quarters in the case of producer equipment, the real rate has virtually no predictive power. Thus, although the data do not reject the presence of a real rate effect, the persistence of a nominal yield innovation in producer equipment is derived from the predictive power of nominal rates in predicting future GNP. This validates the claim made by Fama and Litterman and Weiss.

One further issue involves the timing of peaks in GNP, I, and i. If I_t responds to anticipated GNP_t, then I_t should peak before GNP_t due to a nominal interest rate innovation. In the unconstrained version a nominal rate impulse causes GNP to peak 1 quarter after Investment, which peaks in the tenth quarter. In the constrained system (model B) a nominal rate impulse causes GNP and I to peak together. The standard errors, however, are far too large for any definite conclusions.

One further inference from the data is the lack of any *direct effect* of innovations in inflation on investment spending. In all the restricted models, inflation does not Granger cause investment as measured by producer equipment. One could argue that capital markets designed to fund corporate capital equipment do not suffer from any (nonneutral) liquidity effects, as would be the case, say, in residential housing. This result can be seen by noting the large standard errors in the Monte Carlo simulations in column 3 of tables 6 and 10. All the coefficients of an inflation innovation on future investment are not significantly different from zero. An alternative explanation is that, although inflation is important to the extent that it affects the after-tax real rate of return, the model here fails to capture this. Thus the fact that inflation appears not to Granger cause investment in a linear VAR system could well be due to a misspecification error.

IV. Conclusions

We have explored the impact of interest rates on investment spending in a VAR system. While we admit that the VAR methodology cannot say much about contemporaneous exogeneity, we know of no structural simultaneous model of investment spending that has been accepted by the data. Our Granger causality tests suggests that single-equation structural investment models are misspecified. We thus revert to VARs as a second-best solution and can make some inferences about the cross-correlations between interest rates, investment, and output.

Unrestricted VARs show that nominal interest have a strong and persistent negative dynamic effect on investment spending. Although initially the magnitude is smaller than the output innovation, the nominal rate picks up and has predictive power 17 quarters out of sample. The output innovation has predictive power for about 8 quarters in explaining investment.

We imposed two restrictions on the unrestricted data—nominal rates and anticipated inflation could only affect investment directly through the real rate of return, and instead of four actual output lags we included four anticipated output lags. This model could not be rejected by the data. We then restricted the *direct* real rate lags to zero and tested this nested model with the model including both lags of real rates and anticipated GNP. While our real rates ignore taxes, we could not reject the null hypothesis that real rates do not matter. The old-fashioned accelerator model appeared to capture the dynamics of investment behavior quite adequately. The data still confirm that the real cost of capital does matter in explaining investment initially, but this effect is relatively small and becomes insignificant after two quarters in the case of producer equipment.

The evidence shown here confirms the Fama-Litterman-Weiss hypothesis that nominal rates matter in explaining cyclical patterns of investment in the postwar period. This is so because nominal rates are powerful predictors of GNP. Thus the strong and persistent negative response of investment spending to nominal interest rates is evidence supporting the accelerator model of investment spending.

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