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I. INTRODUCTION

A predominant focus of macroeconomic research in the last ten years has been on the origins of the business cycle. In particular, it has been popular to view the business cycle as arising from surprising movements in aggregate demand and to argue that these impulses are transmitted to real activity through movements in the price level.[1] In order to generate empirically relevant fluctuations, however, such models must incorporate mechanisms to propagate price surprises over time. That is, to replicate economic fluctuations, it is necessary to transform serially uncorrelated price surprises into serially correlated macroeconomic time series. Unfortunately, despite the large amount of effort devoted to this type of equilibrium business cycle modelling in recent years, relatively little attention has been focussed on isolating the empirically important propagation mechanisms.

More recently, we have pursued a line of research that we call 'real business cycle theory', in which disturbances are propagated over time as a result of (i) economic agents' desire to smooth commodity profiles and (ii) capitalistic production with rich intertemporal substitution opportunities.[2]

To date, however, these models incorporate only real 'supply-side' or technological disturbances, abstracting from real 'demand-side' influences (such as government spending) or nominal shocks. Nevertheless, the results on propagation mechanisms appear to be relevant for more fully developing the monetary theories of business fluctuation discussed above.

Of course interest in propagation mechanisms is not new. Indeed, it was the major focus of many of the interwar business cycle theorists. As discussed briefly in King and Plosser (1984b), these theorists (e.g., Hayek (1931)) stressed that the intertemporal character of production was central to understanding economic fluctuations. Keynesian economists were also forced to come to grips with propagation, but because of their narrow focus on demand, propagation was introduced through 'partial adjustment' models or 'accelerator' mechanisms that determined the dynamic character of aggregate demand. As illustrated by Long and Plosser (1983) and Kydland and Prescott (1982), equilibrium theory of the business cycle must involve, as a key element, the earlier focus on capitalistic production.

This paper is an exploratory empirical study that attempts to evaluate the relative contribution of three factors -- price surprises, real factors and propagation mechanisms -- to the overall variance of real economic activity in the post-war United States. Our investigation is divided into two main parts. First, in section II, we lay out a basic real output equation that depends on nominal surprises, real shocks and propagation mechanisms. We develop a statistic we call the propagation ratio for evaluating the contribution of propagation mechanisms to the variance of economic time series. The empirical investigation in section III treats monetary surprises as the pertinent nominal disturbances and is largely supportive of the proposition that propagation mechanisms are the central first-order aspect of business cycles, suggesting an important redirection of macroeconomic research.

In section III, we attempt to isolate the relative importance of price surprises in output and unemployment fluctuations. We employ an instrumental variables procedure to estimate the 'Lucas slope coefficient'. There are two important results of this empirical investigation. Perhaps surprisingly, it is difficult to pin down the relative importance of price surprises. Fundamentally, we believe, this difficulty reflects the fact that it is difficult to explain price surprises with variables typically thought to drive aggregate demand (money, government expenditures, etc.). This is an important finding in its own right, for it calls into question aspects of the mechanisms discussed by Lucas (1972, 1973) and Fischer (1977). Section IV discusses potential extensions to our research and our conclusions from the evidence so far.

II. NEOCLASSICAL PROPAGATION MECHANISMS

The real business cycle theories of Kydland and Prescott (1982) and Long and Plosser (1983) provide important examples of how rich possibilities for intertemporal substitution in production lead the effects of economic disturbances to be propagated over time. In each of these models, the existence of many capital goods leads to the rich intertemporal production possibilities. In this paper, we focus on how these mechanisms lead nominal shocks to be propagated across time, working by analogy to the more completely spelled out general equilibrium models and adopting a linear specification throughout.

We start by considering a Nx1 vector of current activities y_t, which are 'flow' economic decisions such as output, work effort, consumption and investments of various sorts - i.e., the principal endogenous quantity variables of most macroeconomic models. In real business cycle models, the equilibrium levels of these variables depend on the Mx1 vector of previously accumulated captial stocks (k_{t-1}) and the current values of a Px1 vector of exogenous real state variables (s_t). We assume that the vector s_t is Markov, i.e., $s_t = \Lambda s_{t-1} + \epsilon_t$, so that the influence of s_t on y_t incorporates both current and expectational factors. Thus, under a linear real business cycle model the decision rules that govern the evolution of the vector y_t can be expressed as

$$(1) \qquad y_t = \theta k_{t-1} + \beta s_t \quad ,$$

where θ is an NxM matrix and β is an NxP matrix. Next, technological considerations dictate that the vector of capital stocks evolves according to actions taken at date t (y_t) and prior capital stocks:

$$(2) \qquad k_t = A\, y_t + \Delta\, k_{t-1} \quad ,$$

where A is an MxN matrix and Δ is an NxN matrix.

Combining equations (1) and (2), it follows that

$$(3) \qquad k_t = (I - (A\theta + \Delta)L)^{-1} A \beta s_t \quad ,$$

i.e., the capital stock vector is a function of current and past real factors (s_t). Consequently, the current flow variables can be expressed as:

$$(4) \qquad y_t = \beta s_t + \theta(I - (A\theta + \Delta)L)^{-1} A \beta s_{t-1} \quad .$$

For example, even if real factors (s_t) are serially uncorrelated (Λ=0), the capitalistic structure of production permits commodity flows (y_t) to exhibit rich patterns of serial correlation.[3] More generally, though, the dynamics of real fluctuations arise from the interaction of <u>internal propagation mechanisms</u> (governed by $A\theta + \Delta$) and the dynamics of the exogenous, real forcing variables (governed by the matrix Λ).[4] This makes it difficult to distinguish exogenous and endogenous sources of serial correlation if macroeconomic time series are generated by unobservable real disturbances.[5]

<u>Nominal Shocks and the Propagation Ratio</u>

Lucas (1972, 1977, 1980) argues that an empirically relevant theory of business fluctuations arises principally from invoking information frictions that allow nominal shocks to exert temporary real effects on real macroeconomic flows. Given the internal propagation mechanisms, these nominal impulses are transmitted over time, even though they do not themselves have direct long-lived effects. Letting $(x_t - E_{t-1}\, x_t)$ be a vector of nominal shocks, we then modify (1) as follows:

$$(5) \qquad y_t = \tau(x_t - E_{t-1}\, x_t) + \theta(k_{t-1}) + \beta\, s_t,$$

where τ is an NxG matrix and x_t is a Gx1 vector. Thus, we can write the vector of commodity flows as

$$(6) \qquad y_t = (I - (A\theta + \Delta)\, L)^{-1}\, A\tau(x_t - E_{t-1}\, x_t) + y^*_t,$$

where y^*_t represents the influence of real factors (s_t) given by (4) above.

The maintained assumption that only unanticipated nominal disturbances have real effects implies that such shocks are especially useful for studying the statistical importance of internal propagation mechanisms of the economy. If we consider a single nominal shock and a particular element of the real commodity flow vector (y_j), (6) implies that

$$(7) \qquad y_{jt} = \sum_{h=0}^{H} \alpha_{jh}\, (x_{t-h} - E_{t-h-1} x_{t-h}) + y^*_{jt},$$

where H is, in principle, infinite but we assume that the lag structure is well-approximated with a finite lag length H. The α coefficients are functions only of the internal propagation mechanism, i.e., $(I-(A\theta + \Delta)L^{-1}$, and the value of τ. Since nominal surprises are serially uncorrelated, the only way that such a surprise can effect real commodity flows with a lag is through the internal propagation mechanism.[6]

The variance of y_{jt} attributable to the impulse effect of nominal shocks is $(\alpha_{j0})^2 \sigma^2_{\tilde{x}}$, where $\sigma^2_{\tilde{x}}$ is the variance of the nominal surprise $\tilde{x}_t = x_t - E_{t-1} x_t$. The variance of y_{jt} attributable to the propagation effects, i.e., the effects of past values of $\tilde{x}_t$, is $\sum_{h=1}^{H} (\alpha_{jh})^2 \sigma^2_{\tilde{x}}$. As our measure of the relative importance of propagation and impulse effects, we consider the propagation ratio for y_j:

8) $$\Phi_j = \frac{\sum_{h=1}^{H} (\alpha_{jh})^2}{(\alpha_{j0})^2 + \sum_{h=1}^{H} (\alpha_{jh})^2} .$$

This ratio will vary between zero and one. Values close to one are associated with nominal disturbances that are principally important due to propagation. For example, if $\alpha_{j0} = \alpha_{j1} = \ldots = \alpha_{jH}$ it follows that $\Phi_j = H/(H+1)$ i.e., propagation effects explain $H/(H+1) \bullet 100$ percent of the variance in y_j due to the nominal disturbance. As another example, assume a geometric lag structure such that $\alpha_{jh} = \alpha_j^{h+1}$ for $h = 0, \ldots, H$ and $|\alpha|<1$. In this case $\Phi_j = 1-[(1-\alpha_j^2)/(1-\alpha_j^{2(H+1)})]$, which of course approaches α_j^2 as $H \to \infty$.

III. EVIDENCE ON PROPAGATION MECHANISMS

In the empirical analysis that follows, we consider two alternative nominal shock hypotheses. First, we treat the case of unanticipated money growth as developed by Robert Barro in a series of studies (1978, 1979). The key identifying restriction in these studies is, of course, that money is exogenous. As argued by King and Plosser (1984a), however, there are important theoretical reasons for believing the usual measure of money employed in empirical studies is endogenous. Further, on post-war data, King and Plosser (1984a) shows that inside and outside money behave differently with respect to real variables. Consequently, we also investigate the effects of unanticipated money using the monetary base instead of currency plus demand deposits as employed by Barro and other researchers.

Second, we analyze the effects of unanticipated price movements as previously considered by Lucas (1973) and Sargent (1976). Different statistical techniques are necessary in this case since unanticipated price level movements are clearly not exogenous with respect to current quantities in the theoretical analyses of Lucas (1973) and Fisher (1977). In other words, unanticipated price level movements are correlated with the error term y^*_{jt} in (7) through effects of output on money demand.

The data used in the empirical work are summarized in Table I and sources are given in the Appendix. These data exhibit the patterns familiar to students of post-war business cycles. The unemployment rate is highly serially correlated while the growth rates of other real variables are less so. Nominal variables, however, display much more serial dependence than real variables with the exception of the unemployment rate.

Propagation and Unanticipated Money

In order to demonstrate the relative importance of propagation mechanisms and impulses, we begin by estimating the relation between unanticipated money and real variables, specifically the unemployment rate and real output. The results are summarized in Table II. Unanticipated money is estimated as the

Table I

SUMMARY STATISTICS

Variable	Period	Mean(%)	Standard Deviation(%)	Sample Autocorrelations r_1	r_2	r_3	r_4	r_5	r_6
U_t	48QI-83QIII	5.52	1.73	.94	.84	.72	.60	.50	.44
Δy_t	48QI-83QIII	3.31	4.47	.39	.20	-.01	-.16	-.13	-.09
Δp_t	48QI-83QIII	4.03	3.13	.70	.62	.55	.41	.37	.32
Δb_t	48QI-81QIII	4.06	3.70	.53	.53	.49	.50	.41	.32
Δm_t	48QI-83QIII	4.30	3.53	.48	.47	.32	.27	.32	.27
Δg_t	48QI-83QIII	3.43	16.64	.60	.36	.21	.07	.02	.00
ℓ_t	48QI-82QIV	-.53	.03	.96	.94	.91	.89	.86	.84
Δw_t	48QI-83QIII	5.46	3.48	.37	.26	.26	.41	.11	.05
Δn_t	48QI-82QIV	1.50	.47	.52	.51	.52	.49	.48	.45
R_t	48QI-83QIII	4.71	3.27	.92	.87	.86	.81	.77	.73

NOTE — U_t is the unemployment rate for the last month of the quarter; Δy_t, Δp_t and Δg_t are the annualized percentage growth rates of real GNP, the GNP deflator and real federal government purchases respectively; Δb_t, Δm_t, Δw_t and Δn_t, are the annualized growth rates in quarter t of the monetary base, the money supply (M_1), the nominal wage rate and the population. The nominal 3 month T-bill rate is R_t and ℓ_t is the log of the labor force participation rate. The large sample standard error of the sample autocorrelations (r_1,..r_6) is approximately .08.

residual from a regression that predicts monetary growth using 4 quarterly lags of money growth, real output growth, inflation, 3-month treasury bills, labor force participation rate, population growth, wage inflation and the growth rate of real federal purchases of goods and services. The real quantity variables are then regressed on the current and eight lags of unanticipated money using a generalized least squares procedure to correct for serial correlation in the errors.[7]

The results in the first equation in Table II indicate a significantly negative impact of unanticipated money on the unemployment rate that reaches a peak with a lag of about 3 or 4 quarters.[8] However, the error term in this equation contains substantial serial correlation, which should come as no surprise given our discussion of (4) and (6) in the previous section. This serial correlation arises from a mixture of the same internal propagation mechanism that transmits the nominal shock over time as well as potential serial correlation in exogenous real factors.

The unemployment propagation ratio Φ, is estimated to be .98 with a large sample standard error of .013. Thus, in the context of the model outlined in the previous section, 98% of the explanatory power of unanticipated money is attributable to the internal propagation mechanism. Without such a mechanism the effects of unanticipated money on unemployment would be largely uninteresting. Thus, if one maintains the view that monetary disturbances are a central business cycle <u>impulse</u>, then understanding the nature and character of business cycles requires an understanding of propagation mechanisms.

TABLE II

UNANTICIPATED MONEY REGRESSIONS

$$Y_t = \text{Const.} + \sum_{j=0}^{8} a_j (x_{t-j} - E_{t-1-j}\, x_{t-j}) + bt + e_t$$

Dependent Variable	Period	Const.	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	b	r_1	r_2	r_3	r_4	s(e)	φ
A. Money Stock — M_1																		
U_t	48QI-82QIV	5.60	-.04	-.09	-.14	-.16	-.15	-.12	-.09	-.04	-.01		1.19	-.22	-.13	.06	.42	.981
		(.37)	(.02)	(.03)	(.04)	(.04)	(.04)	(.04)	(.04)	(.03)	(.02)		(.09)	(.14)	(.14)	(.09)		(.013)
y_t	48QI-82QIV	6.22	.52	.82	1.52	1.60	1.33	1.03	.65	.41	.01	3.31	1.07	-.15	.02	.09	3.86	.971
		(.01)	(.17)	(.26)	(.32)	(.36)	(.37)	(.36)	(.32)	(.26)	(.18)	(.06)	(.09)	(.13)	(.13)	(.09)		(.012)
Δy_t	48QI-82QIV	3.12	.46	.70	1.34	1.38	1.14	.86	.52	.30	-.05		.38	-.06	.01	-.13	3.64	.973
		(.41)	(.16)	(.26)	(.34)	(.39)	(.41)	(.39)	(.34)	(.27)	(.16)		(.09)	(.09)	(.09)	(.09)		(.020)
B. Money Stock — Base																		
U_t	48QI-81QIII	5.31	-.01	-.01	-.02	-.02	-.05	-.03	.00	.00	.01		1.24	-.26	-.10	.03	.41	.984
		(.38)	(.02)	(.02)	(.03)	(.03)	(.03)	(.03)	(.03)	(.02)	(.02)		(.09)	(.14)	(.14)	(.09)		(.047)
y_t	48QI-81QIII	6.21	.15	.22	.14	.26	.29	.22	.06	.16	.09	3.40	1.10	-.19	.01	-.09	4.05	.925
		(.01)	(.16)	(.22)	(.28)	(.28)	(.29)	(.29)	(.27)	(.23)	(.16)	(.06)	(.09)	(.13)	(.13)	(.09)		(.122)
Δy_t	48QI-81QIII	3.77	.07	.09	.01	.09	.10	.02	-.11	.00	.00		.37	.04	-.06	-.13	3.95	.973
		(.46)	(.14)	(.22)	(.27)	(.30)	(.31)	(.31)	(.28)	(.23)	(.14)		(.09)	(.10)	(.10)	(.09)		(.116)

NOTE — U_t is the unemployment rate, y_t is the log of real GNP and Δy_t is the annual percentage growth rate of real GNP. The coefficients a_j are the estimated coefficients on current (j=0) and lagged (j=1,...,8) money surprises and b is the estimated coefficient for a time trend. The coefficients are estimated using generalized least squares procedure where $r_1,\ldots,r_4$ describes the autocorrelation structure of the errors; s(e) is the standard error of the regression. φ is the propagation ratio. Large sample standard errors are in parentheses.

We have also estimated equation (7) using the log of real GNP (y_t) as the dependent variable and a differenced version where the growth rate of real GNP is the dependent variable. The results are similar and are reported in Table II as well.[9] There is a significantly positive relation between unanticiapted money and output that reaches a peak at lag 3. The *propagation ratio* for both equations exceeds .97, once again supporting the proposition that propagation plays the dominant role in shaping the business cycle at least in the context of Barro's implementation of the equilibrium monetary theory of the cycle.

Results Using the Monetary Base

In some prior research, King and Plosser (1984a), we have constructed model economies in which inside money shocks are driven by real factors rather than being exogenous. Consequently, we re-estimate the reduced form using the monetary base as the exogenous monetary aggregate. The results are presented in panel B of Table II. Unanticipated base growth is generated in a manner analogous to unexpected money growth above. The results are not supportive of the view that exogenous surprise movements in base growth have significant real effects. They suggest that the predominate source of correlation between money surprises and real variables is with the inside money component of M_1. Although the propagation ratios are almost as large as those obtained using M_1, they probably cannot be relied on given the insignificant results. That is, we suspect that the large sample standard errors of Φ are not very good in this instance.

Price Surprises and Real Activity

Some theoretical analyses (e.g., Lucas (1973) and Fischer (1977)) highlight the role of surprise movements in the price level. In these analyses, the nominal impulse is $\tilde{p}_t = p_t - E_{t-1} p_t$. Consequently, we estimate real quantity specifications of the form

$$(9) \qquad y_{jt} = \sum_{h=0}^{H} \alpha_{jh} \tilde{p}_{t-h} + y^*_{jt}$$

where

$$\tilde{p}_{t-h} = p_{t-h} - E_{t-h-1} p_{t-h} .$$

The estimation of the price surprise coefficients $\{\alpha_{jh}\}_{h=0}^{H}$ involves some econometric issues discussed by Sargent (1976). The 'error term' in this equation represents omitted real factors influencing the economy (y^*_{jt}) and is serially correlated for reasons discussed earlier. Further, with the price level determined by monetary equilibrium, surprise movements in the price level will be correlated with surprise movements in real determinants of economic activity ($y^*_{jt} - E_{t-1}y^*_{jt}$). That is, as Sargent (1976) notes, it is not possible to consistently estimate the impact of price surprises by least squares and some form of instrumental variables procedure is required.

For purposes of discussion, we focus on the relation between unemployment and price surprises, previously considered by Sargent (1976). We start by estimating an eight variable, fourth order vector autoregression with a large set of macroeconomic variables (inflation, unemployment, money growth, the treasury bill rate, labor force participation rate, population growth rate, growth rate of nominal wages and the growth rate of real federal expenditures).

Correlation of Innovations

The correlation matrix of one step ahead prediction errors from the multivariate time series model is shown in Table III. Of principal interest for current purposes is the fact that the correlation between money growth and price surprises is small but significant, while the correlation between price surprise and another aggregate demand variable (real federal expenditure) is insignificant. This reflects a more general difficulty we encountered in constructing an instrumental variable for price surprises -- it is difficult to find variables that are significantly correlated with price surprises and whose innovations are plausibly econometrically exogenous, i.e., uncorrelated with current or future y_j^* . (For example, nominal wage innovations satisfy the former but not the latter condition).

Estimates of Price Surprise Effects

Table IV presents some alternative estimates of the effects of price surprises on unemployment. The first panel A estimates the price surprise coefficients, using a variety of different estimation techniques. The unemployment rate is expressed as a percentage and inflation (and its surprises) is an annual percentage rate. Thus, if $a_o = .5$, then this implies

Table III

Correlation Matrix of Innovations

Variable	Abbreviation	Δp_t	U_t	Δm_t	R_t	ℓ_t	Δn_t	Δw_t
Inflation Rate	Δp_t							
Unemployment Rate	U_t	-.20 (.02)						
Money Growth Rate	Δm_t	.19 (.02)	-.29 (.00)					
Treasury Bill Rate	R_t	-.15 (.08)	-.35 (.00)	-.02 (.79)				
Labor Force Participation Rate	ℓ_t	.19 (.03)	-.01 (.94)	-.01 (.92)	.03 (.76)			
Population Growth Rate	Δn_t	.12 (.16)	-.03 (.71)	.07 (.45)	-.12 (.16)	.09 (.27)		
Growth Rate of Wages	Δw_t	.41 (.00)	-.06 (.52)	.03 (.69)	-.17 (.05)	-.06 (.49)	.03 (.72)	
Growth Rate of Real Federal Purchases	Δg_t	-.03 (.77)	.02 (.82)	-.05 (.57)	-.19 (.03)	-.09 (.28)	.12 (.16)	.06 (.51)

Note -- Innovations are obtained from a vector autoregression using all the variables in the table. P-values associated with the hypothesis that the correlation is zero are in parentheses.

that a one percentage point shock to the annual inflation rate is associated with a one half percentage point effect on unemployment in the initial quarter. The first two rows are estimates using the raw price surprises, with and without a correction for serial correlation. In both cases, the coefficients are numerically small and insignificant according to conventional statistical standards.

The final two rows of panel A provide estimates using current money growth as an instrumental variable for price surprises.[10] In the first instrumental variable estimate, we use instruments for current and lagged price shocks. Thus, the results amount to a rescaling of the earlier Table II estimates of effects of unanticipated money. The estimation routine is two stage and involves a correction for a fourth order autoregressive error term. (Although this procedure is not efficient, it is consistent under the assumption that unanticipated money growth is a valid instrument.) These instrumental variables estimators are numerically larger than the OLS estimates and significant by conventional statistical standards. The implied value of the propagation ratio is .977, with an asympototic standard error of .006. Thus the bulk of nominal shock effects is again due to propagation mechanisms.

It is appropriate to be cautious, however, about interpreting this instrumental variables estimates. First, as discussed earlier, monetary shocks may not be exogenous and, hence, may not be a legitimate instrument. Second, even if monetary shocks are exogenous, the R^2 of the first stage regression is very small (.04) and thus money shocks are not a particularly good 'predictor' of $\tilde{p}_t$. Third, there is evidence that the fourth order autoregressive model of the error term is inappropriate, so that the standard errors calculated under that assumption are presumably inaccurate. Specifically, in the fourth row of Table IV, we employ an instrument only for the current price surprise in the second stage of our estimation routine, following a procedure proposed by Hatanaka (1976). If a fourth order autoregression is appropriate, the estimates should be close to those in the third row. But, in fact, they are substantially attenuated, which indicates misspecification (e.g., see Hausman (1978) or Plosser, Schwert and White (1982)) either of the error term and/or an illegitimate instrument.

Autoregressive Estimates as in Sargent (1976)

For purposes of comparison, we also estimate the specification due to Sargent (1976), in which unemployment depends on price surprises ($\tilde{p}_t$), a serially uncorrelated supply shock (ϵ_t) and past values of unemployment.

$$(10) \qquad U_t = \alpha_0(\tilde{p}_t) + \sum_{h=1}^{H} \lambda_h U_{t-h} + \epsilon_t .$$

In terms of our earlier discussion, this sort of specification is appropriate if the real forcing variables (s_t) are serially uncorrelated and the effects of propagation mechanisms are captured by an Hth order polynomial distributed lag.[11]

It is straightforward to demonstrate that the propagation ratio for the Sargent specification is simply the R^2 of an Hth order autoregression (absent the price surprise term), which is .94. That is, because it is assumed that

TABLE IV

PRICE SURPRISES AND UNEMPLOYMENT

A. Distributed lag Effects of Price Surprises

$$U_t = \text{Const.} + \sum_{j=0}^{8} a_j \tilde{P}_{t-j} + e_t$$

Estimation Method	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	r_1	r_2	r_3	r_4	ϕ
OLS	-.02	.00	-.04	-.05	-.02	.01	-.02	.01	.09					
Autoregressive Errors	-.01 (.03)	-.02 (.04)	-.05 (.05)	-.06 (.06)	-.06 (.06)	-.07 (.06)	-.05 (.05)	-.05 (.04)	-.00 (.02)	1.16	-.20	-.04	-.02	.996 (.019
IV (all lags)	-.24 (.04)	-.43 (.06)	-.71 (.09)	-.79 (.12)	-.72 (.13)	-.56 (.12)	-.43 (.09)	-.16 (.06)	.03 (.04)	1.39	-.07	-.54	.15	.977 (.006
IV (first lag only)	-.08 (.02)	-.05 (.05)	-.08 (.07)	-.12 (.08)	-.14 (.09)	-.14 (.08)	-.12 (.07)	-.09 (.07)	-.01 (.05)	1.47	-.23	-.44	.13	.921 (.073

B. Sargent's Autoregressive Model

$$U_t = \text{const.} + a_0 (\tilde{P}_t) + \sum_{j=1}^{4} \lambda_j U_{t-j} + e_t$$

Estimation Method	a_0	λ_1	λ_2	λ_3	λ_4	ϕ^*
OLS	-.04 (.02)	1.44 (.09)	-.35 (.15)	-.28 (.15)	.15 (.09)	.95*
IV	-.33 (.16)	1.47 (.08)	-.36 (.15)	-.30 (.15)	.15 (.09)	.95*

real disturbances are strictly temporary, all of the serial correlation in the time series is due to internal propagation mechanisms.

As in our earlier estimates in panel A of Table IV, the impact effect of price surprises in the Sargent-style autoregressions in panel B is much higher with the instrumental variables estimator (with money surprises as the instrument) than with the ordinary least square estimate. The IV estimate implies that a three percent surprise inflation causes a one percent decline in unemployment on impact, with this being subsequently magnified as it is transmitted over time.

Price Surprises vs. Real Factors

It is of some interest to examine the decomposition of unemployment into effects of price surprises and real factors, using estimates reported in Table IV, panel A. That is, in terms of our earlier discussion, we examine estimated decomposition of y_{jt} into

$$\sum_{h=0}^{H} \alpha_{jh} \tilde{p}_{t-h} \text{ and } y^*_{jt} .$$

We focus on two versions of this decomposition. The first is the ordinary least square decomposition which, by construction, limits the role for real factors (in the sense that the distributed lag on price surprises is selected so as to have the largest contribution to variance of unemployment while maintaining orthogonality with the error term). From the Table IV estimates, however, the estimated coefficients are small and switch sign frequently. Thus, the price surprise component $\sum_{h=0}^{H} \alpha_{jh} \tilde{p}_{t-h}$ (see Table IV), does not exhibit much serial correlation and appears as a choppy series (see Figure 1), exhibiting few business cycle characteristics. Consequently, real factors assume the more familiar pattern, with a high degree of serial correlation (see Table IV) with protracted ups and downs (see Figure 2). In this case, there is (by construction) no correlation between price surprise and real business cycle components.

The second decomposition we study involves instrumental variables estimates of the price surprise parameters reported in Table IV, formed using money as an instrument. But, the price surprise component employs the whole price surprise not just its projection on monetary surprises. In this case, Figure 3 shows the price surprise component has strong positive serial correlation estimate and a much more characteristic business cycle shape. These characteristics are shared by the real business cycle component presented in Figure 4. But, there is a strong <u>negative</u> correlation between these components (-.93). That is, under this interpretation, the economy is <u>less</u> volatile as a result of real factors because these produce price surprises of the opposite sign that set in motion offsetting variations.

IV. <u>CONCLUSIONS</u>

Much of the debate surrounding the equilibrium monetary theories of the business has concerned whether (i) nominal surprises are a major source of economic fluctuations and (ii) the mechanism by which nominal surprises

PRICE SURPRISE COMPONENT OF UNEMPLOYMENT (OLS COEFFICIENT ESTIMATES)

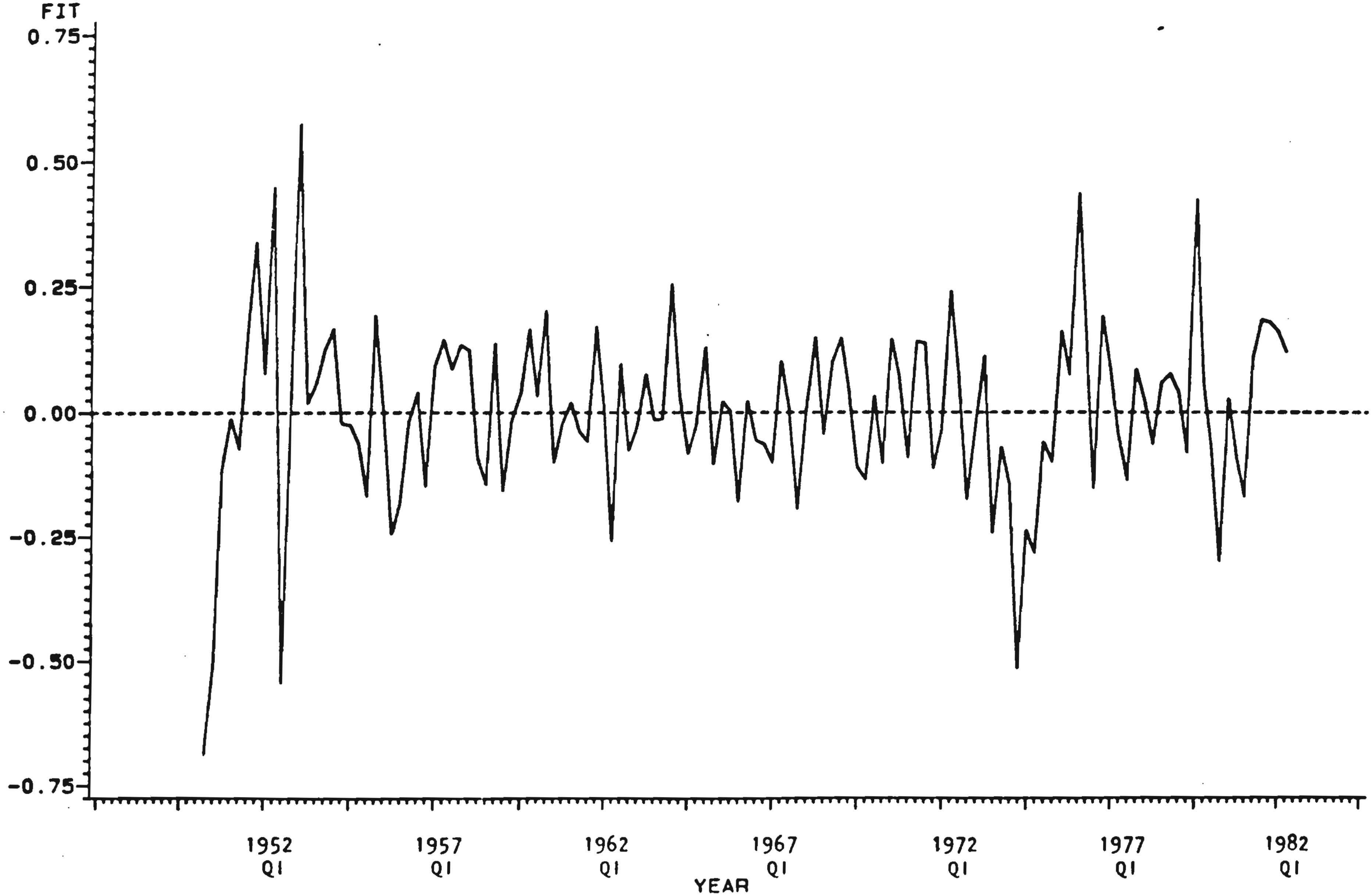

FIGURE 1

REAL COMPONENT OF UNEMPLOYMENT (OLS COEFFICIENT ESTIMATES)

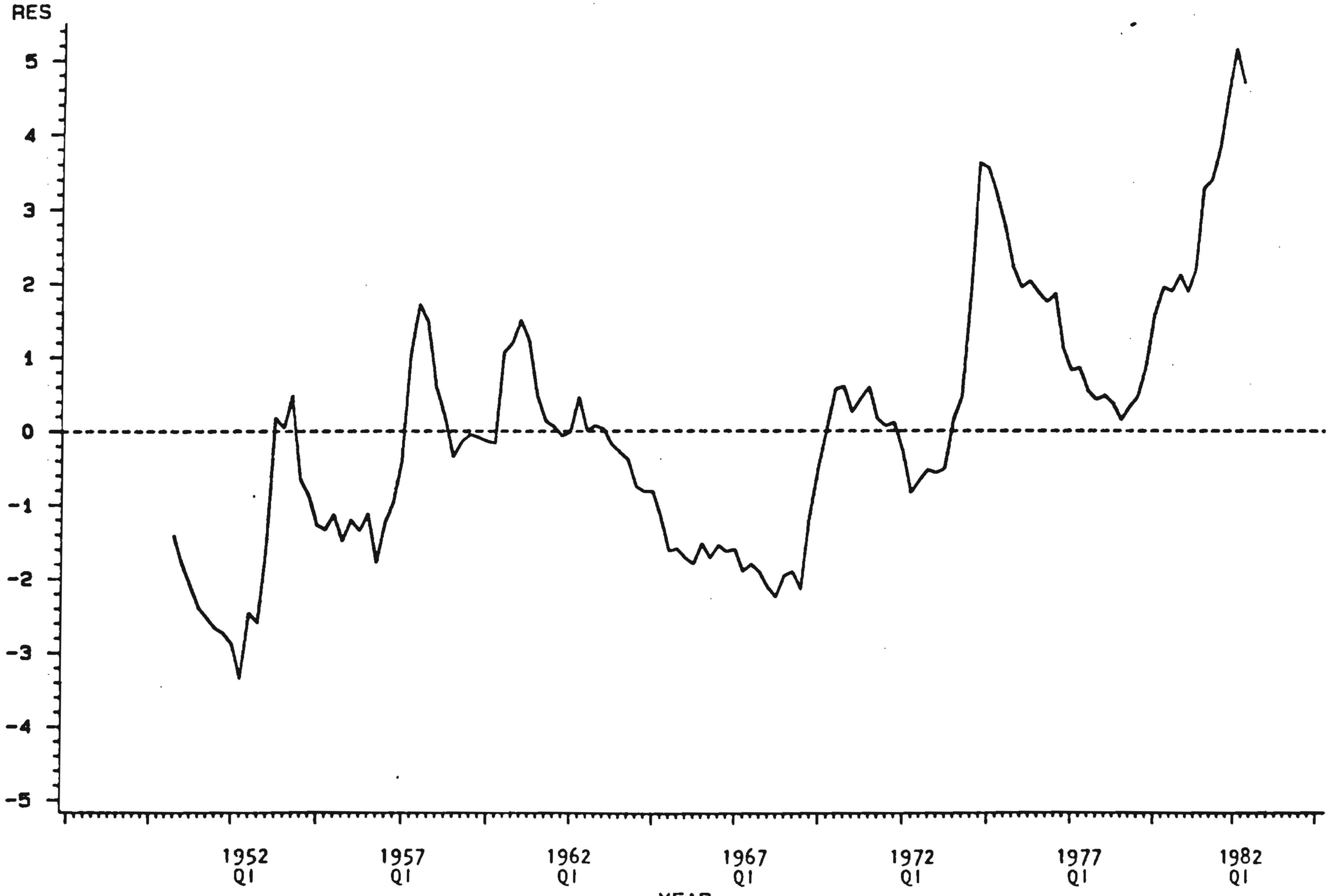

FIGURE 2

PRICE SURPRISE COMPONENT OF UNEMPLOYMENT (IV COEFFICIENT ESTIMATES)

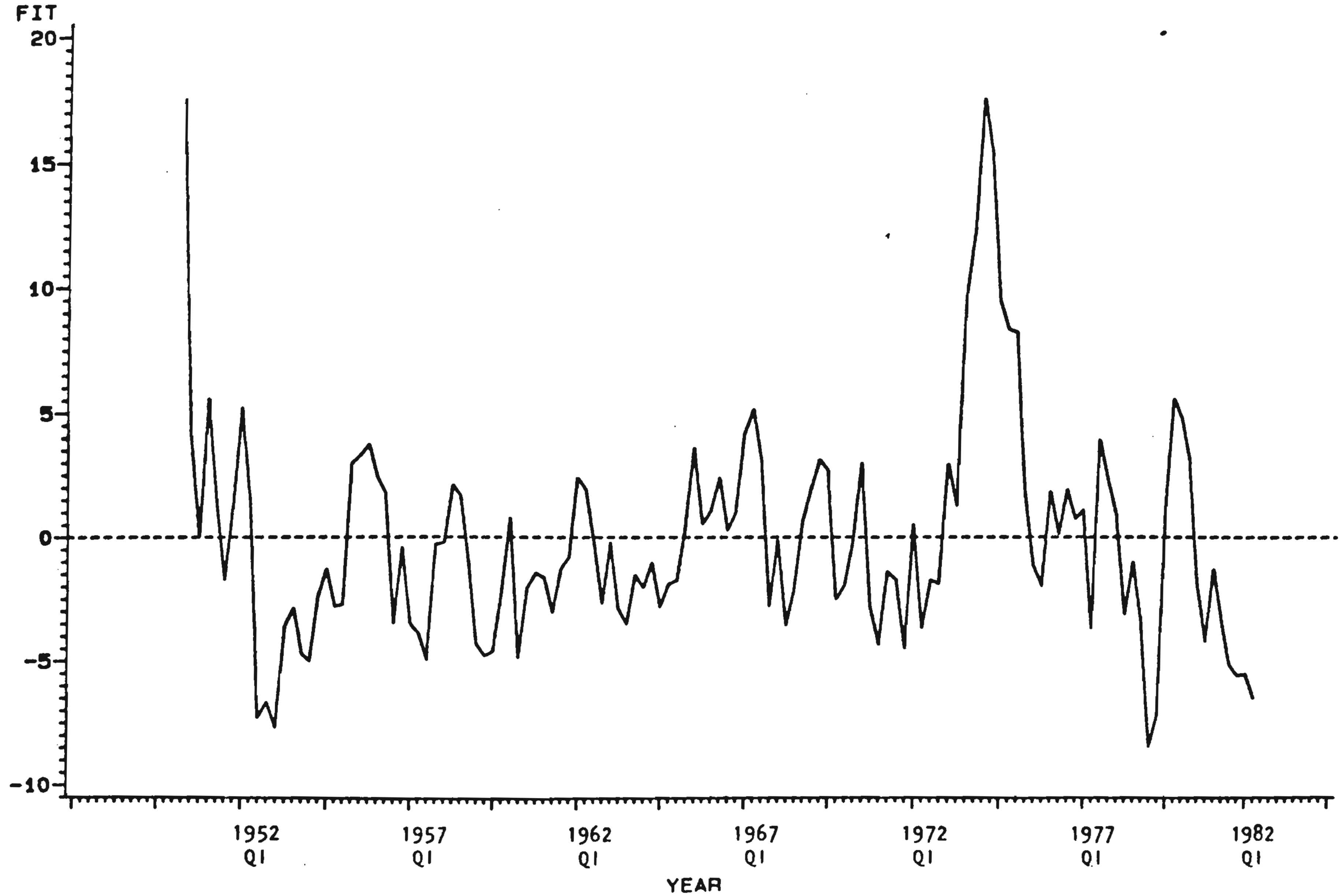

FIGURE 3

REAL COMPONENT OF UNEMPLOYMENT (IV COEFFICIENT ESTIMATES)

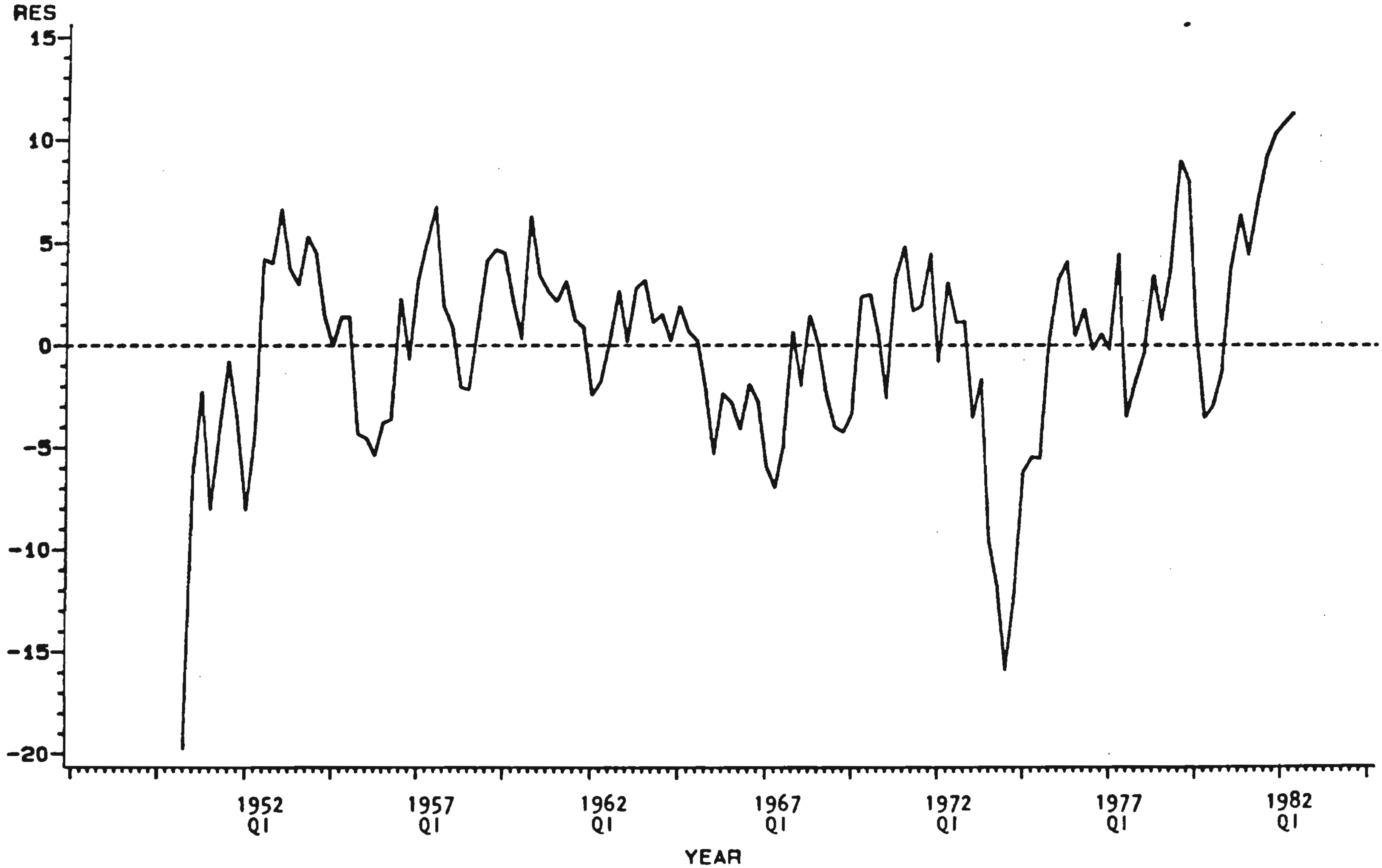

FIGURE 4

affect real variables. In this paper,[12] we argue that an understanding of the character and nature of business cycles requires an understanding of the mechanism by which impulses are propagated through time.

In fact, ironically, this is especially true if one believes that business cycles are induced by surprises in M_1, for the effects of Barro-style unanticipated money shocks are distributed over many quarters (far longer than plausible information lags). In this paper, we document the importance of internal propagation mechanismms with a measure we call the propagation ratio. For unanticipated money regressions of the sort presented by Barro and Rush (1980) our estimates of the propagation ratio range from .92 to .98. That is, the bulk of the explanatory power of unanticipated money is accounted for by the presence of an internal propagation mechanism.

Recent theoretical research has stressed the importance of various types of capital in producing persistent effects of temporary shocks, including finished goods inventories, inventories of goods in process, and plant or equipment.[13] Further, various types of labor market capital can be an important propagation mechanisms (see Lucas and Sargent (1979) and King and Plosser (1984b)). These theoretical investigations provide foundations for future, detailed empirical inquiries into the structure of propagation mechanisms in business cycles. In future empirical research based on these foundations, we envision a valuable interplay between multivariate time series modelling and structural model building in determining the empirically relevant mechanisms that generate business cycles.

References

Barro, R.J., "Unanticipated Money Growth and Unemployment in the United States," American Economic Review, 67, March 1977, 101-115.

Barro, R.J., "Unanticipated Money, Output, and the Price Level in the United States," Journal of Political Economy, 86, August 1978, 549-580.

Barro, R.J., "A Capital Market in an Equilibrium Business Cycle Model," Econometrica, 48, September 1980, 1393-1417.

Barro, R.J., and M. Rush, "Unanticipated Money and Economic Activity," in S. Fischer, ed., Rational Expectations and Economic Policy, Chicago, University of Chicago Press for the National Bureau of Economic Research, 1980.

Blinder, A.S. and S. Fischer, "Inventories, Rational Expectations and the Business Cycle," Journal of Monetary Economics, 8, November 1981, 277-304.

Fischer, Stanley, "Long-Term Contracts Rational Expectations and the Optimal Money Supply Rule," Journal of Political Economy, 85, February 1977, 191-205.

Hatanaka, M., "Several Efficient Two-Step Estimators for the Dynamic Simultaneous Equations Model with Autoregressive Disturbances," Journal of Econometrics, 4, May 1976, 189-204.

Hausman, J.A., "Specification Tests in Econometrics," Econometrica, 46, 1978, 1251-1272.

Hayek, F.A., Prices and Production, London: George Routledge & Sons, 1931.

King, R.G., "Monetary Information and Monetary Neutrality," Journal of Monetary Economics, 7, March 1981, 195-206.

King, R.G., "Notes on Linear Business Cycle Models," manuscript, November 1983.

King, R.G. and C.I. Plosser, "Money, Credit and Prices in a Real Business Cycle," American Economic Review, 74, June 1984a, 363-380.

King, R.G. and C. Plosser, "Production, Growth and Business Cycles," manuscript in progress, 1984b.

Kydland, F. and E.C. Prescott, "Time to Build and Aggregate Fluctuations," Econometrica, 50, November 1982, 1345-1370.

Long, J.B. and C.I. Plosser, "Real Business Cycles," Journal of Political Economy, 91, February 1983, 39-69.

Lucas, R.E., Jr., "Expectations and the Neutrality of Money," Journal of Economic Theory, April 1972, 103-124.

Lucas, R.E., Jr., "Some International Evidence or Output Inflation Tradeoffs," American Economic Review, 63, June 1973, 326-334.

Lucas, R.E., "Understanding Business Cycles" in Stabilization of the Domestic and International Economy, Carnegie-Rochester Conference Series, Vol. 4, K. Brunner and A. Meltzer eds., Amsterdam: North Holland, 1977, 1-29.

Lucas, R.E., "Methods and Problems in Business Cycle Theory," Journal of Money, Credit and Banking, 12, November 1980, 696-715.

Lucas, R.E. and T.J. Sargent "After Keynesian Macroeconomics," Federal Reserve Bank of Minnesota Quarterly Review, 23, Spring 1979, 1-16.

Plosser, C.I., G.W. Schwert and H. White, "Differencing as a Test of Specification," International Economic Review, 23, October 1982, 535-552.

Sargent, T.J., "A Classical Macroeconometric Model for the United States," Journal of Political Economy, 84, April 1967c, 207-237.

DATA APPENDIX

The Citibase data tape was the basic source for all series. The series were obtained in monthly, non-seasonally adjusted form or in quarterly seasonally adjusted form. For monthly series, quarterly values were selected as the last month of each quarter.

The following series (summarized in Table 1) were employed and are listed below along with variable name, description and Citibase identifier:

U: Unemployment, all workers 16 years and older (LHUR), monthly, NSA.

y: Gross National Product, 1972 dollars (GNP), quarterly, SA.

P: GNP Implicit price deflator, (GD), quarterly SA.

B: Monetary base, produced by splicing several Citibase series, monthly NSA

After 1958, monetary base (FMFB).

Before 1959, sum of member bank reserve (FCMB) and currency held by the public (FMSCU).

Series prior to 1959 was multiplied by a ratio of annual averages for 1959 to scale appropriately.

M: Narrow money stock, produced by splicing two Citibase series, monthly NSA:

After 1958 (FMI).

Before 1959 (FMF).

Same splicing techniques as used for the monetary base.

g: Federal government purchases, 1972 dollars (GGE72), quarterly, SA.

l: Labor force participation rate, defined as the ratio of civilian labor force (LHC) to population (POPT16), monthly, NSA.

W: Average hourly earnings for production workers, excluding overtime, in manufacturing, monthly, NSA.

n: population over age of 16 (POPT16) monthly, NSA.

R: 3-month treasury bill rate, percent per annum, (FYGM3), monthly, NSA

FOOTNOTES

[1]For example, both the standard version of Lucas' (1972, 1973) incomplete information theory and the single period contact version of Fischer's (1977) sticky wage model have this implication. By standard version, we mean the version of Lucas' theory that constrains agents to base current perceptions on local prices and not aggregate endogenous variables such as the interest rate (Barro (1980)) or exogenous variables such as the money stock (King (1981)).

[2]See Long and Plosser (1983) and King and Plosser (1984a, b).

[3]As noted by Long and Plosser (1983) this result holds even if ther is not long-lived capital, i.e., the depreciation rate is 100% ($\Delta = 0$).

[4]There is a deeper sense in which this is even more important. If A and Δ are technological, but β and θ are at least partly determined by behavior, the optimal values of β and θ, in principle, depend on Λ. For ecample, the degree of permanence of s_t influences an optimizing agents' response to this factor, i.e., values of β. For a more detailed discussion of such linear business cycle models, see King (1983).

[5]For example, in Kydland and Prescott (1982), it is unclear whether the bulk of serial correlation arises from internal propagation mechanisms or exogenous productivity disturbances.

[6] It is interesting to note that if one assumes that the real shocks are serially uncorrelated then the distributed lag weights for the nominal surprise and the real shocks are proportional for lags greater than one. Alternatively, this fact could be used to uncover the serial correlation properties of the underlying real disturbances.

[7] We use this procedure because it corresponds most closely to what previous authors have done. Marty Eichenbaum, however, has pointed out to us that, alternatively, we could have estimated a vector autoregression and that the coefficients on our unanticipated money variable isolate one portion of the moving average response function of that system. Our identifying restriction would appear through the choice of an orthogonalization of the variance-covariance matrix of the innovations. This perspective makes clear the other orthogonalizations could be chosen and would lead to different impulse response functions and thus different propagation ratios.

[8] These results are similar to those obtained by Barro and Rush (1980) despite the fact that we employ a different money prediction equation.

[9] Once again, these results are similar to those reported by Barro and Rush (1980).

[10] That is, the instrument for the price surprise was formed by regressing price surprises against the current value of money growth and four lags of all variables in Table III. The estimated coefficient of prices on current money was .16 and statistically significant at the usual levels.

[11]As discussed previously, panel A estimates do not appear consistent with a simple autoregressive model for real factors.

[12]See also King and Plosser (1984b).

[13]Blinder and Fischer (1981) study finished good inventories. Long and Plosser's (1983) one period intertemporal production structure can be interpreted as a type of goods in process inventory. Kydland and Prescott (1982) stress multiperiod gestation of investment and effects of plant/equipment accumulation.

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