

The Implications of Systematic Fed Errors
for Studies of Announcement Effects

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Abstract

In this paper we show that the errors in the Federal Reserve's weekly preliminary money supply estimates may be treated as an autoregressive, conditionally heteroskedastic (ARCH) process. We present theoretical and empirical evidence concerning the implications of systematic Fed errors for announcement effect studies. The results show that findings in previous studies of structural change in the response of interest rates to unanticipated changes in the money supply and of significant negative effects of anticipated money changes on interest rates are not robust when corrections are made to incorporate efficient market responses to error-ridden announcements.

1. Introduction

Numerous articles have been written on the empirical relationship between asset prices and money supply behavior. One widely studied area of this research has been the impact of the Federal Reserve Bank's weekly announcements of changes in the money supply on interest rates.^{1/} The typical methodology utilized in these studies is to regress the change in short- or long-term interest rates (taken over a period beginning before and ending after the Fed's announcement) on measures of the market's pre-announcement expectations of the change in the money supply, and on the difference between the announced change and the market's expectation of the change. The theory of efficient markets suggests that only the unanticipated change in the money supply should have an effect on interest rates.

Although these studies differ in their measures of expected money supply changes, the time span over which interest rate changes are taken, and the sample periods selected for analysis, the results are quite consistent. An illustration of a typical empirical specification is:

$$\begin{array}{l} 1978:1-1979:40 \quad R_t = .047 - .013M_{t-}^P + .02(M_t^F - M_{t-}^P); \quad R^2 = .11 \\ \quad \quad \quad (3.62) \quad (1.51) \quad (2.97) \\ \\ 1979:41-1984:2 \quad R_t = .038 - .04M_{t-}^P + .074(M_t^F - M_{t-}^P); \quad R^2 = .23 \\ \quad \quad \quad (1.80) \quad (2.85) \quad (7.72) \end{array} \quad (1)$$

The sample is divided into two subsamples corresponding to periods before and after Fed's announced change in policy in October, 1979. R_t is the change in the 3-month Treasury bill rate taken from the close before the Fed's announcement to the close after the announcement. M_t^F is the Fed's announcement of the change in the money supply^{2/}, and M_{t-}^P is the market's pre-announcement expectation of the Fed's announcement.^{3/} The t-statistics are reported in parentheses.

The results reported in equation (1) are quite representative of the results generally found from announcement effect studies. The coefficients on anticipated money changes are negative and the coefficients on unanticipated money changes are positive. The coefficients on anticipated money changes are often significant in the period after the Fed's October 1979 policy change and are generally not significant at standard levels before then. However, even in the earlier sample periods, the estimated coefficients on anticipated money changes are often similar in magnitude to the coefficients on unanticipated money changes and often have marginal significance levels approaching the 10 percent level.^{4/} Finally, there is a substantial increase in the size of the coefficient on unanticipated money in the second period relative to the first period.

Clearly, the findings of large and significant price responses to anticipated money are puzzling to economists who believe strongly that asset markets react quickly to new information. Recently, Roley (1983); Clark, Joines and Phillips (1985); and Deaves, Melino and Pesando (1987) have explored the possibility that this anomalous result is due to systematic errors in a commonly used measure of market expectations, the Money Market Services, Inc. survey median of market expectations of money supply changes. Belongia, Hafer and Sheehan (1986) explored the possibility that the anomaly is due to misspecification caused by instability in the coefficients on unanticipated money. This paper explores another potential explanation for the puzzle. In particular, we explore the impacts on announcement effect studies when the Fed's weekly announcements of the money supply are subject to systematic errors. We demonstrate that such errors can result in biased coefficients in estimates such as those reported in equation (1). Among other possibilities, these biases can lead to incorrect inference regarding the significance of the coefficient on anticipated money changes and the instability of the coefficient on unanticipated money changes. We also report empirical results that are consistent with this theory.

The remainder of the paper is organized as follows. In Section 2, we develop the theoretical framework and show some conditions under which announcement effect studies will yield biased and inconsistent estimates of the responses of asset prices to anticipated and unanticipated money supply changes. In Section 3, we implement the theory in an empirical analysis of the error structure of the Fed's preliminary money supply announcements. The error structure of the market's estimates of the money supply are analyzed in Section 4. In Section 5, we report the estimation of interest rate responses to money supply announcements incorporating our findings in Sections 3 and 4. A brief summary concludes the paper.

2. Interpreting Error-Ridden Money Supply Estimates

This section illustrates how the structure of the Fed's estimation errors can affect the interpretation of coefficient estimates in studies of announcement effects. This discussion can easily be generalized to encompass market responses to other government announcements. Suppose that on day t , the Fed announces its estimate, M_t^F , of the true money supply, M_t . Given that the Fed's preliminary estimates contain errors, there are two ways to interpret conventional models of how asset prices respond to this announcement. One interpretation is that economic agents are interested in the announcement because it reveals information about the actual behavior of the money supply. In this case, we can represent the change in an asset's price on the day of the announcement, R_t , by the reduced-form equation

$$R_t = \alpha E(M_t | I_{m,t-}) + \beta \{E(M_t | I_{m,t-}, M_t^F) - E(M_t | I_{m,t-})\} + \epsilon_t \quad (2)$$

where $E(M_t | I_{m,t-})$ is the market's estimate of the money supply based upon its information set prior to the Fed's announcement, $I_{m,t-}$, and $E(M_t | I_{m,t-}, M_t^F)$ is its estimate of

the money supply following the Fed's announcement. The disturbance process ϵ_t is assumed to be a white noise process that is orthogonal to these forecasts. The neutrality hypothesis implies that α is equal to zero.

An alternative interpretation of announcement effect studies is that economic agents are interested in the Fed announcements per se, i.e., regardless of their implications about the actual behavior of the money supply. In this case we can represent R_t by the following reduced-form model

$$R_t = \alpha' E(M_t^F | I_{m,t-}) + \beta' (M_t^F - E(M_t^F | I_{m,t-})) + \epsilon_t' \quad (2')$$

where ϵ_t' is a white noise disturbance process and α' will be equal to zero if the neutrality hypothesis pertains to (2').

Since (2) is a reduced-form equation, a regression of R_t on $E(M_t | I_{m,t-})$ and $E(M_t | I_{m,t-}, M_t^F) - E(M_t | I_{m,t-})$ will yield, under general conditions, consistent estimates of α and β . In practice, the market's estimate of the money supply conditioned on the Fed announcement, $E(M_t | I_{m,t-}, M_t^F)$, has been replaced by the Fed announcement itself, M_t^F . Whether the coefficients obtained from a regression of R_t on $E(M_t | I_{m,t-})$ and $M_t^F - E(M_t | I_{m,t-})$ will be a consistent estimator of α and β depends on the relationship between M_t^F and $E(M_t | I_{m,t-}, M_t^F)$ which, in turn, depends on the error structure of the Fed's preliminary estimates. If the Fed's preliminary estimates fully account for all of the relevant information available to the market, then $E(M_t | I_{m,t-}, M_t^F)$ and M_t^F are equivalent, and α and β can be estimated consistently. In that case, the differences between equations (2) and (2') are purely cosmetic. Since there is reason to suspect that the Fed's preliminary estimates fail to account for all relevant information available to the market, however, the equivalence of M_t^F and $E(M_t | I_{m,t-}, M_t^F)$ is suspect. If this equivalence fails, then the coefficients from a

regression of R_t on $E(M_t | I_{m,t-})$ and $M_t^F - E(M_t | I_{m,t-})$ will generally be biased and inconsistent estimators of α and β in (2).

We can write

$$M_t^F - E(M_t | I_{m,t-}) = (M_t^F - M_t) + (M_t - E(M_t | I_{m,t-}))$$

which expresses the discrepancy between the Fed's money supply estimate and the market's pre-announcement estimate into the sum of the Fed's error and the market's error. It will be assumed that the market observes the noisy signal $M_t^F - E(M_t | I_{m,t-})$ and then uses optimal signal extraction procedures to estimate $M_t - E(M_t | I_{m,t-})$. The resulting estimate of $M_t - E(M_t | I_{m,t-})$ is the unanticipated change in the money supply by the market from the Fed's announcement.

Let u_t denote the market's pre-announcement forecast error, $M_t - E(M_t | I_{m,t-})$, and let e_t denote the Fed's forecast error, $M_t^F - M_t$. Since the market is assumed to utilize its information set efficiently in forming its money supply estimates, its pre-announcement estimation errors can be characterized by a white-noise process. Let σ_u^2 denote the (constant) variance of this process. Initially, it will also be assumed that the Fed's estimation errors mimic a white-noise process and σ_e^2 will denote its variance. The covariance between u_t and e_t will be denoted σ_{ue} .^{5/} It follows that the minimum-variance, linear estimator of u_t given $M_t^F - E(M_t | I_{m,t-})$ is \bar{u}_t where

$$\bar{u}_t = [(\sigma_u^2 - \sigma_{ue}) / (\sigma_u^2 + \sigma_e^2 - 2\sigma_{ue})] \cdot [M_t^F - E(M_t | I_{m,t-})]. \quad (3)$$

If $\sigma_{ue} = 0$, i.e., if the Fed's estimation error is uncorrelated with the market's

pre-announcement error, then clearly \hat{u}_t is less than but proportional to $M_t^F - E(M_t | I_{m,t-})$. Even with a nonzero σ_{ue} , studies of announcement effects which use $M_t^F - E(M_t | I_{m,t-})$ instead of \hat{u}_t in regression equations will not be misled in terms of the sign and significance of β in equation (2) unless σ_{ue} is sufficiently negative.^{6/}

Now suppose that the Fed's errors are serially correlated. For example, suppose that e_t follows an AR(1) process. As before, upon hearing the Fed's preliminary money supply estimate the market faces the problem of trying to decompose $M_t^F - E(M_t | I_{m,t-})$ into u_t and e_t . However, in this case it will obtain a better estimate of u_t by adding the Fed's error from the previous week, e_{t-1} , to its conditioning set.^{7/} The optimal linear estimator of u_t conditioned upon $M_t^F - E(M_t | I_{m,t-})$ and e_{t-1} will be of the form

$$\hat{u}_t = \gamma [M_t^F - E(M_t | I_{m,t-})] + \delta e_{t-1} \quad (4)$$

where $\delta \neq 0$. The precise forms of γ and δ will depend upon the joint distribution of the $u(t)$ and $e(t)$ processes and they can be derived using conventional methods.^{8/} It is clear, however, that even if $u(t)$ and $e(t)$ are independent processes, \hat{u}_t will no longer be strictly proportional to $M_t^F - E(M_t | I_{m,t-})$. Therefore, when $M_t^F - E(M_t | I_{m,t-})$ is used as a proxy for $M_t^F - E(M_t | I_{m,t-})$ the coefficient on $M_t^F - E(M_t | I_{m,t-})$ will not yield direct information on either the sign or the significance of the coefficient β in (2).

Next suppose that e_t is serially uncorrelated but is conditionally heteroskedastic, i.e., $\text{Var}(e_t | e_{t-1}, \dots)$ is time dependent. For example, suppose that e_t evolves according to the ARCH (1) process:^{9/}

$$e_t = v_t(a_0 + a_1 e_{t-1}^2)^{1/2} \quad (5)$$

where a_0 and a_1 are constants and v_t is an independently drawn random variable with zero mean and unit variance. It follows that $\text{Var}(e_t | e_{t-1}, \dots) = a_0 + a_1(e_{t-1}^2) = \sigma_{e,t}^2$. In this case the optimal linear estimator of u_t given $M_t^F - E(M_t | I_{m,t-})$ and e_{t-1} will have the form

$$\tilde{u}_t = \gamma_t [M_t^F - E(M_t | I_{m,t-})] \cdot \frac{10}{\sigma_{e,t}^2} \quad (6)$$

That is, the relationship between \tilde{u}_t and $M_t^F - E(M_t | I_{m,t-})$ will not be characterized by a constant of proportionality but rather by the time dependent parameter γ_t . This result follows even if $\sigma_{ue} = 0$.

Finally, it is possible that the Fed's errors are systematically related to information available to the market at time t other than $M_t^F - E(M_t | I_{m,t-})$ and past Fed errors. For example, suppose that x_t is a $k \times 1$ vector of variables which are observable at t and which are related to the Fed's error at t according to

$$e_t = Dx_t + v_t \quad (7)$$

where D is a $1 \times k$ constant vector and $E(x_t v_t) = 0$. Then even if v_t is a white noise process the market's optimal estimate of u_t will not be strictly proportional to $M_t^F - E(M_t | I_{m,t-})$. Instead it will have the form

$$\tilde{u}_t = \gamma [M_t^F - E(M_t | I_{m,t-})] - (\gamma D)x_t \quad (8)$$

Our theoretical discussion establishes that if market participants use information efficiently, then the relationship between the "surprise" component of the Fed's preliminary money supply announcement, $M_t^F - E(M_t | I_{m,t-})$, and the market's perception of the actual money supply innovation upon hearing the announcement, \tilde{u}_t , will be characterized by a constant of proportionality only under a special set of circumstances. Specifically, it requires that the Fed's errors are white noise and are "not too" negatively correlated with the market's pre-announcement estimation errors. If these circumstances do not apply, then empirical studies which replace \tilde{u}_t with $M_t^F - E(M_t | I_{m,t-})$ cannot yield a direct interpretation for the sign or the significance of the parameter β in (2).

The structure of the Fed's estimation errors also has implications for the interpretation of the coefficient on anticipated money supply changes in empirical estimates of (2). It is shown in the Appendix that if $M_t^F - E(M_t | I_{m,t-})$ measures \tilde{u}_t with error, then the estimates of both α and β in (2) will be biased when e_t is serially correlated or conditionally heteroskedastic. In particular, the estimate of α , the coefficient on anticipated money, will be biased downward. Since α should equal zero according to the efficient markets hypothesis, empirical estimates of α when $M_t^F - E(M_t | I_{m,t-})$ is used instead of \tilde{u}_t should be negative in the presence of ill-behaved Fed estimation errors if the market attempts the type of error decomposition process we proposed above. As we pointed out in the introduction, the estimated coefficients on anticipated money supply changes have typically been negative in studies of responses to money supply announcements. Rather than violating the efficient market condition, such results actually support it provided that the market attempts to extract and respond to the true component of the Fed's preliminary announcement.

3. An Empirical Analysis of Fed Estimation Errors

A general model that allows the Fed's estimation error in week t , e_t to depend systematically upon past estimation errors and/or other information available at that time is the following version of Engle's (1982) ARCH model:

$$e_t = a_0 + \sum_{i=1}^s a_i e_{t-i} + \sum_{i=1}^n c_i x_{it} + v_t h_t^{1/2} \quad (9)$$

where the x_{it} 's are exogenous variables whose values are observable at t and which are helpful in estimating the money supply; $h_t = b_0 + \sum_{i=1}^p b_i e_{t-i}^2$; and, v_t is a zero mean, unit variance, serially uncorrelated random variable which is uncorrelated with the x_{it} 's and past drawings of e_t . Under these assumptions,

$$E(e_t | x_{1t}, \dots, x_{nt}, e_{t-1}, \dots, e_1) = a_0 + \sum_{i=1}^s a_i e_{t-i} + \sum_{i=1}^n c_i x_{it} \quad (10)$$

and

$$\text{Var}(e_t | x_{1t}, \dots, x_{nt}, e_{t-1}, \dots, e_1) = h_t = b_0 + \sum_{i=1}^p b_i e_{t-i}^2. \quad (11)$$

The null hypothesis that the Fed's preliminary money supply estimates are efficient can be expressed as the hypothesis that in (9), $a_i=0, i=0, \dots, s$; $b_i=0, i=1, \dots, p$; and $c_i=0, i=1, \dots, n$.

Using the equality $E(y_t) = E(E(y_t | z_t))$, it is clear that $v_t h_t^{1/2}$ is uncorrelated with $x_{1t}, \dots, x_{nt}, e_{t-1}, \dots, e_1$ so that a regression of e_t on the x 's and lagged e 's will

be a consistent estimator of the a's and c's. Furthermore, under the null hypothesis the usual t- and F-tests may be derived from this regression to test the restrictions on the a's and c's. The regression and test results are reported in Table II.^{11/} The x-vector used in this analysis included: M_t^F - the Fed's money supply announcement at time t; $WEEK1_t$ - a dummy variable which equals one if the announcement corresponds to a week containing the third day of the month; and SSW_t - a dummy variable which takes the value of one if the announcement corresponds to a so-called "Social Security Week". Social Security Weeks occur if the third day of the month falls on a weekend or on a Monday or Friday holiday. Hafer (1984) and Clark, Joines and Phillips (1985) have demonstrated that the first week in the month, and these social security weeks in particular, correspond to persistent exogenous shocks to the money supply. If Fed money announcements are rational, then the Fed announcement and these exogenous variables should be uncorrelated with the errors in the Fed's announcement.

Although different lag lengths were tested, the results were consistent across specifications. Therefore, only the third-order specifications are presented here. The sample was divided into two parts, corresponding to the two presumably distinct Fed policy regimes. Consistent with the Mankiw, et al., results for quarterly data, the results strongly reject the hypothesis that Fed weekly announcement errors are white noise. In the first subsample, the Fed's errors are correlated with the Fed's preliminary announcement, M_t^F , and the dummy variable for social security weeks. The Fed's errors appear to be serially independent, conditional upon the x-vector, in the first subsample. In the second subsample, the Fed's errors are correlated with the preliminary estimate and they exhibit serially correlation whether the x-vector is or is not included among the regressors.

While the rejection of the hypothesis that the parameters in (9) are jointly equal to zero is sufficient to reject the white noise hypothesis, we also allowed for

the possibility that the variance of the error process in week t depended systematically on past errors and/or x_{1t}, \dots, x_{nt} . That is, in equation (9) we allowed for the possibility that one or more elements of the vector $[b_1, \dots, b_p]$ was nonzero. Following Engle (1982, pp. 999-1000) we can test the null hypothesis that the revisions are homoskedastic, both conditionally and unconditionally, by using a Lagrange multiplier test. Let w_t denote the disturbance in equation (9), i.e., $w_t = v_t h_t^{1/2}$. Next, consider the regression of \tilde{w}_t^2 on a constant and $\tilde{w}_{t-1}^2, \tilde{w}_{t-2}^2, \dots, \tilde{w}_{t-p}^2$, where \tilde{w}_t is the residual from the regressions in Table II. With T being the sample size, the statistic $T \cdot R^2$ obtained from the p -th order autoregression of \tilde{w}_t^2 will be distributed as a Chi-square with p degrees of freedom. We summarize the results in Table III.

The intercept term in these regressions is an estimate of the unconditional variance of the Fed's preliminary money supply announcement. We find that the variance rose to 1.19 in the second subsample relative to 0.18 in the first. More importantly for our present interests, the null hypothesis of conditionally homoskedastic errors in the Fed's preliminary money supply estimates is soundly rejected in both samples. These results were robust to changes in the lag specification.

The evidence which we have presented in this section makes a strong case in favor of the argument that the estimation errors in the Fed's preliminary money supply announcements have been serially correlated in mean and/or variance. If market agents are interested in the Fed's preliminary money supply announcements primarily because of the information they convey about the actual money supply, then this evidence invalidates the common practice of equating the Fed's preliminary money supply estimate with the market's own post-announcement estimate. In other words, if (2) is the relevant model, then a regression of R_t on $E(M_t | I_{m,t-})$ and $M_t^F - E(M_t | I_{m,t-})$ will yield inconsistent estimates of α and β .

4. The Efficiency of Market Money Supply Estimates

Our critique of conventional empirical studies of money supply announcement effects has relied upon the assumption that market participants use their available information sets efficiently to estimate the actual money supply. Typically, these studies use the median value of the Money Market Services, Inc. survey to measure the market's pre-announcement estimate of the actual money supply or the Fed's perception of the money supply.^{12/} Therefore, it is interesting to explore whether these market surveys are also subject to systematic errors.

Suppose that the market does use information efficiently and that the Money Market Services, Inc. estimates are estimates of the actual money supply behavior. Let M_t denote the actual weekly change in the money supply and let $E(M_t | I_{m,t-})$ denote the market's pre-announcement estimate of M_t as given by the median value of the Money Market Services, Inc.'s weekly survey. Then the market's estimation errors, $M_t - E(M_t | I_{m,t-})$, should have a zero mean and constant variance both unconditionally and conditional upon information available to the market prior to the Fed's announcement. This hypothesis may be tested using the same ARCH model structure as that used to analyze the Fed errors in the previous section, specifically:

$$M_t - E(M_t | I_{m,t-}) = a_0 + \sum_{i=1}^s a_i [M_{t-i} - E(M_{t-i} | I_{m,t-i-})] + \sum_{i=1}^n c_i x_{it} + v_t h_t^{1/2} \quad (12)$$

where v_t is a zero mean, unit variance and serially uncorrelated random variable which is uncorrelated with past estimation errors and the vector of exogenous variables

x_{1t}, \dots, x_{nt} . The random variable h_t is defined according to $h_t = b_0 + \sum_{i=1}^p b_i [M_{t-i} - E(M_{t-i} | I_{m,t-i-})]^2$. The null hypothesis that the market's estimation errors evolve according to a white noise process is equivalent to the hypothesis that in (12), $a_i =$

$0, i=0, \dots, s; b_i=0, i=1, \dots, p; \text{ and } c_i=0, i=1, \dots, n.$

Alternatively, it is possible that the Money Market Services, Inc. estimates represent the market's forecasts of the Fed's preliminary money supply announcements (which, we have argued previously, are inefficient estimates of the true money supply). In this case, if the market uses its information set efficiently, $M_t^F - E(M_t^F | I_{m,t-})$ should mimic a white noise process where M_t^F is the Fed's preliminary estimate of M_t and $E(M_t^F | I_{m,t-})$ denotes the median value of the Money Market Services, Inc. weekly survey. As before, we assume that $M_t^F - E(M_t^F | I_{m,t-})$ can be represented by the ARCH model:

$$M_t^F - E(M_t^F | I_{m,t-}) = a_0 + \sum_{i=1}^s a_i [M_{t-i}^F - E(M_{t-i}^F | I_{m,t-i-})] + \sum_{i=1}^n c_i x_{it} + v_t h_t^{1/2} \quad (13)$$

where the coefficients and variables are defined as before, and $h_t = b_0 + \sum_{i=1}^p b_i [M_{t-i}^F - E(M_{t-i}^F | I_{m,t-i-})]^2$. Under the null hypothesis that $E(M_t^F | I_{m,t-})$ is an efficient estimator of M_t^F , $a_0 = a_1 = \dots = a_s = 0; b_1 = \dots = b_p = 0; \text{ and } c_1 = \dots = c_n = 0.$

The tests of the two null hypotheses are reported in Table IV. The null hypothesis that the Money Market Services, Inc. median survey responses represent efficient estimates of the true money supply is strongly rejected. However, the tests also lead us to reject the null hypothesis that the survey responses represent efficient estimates of the Fed's preliminary money supply estimates. In particular, for each subsample, the differences between the Fed's final money supply announcement and the survey median are serially correlated, correlated with the survey median itself, correlated with the social security week dummy, and conditionally heteroskedastic. When treated as a forecast of the preliminary Fed announcement, the forecast errors are

shown to be conditionally homoskedastic but serially correlated in the second subsample, correlated with the survey median in the second subsample, and correlated with the social security week dummy in both subsamples.

Thus, we conclude that the median of the Money Market Services, Inc. weekly survey cannot be taken as a proxy for rational market forecasts of either the initial or the final Fed money supply announcement. It follows that tests of asset price responses to anticipated and unanticipated money supply changes will be incorrect if they use the Money Market Services, Inc. median response as a measure of market forecasts.^{13/}

5. Estimation of Interest Rate Responses to Money Supply Announcements

We can now return to our original objective: to illustrate the impact of systematic Fed errors on the estimation of asset price responses to money supply announcements. To do this, we estimate equations (2) and (2'), using the information in Section 4 to guide our choice of proxies for rational market forecasts.

First, we take as our working hypothesis that equation (2') is the true model, implying that the market's response to the Fed's preliminary announcement is based on new information about the announced money supply and not the true money supply. For this case, we measure the market's forecast of the Fed announcement, $E(M_t^F | I_{m,t-})$, as the fitted value from the regressions reported under Hypothesis I in Appendix B. The results we obtain from estimating equation (2') are given in Table V. They are consistent with those reported in equation (1) except that the negative coefficients on the anticipated component of the announcement are now much smaller in magnitude and significance. The null hypothesis that the coefficients on the unanticipated component of the announcement are equal across the two subsamples is rejected at the five-percent significance level.^{14/}

The second set of estimates reported in Table V correspond to estimates of equation (2) which is valid when interest rate movements following the Fed's weekly money supply announcements represent responses to information about the true money supply. Prior to estimating equation (2) we require measures of $E(M_t | I_{m,t-})$, the market's pre-announcement estimate of M_t , and $E(M_t | I_{m,t-}, M_t^F)$, the market's post-announcement estimate of M_t . These measures were obtained as the fitted values of the regressions reported under Hypothesis II in Appendix B. The estimates of equation (2) are given in Table V. The results are quite different from those obtained under the hypothesis that the market responds only to what it perceives the Fed to believe about the money supply. The coefficients on anticipated money are still insignificant but now are positive in both subsamples.^{15/} The coefficients on unanticipated money are now substantially larger in magnitude, increasing by a factor of seven in the first subsample and by a factor of two in the second subsample. The null hypothesis of no structural change in the response of interest rates to unanticipated money supply changes is no longer rejected at standard levels.^{16/} Therefore, the finding of significant changes in interest rate responses to monetary shocks is not robust to changes in the assumptions made concerning whether the market is responding to new information on the Fed's preliminary money supply announcement or to new information on the true money supply.

The hypotheses: that the response of interest rates to the Fed's money supply announcement represents new information about the actual money supply; and that the response represents new information about the Fed's estimate of the money supply; are both supported by the regressions reported in Table V. Because these hypotheses are not nested, we cannot use classical procedures to distinguish between the two. However, further evaluation of the relative validity of the two hypotheses is possible using the nonnested test procedures introduced by Davidson and MacKinnon (1981).

Consider the nonlinear model

$$R_t = (1-a)\{\alpha'E(M_t^F|I_{m,t-}) + \beta'[M_t^F - E(M_t^F|I_{m,t-})] + \gamma'\} + a\tilde{R}_t + u_t' \quad (14)$$

where \tilde{R}_t is the the fitted value of R_t from our estimated equation (2) in Table V; u_t' is an unobservable white-noise disturbance process; and a , α' , β' , and γ' are unknown parameters. The hypothesis that the interest rate evolves according to (2) is rejected in favor of (2') if the parameter a in (14) is equal to zero. Similarly, model (2') is rejected in favor of model (2) if the parameter b in the following model is equal to zero:

$$R_t = (1-b)\{\alpha E(M_t|I_{m,t-}) + \beta[E(M_t|I_{m,t-}, M_t^F) - E(M_t|I_{m,t-})] + \gamma\} + b\tilde{R}_t' + u_t \quad (15)$$

where \tilde{R}_t' is the fitted value of R_t from the estimated equation (2') reported in Table V; u_t is an unobservable white-noise disturbance; and b , α , β , and γ are unknown constants.

We estimated the parameters in (14) and (15) by least-squares methods and then applied t-tests to determine the significance of a and b . The results indicate that neither hypothesis can be rejected in favor of the other. Specifically, the estimates of a and b are significantly different from zero at the five-percent level in each subsample.^{17/}

These results imply that interest rate responses to Fed preliminary money supply announcements cannot be satisfactorily explained by either hypothesis alone. Instead, the market appears to respond both to new information regarding the Fed's current perception of the money supply and to new information regarding the true money supply. The results in Table V show that the distinction between a market attempting to fore-

cast an announced estimate of a random variable and a market attempting to forecast the realization of the random variable can indeed mislead the econometrician regarding the sign and significance of market responses to money supply announcements. At minimum, these results indicate that caution must be exercised in deriving conclusions from announcement effect studies.

6. Summary

This paper has been concerned with the methodology used in "announcement effect studies" to test money neutrality propositions. It has been a standard practice to measure the relevant new information conveyed by these announcements as the difference between the Fed's preliminary money supply estimate and some measure of the market's pre-announcement estimate. We showed that the Fed's preliminary money supply estimates have been systematically wrong so that the standard approach is appropriate only if: (1) the market's response to the Fed's preliminary estimate is a response to the Fed estimate per se, rather than being a response to the information being conveyed about the actual money supply and (2) the empirical measure of the market's pre-announcement estimate is a measure of the market's forecast of the Fed's preliminary money supply estimate (rather than being a measure of the market's estimate of the actual money supply). We also analyzed the time series properties of the most commonly used measure of the market's pre-announcement estimate, the median value of Money Market Services, Inc.'s weekly survey, in order to check whether condition (2) can be maintained in studies that use this measure. We found that the survey median deviates systematically from both the Fed's preliminary and final estimates of the money supply. We then proceeded to derive better conditional estimators of the Fed's preliminary and final money supply estimates in order to evaluate the applicability of condition (1). We found that, if condition (1) is taken as a maintained hypothesis, then the coefficient on anticipated money remains negative but is no longer significant

and that strong evidence is obtained for structural change in the response to unanticipated changes in the money supply around October 1979. However, if condition (1) is violated so that the market attempts to extract and respond to information on true money supply behavior conditional on the Fed's preliminary announcement, then the coefficient on anticipated money becomes positive and insignificant and we no longer reject the hypothesis of no structural change in the response to unanticipated money changes.

The main conclusion to be derived from this analysis is that it is extremely difficult to derive structural interpretations of the coefficients in announcement effect studies without knowledge of the error structure of the preliminary announcement, and without knowledge of whether the market is interested in the announcement itself or in the final realization of the announced random variable. One market where such knowledge may be available is in federal crop forecasts where the market may be safely assumed to be interested in the true harvest size and not the government's preliminary perception of the harvest size. However, no such consensus exists on the nature of the market's interest in the Fed's money announcements. Indeed, our results suggest that the market is interested in both Fed preliminary perceptions and the final realized value of the change in the money supply.

Table I
Summary of Notation

- M_t^F : The preliminary announcement of the money stock made by the Federal Reserve at time t .
- M_t : The true value of the money stock corresponding to the Fed announcement at t .
- $I_{m,t-}$: The market's information set leading up to the Fed's announcement at t .
- u_t : $M_t - E(M_t | I_{m,t-}) \equiv$ market's preannouncement forecast error of the true value of the money supply.
- e_t : $M_t - M_t^F \equiv$ The Fed's forecast error in its preliminary announcement at time t .
- σ_u^2 : The market's preannouncement error variance
- σ_e^2 : The Fed's error variance
- σ_{ue} : The covariance between the Fed's errors and the market's preannouncement errors.
- x_t : A vector of exogenous variables whose values are known at the time of the Fed's announcement at t .
- M_{t-}^P : The median of the Money Market Services, Inc. survey of expectations concerning the Fed's announcement at t .

Table II
 Analysis of the Error Structure of Fed Weekly Money Supply Announcements

	Constant	e_{t-1}	e_{t-2}	e_{t-3}	SSW_t	SSW_{t-1}	WEEK1 _t	M_t^F	R^2
First Subsample 1978:1 - 1979:40	.445* (2.39)	-.382* (3.52)	-.378* (3.46)	-.199 (1.83)					.18
	.489* (7.46)	-.033 (.94)	-.037 (1.04)	-.009 (.27)	.821* (3.47)	-.024 (.11)	-.179 (1.17)	-.853* (27.4)	.93
Second Subsample 1979:41 - 1984:2	.039 (.34)	-.402* (6.31)	-.322* (4.90)	-.324 (5.10)					.21
	.332* (3.23)	-.208* (3.95)	-.179* (3.57)	-.168 (3.44)	-.08 (.19)	.075 (.21)	-.055 (.21)	-.455* (10.9)	.58

t-statistics in parentheses. The dependent variable is the Fed's forecast error on their money supply announcement at time t, $e_t = M_t^F - M_t$. (*) indicates significance at the .05 level.

Table III
Tests of the Conditional Homoskedasticity of Fed Revisions

	Constant	\bar{w}_{t-1}^2	\bar{w}_{t-2}^2	R^2	TR^2
First Subsample 1978:1 - 1979:40	.177 (2.91)	.442 (4.05)	-.227 (2.08)	.17	14.3
Second Subsample 1978:41 - 1984:2	1.19 (5.80)	.264 (3.88)	-.039 (.57)	.066	14.4

t-statistics in parentheses. Under the null hypothesis of conditional homoskedasticity, TR^2 is distributed chi-square with 2 degrees of freedom. The critical value at the 5 percent level of significance is 5.99. The dependent variable, \bar{w}_t^2 , is the square of the error from the regressions reported in Table II which include SSW_t , SSW_{t-1} , $WEEK1_t$, and M_t^F .

Table IV
 Analysis of the Error Structure of the Money Market Services, Inc. Forecast Errors Relative to the Fed's Preliminary and Final Announcements.

Dependent variable = $m_t = M_t - M_t^P$

	Constant	m_{t-1}	m_{t-2}	m_{t-3}	SSW _t	SSW _{t-1}	WEEK _t	M_t^P	R ²	TR ²
First Subsample 1978:1 - 1979:40	.445* (5.64)	.04 (.83)	-.027 (.56)	.115* (2.30)	1.09* (4.44)	-.127 (.61)	.135 (.84)	-.896* (17.7)	.82	14.9*
Second Subsample 1979:41 - 1984:2	.337* (2.45)	-.028 (.46)	.120* (1.96)	.065 (1.07)	1.58* (2.9)	-.26 (.58)	.256 (.76)	-.736* (7.12)	.23	8.5*

Dependent variable = $m_t^F = M_t^F - M_t^P$

	Constant	m_{t-1}^F	m_{t-2}^F	m_{t-3}^F	SSW _t	SSW _{t-1}	WEEK _t	M_t^P	R ²	TR ²
First Subsample 1978:1 - 1979:40	-.553* (2.56)	.085 (.64)	-.008 (.08)	.124 (1.18)	1.69* (2.40)	-.63 (.92)	.58 (1.24)	-.03 (.19)	.19	.88
Second Subsample 1979:41 - 1984:2	-.116 (.71)	-.044 (.63)	1.51* (2.36)	.049 (.78)	2.81* (4.44)	-.34 (.62)	1.16* (2.96)	-.339* (2.73)	.19	.73

t-statistics in parentheses. The dependent variable in the first set of regressions is the difference between the Money Market Services, Inc. median forecast of the money supply change and the Fed's and the final revised money supply estimate. The dependent variable in the second set of regressions is the difference between the Money Market Services, Inc. median forecast of the money supply change and the Fed's preliminary announced money supply change. TR² refers to the corresponding ARCH test of heteroskedastic errors with a critical value of 5.99 at the .05 level of significance. (*) indicates significance at the .05 level.

Table V

The Response of Interest Rates to Perceived Weekly Monetary Shocks

Hypothesis: Equation (2') is the correct model, implying that the market is interested in the Fed's preliminary announcement per se.

$$R_t = \alpha' E(M_t^F | I_{m,t-}) + \beta' \{M_t^F - E(M_t^F | I_{m,t-})\} + \epsilon_t'$$

	α'	B'	Constant	R ²
First Subsample 1978:1 - 1979:40	-.006 (.74)	.023* (3.05)	.032* (2.89)	.10
Second Subsample 1979:41 - 1984:2	-.003 (.26)	.075* (6.88)	.047* (2.16)	.18

Hypothesis: Equation (2) is the correct model, implying that the market attempts to extract information on the true money change, conditional on the Fed's announcement and other available information.

$$R_t = \alpha E(M_t | I_{m,t-}) + \beta \{E(M_t | I_{m,t-}, M_t^F) - E(M_t | I_{m,t-})\} + \epsilon_t$$

	α	B	Constant	R ²
First Subsample 1978:1 - 1979:40	.016 (.49)	.165* (3.04)	.022 (1.07)	.10
Second Subsample 1979:41 - 1984:2	.021 (.93)	.146* (6.89)	.032 (1.28)	.18

t-statistics in parentheses. The dependent variable is the change in the 90 day T-bill rate from the close before the Fed's weekly money announcement to the close after the Fed's weekly money announcement. (*) indicates significance at the .05 level.

Notes

^{1/} These include Bolongia, Hafer and Sheehan (1986); Clark, Joines and Phillips (1985); Cornell (1983, 1985); Deaves, Melino and Pesando (1987); Falk and Orazem (1985); Roley and Walsh (1984); Urich (1982); and Urich and Wachtel (1981).

^{2/} The weekly announcements of changes in the narrowly defined money stock are reported in the Federal Reserve's H.6 releases. The announcement on day t refers to the change in the money stock over a one-week period ending on the Wednesday of the previous calendar week. Urich and Wachtel (1981) and Roley have good summaries of these data.

^{3/} In the regressions reported in equation (1), we proxy M_{t-}^P by the commonly used median of the Money Market Services, Inc. survey of market predictions of the change in the money supply to be announced on day t . Researchers have also used ARIMA models (Urich and Wachtel) and the fitted values of regressions of Fed announcements on the Money Market Services, Inc. median and other information available to the market (Bolongia et al, Clark et al, Deaves et al, and Roley).

^{4/} For example, over the sample period following the Fed's October 10, 1979 policy announcement, Roley, Falk and Orazem, Deaves et al, and Urich and Wachtel find a significant relationship between anticipated money supply changes and asset price changes. Cornell (1985) does not, although the coefficient has a marginal significance level of about .135. Urich and Wachtel (1981) find a significant relationship between these measures prior to October 10, 1979, but most studies using the Money Market Services, Inc. data show marginal significance levels between .2 and .1. Marginal significance levels drop in both periods when other information is added to the survey median, but coefficients significant at the .1 level are still often

obtained in the period after October 10, 1979 (see Clark et al, Deaves et al, and Roley).

^{5/}Mankiw et al implicitly assume σ_{ue} to equal zero.

^{6/}Our examination of the data indicates that, over the sample period 1978:1 - 1984:2, the sample value of σ_{ue} was negative but sufficiently close to zero so that the Mankiw et al conclusion is not reversed when $\sigma_{ue} \neq 0$ is allowed.

^{7/}In reality, e_{t-1} is not observed directly by the market (or the Fed) until some time after week t , if ever. Therefore, e_{t-1} cannot be in the information set that market agents use in responding to the Fed's announcement in week t . The market's signal extraction problem in the case of serially correlated Fed errors would be more correctly viewed as one in which the market tries to decompose $M_t^F - E(M_t | I_{m,t-})$ into u_t and e_t conditional upon that difference and new information received during week t that can be used to draw inferences about e_{t-1}, e_{t-2}, \dots . For example, at the time that the Fed announces its initial estimate of M_t it also announces revisions to its previous weeks' estimates. This complication only serves to strengthen the main point of this section.

^{8/}The problem can be stated formally as finding the projection of $M_t - E(M_t | I_{m,t-})$ on $M_t^F - E(M_t | I_{m,t-})$ and e_{t-1} given the first and second moments of the joint distribution of that three-dimensional random vector. See Sargent (1979, Chapter X) for a discussion of the solution to this type of problem.

^{9/}The p -th order autoregressive conditional heteroskedasticity (ARCH) model was introduced by Engle (1982) as a tractable way to deal with the possibility of a nonconstant one-period ahead forecast variance.

^{10/}This conclusion follows directly from the deduction of equation (3) noting that, under the ARCH assumption, σ_e^2 will be time dependent. Notice that the existence

of serial correlation and/or conditional heteroskedasticity in Fed errors could cause the frequently reported instability of estimated coefficients on unanticipated money changes over different sample periods, even if the true structural response of interest rates to monetary shocks is unchanged.

^{11/}Our measure of the true weekly change in the money supply is the final revised figure available for the relevant weekly change in the money stock. These data are taken from the Banking Section of the Division of Research Statistics from 1978 through the end of 1982. Starting in 1983, the Fed stopped reporting revised figures for weeks ending on Wednesday, and instead reported money stock figures for weeks ending on Monday. Any attempt to adjust this data to week-ending-in-Wednesday numbers would risk creating systematic errors. Therefore, starting in 1983, we used the final reported week-ending-on-Wednesday figures from the Fed's H.6 release as our measure of the true money supply.

^{2/}Other studies of the rationality of the Money Market Services, Inc. data include Grossman, Hafer, Urich and Wachtel (1984) and Deaves et al.

^{13/}Deaves et al show that in principle, using a biased measure of anticipated money can generate downward bias in the coefficient on anticipated money. However, their empirical work indicates that at most, the bias in the Money Market Services, Inc. median forecasts can only explain part of the puzzle. Furthermore, our analysis shows that the incorporation of serial correlation in market errors complicates the derivation of the direction of bias. The problem becomes even more complex once the problem of systematic Fed errors is added to the model and quickly degenerates to one where no unambiguous direction of bias can be established.

^{14/}The F-statistic was 5.39, whereas the critical value at the .05 level was 3.88.

^{15/}The F-statistic was .018 with a marginal significance level of .89.

^{16/}Some authors have closed the second sample at October 1982 when the Federal Reserve switched its operating instrument from the federal funds rate to borrowed reserves. This period has proven most troublesome in terms of finding significant coefficients on anticipated money. When we truncate the second sample at week 39 in 1982, our results are:

Sample 1979:41 - 1982:39

$$(2') \quad \alpha' = -.006; \beta' = .096^*; \text{constant} = .067; R^2 = .19$$

(.35) (6.14) (2.22)

$$(2) \quad \alpha = .034; \beta = .184^*; \text{constant} = .044; R^2 = .20$$

(1.01) (6.08) (1.27)

The null hypothesis of no change in the response to unanticipated changes in the money supply is still strongly rejected using equation (2') and not rejected (marginal significance level of .91) using equation (2).

^{17/}The t-statistics corresponding to the estimate of a in equation (14) were 3.4 in the first sample and 3.3 in the second sample. The t-statistics corresponding to the estimates of b in equation (15) were 2.0 in the first sample and 2.1 in the second sample.

Appendix A

In this Appendix we formalize the argument that using the difference between the Fed's preliminary money supply estimate and the market's preannouncement estimate as a measure of the unanticipated change in the money supply will bias conventional tests of money neutrality against that hypothesis when the Fed's estimation errors are serially correlated and/or conditionally heteroskedastic.

Define R_t , M_t^F and M_t as in the text. For notational simplicity, define the market's preannouncement expectation of the true money stock as $M_{t-}^E = E(M_t | I_{m,t-})$. We can decompose the difference between the Fed's preliminary announcement and the market's preannouncement expectations, $M_t^F - M_{t-}^E$, as

$$M_t^F - M_{t-}^E = \tilde{u}_t + v_t \quad (\text{A.1})$$

where \tilde{u}_t , defined by equation (3), is the market's optimal estimate of the unanticipated change in the money supply conditional on the Fed's preliminary announcement and v_t is the measurement error resulting from using $M_t^F - M_{t-}^E$ rather than \tilde{u}_t as the measure of unanticipated money. We assume that \tilde{u}_t and v_t are uncorrelated. Combining (A.1), our definition of M_{t-}^E , and equation (2) in the text, we obtain

$$R_t = \alpha M_{t-}^E + \beta (M_t^F - M_{t-}^E) + w_t \quad (\text{A.2})$$

where $w_t = \epsilon_t - \beta v_t$. Since $\text{cov}(M_t^F - M_{t-}^E, v_t) = \sigma_v^2 = E(v_t^2)$, it is clear that a regression of R_t on M_{t-}^E and $M_t^F - M_{t-}^E$ will generate an inconsistent estimate of β . Under our previous assumption that $E(M_{t-}^E \epsilon_t) = 0$, and if $E(M_{t-}^E \tilde{u}_t) = 0$, then

it is straightforward to show that

$$\text{plim } (\tilde{\alpha} - \alpha) \propto -\beta \text{ cov}(M_{t-}^E, M_t^F - M_{t-}^E) \quad (\text{A.3})$$

where $\tilde{\alpha}$ is the regression coefficient on M_{t-}^E in (A.2)

To interpret (A.3) first notice, from (A.1), that since $M_t^F - M_{t-}^E = \tilde{u}_t + v_t$, $\text{cov}(M_{t-}^E, M_t^F - M_{t-}^E) = 0$ if and only if M_{t-}^E and v_t are uncorrelated. According to (A.1), v_t can be interpreted as the market's post-announcement estimate of the Fed's estimation error. That is, v_t can be viewed as the market's expectation of the Fed's subsequent revision given the market's current information set. If the Fed's revisions follow a white noise process, then M_{t-}^E and v_t will be uncorrelated. On the other hand, if the Fed's revisions are serially correlated and/or conditionally heteroskedastic, then M_{t-}^E and v_t will be correlated. Consequently, regressions of R_t on M_{t-}^E and $M_t^F - M_{t-}^E$ will generate a consistent estimate of α only if the Fed's revisions are serially uncorrelated and conditionally homoskedastic.

Since, as we argued in the text, the Fed's revisions appears to have been serially correlated and conditionally heteroskedastic, regressions of R_t on M_{t-}^F and $M_t^F - M_{t-}^E$, would not be expected to generate a value of α equal to zero even if the neutrality hypothesis is correct. According to (A.3), the direction of the bias in this case would depend upon whether β and $\text{cov}(M_{t-}^E, M_t^F - M_{t-}^E)$ are of like or opposite signs. The sample correlation statistic pertaining to M_{t-}^E and $M_t^F - M_{t-}^E$ was small but positive. Estimates of β in our study are also positive.

It would follow that the sign of $\text{plim } (\tilde{\alpha} - \alpha)$ would be negative. This could explain the common finding of $\tilde{\alpha} < 0$ (and often significantly less than zero) even though the true value of α may be equal to zero.

Appendix B

Equations Used to Derive Proxies for Anticipated and Unanticipated Money in Equations (2) and (2')

Hypothesis I: The Market attempts to forecast only the preliminary money announcement.

Dependent Variable: M_t^F	Constant	\hat{e}_{t-1}	\hat{e}_{t-2}	\hat{e}_{t-3}	SSW _t	SSW _{t-1}	WEEK1 _t	M_{t-}^F	R^2
First Subsample	.535* (2.51)	.086 (.65)	-.011 (.10)	.132 (1.27)	1.69* (2.41)	-.633 (.93)	-.568 (1.23)	.964* (5.58)	.51
Second Subsample	-.116 (.71)	.044 (.63)	.151 (2.40)	.049 (.78)	2.81* (4.44)	-.34 (.62)	1.16* (2.96)	.661* (5.32)	.50

Hypothesis II: The Market attempts to forecast the actual money supply

Dependent Variable: M_t	Constant	\hat{e}_{t-1}	\hat{e}_{t-2}	\hat{e}_{t-3}	SSW _t	SSW _{t-1}	WEEK1 _t	M_{t-}^F	M_t^F	R^2
First Subsample										
Before announcement	.419* (5.56)	.061 (1.29)	.01 (.27)	.039 (1.06)	1.04 (4.18)	-.144 (.60)	-.10 (.61)	.149 (2.44)	-	.30
After announcement	.494* (6.85)	.049 (1.12)	.012 (.34)	.02 (.59)	.803* (3.38)	.055 (.25)	-.18 (1.18)	.013 (.20)	.141* (3.88)	.41
Second Subsample										
Before announcement	.226 (1.64)	.077 (1.29)	.178* (3.32)	.085 (1.60)	1.66 (3.12)	-.065 (.14)	3.49 (1.06)	.327* (3.13)	-	.24
After announcement	.285* (2.61)	.099* (2.12)	.101* (2.34)	.06 (1.41)	.216 (.49)	.11 (.92)	-.246 (.92)	-.013 (.15)	.515* (11.3)	.53

t-statistics in parentheses. (*) indicated significance at the .05 level. The first subsample covers the period 1978:1 - 1979:40 and the second covers the period 1979:41 - 1984:2. $\hat{e}_t = M_t^F - M_{t-}^F$. M_{t-}^F is the median of the Money Market Services, Inc. Survey.

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