No. 8704

RANDOM COEFFICIENTS MODELS OF THE INFLATIONARY CONSEQUENCES OF DISCRETIONARY CENTRAL BANK BEHAVIOR

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June 1987

* The views expressed in this article are solely those of the author, and should not be attributed to the Federal Reserve Bank of Dallas or the Federal Reserve System.

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There exists fairly widespread agreement that, especially over a long-run time period, inflation is always and everywhere a monetary phenomenon. This proposition, however, leaves unanswered the question why a central bank would allow, or possibly persue, an inflationary monetary policy. To answer this question, a central bank objective function is derived which recognizes the existence of both benefits and costs associated with inflation. The empirical results indicate that while Federal Reserve behavior is random in nature, benefits, in the form of seigniorage, and costs, composed of deviations of unemployment from the policymaker's preferred rate, are significant factors in explaining Federal Reserve behavior.

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1. INTRODUCTION

In every major industrialized country of the world, government possesses a virtual monopoly franchise in the supply of money. Such control, as Hayek (1976) points out, has resulted in a "history of inflation, and usually of inflations engineered by government and for the gain of governments." This gain accrues to government through several benefits associated with continuous increases in the price level. First, government, in its role as a supplier of money, collects seigniorage. Second, unanticipated inflation results in certain redistribution effects, particularly as regards debtors versus creditors. Since the federal government is a huge debtor, it stands to gain from such a redistribution. Third, unexpected increases in the price level allow government to exploit a short-term Phillips curve resulting in a reduction in unemployment.

An analysis of inflation, however, must also consider the costs involved to the elected government. Inflation, whether anticipated or unanticipated, imposes costs upon the economy for which the elected government may be held accountable. Anticipated inflation can be thought of as imposing "menu" costs or direct costs associated with changing prices. Further, unanticipated inflation results in an ex-post capital levy on the holders of nominally-denominated instruments. Curiously, political costs associated with inflation have not received much attention.

Recognizing the presence of benefits and costs associated with inflation, the operative question becomes does the Federal Reserve, in its conduct of monetary policy, respond to these benefits and costs and if so, how? To answer this question, we develop a model of central bank behavior within which the inflation rate becomes an endogenous variable. Unlike previously-estimated "reaction functions", the model includes as arguments: (1) seigniorage; (2) revenue from reducing federal debt outstanding; (3) deviations of unemployment from the policymaker's preferred rate; and (4) consideration of the costs of inflation. We then estimate this model over the post-Accord period (1951-1983), using two-stage least squares under a random-coefficients specification. Such a specification allows us to test for the stablity of Fed policymaking. That is, are the benefit and cost parameters confronting the policymaker stable over time, or do they shift and, if so, when? These questions ultimately confront the "independent" nature of the central bank. If policy-making is unstable, then the central bank behaves rather erratically, attempting to achieve either lower or higher rates of inflation at different times in response to the varying costs and benefits which it might confront. Such behavior casts doubt upon the hypothesis of a "traditional" view of montary policy of an independent central bank conducting policy free from outside pressures. The empirical results indicate that Federal Reserve behavior is random in nature. Further, seigniorage and unemployment deviations are significant factors in explaining observed inflation rates. The revenue variables are found to vary systematically over time, while unemployment deviations are not affected by election-year considerations. We proceed as follows. Section 2 presents a brief review of the arguments of the objective function. Given these objectives, a model of central-bank behavior is derived in section 3. Section 4 presents a description of the estimation techniques employed and examines the empirical findings, following which section 5 sets forth conclusions and suggestions for future research.

2. OBJECTIVES OF THE POLICYMAKER

It is assumed that the Fed values, or derives certain benefits from, both seigniorage and reducing the value of federal debt outstanding. These revenue sources lessen the need for government to resort to more conventional, overt methods of taxation to finance its spending. [1] It is also assumed that the central bank considers more "traditional" goals, in the form of unemployment and the costs associated with inflation.

2.1. Revenue

Friedman (1953) points out that inflation amounts to an implicit tax on the holdings of cash balances. Classic analyses of inflationary finance and the associated welfare costs have a common basic structure [Bailey (1956), Cagan (1956)] These studies make use of the Cagan (1956) money demand function in a situation in which all adjustments to inflation are assumed to have been completed. Revenue, in real terms, from the inflation tax is composed of two parts: (1) the base of the tax, which is the level of real cash balances demanded, and (2) the rate of the tax which is the rate of depreciation in the real value of money.

Inflation, especially when unanticipated, favors some groups over others. Inflation reduces the repayment burden of debtors and may encourage various types of investments (Kane 1982). Since government is a large debtor, it stands to gain from this redistribution favoring debtors at the expense of creditors. As Barro (1983) and Barro and Gordon (1983a) point out, this redistribution effect is analogous to that associated with seigniorage. Unanticipated inflation, in effect, reduces the real resources embodied in the government's commitment to repay its principal and interest.

2.2. Performance Variables

Ample evidence exists that the Federal Reserve, in its conduct of policy, is guided by macroeconomic goal variables. Federal Reserve "reaction functions" are estimated in an attempt to capture the effect on monetary policy of departures of certain macroeconomic targets from their "desired" levels (Wood, 1968).

Reaction functions estimated over the years differ in what is assumed to be the policy variable (or dependent variable). These functions also differ in the definition and measure of the actual targets from their desired levels. Regardless of the policy instrument considered, these studies find a strong, consistent response by the monetary authorities to departures of unemployment from the target rate. Departures of other goal variables from their targets, such as inflation, balance-of-payments surplus and real GNP exhibited a less systematic response by the Fed in the models estimated (Barth, Sickles and Wiest, 1982).

2.3. Costs of Inflation

As Barro (1983) points out, inflation imposes direct costs upon the economy. Economists often have trouble, however, specifying the exact nature of these costs. Fischer and Modigliani (1978) provide a descriptive analysis of the costs of anticipated and unanticipated inflation. According to Alt and Chrystal (1983), unanticipated inflation imposes political costs upon incumbent administrations as regards their future electoral outcomes.

Inflation also inflicts welfare costs upon the economy as increases in the rate of inflation result in reductions in the amount of real money balances demanded. Fischer (1981) provides rough estimates of the welfare costs of open inflation in the presence of interest rate controls on various deposits. In addition, estimates of the welfare effects of anticipated inflation arising from its impact on capital are derived amounting to as much as 2-3 percent of GNP. Fischer concludes that "While the evidence and numbers cited...are far from definitive, they support the notion that the welfare costs of high inflation, even if the inflation is expected, are large in the current United States economy" (Fischer, 1981, p. 36).

3. A MODEL OF CENTRAL BANK BEHAVIOR

3.1. Definitions

We assume the Fed considers both the benefits it derives and the costs incurred in conducting monetary policy. The central bank controls its instruments to achieve its policy target (ostensibly, monetary growth) in an attempt to obtain the goal of maximizing its objective function. The objective function contains as arguments: seigniorage, redistribution effects (here, those associated with reducing the value of government debt), deviations of unemployment from a preferred rate or goal and consideration of the direct costs associated with inflation.

The model makes use of the following definitions:

M_t = nominal money stock in period t

G_t = nominal stock of net federal debt

P_t = the general price level

$\Pi_t = \log(P_t/P_{t-1})$

$\mu_t = \log(M_t/M_{t-1})$

Π^e_{t+1} = expected inflation from t to t+1

R_{mt} = seigniorage in period t

R_{gt} = revenue from depreciating federal debt outstanding

y_t = level of real income

where μ_t is the Fed's target variable, G_t, Π^e_{t+1} and y_t are exogenous, Π_t, P_t and M_t are endogenous variables and R_{mt} and R_{gt} are arguments of the Fed's objective function.

3.2. Revenue

3.2.1. Seigniorage

Seigniorage in period t is defined as:

$$R_{mt} = (M_t - M_{t-1})/P_t = M_t/P_t - (M_{t-1}/P_{t-1})(P_{t-1}/P_t) \qquad (1)$$

It is assumed that the demand for real money balances depends inversely on expected inflation, as in Cagan (1956), and positively on real income:

$$M_t/P_t = \exp(ay_t - b\Pi^e_{t+1}). \qquad (2)$$

Under a fractional-reserve banking system the central bank receives as seigniorage only a portion of the actual money supply. The Fed supplies the (real) monetary base and the actual money supply is some multiple, m_t, of the real base. Therefore:

$$R_{mt} = (1/m_t)[\exp(ay_t - b\Pi^e_{t+1}) - \exp(ay_{t-1} - b\Pi^e_t - \Pi_t)]. \qquad (3)$$

If the money supply multiplier exceeds unity, the Fed shares a portion of the revenue with the banking system. A reduction in the multiplier results in an increase in that portion of inflationary finance accruing to the central bank.[2]

3.2.2. Redistribution Effects

Redistribution effects associated with reducing the value of nominal federal debt outstanding generate revenue to government in a manner analogous to seigniorage and are expressed as:

$$R_{gt}=[G_{t-1}/P_{t-1}-G_{t-1}/P_t] \tag{4}$$

Holdings of government debt are assumed to depend upon the difference between the nominal interest paid on such debt, i_t, and expected inflation:

$$G_t/P_t=\exp[g(i_t-\Pi^e_{t+1})]. \tag{5}$$

Then:

$$R_{gt}=\exp[g(i_{t-1}-\Pi^e_t)]-\exp[g(i_{t-1}-\Pi^e_t)-\Pi_t]. \tag{6}$$

According to Bach and Stephenson (1974), households have consistently been large net creditors, while government was the main offsetting debtor. "Thus, since World War II inflation has apparently caused a massive transfer of wealth from households, as the major net creditor, to the federal government, as the major net debtor."[3] (Bach and Stephenson, 1974, p. 4)

The Fed may be motivated to provide seigniorage and to depreciate federal debt due to the gains which accrue to government. If the Fed is a quasi-independent agency, it may derive certain benefits from following such a policy. These benefits are assumed to rise monotonically with these two sources of government revenue:

$$\beta_t=\beta_{1t}R_{mt}+\beta_{2t}R_{gt}, \tag{7}$$

where β_{1t} and β_{2t} represent the Fed's "benefit parameters."

3.2.3. Costs

The Federal Reserve is hypothesized to be concerned with the consequences of its actions, particularly as regards unemployment and the costs associated with inflation. Given the following Phillips-curve relationship:

$$U_t=U_t^n-z(\Pi_t-\Pi_t^e), \tag{8}$$

where U_t is the current unemployment rate and U_t^n is the "natural" rate of unemployment, inflation surprises result in reductions in the unemployment rate[4].

As in Barro and Gordon (1983b), it is assumed the natural rate can shift over time due to autonomous real shocks, ε. Further, these shocks generate a persisting influence on the unemployment rate:

$$U_t^n=\lambda U_{t-1}^n+(1-\lambda)U^n+\varepsilon_t, \tag{9}$$

where $0\leq\lambda\leq1$ and U^n is the long-run mean of U_t^n. Therefore:

$$U_t=\lambda U_{t-1}^n+(1-\lambda)U^n+\varepsilon_t-z(\Pi_t-\Pi_t^e). \tag{10}$$

The Fed is assumed to view deviations, in either direction, of unemployment from some goal or desired level as generating costs. Unemployment rates below that sought by the Fed, to the extent they result in expectations of accelerating inflation, are considered costly as it then becomes more difficult to extract revenue or exploit a Phillips curve in the future. Increases in the unemployment rate above the optimum are also assumed to generate costs due to obvious factors such as forgone output and human suffering. In effect, a simple quadratic "loss function" is employed which implies that these costs increase at an increasing rate with departures of unemployment from its preferred level. That is, the loss function appears as:

$$(U_t - kU_t^n)^2. \tag{11}$$

That unemployment rate deemed optimal by the policymaker is assumed to be proportional to the natural rate. If k is less than unity, the policymaker considers the natural rate "too high" relative to an efficiency criteria. This reflects distortions such as unemployment compensation, income taxation and transfer payments which may result in privately chosen quantities of employment being too low (Barro and Gordon, 1983b). If k equals unity, then the policymaker views the natural rate as optimal.

Therefore, the costs which the Fed incurrs in its conduct of policy are assumed to include the following:

$$C_t = (\beta_{3t}/2)(U_t - kU_t^n)^2 + (\beta_{4t}/2)(\Pi_t)^2, \tag{12}$$

where $\beta_{3t}/2$ and $\beta_{4t}/2$ are the Fed's "cost parameters."

The last term in Equation 12 assumes that departures of inflation from zero also generate costs as described in Bailey (1956) and Fischer and Modigliani (1978) which the Fed considers in its policymaking.

3.2.4. Federal Reserve Objective Function

Combining these benefits and costs which the Fed confronts in its conduct of policy, we derive the following objective function for the Federal Reserve:

$$Z_t = [\beta_{1t}R_{mt} + \beta_{2t}R_{gt} - (\beta_{3t}/2)(U_t - kU_t^n)^2 - (\beta_{4t}/2)(\Pi_t)^2]. \tag{13}$$

The Fed chooses its policy target, the monetary growth rate, to achieve its ultimate goal of maximizing the expected value of Equation 13. Since the Federal Reserve system has never bound itself to any monetary rule, we proceed under the assumption that the Fed is a discretionary policymaker. This analysis of discretionary policy follows the general line of argument presented in Barro (1983) and Barro and Gordon (1983a and b). Discretion implies no possibilities for prior constraints or commitments that would restrict subsequent choices for money growth rates. Discretionary policy is viewed as a noncooperative game between the policymaker and private agents in which the former must take as given the expectations of the latter. With expectations given, and future values of money growth rates unrestricted, there are no effects in this model of the choice of current money growth rates on future values of the objective function. Therefore, the optimizing policymaker chooses μ_t to maximize the contemporaneous expected objective function.

The assumption that the policymaker treats future expectations as given follows from the discretionary nature of monetary policy. Under discretion, the central bank's choice of μ_t in no way constrains its choice of μ_{t+1}. That is, μ_t supplies no additional information about the objectives or technology of the policymaker. Expectations of future inflation are a function of expectations of future monetary growth rates. In determining expectations, agents consider the policymaker's optimization problem which determines the inflation rate from Equation 13. The determination of expectations this period is divorced from the particular realization of inflation. That is, at the start of period t, agents form expectations by forecasting the policymaker's best action contingent on the information set. In addition, Π^e_{t+1} is not conditioned on the current inflation rate. Therefore, the policymaker faces a problem in which expectations are exogenous and, in forming their expectations, agents understand the policymaker is in this position (Barro, 1983, Barro and Gordon, 1983a and b).

In effect, expectations of inflation are assumed given to the Fed only if the choice of current money growth has no implications for expectations of future money growth rates (and thus no implications for expectations of future inflation), which is the essence of discretionary policymaking. In particular, this concentration only on the present does not derive from myopia on the part of the policymaker. "Rather, with given expectations, the policymaker has no way at date t to influence (future values of the objective function)" (Barro, 1983).[5,6]

Therefore, a discretionary policymaker chooses the monetary growth rate, μ_t, to maximize the current expected value of Equation 13, given expectations. Substituting for R_{mt} from Equation 3, R_{gt} from Equation 6 and U_t from Equation 10, the first-order condition is as follows:

$$\beta_{1t}(1/m_t)[\exp(ay_{t-1}-b\Pi_t^e-\Pi_t)]+\beta_{2t}[\exp(g[i_{t-1}-\Pi_t^e]-\Pi_t)] \quad (14)$$
$$+z\beta_{3t}[(1-k)(\lambda U_{t-1}^n+(1-\lambda)U^n)-z(\Pi_t-\Pi_t^e)]$$
$$-\beta_{4t}\Pi_t=0.$$

Equation 14 states that the inflation rate is chosen such that the marginal benefits of an extra unit of inflation just equal the marginal costs.[7] This calculation uses three conditions: $(d\Pi_t/d\mu_t)|\Pi_t^e,\Pi_{t+1}^e)=1$ from Equation 2, $(d\Pi_{t+1}^e/d\mu_t)=0$, and $E(\varepsilon_t)=0$.

Solving for the rate of inflation, we assume that:

$$E(U_t-kU_t^n)=(U_t-kU_t^n), \quad (15)$$

which implies that the Fed's forecast of the gap between unemployment and the target unemployment rate equals the actual gap. Such an assumption implies perfect foresight on the part of the policymaker as in DeWald and Johnson (1963), Friedlander (1973) and Havrilesky (1967).[8] This leads to the following "reaction function":

$$\Pi_t=(\beta_{1t}/\beta_{4t})[(1/m_t)(M_{t-1}/P_t)]+(\beta_{2t}/\beta_{4t})(G_{t-1}/P_t) \qquad (16)$$
$$+z[(\beta_{3t}/\beta_{4t})(U_t-kU_t^n)].$$

Interpreting Equation 16 as a reaction function employs the pivotal assumption that the Fed is capable of controlling the inflation rate. Further, the signs attached to the coefficients of the reaction function reflect the "utility weights" of Equation 13 and the assumption that, in the central bank's view, increases in the inflation rate increase revenue and reduce deviations of unemployment above its target. If unemployment is below its desired level, decreases in the inflation rate occur.

Equation 16 represents that (equilibrium) rate of inflation which results when the policymaker maximizes the expected value of his objective function taking as given the formation of expectations. Further, Equation 16 represents a rational-expectations equilibrium in the sense that the inflation rate is sufficiently high such that the marginal benefits of a hypothetical unit of surprise inflation just balance the marginal costs involved. That is, <u>systematic</u> surprises do not occur in equilibrium.

Several implications follow from Equation 16. With an increase in the benefit parameters, β_{1t} and β_{2t}, confronting the Fed, the rate of inflation should increase. These benefit parameters might be especially high during wartime, in periods where government expenditures have risen rapidly or in periods when alternate sources of revenue result in greater welfare losses at the margin (Barro, 1983). If the actual costs of inflation (as preceived by the Fed), β_{4t}, increase, then inflation should decrease. If the gap between unemployment and its desired rate increases, the extent of the response of inflation depends on the relative cost parameter β_{3t}/β_{4t}.

The rate of inflation should increase if the costs of this gap, β_{3t}, increase more than does the cost of actual inflation, β_{4t}.

Therefore, estimating Equation 16 under a random-coefficients specification allows us to test for the presence of movements in these parameters. If the parameters prove time-varying, taking account of this improves the estimates derived. Further, any information as to the timing or magnitude of shifts in these parameters confronting the Fed provides evidence of the degree of Federal Reserve independence. For example, do the costs, as perceived by the Fed, resulting from an excess of unemployment over its target increase in an election year and then decrease after an election? Or, do these costs remain the same regardless of where in the political cycle the Fed finds itself?

This interpretation of instability of the reaction function is consistent with that of Froyen (1974), Potts and Luckett (1978), Abrams, Froyen and Waud (1980), Hamburger and Zwick (1981) and Beck (1982). These studies attempt to assess the degree of outside influences operating on the Fed by examining the stability of central-bank behavior.

If a "traditional" model of central-bank behavior guides Federal Reserve policymaking, the Fed is viewed as an autonomous institution "inhabited by individuals who are motivated to manage the economy according to their perception of what is best" (Toma 1982, p. 1981). We may thus "...treat the Federal Reserve System as a sovereign decisionmaker whose managers seek singlemindedly to promote the public interest at every turn" (Kane 1980, p. 199).

Therefore, in the traditional view of monetary policymaking, revenue derived from implicit taxation such as seigniorage or depreciating federal debt is insignificant as an explanation of observed inflation rates. Further, such a policymaker conducts policy in a stable, consistent manner. That is, the basic goals of policy do not fluctuate.

Tests of the hypothesis that a traditional model holds are conducted by deriving estimates of Equation 16. If this hypothesis is correct, the parameters associated with the revenue terms are statistically insignificant. That is, policy is not conducted with the goal of extracting revenue from the private sector. The "cost" parameters, β_{3t} and β_{4t} are assumed significant in the traditional model of policymaking. The Fed would be concerned with deviations of unemployment from its perferred rate and with the direct costs associated with inflation. However, the cost parameters confronting the Fed are fixed under the traditional model. Allowing them to vary ought not to improve upon the estimates. Therefore, if the revenue parameters of the reaction function are statistically significant, and/or if allowing the parameters to vary improves the estimates, central bank independence is questioned. The estimation technique and empirical results are in the next section.

4. EMPIRICAL RESULTS

4.1. Two-Stage Least Squares

In an effort to determine whether the hypothesized benefits and costs are significant determinants of Federal Reserve behavior, we derive two-stage least squares, or instrumental variables, estimates of the parameters of the following:

$$ANNUAL=\alpha_0+\alpha_1*SEIGN+\alpha_2*RLDEBT+\alpha_3(UNEMP-NATUN)+\varepsilon_t, \tag{17}$$

where ANNUAL=Annual rate of inflation per quarter

$SEIGN=(1/m_t)*(M_{t-1}/P_t)$

$RLDEBT=(G_{t-1}/P_t)$

$UNEMP=z*U_t$

$NATUN=z*k*U_t^n$

α_0=intercept

$\alpha_1=\beta_{1t}/\beta_{4t}$

$\alpha_2=\beta_{2t}/\beta_{4t}$

$\alpha_3=\beta_{3t}/\beta_{4t}$

ε_t=random disturbance

Quarterly data are used for the time period 1951-1983 [9]. Estimates of z, the Phillips curve slope parameter are obtained from Barro and Rush (1981). Their study examines the effect of unanticipated money growth on the unemployment rate for both annual and quarterly data. It is estimated that a one percentage-point increase in unanticipated money growth reduces the unemployment rate by a proportion of 3.5 to 5.8 percent. If we assume that unanticipated money growth results in unanticipated inflation, the Barro and Rush estimates may be employed for the z parameter in Equation 16.

Equation 17 is estimated for various values of z and k. The parameter estimates are not sensitive to variations in k or to values of z within the Barro-Rush range.[10] Therefore, we report results for z=4.0 (which also accords with Rush's (1986, p. 271) maximum-likelihood estimates) and k=1.0. The Breusch (1978) and Godfrey (1978) test statistic indicates the presence of serial correlation in the error term. [11] Therefore, the Cochran-Orcutt process is used to obtain estimates of the first-order autocorrelation coefficient along with the Prais-Winsten modification to account for the first observation. The estimated value of ρ, the autocorrelation coefficient is 0.383. [12]

In addition, as an indicator of the degree of Fed independence, we desire to determine the extent to which policymaking is stable. That is, are the parameters of Equation 17 subject to structural changes or random variation? If so, the estimates are inefficient and are improved by introducing a randon-coefficients specification. Therefore, a test for the presence of variation in the parameters of Equation 17 is appropriate. [13]

4.2. Random-Coefficients Specification

Let us suppose Equation 17 is respecified as follows:

$$\begin{aligned} \text{ANNUAL} = &(\alpha_0+\nu_{0t})+(\alpha_1+\nu_{1t})*\text{SEIGN} \\ &+(\alpha_2+\nu_{2t})*\text{RLDEBT}+(\alpha_3+\nu_{3t})*(\text{UNEMP-NATUN}), \end{aligned} \tag{18}$$

where the α_k are regarded as mean response coefficients and $\alpha_{kt}=\alpha_k+\nu_{kt}$ as actual (random) response coefficients for the t^{th} observation. (It could be argued that Equation 18 should contain another additive disturbance, the ε_t of Equation 17, in addition to ν_{0t}. If this extra disturbance is included, its variance cannot be estimated separately and is thus ignored [Judge, et. al., 1980, p. 375]). If the parameters of Equation 17 are random as specified in Equation 18, the model has a heteroscedastic disturbance term. The variance at each point is the same linear combination of the squares of the explanatory variables at that point (Hildreth and Houck, 1968).

Given the characteristics of a model containing random coefficients, it is desirable to test for the presence of the type of heteroscedasticity implied by Equation 18. Breusch and Pagan (1979) provide such a test. The test statistic developed is a Lagrange-multiplier procedure for testing the null hypothesis of homoscedastic disturbances and yields a χ^2 statistic of 75.41, decisively rejecting this null hypothesis. Thus, a random-coefficients specification fits the data better than does a homoscedastic model. This model of parameter variation does not require the assumption of abrupt structural changes at known points of time as in Froyen (1974) and Hamburger and Zwick (1981). Also, unlike the method proposed by Goldfeld and Quandt (1976), allowing the parameters to enter as random variables obviates the need to identify various "regimes" and allows for the possibility of a heteroscedastic error term at each observation. We therefore use Amemiya's (1977, 1978) modification of the Hildreth-Houck (1968) technique to obtain consistent parameter estimates of Equation 18 as follows:

$$\begin{aligned} \text{ANNUAL} = & \underset{(4.3673)}{-17.2636^{*}} + \underset{(4.4440)}{31.029839^{*}} {*}\text{SEIGN} \\ & \underset{(0.6958)}{-1.311065} {*}\text{RLDEBT} + \underset{(0.0438)}{0.107176^{*}} {*}(\text{UNEMP-NATUN}), \end{aligned} \tag{19}$$

R^2=0.71, B-G=0.3937, *=significance at the one-percent level.

Values in parentheses are standard errors and B-G is the value of the Breusch (1978) and Godfrey (1978) test statistic for autocorrelation. The results of Equation 19 indicate that a desire to extract seigniorage and deviations of unemployment from the Fed's preferred level are significant factors in explaining observed rates of inflation. RLDEBT possesses the wrong sign, but is not significant at the five-percent level. These parameter estimates cast doubt upon the hypothesis of a traditional model of central bank behavior. Seigniorage is not a significant variable in such a model. Also, the instability of policymaking as evidenced by the Breusch-Pagan (1979) test further undermines the hypothesis of central bank autonomy.

4.3. Model With Time Trend

Barro (1982, p. 332) points out that the amount of revenue the Fed collects from inflationary finance has roughly doubled over the past twenty years, indicating the desire to extract revenue may vary with time. That is, ANNUAL may respond differently to per unit changes in the independent variables of Equation 17 over different time periods. If so, a model which allows the coefficients to capture this possibility results in more efficient parameter estimates. Singh et. al. (1976) consider such a specification in which the regression coefficient, α_{kt}, is subject to two influences which cause it to deviate from its mean value, α_k. The first of these is a random disturbance as in Hildreth and Houck (1968). The second influence reflects the presence of factors that may vary with time. The essence of this specification is that it assumes no knowledge of where parameter shifts occur but attempts to investigate whether and when such shifts take place. Unlike the procedure employed by Beck (1982), the technique developed by Singh et. al. (1976, p. 342) permits appropriate tests of significance of the estimated parameters. The model estimated is that of Equation 17 with the following specification for the coefficients:

$$\alpha_{kt}=\alpha_k+\phi_k f_k(t)+\nu_{kt}, \tag{20}$$

where $f_k(t)$ is some function of time. Calendar time is used as a surrogate for those causes that affect α_{kt} systematically, while the error term, ν_{kt}, is the random component. The specification of the trend term is guided by the sample information according to Singh, et. al. (1976, p. 344). These authors recommend estimating the model with alternative forms of $f_k(t)$ such as $f(t)=t$, $f(t)=t^2$, $f(t)=\ln(t)$, etc. and choosing the specification which explains the maximum variation in the dependent variable. Therefore, we report results for $f_1(t)=f_2(t)=t$. For $f_3(t)$ we approximate a parabolic trend which assumes increasing response beginning two years before a presidential election year followed by decreasing response in the subsequent two years. This concentration on presidential elections facilitates comparisons with Froyen (1974), Potts and Luckett (1978) and Beck (1982). Substituting Equation 20 into Equation 17 amounts to a model containing interaction terms plus a heteroscedastic error term. This specification attempts to capture an increasing trend associated with revenue over time plus a concern regarding unemployment which is influenced by the electoral cycle. Under this specification Singh et. al. (1976) provide a four-step procedure for obtaining consistent parameter estimates. The results are as follows:

$$
\begin{aligned}
\text{ANNUAL} = & \underset{(3.378)}{-9.7781^*} \underset{(9.220)}{-12.2629}*\text{SEIGN} \underset{(2.045)}{+6.3509^*}*\text{RLDEBT} \\
& \underset{(0.044)}{-0.0602}*(\text{UNEMP}-\text{NATUN}) \underset{(0.084)}{+0.3525^*}*f_1(t)*\text{SEIGN} \\
& \underset{(0.0201)}{-0.0738^*}*f_2(t)*\text{RLDEBT} \underset{(0.0136)}{-0.01229}*f_3(t)*(\text{UNEMP}-\text{NATUN}),
\end{aligned}
\tag{21}
$$

$R^2=0.8946$, B-G=0.2976.

The response coefficient for SEIGN is now insignificant. A statistically significant estimate for ϕ_1, however, indicates the variable SEIGN exhibits increasing shifts with time. The mean response coefficient for RLDEBT is now significant and correctly signed, while the estimate for ϕ_2 shows a decreasing tendency in response over time. Thus, the data indicate that the revenue variables have tended to move in opposite directions over time. Deviations in unemployment are now no longer significant and also do not appear to elicit a response on the part of the Fed dependent upon presidential election years.

5. CONCLUSION AND FUTURE RESEARCH

5.1. Summary

Estimates of a Federal Reserve reaction function are derived using two-stage least squares. Revenue attainable through money creation and deviations of unemployment from the Fed's target are significant variables in explaining observed inflation rates. A significant revenue term casts doubts regarding the extent to which Fed policy is appropriately viewed in "traditional" terms. A further indicator of the degree of central bank independence is the extent to which policy is stable. Tests for stability are conducted which obviate the need to identify various "regimes." In addition, non-constant error variances are allowed at each observation. Federal Reserve policymaking is found to be random in nature supporting the conclusion that "...the Federal Reserve has not responded in a balanced, systematic way...that instead it has responded erratically, attempting to achieve one goal then another, some say in response to an increased sensitivity to political pressures" (Abrams, Froyen and Waud, 1980, pp.

30-31). Finally, we present a specification which allows the effect of the explanatory variables on the dependent variable to vary with time. We find an increasing trend associated with the response of seigniorage, a trend which decreases over time for RLDEBT and deviations of unemployment from target not affected by political considerations.

5.2. Suggestions for Future Research

The model of central bank behavior considered does not allow the Fed to invest in its reputation or credibility in that the Fed is assumed to view expectations as exogenous. Reputational models allow for a link between expectations formation and current policy. This link is the central bank's reputation. In our model, reputation or credibility concerns are incorporated by relaxing the assumption of discretionary policymaking. The policymaker then realizes that the choice for the current target constrains his choice next period. As such, expectations are affected by current policy actions and are no longer considered exogenous. Concern over reputation or credibility may substitute for formal commitments or the use of stationary rules on the part of the policymaker.

It is also of interest to examine the stability of Fed policymaking as a function of shifting coalitions within the Fed itself. That is, to what degree is observed instability of central bank policymaking the result of a new chairman of the Board of Governors? Are periods of different chairmen meaningful sub-periods by which to classify monetary policy? Methods suggested by Goldfeld and Quandt (1976) are useful in investigating these questions.

Finally, the extent to which the model developed in this analysis is applicable to other countries can be investigated. It is not only the Federal Reserve System which is assumed to be autonomous. As such, we might examine the role revenue considerations and unemployment play in observed inflation rates in other countries. An analysis of a cross-section of countries over time may be attempted. Such fixed and/or random effects models as in Maddala (1971) would be appropriate for the use of such "panel data." Swamy (1970) provides a model by which to combine cross-section and time-series data in a random-coefficients specification.

ENDNOTES

[1] For an explanation of why the Federal Reserve might benefit by responding to certain (implicit) incentives proferred by particular branches of government, see Kane (1980, 1982), Macesich (1984) and Woolley (1984, 1985).

[2] Toma (1982) descripes several alterations in the "monetary constitution" which effectively decreased the value of the multiplier. Barro (1982) provides empirical evidence of the importance of seigniorage. In actuality, the U.S. Treasury does not simply regard newly-created monetary base as current revenue. However, when the Fed permanently increases the base, it usually lends money indirectly to the Treasury by increasing its holdings of U.S. government securities. While the Treasury pays the Fed interest, the Fed transfers its profits (composed mostly of these interest payments) back to the Treasury. "Over the entire period from 1914-1983, System payments to the Treasury have totaled...almost 90 percent of the System's gross income" (Johnston, V., 1984). Therefore, the Treasury in effect receives an interest-free loan equal to the increase in base money.

[3] Bach and Stephenson (1974), Moore (1979) and Mumper and Uslaner (1982) describe other redistribution effects associated with inflation. See Fischer and Modigliani (1978, p. 827) for an explanation of the difficulties involved in considering these other redistribution effects when examining central bank behavior.

[4] Equation 8 implies that only unanticipated monetary expansions, as reflected in positive values for $(\Pi_t - \Pi_t^e)$ lead to increases in real economic activity. Equivalently, these nominal shocks lower the unemployment rate below its natural rate. This hypothesis is consistent with rational expectations models used in Lucas (1973) and Barro (1976)

[5] This assumption of discretion on the part of the policymaker ignores the possibility that the central bank invests in its reputation or credibility. In reputational models of central bank behavior, it is assumed that current actions of the policymaker influence expectations regarding future actions. The link between current actions and expectations is the Fed's reputation (Barro and Gordon, 1983a). For a summary of the research to date on credibility, see Cukierman (1986).

[6] Kydland and Prescott (1977) argue that the process of selecting the policy variable which is best, given current conditions, will likely converge to a time-consistent but suboptimal policy. A time-consistent policy is one in which, for each period, the policymaker maximizes an agreed-upon objective function taking as given previous decisions of economic agents and in which future policy decisions are similarly selected. Thus, a rules-type equilibrium may be optimal but time-inconsistent as the policymaker has an incentive to deviate from the rule when agents expect it to be followed, leading to low credibility.

Discretionary policymaking is suboptimal, but meets the requirements of dynamic consistency. As Barro and Gordon (1983b) point out "This terminology is deceptive in that it suggests that these decision rules represent alternative solutions to the same problem. Though the objective function and decision rules of private agents are identical, the problems differ in the opportunity sets of the policymaker."

[7] The second-order condition satisfies the requirements for a maximum as:

$$d^2Z_t/d\mu_t{}^2 = -\beta_{1t}(1/m_t)[\exp(ay_{t-1}-b\Pi_t^e-\Pi_t)]$$
$$-\beta_{2t}[\exp(g[i_{t-1}-\Pi_t^e]-\Pi_t)]$$
$$-z^2\beta_{3t}-\beta_{4t}<0.$$

[8] Abrams, Froyen and Waud (1980, p. 33) argue this assumption introduces two sources of bias. First, simultaneous-equation bias is present if the dependent variable of the reaction function affects the explanatory variables within the period. Second, an errors-in-variables problem is present since the policymakers forecast differs from the actual variable. Therefore, inconsistent parameter estimates are obtained. We introduce instrumental variables to resolve the first problem. Abrams, Froyen and Waud (1980, p. 34) suggest an instrumental variable procedure to overcome the errors in variables. Judging the relative merits of the instruments in this case, however, is impossible as these authors point out. "How efficient these (instruments) will be depends on how high the correlation is between the actual forecasts and our measures of these forecasts...The unobservability of the true policymaking forecasts makes the measurement of these correlations impossible" (Abrams, Froyen and Waud, 1980, p. 34)(emphasis added).

[9] See Appendix A for a description of the instruments generated and data used.

[10] See Appendix B for estimates of Equaiton 17 under various values of z and k.

[11] This discussion assumes the absence of vector autocorrelation of the type described in Guilkey (1974). That is, we assume the error terms of Equations A1-A3 are serially uncorrelated and uncorrelated with each other.

[12] A possible explanation for the nonindependence of the error term is omitted variables. The exclusion of relevant variables imparts autocorrelation to the disturbance term if the excluded variables are themselves autocorrelated. Further, the exclusion of relevant variables could give rise to observed instability of the parameters of Equation 17. Ramsey's (1969) RESET procedure is useful for detecting this problem since, as Thursby (1981) points out, RESET is robust to autocorrelation. Thursby and Schmidt (1977) find that the "test variables" which yield the most powerful results are composed of powers of the regressors. Utilizing RESET in this manner, an F-statistic of 2.98 with (6,118) degrees of freedom implies that we accept the null hypothesis, at the five-percent level,that no specification error is present due to omitted variables.

[13] It should be pointed out that instability in Fed policy response does not necessarily indicate policy formation is subject to political influences. Such observed unsteadiness might reflect instability in the "first stage" regressions which characterize the instruments (Abrams, Froyen and Waud, 1980, p. 31)

APPENDIX A

The technique of instrumental variables, or two-stage least squares, resolves the simultaneity present in Equation 17. The problem is that inflation influences as well as is influenced by SEIGN, RLDEBT and deviations of unemployment from that rate deemed acceptable by the Fed. For SEIGN and RLDEBT the reverse causation flows through the current price level, P_t. A change in P_t changes ANNUAL and will, by definition, change SEIGN and RLDEBT. The simultaneity associated with unemployment operates through a usual Phillips curve mechanism as in Equation 8. As instruments, we propose the following:

$$\begin{aligned}\text{SEIGN}=s_0&+\Sigma_{i=1}^{3}s_{1i}{*}\text{PI}_{t-1}-\Sigma_{i=1}^{3}s_{2i}{*}\text{TBILL}_{t-i}\\&+\Sigma_{i=1}^{4}s_{3i}{*}\text{SEIGN}_{t-i}\quad R^2=0.9040\end{aligned}\tag{A-1}$$

$$\begin{aligned}\text{RLDEBT}=d_0&+\Sigma_{i=1}^{3}d_{1i}{*}\text{GOV}_{t-i}+\Sigma_{i=2}^{3}g_{2i}{*}\text{PI}_{t-i}\\&+\Sigma_{i=2}^{4}g_{3i}{*}\text{RLDEBT}_{t-i}\quad R^2=0.9624\end{aligned}\tag{A-2}$$

$$\begin{aligned}(\text{UNEMP-NATUN})=u_0&+\Sigma_{i=1}^{3}u_{1i}{*}\text{INDPRO}_{t-i}+\Sigma_{i=1}^{3}u_{2i}{*}\text{RESAL}_{t-i}\\&+\Sigma_{i=1}^{4}u_{3i}{*}(\text{UNEMP-NATUN})_{t-i}\quad R^2=0.9562,\end{aligned}\tag{A-3}$$

where PI=Personal Income

TBILL=Three-month Treasury Bill rate

GOV=Government Expenditures

INDPRO=Index of Industrial Production

RESAL=Retail sales.

Equations A1-A3 are used to generate predicted values of the independent variables of Equation 17 As such, these equations may be thought of as "first-stage" regressions. Then, in the "second stage," these predicted values are used as instruments. As lagged variables are used to generate predicted values, the instruments are not affected by (are exogenous with respect to) the current rate of inflation. This condition holds, however, only if the error term of Equation 17 is serially independent.

The first-stage regressions attempt to capture those variables which explain SEIGN, RLDEBT and (UNEMP-NATUN), and are also exogenous with respect to the current inflation rate. That is, as SEIGN is a function of the amount of the medium of exchange demanded, lags of personal income appear to represent a "scale variable" common in money demand functions. Lags of interest rates are included to capture the opportunity cost of money holdings. Finally, lags of the regressor itself are used. Similar considerations were employed in the construction of the other instruments. Using these instruments, we then concentrate on obtaining estimates of the parameters of Equation 17 This focus on a single equation is consistent with reaction functions as estimated by Wood (1968), Froyen (1974) and Abrams, Froyen and Waud (1980) who also make use of instrumental variables.

Description of Data Set

Quarterly data were collected for the explanatory variables of Equation 17 and the instruments in Equations A1-A3. The time period chosen for the analysis is the post-Accord period (1951-1983), to assume a maximum amount of independence of the Federal Reserve System. The criteria we use for "independence" is described by Woolley (1985, p. 320):

> At a minimal level, a central bank can be considered to be independent if it can set policy instruments without approval from outside authorities, and if, for some minimal period of time, the instrument settings clearly differ from those preferred by the fiscal authority.

Data between the post-War period and 1951 exhibit the effects of the Fed's "pegging" operations as directed by the U.S. Treasury. From 1914 until the mid-1930's, the Comptroller of the Currency and Secretary of the Treasury were members of the Board of Governors, rendering this time period questional in meeting the criteria of independence. Finally, we exclude the remaining years due to the distortions caused by the depression and second world war.

M_t is defined as the narrow money stock, or M1. This constitutes currency plus demand deposits plus other checkable deposits (available after 1980). The data for the series are unadjusted for seasonal variation as it is this amount from which the Fed's revenue accrues. P_t is defined as the Implicit Price Deflator, G.N.P. total, 1972=100.

Data on U_t are defined as the total unemployment rate - all civilian workers as percent of the civilian labor force, adjusted for seasonal variation. M_t, P_t and U_t are found in Business Statistics: The Biennial Supplement to the Survey of Current Business, Bureau of Economic Analysis, U.S. Department of Commerce, 1979 and 1982 editions and also in various issues of the Federal Reserve Bulletin.

The money supply multiplier, m_t, is derived by dividing the money supply by the monetary base. The monetary base is defined as total reserves plus currency outside the U.S. Treasury, Federal Reserve Banks and valuts of nonmember banks, not seasonally adjusted. Data for the base are found in Annual Statistical Digest, Board of Governors of the Federal

Reserve System, 1970-1979 and 1982 editions, plus various editions of the *Federal Reserve Bulletin*. G_t is defined as total gross public debt of the U.S. government held by the public, excluding that held by U.S. government agencies and trust funds and that held by Federal Reserve banks. These data are available in various issues of the *Federal Reserve Bulletin*.

Estimates of the natural rate of unemployment were obtained from Gordon (1984, Appendix b). PI is defined as personal income, seasonally adjusted totals at annual rates. Data on GOV are defined as federal government outlays while those on TBILL represent the yield on U.S. government securities (taxable) three-month bills (rate on new issues-open market rates in New York city. INDPRO represents the index of industrial production (1967=100) adjusted for seasonal variation and RESAL is defined as (estimated) retail sales adjusted for seasonal variation and trading-day differences, all types of retail stores. Data for these variables are found in *Business Statistics: The Biennial Supplement to the Survey of Current Business*.

Data for personal tax and nontax payments, the federal government deficit and for gross national product are found in *Business Statistics:* 1982, 23rd edition *A Supplement to the Survey of Current Business,* November 1983 and various issues of the Survey of Current Business.

APPENDIX B

Estimates of Equation 17 Under Various Values of z and k

$z=3,\ k=0.6$

$$\text{ANNUAL}=-\underset{(3.3189)}{20.143124^{*}}+\underset{(3.3659)}{33.41066^{*}}*\text{SEIGN}-\underset{(0.4901)}{1.39291^{*}}*\text{RLDEBT} \tag{B-1}$$

$$+\underset{(0.0404)}{0.172181^{*}}*(\text{UNEMP-NATUN}),\quad R^2=0.5222$$

$z=3,\ k=0.9$

$$\text{ANNUAL}=-\underset{(3.3535)}{19.7699}+\underset{(3.3811)}{34.0107^{*}}*\text{SEIGN}-\underset{(0.4955)}{1.3949^{*}}*\text{RLDEBT} \tag{B-2}$$

$$+\underset{(0.0421)}{0.1719^{*}}*(\text{UNEMP-NATUN}),\quad R^2=0.5168$$

$z=3,\ k=1$

$$\text{ANNUAL}=-\underset{(3.3664)}{19.648804^{*}}+\underset{(3.3877)}{34.219097^{*}}*\text{SEIGN}-\underset{(0.4974)}{1.394601^{*}}*\text{RLDEBT} \tag{B-3}$$

$$+\underset{(0.0427)}{0.17166^{*}}*(\text{UNEMP-NATUN}),\quad R^2=0.5149$$

$z=3.5,\ k=0.6$

$$\text{ANNUAL}=-\underset{(3.3189)}{20.143124^{*}}+\underset{(3.3659)}{33.410663^{*}}*\text{SEIGN}-\underset{(0.4901)}{1.392910^{*}}*\text{RLDEBT} \tag{B-4}$$

$$+\underset{(0.0346)}{0.147584^{*}}*(\text{UNEMP-NATUN}),\quad R^2=0.5222$$

$z=3.5,\ k=0.9$

$$\text{ANNUAL}=-\underset{(3.3535)}{19.769937^{*}}+\underset{(3.3811)}{34.017066^{*}}*\text{SEIGN}-\underset{(0.4955)}{1.394927^{*}}*\text{RLDEBT} \tag{B-5}$$

$$+\underset{(0.0361)}{0.147406^{*}}*(\text{UNEMP-NATUN}),\quad R^2=0.5168$$

$$z=3.5,\ k=1$$

$$\text{ANNUAL}=\underset{(3.3664)}{-19.648804^{*}}+\underset{(3.3877)}{34.219097^{*}}*\text{SEIGN}-\underset{(0.4974)}{1.394601^{*}}*\text{RLDEBT} \tag{B-6}$$

$$+\underset{(0.0366)}{0.147143^{*}}*(\text{UNEMP}-\text{NATUN}),\quad R^2=0.5149$$

$$z=4,\ k=0.6$$

$$\text{ANNUAL}=\underset{(3.3189)}{-20.143124^{*}}+\underset{(3.3659)}{33.410663^{*}}*\text{SEIGN}-\underset{(0.4901)}{1.392910^{*}}*\text{RLDEBT} \tag{B-7}$$

$$+\underset{(0.0303)}{0.129136^{*}}*(\text{UNEMP}-\text{NATUN}),\quad R^2=0.5222.$$

$$z=4,\ k=0.9$$

$$\text{ANNUAL}=\underset{(3.3535)}{-19.769937^{*}}+\underset{(3.3811)}{34.017066^{*}}*\text{SEIGN}-\underset{(0.4955)}{1.394927^{*}}*\text{RLDEBT} \tag{B-8}$$

$$+\underset{(0.0316)}{0.128980^{*}}*(\text{UNEMP}-\text{NATUN}),\quad R^2=0.5168$$

$$z=4.5,\ k=0.6$$

$$\text{ANNUAL}=\underset{(3.3189)}{-20.143124^{*}}+\underset{(3.3659)}{33.410663^{*}}*\text{SEIGN}-\underset{(0.4908)}{1.392910^{*}}*\text{RLDEBT} \tag{B-9}$$

$$+\underset{(0.0269)}{0.114787^{*}}*(\text{UNEMP}-\text{NATUN}),\quad R^2=0.5222$$

$$z=4.5,\ k=0.9$$

$$\text{ANNUAL}=\underset{(3.3535)}{-19.769937^{*}}+\underset{(3.8114)}{34.017066^{*}}*\text{SEIGN}-\underset{(0.4955)}{1.394927^{*}}*\text{RLDEBT} \tag{B-10}$$

$$+\underset{(0.0280)}{0.114649^{*}}*(\text{UNEMP}-\text{NATUN}),\quad R^2=0.5168$$

z=4.5, k=1

$$ANNUAL=-\underset{(3.3664)}{19.648804^*}+\underset{(3.3877)}{34.219097^*}*SEIGN-\underset{(0.4974)}{1.394061^*}*RLDEBT \tag{B-11}$$

$$+\underset{(0.0284)}{0.11444^*}*(UNEMP-NATUN), \quad R^2=0.5149.$$

z=5, k=0.6

$$ANNUAL=-\underset{(3.3189)}{20.143124^*}+\underset{(3.3659)}{33.410663^*}*SEIGN-\underset{(0.4901)}{1.392910^*}*RLDEBT \tag{B-12}$$

$$+\underset{(0.0242)}{0.103309^*}*(UNEMP-NATUN), \quad R^2=0.5222.$$

z=5, k=0.9

$$ANNUAL=-\underset{(3.3535)}{19.769937^*}+\underset{(3.3811)}{34.017066^*}*SEIGN-\underset{(0.4955)}{1.394927^*}*RLDEBT \tag{B-13}$$

$$+\underset{(0.0252)}{0.103184^*}*(UNEMP-NATUN), \quad R^2=0.5168$$

z=5, k=1

$$ANNUAL=-\underset{(3.3664)}{19.648804^*}+\underset{(3.3877)}{34.219097^*}*SEIGN-\underset{(0.4974)}{1.394601^*}*RLDEBT \tag{B-14}$$

$$+\underset{(0.0256)}{0.10300^*}*(UNEMP-NATUN), \quad R^2=0.5149$$

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