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ABSTRACT

Natural Rate Doubts*

This paper provides evidence for a low frequency relationship between unemployment, inflation and the nominal interest rate. I show that in the United States from 1959.1 to 1991.3, the unemployment rate, the inflation rate and the federal funds rate can be modelled as non-stationary time series linked by two co-integrating equations. One of these equations is stable over the whole sample period, the other is different over the sub periods 1959.1 to 1979.4 and 1980.1 to 1999.3. I evaluate the ability of a class of models to explain these facts and conclude that models that incorporate the natural rate hypothesis are inadequate. An alternative class of models, characterized by the existence of an upward sloping long-run Phillips Curve, can account for the data.

JEL Classification: E30, E40, E50
Keywords: cointegration, the natural rate hypothesis, the Phillips Curve

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NON-TECHNICAL SUMMARY

This paper re-examines the evidence for the existence of a long-run Phillips Curve – that is, a permanent relationship between unemployment and inflation. In the 1970s, Edmund Phelps and Milton Friedman argued that one should not expect there to be a long-run trade-off between inflation and unemployment. They argued that only the real value of money should enter utility or production functions. Hence money should be *neutral* and, if the stock of money doubles, all nominal prices should double but unemployment and other real variables should be unaffected. The Phelps-Friedman argument, called the *natural rate hypothesis*, quickly became a cornerstone of all modern macroeconomic models. Today, models that incorporate this hypothesis are widely used to forecast inflation and unemployment and to assess the likely effects of changes in interest rates.

The natural rate hypothesis helped explain the disappearance of the Phillips Curve following the oil price shocks of 1973 and 1979 and its empirical success led to its quick acceptance as received wisdom. But, as argued in this paper, evidence that has accumulated since the 1970s should lead one to reassess the facts. The data since 1959 reveals a steady increase in unemployment until 1980, followed by a steady decline. The interest rate and the inflation rate follow a similar pattern. This paper argues that the co-movements in these series at low frequencies cannot easily be explained by simple economic theories that incorporate the natural rate hypothesis. Instead, they are better understood if one assumes a stable long-run relationship between unemployment and inflation. This relationship can be interpreted as a long-run Phillips Curve with a positive slope.

To establish the relationships between inflation, unemployment and the interest rate the technique of *co-integration analysis*, developed by time series econometricians in the last decade, is used. Cointegration analysis is a way of studying relationships between variables that are drifting slowly over time as a result of one or more common stochastic trends. In the data one common trend and two co-integrating equations are found. One of these, between unemployment and inflation, is stable over the entire period and it is this relationship that is interpreted in this paper as a long-run Phillips Curve. The second equation shows a distinct break in 1980 at about the time that the Fed changed the way it conducts monetary policy. This paper ascribes this second equation to the effects of Fed policy.

Although this paper argues that we should drop the natural rate hypothesis, this does not imply that one should give up on models based on individual maximizing behaviour. It is true that economic theory implies that money should be neutral in the long-run. But this does not imply that we should expect no long-run relationship between inflation and unemployment since continual increases in the money supply can alter the nominal rate of interest and this, in turn, may influence economic activity through a variety of channels. These effects are called non *superneutralities*. The evidence suggests that money is neutral but not super neutral.

1 Introduction

Much recent work in macroeconomics is based on the representative agent model. According to this approach, aggregate macroeconomic time series can be viewed as if they were chosen by a maximizing representative agent with rational expectations of future prices. Although initial work on the RA model studied the relationships between consumption, employment and capital accumulation, recent attention has been focused on a monetary version of the model in which there are nominal rigidities. The demand side of this monetary model resembles the IS-LM framework that dominated macroeconomic theory in the immediate post-war period and the supply side, built up from a theory of price setting agents, provides a microeconomic foundation for the expectations augmented Phillips curve.

A key ingredient of the expectations augmented Phillips curve is the natural rate hypothesis. This hypothesis, advanced by Edmund Phelps and Milton Friedman, asserts that the growth rate and the long run unemployment rate are independent of monetary policy. When the natural rate hypothesis was first proposed, some economists had suggested that the Phillips curve might represent a permanent exploitable trade–off between unemployment and inflation. Phelps and Friedman argued instead that there can be no long-run trade-off. They pointed out that if rational agents are free of money illusion, only the real value of money should enter preferences and technology. They went on to argue that if output and employment are determined by purely real factors, money should be *neutral* and the long-run Phillips curve should be vertical. In other words, the unemployment rate cannot be permanently influenced by monetary policy.

The neutrality of money is an important element of any micro-based explanation of aggregate macroeconomic activity. But although neutrality is central to neoclassical economics, it is not true that neutrality implies the natural rate hypothesis. Natural rate theory requires not only that money is neutral but also that it is *superneutral*. Superneutrality states that a doubling of the money growth rate will result in a doubling of the inflation rate but leave unemployment and growth unaffected. This is a stronger proposition than neutrality and it is *not* implied by the absence of money illusion.

There are many reasons why one might expect superneutrality to be false. Inflation might cause agents to hold less money and, to the extent that money is a productive asset, economic activity may be lower. Inflation might cause the real interest rate to increase and agents might decide to hold less capital.

As a result of imperfect indexation of the tax system, effective tax rates may rise as inflation increases. This could cause individuals to work less hard or invest less in productive capital. For all these reasons, inflation may have a permanent effect on the unemployment rate or on the level of economic activity. Although these effects were understood by Phelps and Friedman, they were thought to be quantitatively unimportant. In this paper I argue that evidence that has accumulated since Phelps and Friedman introduced the natural rate hypothesis should lead us to re-evaluate this assessment. This evidence suggests that the hypothesis is false and that the long-run Phillips curve is upward sloping and not vertical as required by the theory of the natural rate of unemployment.

2 Why my Argument is Important

In a recent conference volume edited by John Taylor, [8], a number of authors sought to understand how alternative monetary policy rules behave by embedding them into economic models of the form:

$$x_t = A(L)\, x_{t-1} + b + u_t. \tag{1}$$

Equation (1) represents the reduced form of a model in which x_t is a vector of endogenous variables, b is a vector of constants u_t is a serially uncorrelated random variable with covariance matrix Σ and the matrix $A(L)$ is a polynomial in the lag operator L.

The goal of the Taylor volume is to examine the robustness of alternative policy rules by studying how output and inflation behave in many different simulated economies when one assumes that the central bank follows a given rule. The models studied in this volume differ in several respects. Some assume rational expectations, others do not. Some are large, some are small. Some are open economy models, others are closed. There is, however, one common element to these studies. They each include a Phillips curve that embodies the natural rate hypothesis.

In a recent paper, Benhabib and Farmer [2] have proposed an alternative theory of aggregate supply that has different implications for the monetary transmission mechanism. In their model the nominal interest rate has permanent long-run effects on the unemployment rate. If the Benhabib-Farmer model is correct then the robustness studies in the Taylor volume are misspecified since each of them is conducted in a model in which the Fed cannot influence the long run level of economic activity. If this assumption is false there may be a long run relationship between inflation and unemployment, similar to the long run Phillips curve that was widely discussed in the 1960's. But if this is so, one might hope to uncover this relationship by studying the low frequency component of movements in the data. Natural rate theories and non natural rate theories have very different implications for these low frequency movements. The idea of this paper is to exploit this difference by comparing the low frequency movements in unemployment, the inflation rate and the nominal interest rate in U.S. data with the predictions of theories that embody the natural rate hypothesis.

3 A Plan of Attack

Let the long run of an economic model be defined as the vector x that solves the equation

$$x = A(1)x + b. \tag{2}$$

According to this definition, the long-run of a model is the set of values that would be attained by its variables in the absence of stochastic shocks. In linear models, this definition corresponds to the unconditional expectation of the vector x. If x_t were stationary, one could hope to recover a consistent estimate of x from the sample mean. But if one or more of the components of x_t is non-stationary this method breaks down since the steady state of the system is constantly moving. In this case, one needs to resort to the study of co-integrated systems.

In U.S. time series from 1959 through 1999 the stationarity assumption is a poor characterization of the data even if one restricts attention to variables like the unemployment rate, the interest rate and the inflation rate, that one might reasonably expect to converge to a steady state. Figure 1 plots the Fed funds rate, i, the unemployment rate, U and the inflation rate, π from 1959.1 through 1999.3. The top graph plots unemployment and the interest rate measured in normalized units to highlight their co-movements. Notice that both variables display a clear tendency to move in opposite directions at high frequencies but to move together at low frequencies. This low frequency co-movement is characterized by a slow increase in the two variables from 1960 through 1979 that is reversed after 1980. The bottom panel of figure 1 plots the Fed Funds rate and the inflation rate. Once again, both variables drift together. In the first half of the sample they drift up and over the second half they drift back down.

According to conventional theories of the expectations augmented Phillips curve, for unemployment to be above its natural rate, inflation must exceed expected inflation. For unemployment to be below its natural rate, the reverse should be true. By averaging unemployment and the interest rate over periods of ten years, one would expect that years of above average inflationary expectations should be balanced by periods of below average expectations. The natural rate hypothesis then suggests that there should be no discernible relationship between the nominal interest rate and the unemployment rate.

The evidence is rather different. Figure 2 plots the interest rate against the unemployment rate and the inflation rate for the 1950's through the 1990's using decade averages of annual data. The upward sloping line on the top panel is the least squares regression line. The upward sloping line on the lower panel is the relationship predicted by the Fisher equation if the real rate of interest had been constant at 2.2% over the entire sample. This line has a slope of 1 (the Fisher hypothesis) and an intercept of 2.2 (the average real interest rate over this period). These graphs show that there have been positive relationships between the average nominal interest rate, the average unemployment rate and the average inflation rate. Although it is possible that unemployment and the nominal interest rate increased and then decreased for different reasons, the coincidence of the trends in the two series is suggestive that there are causal factors at play.

4 Preliminary Data Analysis

If the model suggested by equation (1) is correct, the series $\{i, \pi, U\}$ should have univariate representations that are stationary. As a formal test of stationarity, I ran the augmented Dickey Fuller regressions

$$\Delta x_t^i = b(L)\, \Delta x_{t-1}^i + c x_{t-T}^i + d + + u_t, \tag{3}$$

for $x_t^i = \{i_t, \pi_t, U_t\}$ where $b(L)$ is a $T'th$ degree polynomial in the lag operator. Table 1 reports the t-statistic for the coefficient of c in each of the three regressions for the whole sample and for each of two sub-samples broken in 1979.4. These t-values should be below the critical value reported in the table to reject the null hypothesis that the series is non-stationary at the 1%, 5% or 10% levels. All three series fail this test at the 10% level in each of the sub-samples. Although one can reject non-stationarity of the interest rate at the 5% level in the entire sample, the test is invalid in the presence of parameter instability. Since one can reject the hypothesis of a constant-parameter reduced-form-model across the entire period, the results for the entire period are invalid.

Although the three series are apparently non-stationary, figures 1 and 2 suggests that linear combinations of them are stationary. In other words, the three series are co-integrated. A complicating factor is that there may have been shifts in the co-integrating relationships as a result of changes in the monetary policy rule. Some evidence of this possibility appears in figure 1 (lower panel) which suggests that there were changes in the real interest rate around the times when there were significant changes in monetary policy.

Many models that one might write down impose the assumption that the real interest rate is stationary. Stationarity follows from the representative agent assumption in conjunction with the hypothesis that the representative agent has a constant rate of time preference. But a test of stationarity of the real rate, by running equation (3) using the ex-post real interest rate as the left side variable, leads to a test statistic of -2.46 which fails to reject the unit root hypothesis at the 10% level.

A weaker form of the constant real rate hypothesis would allow the real rate of interest to differ across monetary policy regimes. Examples of models in this class include the IS-LM model, the overlapping generations model, or representative agent models with tax distortions. To allow for this possibility I ran the regression,

$$r_t = c_0 + c_1 d_1 + c_2 d_2 + c_3 d_3 + u_t$$

where r_t is the Fed funds rate minus the realized inflation rate, and d_1, d_2, and d_3 are step dummies for 1970.1, 1979.4 and 1982.4. These dummies allow for intercept shifts in the model in 1970.1, when Burns took over as governor of the Fed, in 1979.4, when Volcker initiated a policy of control of the rate of growth of the money supply, and in 1982.4 when this policy was abandoned.

Figure 3 demonstrates how these dummies help the data to fit with economic theory. The series of stepped lines in the upper part of this figure correspond to estimates of the real rate over each of the sub periods 1959.3–1970.1, 1970.1–1979.4, 1979.4–1982.2 and 1982.2–1999.3. The implied real interest rates from this regression are given in table 2 and an ADF stationarity test of the residuals gives a test statistic of -4.04 which rejects the hypothesis of a unit root at the 1% level. In other words, the real rate is stationary within monetary policy regimes.

5 Interpreting the Data

To recap my argument; for all three variables one cannot reject the hypothesis of non-stationarity. This suggests that equation (1) provides a poor characterization of data. However, figures 1 and 2 suggest that the variables move together at low frequency, at least over sub-periods of the model for which the policy rule could reasonably have been expected to remain stable. Taken together, this evidence suggests that one should look for a model that can explain the variables as a cointegrated system with one common trend and two cointegrating equations.

Existing studies use the statistical model

$$x_t = A(L)\, x_{t-1} + u_t, \tag{4}$$

where $A(L)$ is a polynomial in the lag operator and x_t and u_t are stationary variables. Since in practice x_t is non-stationary, I propose instead to study models in the class

$$\Delta x_t = A(L)\, \Delta x_{t-1} + BCx_{t-T} + u_t, \tag{5}$$

where C is a 2×3 matrix whose columns are the cointegrating relationships and B is a 3×2 matrix that reflects the weights with which each of the cointegrating equations affects the dynamics of the variables U, i and π in the reduced form.

In a three variable system one cannot identify two cointegrating equations by studying low frequency movements since data will cluster around the vector that defines their intersection. Rotations of either of the two cointegrating equations around this vector leave the long run properties of the system unaltered. Instead, one must choose arbitrary normalizations of the cointegrating equations. In the following analysis I chose the normalization for the matrix C reported in table 3. This normalization is interesting since there is evidence that one of the proposed cointegrating relationships, the relationship between inflation and unemployment, is stable over the two sub-periods that I studied.

In tables 4, 5 and 6 I present estimates of the co-integrating relationships in the data. Table 4 presents estimates of the sub-period from 1959.1 to

1979.4. Table 5 is the second sub-period from 1980.1 to 1999.3 and table 6 presents estimates for the entire sample. For the two sub-periods, the regressions include two lags of differenced data and for the entire period the regressions use four lags. I broke the data into two sub periods because preliminary investigations of the unrestricted model reveal considerable parameter instability that invalidates the cointegration tests over the whole sample.

The statistics reported in tables 4–6 are tests of reduced rank of the matrix BC and the eigenvalues reported in the left columns are zero if and only if the eigenvalues of BC are zero. I conducted this test under the assumption that there is no deterministic trend in the data, but I allowed for constants in the two cointegrating relationships. Formally, at the 1% level, one can reject the hypothesis of zero cointegrating relationships in favor of one, in both sub-periods. Similarly, one can reject the hypothesis that there are three cointegrating equations. The hypothesis that there is one cointegrating equation, rather than two, is not clearly rejected although the likelihood ratio for this hypothesis is close enough to the tail of the asymptotic distribution in each case for one to be comfortable with a statistical model with two cointegrating equations and a single common trend.

Conditional on choosing a model with two cointegrating relationships, table 7 presents estimates of these equations over the two sub-periods 1959:1–1979:4 and 1980:1–1999:3. Figure 4 is a graph of the parameters a_1, c_1 of the cointegrating relationship between the Fed funds rate and inflation for the two sub-periods with 2-standard error bounds. Figure 5 presents the same information for the cointegrating equation between unemployment and inflation. Figure 4 indicates strong evidence against the hypothesis of a single cointegrating equation between the interest rate and inflation across the two subperiods. But from figure 5 it appears that the hypothesis of a single stable cointegrating equation between unemployment and inflation is unlikely to be rejected.

6 An Organizing Framework

I will take it as given that the U.S. data are to be described by a vector error correction model with two cointegrating vectors. There is evidence that one of these cointegrating vectors, an equation relating inflation to the nominal interest rate, shifted dramatically in 1979.4, when the Fed changed its monetary policy. The second, an equation relating unemployment to inflation, is relatively stable. This section evaluates the ability of a series of simple economic models to explain these facts.

The models I will evaluate are in the class:

$$E_t \left[A_2 x_{t+1} + A_0 x_t + A_1 (L) x_{t-1} \right] + v_t = 0, \tag{6}$$

where A_2 is a matrix that describes the influence of future expectations, A_0 is a matrix that describes the contemporaneous links between the variables of the system and $A_1 (L)$ is a polynomial in the lag operator. I will assume that v_t is a vector of errors with diagonal covariance matrix Σ and that one of these errors v_t^i is a random walk. By differencing the equation with the unit root, and using the transformation $\Delta = 1 - L$, one can always rewrite this system as follows

$$E_t \left[\tilde{A}_2 \Delta x_{t+1} + \tilde{A}_0 \Delta x_t + \tilde{A}_1 (L) \Delta x_{t-1} \right] + BCx_{t-T} + u_t = 0, \tag{7}$$

where C is a 2×3 matrix of cointegrating vectors, B contains the weights with which these vectors enter the three structural equations and u_t is a vector of stationary uncorrelated structural errors. This error vector contains the errors v_t^j $j \neq i$, for the two equations of (6) that have stationary errors and the difference Δv_t^i for the equation with a non-stationary error.

The assumption that the vector u_t is diagonal is important to my argument. The system (7) is not itself a structural vector autoregression since it contains the expectations terms $E_t [x_{t+1}]$. But it is a structural model and it is this fact that enables me to make assumptions about the inter-relationships of the errors.

7 A Class of Structural Models

I will consider a subset of models in the class defined by equation (7). All of these models consist of an aggregate demand equation, an aggregate supply equation and a policy rule. My strategy is to ask if this class of models can explain the cointegrating relationships uncovered in data.

The aggregate demand equation I will consider is of the form

$$E_t \left[\phi_1 (L) \Delta U_{t+1} \right] + a (i_t - \pi_t - \rho) + u_t^1 = 0, \tag{8}$$

where a is a parameter. This equation can be derived from the specification of Rotemburg and Woodford, [9] or that of McCallum and Nelson [6] by adding the assumption that unemployment is linearly related to the output gap. In simple models the polynomial $\phi_1(L)$ is a constant: it may contain higher order terms in L if agents have non-separable preferences or if utility allows for habit formation.

The supply equation I consider is an expectations augmented Phillips curve of the form

$$\pi_t = \lambda_1(L)\pi_{t-1} + E_t[(1-\lambda_1(L))\pi_{t+1}] - \lambda_2(L)\left(U_t - \bar{U}\right) + u_t^2 = 0, \quad (9)$$

where $\bar{U}$ is the natural rate of unemployment. This specification is rich enough to capture both forward and backward looking versions of the Phillips curve. In the simplest models the polynomials $\lambda_1(L)$ and $\lambda_2(L)$ are constants. By allowing for non-zero terms in L one arrives at a specification that may better capture the dynamics of employment adjustment. The natural rate hypothesis is captured by the fact that the coefficients on all lags of inflation sum to zero so that there is no long-run trade-off between inflation and unemployment.

The final equation that closes this system is the policy rule that I write as

$$i_t = \delta(L)i_{t-1} + [1-\delta(L)]\left[\alpha\pi_t - \beta\left(U_t - \bar{U}\right) + \gamma\right] + u_t^3 = 0, \quad (10)$$

where $\delta(L)$ is a polynomial that captures interest rate smoothing behavior by the Fed and α, β, γ represent the Fed's reaction to inflation and unemployment.

The solution to the above rational expectations model can be written as a vector autoregression. If the error vector u_t is stationary and the dynamics of the model are stable, the variables will converge to an invariant probability distribution with means that satisfy equations (11)–(13).

$$i - \pi - \rho = 0, \quad (11)$$

$$U - \bar{U} = 0, \quad (12)$$

$$i - \alpha\pi + \beta U + \gamma_0 = 0, \quad (13)$$

where $\gamma_0 = \gamma - \beta\bar{U}$. If one or more of the error terms u_t^i, is non-stationary, the system will have a vector error correction representation. In the following section of the paper I explore the implications of assuming that one of or other of these errors is non-stationary.

8 Is the NRH Consistent with Data?

The models I have described contain a policy rule and two equations that describe current behavior as a function of current and future expected endogenous variables. The covariance matrix of structural shocks, Σ, is assumed diagonal and I identify u^1 as a demand shock, u^2 as a supply shock and u^3 as a policy shock. I will then ask if it is possible for models described by equations (8)–(10) to explain the two cointegrating relationships found in data by dropping the assumption that all three fundamental errors are stationary.

This strategy gives rise to three possibilities for the co-integrating vectors. First, suppose that the aggregate supply curve has drifted over time. This hypothesis implies that u^2 is non-stationary and that the two co-integrating vectors, from equations (11) and (13), are $\{1, -1, \rho\}$ and $\left\{1, \frac{1-\alpha}{\beta}, \frac{\gamma_0}{\beta}\right\}$. Second, the non-stationary component may be coming from the policy rule. In this case the co-integrating vectors, given by (11) and (12), are $\{1, -1, \rho\}$ and $\left\{1, 0, \bar{U}\right\}$. Finally, the aggregate demand equation may be non-stationary. In this case the cointegrating vectors, given by equations (12) and (13), are $\{1, -\alpha, \gamma_0\}$ and $\left\{1, 0, -\bar{U}\right\}$. The following three sections discuss each of these possibilities.

8.1 Drift in the Natural Rate Can't Explain the Common Trend

The most common explanation for the unit root in unemployment is that the natural rate has been drifting over time due to structural changes in the labor market. If this explanation is to have any hope of explaining why there is cointegration between inflation and unemployment, one must assume that the Fed cannot observe the natural rate. If this were not the case, the Fed would presumably react only to the unemployment gap, rather than the level of unemployment, and a drifting natural rate would not lead to drift in inflation.

Suppose, that $\bar{U}$ is un-observable and has a unit root. An equivalent assumption is that there is a non-stationary error term to the supply equation u_t^2. This leads to a model of the inflation build-up similar to a recent explanation of Orphanides [7] who argues that the Fed was too loose in its inflation policy in the 1970's because policy makers systematically underestimated the natural rate. I will refer to this hypothesis as the supply side explanation of cointegration.

According to the supply side explanation, the error term u_t^2 is a random walk and hence $U - \bar{U} = 0$ cannot be one of the co-integrating equations. Instead, the co-integrating vectors are $i - \pi - \rho = 0$, (the Fisher equation) and $i - \alpha\pi + \beta U + \gamma_0 = 0$, (the policy rule). But if the Fisher equation and the policy rule are co-integrating relationships then the Fed funds rate and the inflation rate should co-integrate with the vector $\{1, -1, \rho\}$. This contradicts the facts presented in table 7. According to this evidence, the interest rate–inflation co-integrating vector in the pre 1980 period was $\{1, -0.57, -2.5\}$ and in the post 1980 period it was $\{1, -2.3, 0.42\}$. Further, these co-integrating vectors are tightly estimated with standard errors that allow one easily to reject the hypothesis that the true relationship is $\{1, -1, \rho\}$.

A weaker form of the aggregate demand equation would replace equation (11) with equation (14a),

$$i - \pi - \rho - \psi U = 0, \quad \psi > 0. \tag{14a}$$

This equation would arise as the long-run demand equation in an IS-LM model in which it has the interpretation of an IS curve. It is possible to derive a similar long-run relationships in overlapping generations models or in representative agent models with tax distortions that allow the real interest rate to vary with policy. Under this interpretation the Fisher equation is a special case of the IS curve in which the long-run IS curve is horizontal. But the IS curve interpretation does no better than the Fisher explanation since it implies co-integrating relationships $\{1, a_1, c_1\}$, $\{1, a_2, c_2\}$ where

$$\begin{array}{ll} a_1 = -\frac{(\beta+\alpha\psi)}{\beta+\psi} & c_1 = \frac{(\gamma_0\psi - \beta\rho)}{(\beta+\psi)} \\ a_2 = \frac{(1-\alpha)}{(\beta+\psi)} & c_2 = \frac{(\rho+\gamma_0)}{(\beta+\psi)}. \end{array}$$

The parameters ψ and β are both predicted by theory to be positive. But from table 7 we see that the absolute value of coefficient a_1 was estimated to be significantly less than one in the first sub-period. This implies that α must be between zero and one. But the coefficient on the second co-integrating relationship, a_2, was estimated to be negative, implying $\alpha > 1$, which is a contradiction.

8.2 Drift in the Policy Rule Can't Explain the Common Trend

According to a popular interpretation of the inflation build-up in the 70's, monetary policy in the post-war period resulted from time inconsistency of the optimal policy. This idea, due to Kydland and Prescott [5] and Barro and Gordon [1], has recently been explored by Ireland [4]. I will interpret the time inconsistency hypothesis as a non-stationary value of u^3, the error term in the policy rule. If policy is the source of the common trend then, under the strict form of the rational expectations representative agent model, one would expect to observe the co-integrating vectors $i - \pi - \rho = 0$ and $U - \bar{U} = 0$. Once again, this contradicts the estimates in table 7 since the interest rate and inflation do not co-integrate with coefficients $\{1, -1\}$. Under the weak form of the aggregate demand hypothesis that replaces the Fisher equation with an IS curve, one would expect to observe the cointegrating equations $i - \pi - \rho - \psi U$ and $U - \bar{U} = 0$. This modification also falls foul of the data for the reasons explained below.

In the second sub-period, one cannot reject the hypothesis that unemployment is stationary since $a_2 = 0$ falls just within two standard error bands of the estimated point value of -0.06. This implies that the natural rate hypothesis has some chance of success, at least after 1982, since one cannot reject that $\{1, 0, -\bar{U}\}$ is the unemployment-inflation cointegrating vector. The first sub-period is still a problem since the point estimate of a_2 is -0.15 and 0 is more than two standard errors away from this value. But even if one were to accept that unemployment is stationary, one would still reject the complete model. If unemployment is stationary and if the common trend in the model arises from non-stationary policy, the Fisher equation should hold as a co-integrating equation. In other words, one would expect to find that the interest rate and inflation co-integrate with coefficients $\{1, -1\}$. As explained above, this hypothesis is rejected in both sample periods.

8.3 Drift in Aggregate Demand Can Explain the Common Trend if One Drops the Natural Rate Hypothesis

As a final possibility, suppose that the error term u^1 is non-stationary. This assumption implies that the common trend in data arises from drift in the aggregate demand equation. If one maintains the natural rate hypothesis, the co-integrating relationships should be $U - \bar{U} = 0$, and $i - \alpha\pi + \beta U + \gamma_0 = 0$. Once again, this hypothesis is rejected by evidence from the first sub-period. During this period there is evidence of a co-integrating relationship between unemployment and the inflation rate with a co-efficient on inflation that is significantly different from zero. In the second sub-period, one cannot reject the hypothesis that unemployment is stationary. This case is consistent with the natural rate hypothesis since the cointegrating relationship between inflation and the interest rate is given by the vector $\{1, -2.3\}$ which could arise from a policy rule in which the Fed aggressively fights inflation.

Taken on its own, one could accept that the post 1982 data is consistent with the natural rate hypothesis, particularly if one had strong priors in this direction. But the pre 1982 evidence is inconsistent with this hypothesis and it is somewhat unsatisfactory to have an explanation of the facts that only works for subperiods of the data. The title of this paper, natural rate doubts, arises from the fact that there is an alternative to the natural rate hypothesis that fits the evidence somewhat better.

In a class of models, put forward by Benhabib and Farmer [2], the Phillips curve is replaced by a long run aggregate supply relationship between unemployment and real balances. Since high inflation economies are ones in which agents choose to hold less real balances, this class of models predicts a positively sloped long run Phillips curve. In Benhabib-Farmer economies, the natural rate hypothesis (12) would be replaced, in the long-run, by an equation of the form

$$U - \bar{U} = \theta\pi.$$

The Benhabib-Farmer model has the same problems explaining data as the natural rate model if the common trend arises from aggregate supply or from policy. But if aggregate demand is the source of non-stationarity, the model can explain both co-integrating vectors. In addition it can account for the shift in direction of the drift in inflation before and after 1982 and for the shift in the co-integrating vector at the date of the change.

Suppose there exists a long-run positively-sloped Phillips curve and suppose further that the common trend in all three series arises from a non-stationary shock to the aggregate demand equation. In this case one would expect to see two co-integrating vectors. One is $U = \bar{U} + \theta\pi$, (the long-run aggregate supply curve) and the other is $i = \alpha\pi - \beta U + \gamma_0$ (the policy rule). According to this interpretation of the data the stable cointegrating vector between unemployment and inflation is evidence of a stable long run supply relationship between inflation and unemployment with a slope of approximately 0.1, (a figure that averages the pre and post 1982 estimates of a_2).

Evidence in support of the hypothesis of a stable upward sloping long-run Phillips curve can be found in figure 5 which plots estimates of the unemployment-inflation cointegrating parameters for the pre and post 1982 periods, together with 2-standard error bands. This evidence indicates support for the hypothesis that the pre-war estimate of $a_2 = -0.15$ is insignificantly different from the post-war estimate of $a_2 = -0.06$.

Under the upward sloping Phillips curve hypothesis, the interest rate-inflation co-integrating vector is the policy rule. This co-integrating relationship has coefficients on the interest rate and inflation of $\{1, -(\alpha + \beta\theta)\}$ and the parameters α and β cannot be separately identified. One can, however, infer from the fact that $\alpha + \beta\theta$ increased from -0.57 to 2.3 that a combination of the response of the Fed to unemployment and inflation, by raising or lowering the interest rate, was much more aggressive after 1982 than before.[1]

In addition to explaining the co-integrating relationship before and after 1982, the upward sloping Phillips curve hypothesis has a second attractive feature. It explains why inflation reversed direction at the point of the policy shift in 1982. To see how this explanation works, notice that the long-run behavior of inflation is governed by the equation

$$i - \pi - \rho = u^1$$

where u^1 has a unit root. But inflation and the interest rate are co-integrated with co-integrating vector $\{1, -\alpha_1\}$ where $\alpha_1 \equiv \alpha + \beta\theta$. It follows that the long-run behavior of inflation is governed by the equation

$$\left(\frac{1-\alpha_1}{\alpha_1}\right)\pi = \rho + u^1.$$

[1]This interpretation of the change in the relationship between the interest rate and inflation, as a change in Fed policy, is by now widely accepted. See, for example, the paper by Clarida Gali and Gertler [3]. What is novel in my analysis is the recognition that this coefficient is identified by a cointegrating relationship in a model in which there is a non-stationary aggregate demand curve.

Suppose that u^1 has a unit root and is drifting over time. Then inflation will also be a unit root process with drift; but the direction of the drift in inflation will depend on the magnitude of α_1. If α_1 is less than one in absolute value, as it was before 1982, inflation and u^1 will move in the same direction. If it is greater than 1, as it was after 1982, π and u^1 will drift in opposite directions. Hence the model in which there is a long-run Phillips curve can explain the cointegrating relationships between the variables, and the change in the direction of the drift, by invoking a single policy change in 1982. In my view, this explanation of events is more compelling than explanations that invoke the natural rate hypothesis and it is this fact that leads to my "natural rate doubts".

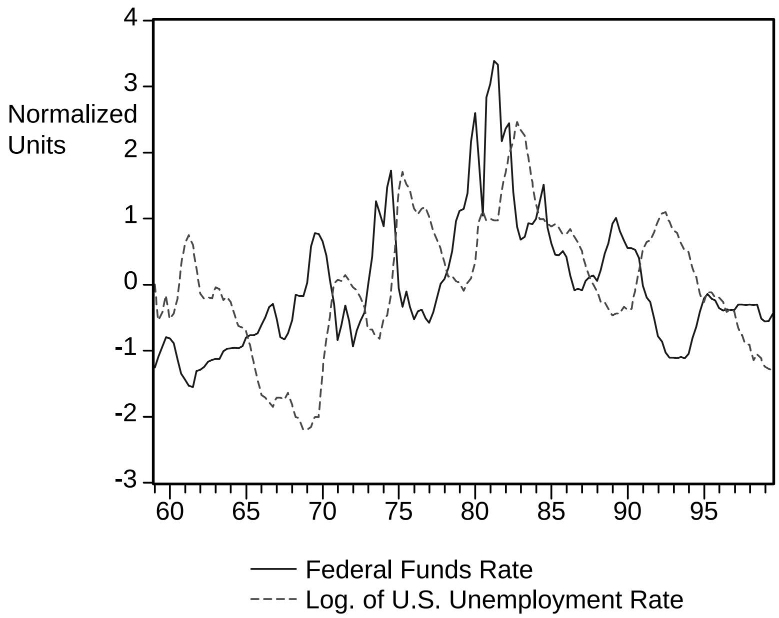
9 Conclusion

In summary, there is strong evidence that the inflation rate, the unemployment rate and the nominal interest rate are non-stationary in U.S. data from 1959 through 1999. There is further evidence of two co-integrating equations, one between the interest rate and the inflation rate and a second between unemployment and the inflation rate. The first cointegrating equation displays a much larger response of the interest rate to inflation after 1980 than before 1980. The second has been stable over the entire period studied.

It is frequently pointed out that the unemployment rate is a bounded variable and cannot be described by a random walk. This criticism is logically correct but irrelevant since unemployment may well behave approximately as a random walk over the period of interest. It may also be pointed out that formal tests have little power to distinguish a unit root from a stationary process with a root close to one. This second point is also correct, but when roots are close to one, a mis-specified model that assumes an I(1) process may be a good approximation to the data generating process. Errors of inference introduced by this mis-specification are unlikely to be serious. If the true process is non-stationary, on the other hand, mis-specification bias from assuming stationarity can lead to serious errors of inference. For these reasons, the assumption of a cointegrated system should be taken seriously as a parsimonious description of the data.

Given that one accepts this statistical representation of the data, how might one respond to the evidence? In the paper I have made two separate claims, both based on the assumption that one should seek a common cause for the break in data that appears in 1980. The first is that the source of non-stationarity in the data is a unit root in the shock to the aggregate demand equation. The second is that the natural rate hypothesis is false. If one is willing to accept the coincidental and simultaneous change in two different structural equations, then my arguments break down. For example, the trend in the inflation rate may have been caused by a Fed policy that reversed itself in 1980 at the same time that fundamental factors caused a reversal in the upward trend in unemployment.

The claim for non-stationarity in the aggregate demand equation is the stronger of my two claims. It is based primarily on the absence of a Fisher relationship over the two subperiods. Alternative explanations are possible. For example, the price index may be mis-measured and should perhaps include an index of the prices of imported goods. But given the maintained assumptions of the model, it is difficult to see where else to place the source of non-stationarity. Evidence against the natural rate hypothesis is weaker, and one cannot reject the hypothesis that unemployment is stationary in the post 1980 period. But if one seeks a common explanation of the entire period, the interpretation of an upward sloping long-run Phillips curve is more plausible. The Benhabib-Farmer model is one possible explanation of a micro-based theory with this property, but there are others that are equally well rooted in rational behavior by individual agents. Rejection of the natural rate hypothesis should not lead us to give up on rational choice. The evidence suggests however, that we should be skeptical of theories that incorporate superneutrality as a maintained assumption of an economic model.


Normalized Units
Federal Funds Rate
Log. of U.S. Unemployment Rate

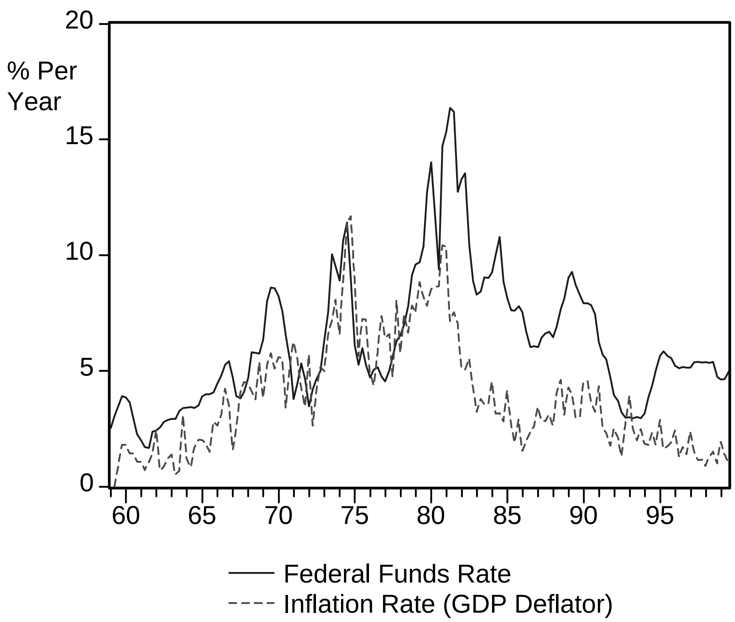

% Per Year
Federal Funds Rate
Inflation Rate (GDP Deflator)

Figure 1

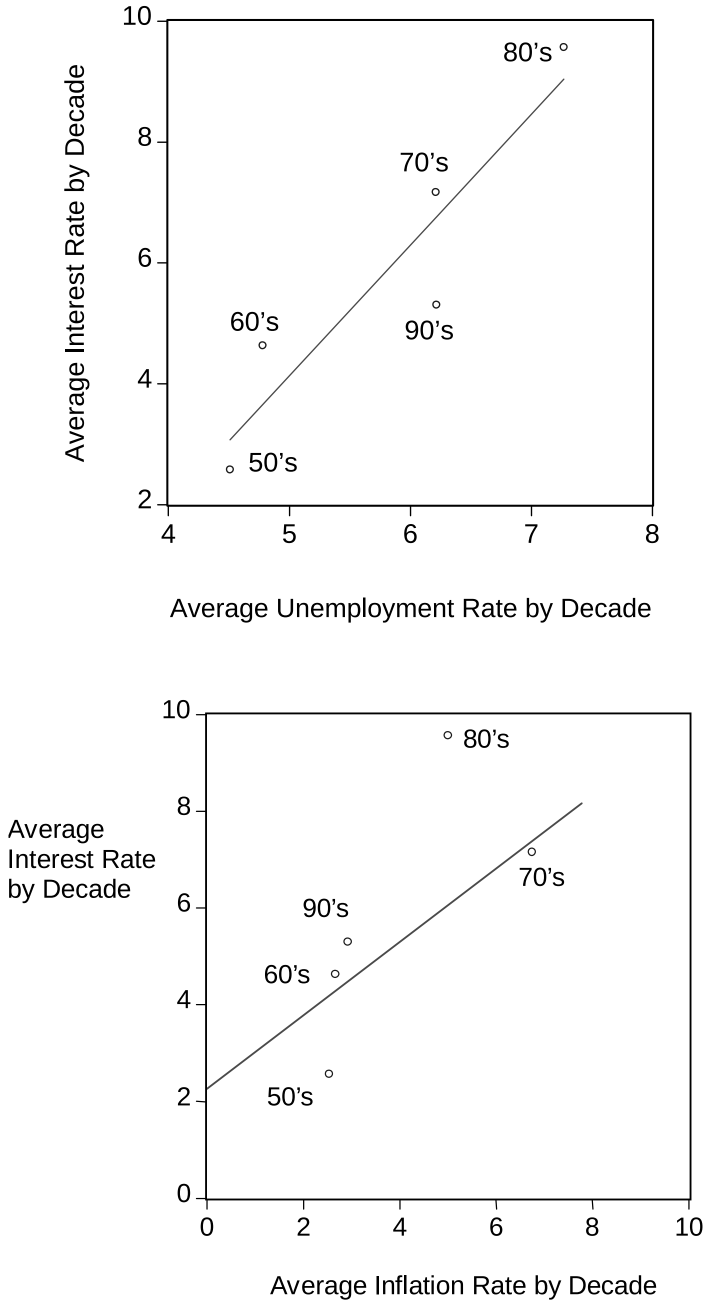

Average Interest Rate by Decade
Average Unemployment Rate by Decade
50's
60's
70's
80's
90's
Average Interest Rate by Decade
Average Inflation Rate by Decade
50's
60's
70's
80's
90's

Figure 2

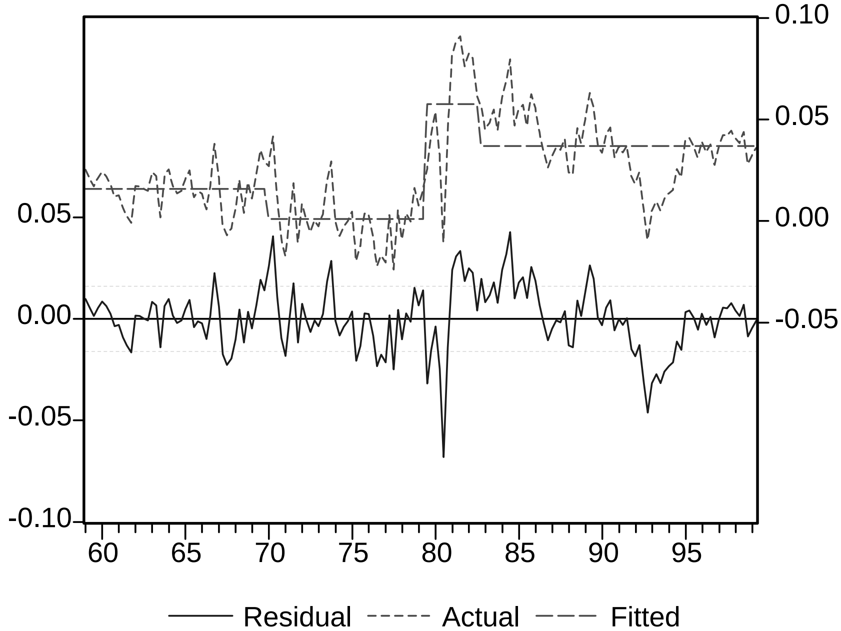

0.10
0.05
0.00
-0.05
0.05
0.00
-0.05
-0.10
60
65
70
75
80
85
90
95
Residual
Actual
Fitted

Figure 3

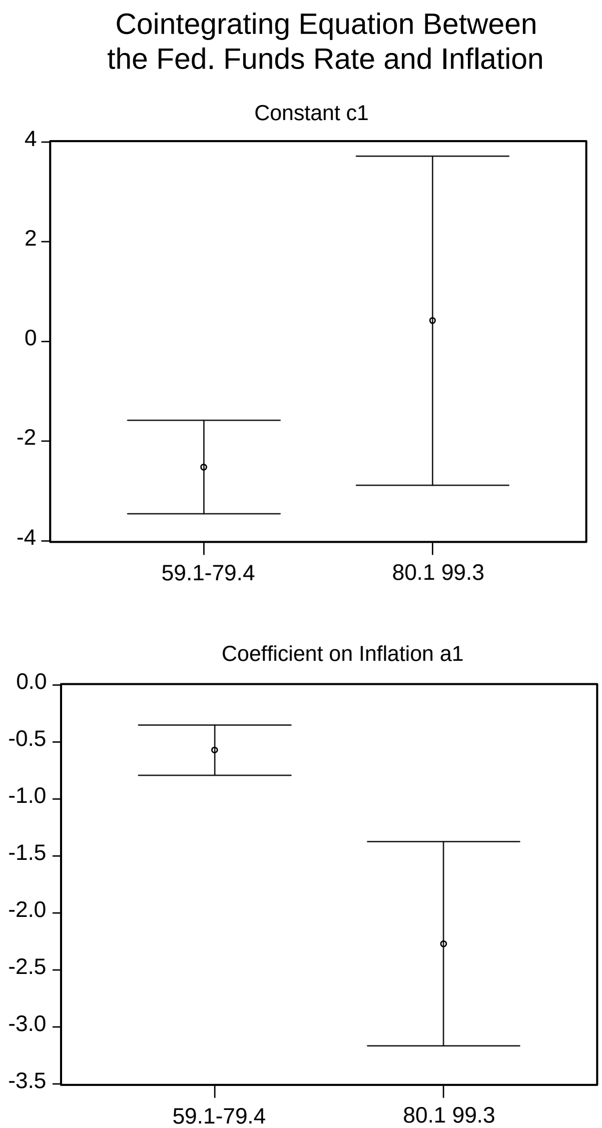

Cointegrating Equation Between
the Fed. Funds Rate and Inflation
Constant c1
4
2
0
-2
-4
59.1-79.4
80.1 99.3
Coefficient on Inflation a1
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
59.1-79.4
80.1 99.3

Figure 4

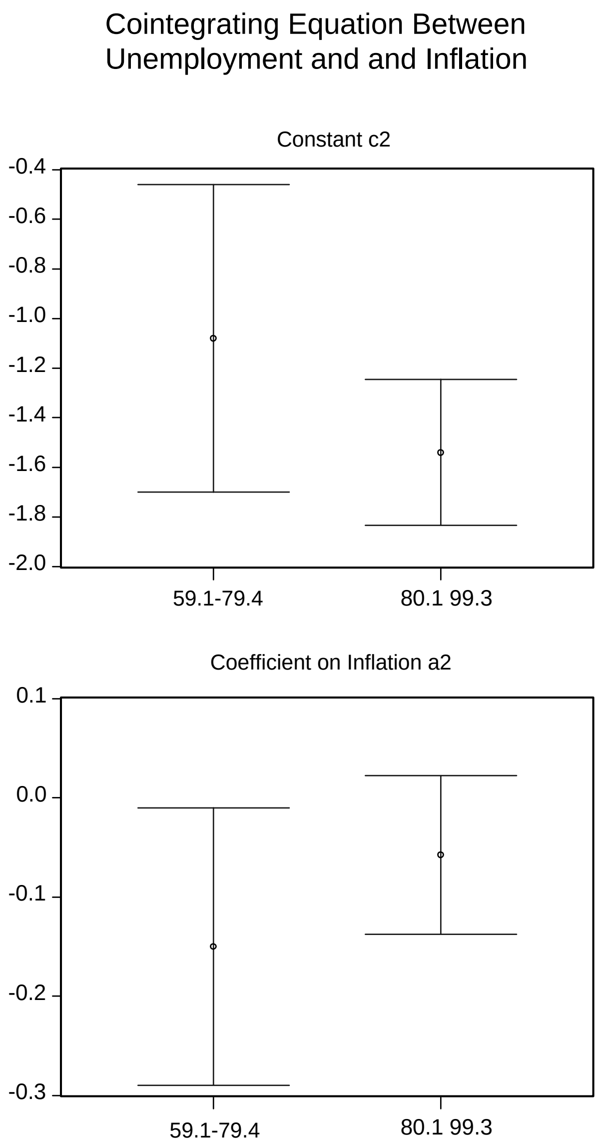

Cointegrating Equation Between
Unemployment and and Inflation
Constant c2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
59.1-79.4
80.1 99.3
Coefficient on Inflation a2
0.1
0.0
-0.1
-0.2
-0.3
59.1-79.4
80.1 99.3

Figure 5

Table 1:	ADF Test Statistic	Whole Sample 59.1 99.3
Inflation Interest Rate Unemployment	-1.749322 -2.945355 -2.058254	1% Critical Value -3.4715 5% Critical Value -2.8792 10% Critical Value -2.5761

	ADF Test Statistic	Sub Period 59.1 79.4
Inflation Interest Rate Unemployment	-1.302998 -1.186703 -2.106276	1% Critical value -3.5092 5% Critical Value -2.8959 10% Critical Value -2.5849

	ADF Test Statistic	Sub Period 80.1 99.7
Inflation Interest Rate Unemployment	-1.982781 -1.639029 -1.374947	1% Critical value -3.5142 5% Critical Value -2.8981 10% Critical Value -2.5680

Table 2:	Real Interest Rate
1959.3 – 1970.1	1.6%
1970.2 – 1979.3	0.1%
1979.4 – 1982.2	6.7%
1982.3 – 1999.3	4.6%

Table 3:	*i*	*U*	π	*Constant*
	1	0	a_1	c_1
	0	1	a_2	c_2

Table 4 Sample1959:1 1979:4

Lags interval: 1 to 2:

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.341886	45.09370	34.91	41.07	None **
0.113389	11.62357	19.96	24.60	At most 1
0.024638	1.995697	9.24	12.97	At most 2

Normalized Cointegrating Coefficients: 2 Cointegrating Equation(s)

Fed. Funds Rate	Unemployment	Inflation	Constant
1.000000	0.000000	-0.574696	-2.523327
		(0.11268)	(0.47236)
0.000000	1.000000	-0.155720	-1.084707
		(0.07550)	(0.31653)

Table 5

Sample1980:1 1999:3
Lags interval: 1 to 2:

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.388743	57.07889	34.91	41.07	None **
0.120510	18.19213	19.96	24.60	At most 1
0.096851	8.047512	9.24	12.97	At most 2

Normalized Cointegrating Coefficients: 2 Cointegrating Equation(s)

Fed. Funds Rate	Unemployment	Inflation	Constant
1.000000	0.000000	-2.271630	0.423117
		(0.44886)	(1.65211)
0.000000	1.000000	-0.057736	-1.549507
		(0.04006)	(0.14745)

Table 6

Sample1959:1 1999:3
Lags interval: 1 to 4:

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.113183	32.29676	34.91	41.07	None
0.048443	13.43845	19.96	24.60	At most 1
0.035302	5.642535	9.24	12.97	At most 2

Normalized Cointegrating Coefficients: 2 Cointegrating Equation(s)

Fed. Funds Rate	Unemployment	Inflation	Constant
1.000000	0.000000	-1.353125	-1.096836
		(0.57469)	(2.41282)
0.000000	1.000000	-0.160312	-1.123353
		(0.05017)	(0.21063)

Table 7		Fed Funds Rate	Unemployment	Inflation	Constant
1959.1-1979.4	First Equation.	1	0	-0.57 (0.11)	-2.5 (0.47)
	Second Equation.	0	1	-0.15 (0.07)	-1.08 (0.31)
1980.1-1999.3	First Equation.	1	0	-2.27 (0.45)	0.42 (1.65)
	Second Equation.	0	1	-0.06 (0.04)	-1.5 (0.14)

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