Monetary Policy Rules in Zero Nominal Interest Rate Environments: Exiting the Zero Bound

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Abstract:

The zero bound of nominal interest is known as a liquidity trap, where expansions in the monetary base no longer are effective in lowering the nominal interest rate. This takes away the main tool of traditional monetary policy, and eliminates the ability of monetary policy to stabilize economic conditions. It has been noted that monetary policy rules, such as the Taylor Rule, fail in this situation. The Federal Reserve of the United States solved this problem by massively increasing the monetary base even after the zero bound was reached. Yet another problem loomed even as the economy began to stabilize: when should interest rates rise? This paper seeks to show whether or not monetary policy rules can be an effective tool in addressing when interest rates should be increased coming out of a zero bound environment. An augmentation of the Taylor (1993) rule from Clark (2012) was used in tandem with a vector autoregression analysis based on the Clark (2012) rule.

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I. Introduction:

The course of monetary policy strategy has evolved greatly from its roots. It has been influenced by changes in the political environment, and has influenced it in return. For the last ten years, the primary monetary policy setters of the world, including the European Central Bank, the Bank of Japan, and the Federal Reserve of the United States have faced challenging decisions. These challenges were highlighted by the 2007 financial crisis.

All major central banks were affected by the global crisis, and they all eventually faced the same question: how can the economy be further stimulated with zero nominal short term interest rates?

Although different central banks have taken different approaches to solving the zero bound limit problem, their difficulties underscore the weaknesses of traditional monetary approaches, such as those based on monetary policy rules. This paper seeks to utilize the considerable literature on monetary policy rules, as well as analyses of Fed responses to the financial crisis to evaluate the effectiveness of monetary policy rules in exiting a zero bound interest rate scenario.

As Poole (1999) notes, monetary policy tactics did not differ significantly from the 1960s to the 2000s. Indeed, even quantitative easing was a form of traditional open market operations, albeit with different goals, and a much different scale. That said, the Fed still essentially uses an interest rate target to manipulate the economy.

The Fed's goals of price stability and full employment have not always been effectively met with the use of open market operations. Poole (1999) analyzes this problem, concluding that there is no guarantee of maintaining price stability using open market operations.

Although implementation of Fed policy has been relatively consistent, its strategy has seen dramatic shifts. The dual mandate was officially incorporated into the Federal Reserve Act in 1977. Since that date, several shifts have occurred to and from a monetary policy rule based strategy. For example, Taylor (2007) shows that the Fed held interest rates lower than an interest rate feedback rule would have suggested. Taylor (2007) goes on to conjecture that these lower rates may have contributed to the housing market bubble.

The results of such policy shifts are shown by Taylor (2013). Taylor (2013) found that the standard deviation of output in 1965-1984 was 3.6, and the standard deviation of inflation was 2.4. Taylor compared this period to "the Great Moderation" of 1984-2007, as well as comparing it to 2007-2012. It was found that during the Great Moderation both output and inflation became more stable. Output had a standard deviation of 1.5 and inflation had a standard deviation of 0.8. In the final period, output became highly volatile with a standard deviation of 5.4; while inflation remained stable with a standard deviation of 0.8.

The results of Taylor (2013) imply that although the Fed has improved in their attempts to stabilize prices, they have not achieved stability in output. Of course, stability in output is not necessarily desirable. Yet a lack of stability, coupled with slow growth of output is certainly concerning. The average annual growth rate of real GDP from 2007-2012 was only 0.8%. Paired with a high standard deviation of 5.4, this indicates that output was highly unstable. Taylor (2013) implicates that this instability was related to a change in monetary policy regime to a discretionary approach instead of a rules approach. Perhaps the poor output performance could be related to this shift as well.

Of course these data are highly skewed due to the Great Recession. This could indicate that there was not a major shift in Federal Reserve effectiveness even post Great Moderation, if the Great Recession was merely an exogenous shock, with no long term implications for monetary policy. Indeed it is possible that economic performance could have been significantly worse if not for the Fed's activist intervention. Too often in the literature, and in economic decision making, the possibility of a marked shift in the course of the economy away from a status quo is ignored.

Examples like those in Taylor(2013) may show the impact of structural breaks on the path of the variables that the Fed and others use to evaluate the state of the economy. This research is concerned with a possible structural break in the time series of the Federal Funds Rate as a result of the financial crisis of 2007-2008.

This paper seeks to evaluate the course of the variables that have traditionally been used to predict the path of the macro economy. In particular, this paper will examine the effectiveness of monetary policy rules in the presence of zero bound interest rates. Much literature already addresses this problem, as it was proven in Benhabib et al. (2001) that multiple equilibria occur at the zero bound for arbitrary interest rate feedback rules. However, given the actions of the Federal Reserve from 2008-2015, it is clear that a policy rule would be helpful as a guide of when to *raise* interest rates.

The literature cautions against the use of monetary policy rules in zero bound scenarios, but it virtual ignores the possibility of using them as a guide for exiting a zero bound scenario.

Empirically, a vector autoregression (VAR) method will be used to estimate impulse responses of monetary policy moves. A recent update of the rule that replaces Taylor's use of GDP's deviation from a trend with an unemployment gap in order to better proxy the output gap from Clark (2012) will be used.

The remaining pages of this research will begin with a literature review, followed by an overview of the data, and an econometric analysis. The paper will conclude with a discussion of results, implications, and areas for further study.

II. Literature Review:

Poole (1999) provides an overview of monetary policy rules. A particularly emphasized point Poole (1999) makes is that monetary policy rules must provide a stable groundwork to allow the public to form accurate expectations of monetary policy. According to Poole, this requires the designer of the monetary policy rule to first account for the influence of expectations. Further, Poole (1999) adds two additional requirements of an optimal monetary policy rule. The first is that the rule must have appropriate long run properties. A rule should not allow variables to explode upwards or downwards. The final qualification of a monetary policy rule, in the eyes of Poole (1999) is that it allows for markets to do most of the heavy lifting.

Of the monetary policy rules that most relate to a zero nominal interest rate environment it is interesting to note that the Friedman (1962) rule actually recommends zero nominal interest. This rule was designed such that inflation is minimized, due to the welfare concerns that were also raised by Friedman (1969). Unfortunately, it does not deal with the possibility of persistent deflation crippling the economy such as occurred in Japan's lost decade, or in the Great Depression.

The rule[1] of Taylor (1993) was formulated with these objectives in mind to some extent, although it is perhaps more activist in nature than Poole (1999) would recommend. Taylor (1993) came to be the de facto monetary policy rule against which others are judged. Yet even Taylor (1993) admits some of the weaknesses of monetary policy rules. Namely, transitioning into or out of a monetary policy rule is much more difficult than conceiving of one. Taylor (1993) gives an example of one such scenario. If the inflation level needs to be adjusted to a new equilibrium (Taylor gives the example of 5% to 2%) then the side effect of the transition would be disinflation. More importantly, Taylor(1993) notes that a basic assumption of monetary policy rules is rational expectations. Although this assumption holds in the presence of a stable, predictable, monetary policy rule, it is too strong an assumption for transition periods. People may not yet be able to factor a new monetary policy rule into their decision making process. Indeed, there could be public questions on the permanence of the new rule. A failure of the rational expectations assumption is not merely an empirical problem, but rather a problem that would result in uncertainty in the economy.

The Taylor (1993) rule, also proved difficult to implement in practice, in part, because of the structure of macroeconomic data. Compared to quarterly data monthly data provide better forecasts. For this reason, literature such as Clark (2012) augmented the original rule, in order to provide a more responsive model. One major change from the Taylor (1993) rule to the Clark (2012) rule, is the substitution of the unemployment gap (U3 – NAIRU) for the GDP gap.

A major problem with monetary policy rules in general, is that they often fail to deal with unusual circumstances. Taylor (1993) notes that in response to crisis, discretionary policy takes control. That does not mean that absolute discretion should be favored all the time, instead, Taylor (1993) suggests that a monetary policy rule need not be formulaic in its application, and that any algebraic representation of a monetary policy rule is merely an attempt to give structure to the underlying concept of the rule.

[1] The Taylor Rule: $r_t = \pi_{t,t-4} + .5\frac{(y_t - y^*)}{y^*} + .5(\pi_{t,t-4} - 2) + 2$

Where: r = the federal funds rate

$\pi_{t,t-4}$ = four quarter average inflation

y_t = Real GDP

y^* = Trend Real GDP

What is not explicitly mentioned in either Taylor (1993) or Clark (2012) is the possibility of a liquidity trap. At the zero bound interest rate level (such as that seen in the federal funds rate from 2008 on) interest rates can no longer be adjusted downward to increase inflation.

Woodford and Eggertsson (2003) suggest that this is a failing of monetary policy rules in general, and that monetary policy rules will lead to a deflationary spiral in the presence of a liquidity trap. Benhabib et al. (2001) show that in the presence of zero bound rates, monetary policy rules have multiple equilibria, and do not consistently converge to an inflation rate.

III. Trend Analysis

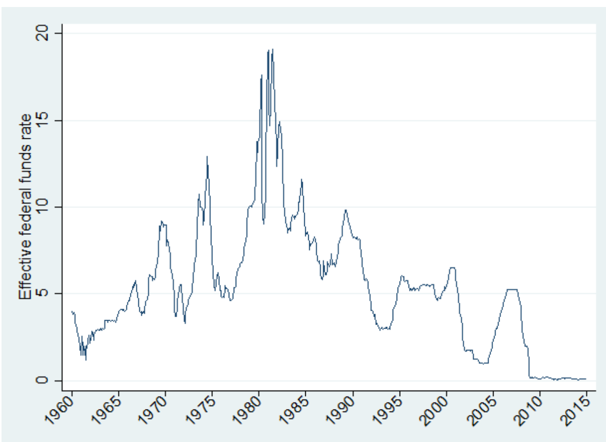

Figure 1: Effective Federal Funds Rate Time Series

Inflation faced a similar series of structural breaks. Especially noteworthy is the spike of inflation from 1973-1983. In this period, the mean was 7.73, compared to an overall mean of 3.43.

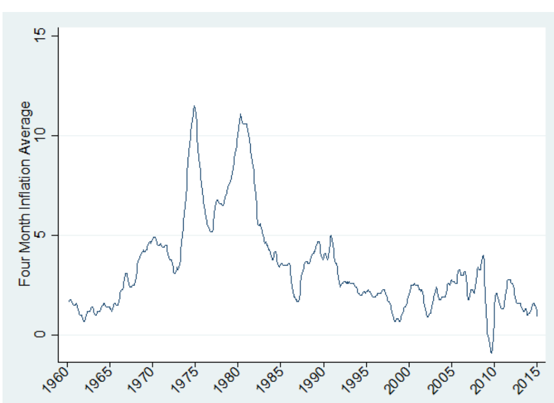

Figure 2: Inflation

The unemployment gap (NAIRU – U3) shows a slightly different story. Although recessions show up as dips and expansions show up as bumps, the variability of the series is relatively consistent throughout. Additionally, the mean does not shift drastically as it did in the other two series.

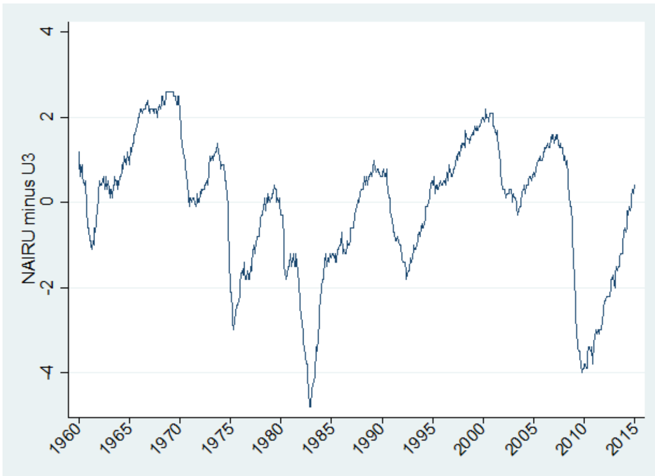

Figure 3: Unemployment gap

IV. Data

All macroeconomic data was recovered from its original sources. PCE inflation was acquired from the BEA, the Federal Funds Rate is from the Federal Reserve, and the U3 unemployment rate is from the BLS.

V. Empirical Model

The monetary policy rule comes from Clark (2012).

$$r_t = .8r_{t-1} + .2(2 + \pi_{t,t-4} + .5(\pi_{t,t-4} - 2)) + 2(6 - U_t)$$

Monetary rules like this one have been criticized as being too simplistic to be useful in setting monetary policy. Indeed, although the Greenspan era more or less followed the Taylor rule, the Fed abandoned a rules based approach as soon as difficult decisions presented themselves. The Greenspan era, and the Great Moderation that followed seemed to show that the Fed had "solved" monetary policy. The 2007-2009 crisis and the Fed's often ad-hoc response to it show that this hypothesis is false. Now the Fed has adopted an entirely discretionary approach, coupled with forward guidance to address future expectations in the same way that a monetary policy rule is designed to.

Empirically, the question of a rules based approach comes down to the simple question: can a monetary policy rule provide enough information to guide policy decision, while remaining transparent enough to address expectations? The below models are designed to answer such a question.

Woodford (2001) notes that a monetary policy rule has a long run equilibrium if and only if it has a stationary error term. In order for VARs of the above rule to have stationary error terms, the variables must be individually stationary.

Via trend analysis, it is easy to see that the above variables are not stationary. However for formal proof the augmented Dickey Fuller (ADF) test from Dickey and Fuller (1979) will be used to test each variable for unit roots.

The first variable of interest is the federal funds rate. Since the data has 661 observations, a maximum lag length of 19[2] will be used in lag length selection criteria functions. The SBIC recommends a lag length of 14 for the federal funds rate.

The ADF test uses the following specification in the case of the Federal funds rate, where *r* is the federal funds rate:

$$\Delta r_t = \alpha + \rho r_{t-1} + \delta t + \sum_{j=1}^{14} \varphi_j \, \Delta r_{t-j} + e_t$$

Using a lag length of 14 in the ADF test yields a statistic of -2.43, with a 5% critical value equal to -2.86, and a 10% critical value of -2.57. Therefore, the ADF test fails to reject the null that there is unit root. The federal funds rate is not stationary.

The other two variables follow the same specification as the one above, except that the adjusted unemployment rate (NAIRU – U3) has a lag length of 5, and the 4 month inflation rate has a lag length of 15. The ADF statistic of the 4 month inflation rate is -2.50 with the same critical values as above. Again the ADF test fails to reject the null that there is unit root, implying that like the federal funds rate, 4 month average inflation is also non-stationary. The ADF statistic of the adjusted unemployment rate is 3.36, with critical values identical to the first two tests. This third test rejects the null, indicating that adjusted unemployment *is* stationary.

These results a major problem: the error term of a vector autoregression that combines the three variables will not be stationary. In matrix form, the specification in question is:

$$\begin{bmatrix} r_t \\ \pi_t^{4m} \\ u^*{}_t \end{bmatrix} = \begin{bmatrix} A_{10}(L) \\ A_{20}(L) \\ A_{30}(L) \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} r_{t-1} \\ \pi_{t-1}^{4m} \\ u^*{}_{t-1} \end{bmatrix} + \begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix}$$

The vector $\begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix}$ will not be stationary because of the unit roots found in the federal funds rate and inflation rate. One option to correct this problem is estimate the system of equations in first differences.

$$\begin{bmatrix} \Delta r_t \\ \Delta\pi_t^{4m} \\ \Delta u^*{}_t \end{bmatrix} = \begin{bmatrix} A_{10}(L) \\ A_{20}(L) \\ A_{30}(L) \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} \Delta r_{t-1} \\ \Delta\pi_{t-1}^{4m} \\ \Delta u^*{}_{t-1} \end{bmatrix} + \begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix}$$

The next issue is one of lag length selection for the first differences VAR. To do this, again a maximum number of lags of 19 will be used for selection criteria, but all three variables will be tested at once. This results in an SBIC recommendation of three lags. However the HQIC recommends six lags, and the AIC and FPE recommend 17 lags. Both the SBIC and HQIC recommendations are feasible, but 17 lags would use many more observations. That said, all three models will be estimated and discussed.

Therefore, the standard form VAR model can be represented algebraically:

[2] This value was determined with the formula $12(T/100)^{1/4}$ where T=number of observations.

$$\Delta r_t = \alpha_{10} + \sum_{j=1}^{l} \alpha_{11}\Delta r_{t-j} + \sum_{j=1}^{l} \alpha_{12}\Delta\pi_{t-j}^{4m} \sum_{j=1}^{l} \alpha_{13}\Delta u^*{}_{t-j} + e_{1t}$$

$$\Delta\pi_t^{4m} = \alpha_{20} + \sum_{j=1}^{l} \alpha_{12}\Delta\pi_{t-j}^{4m} + \sum_{j=1}^{l} \alpha_{11}\Delta r_{t-j} + \sum_{j=1}^{l} \alpha_{13}\Delta u^*{}_{t-j} + e_{2t}$$

$$\Delta u_t^* = \alpha_{30} + \sum_{j=1}^{l} \alpha_{13}\Delta u^*{}_{t-j} + \sum_{j=1}^{l} \alpha_{11}\Delta r_{t-j} + \sum_{j=1}^{l} \alpha_{12}\Delta\pi_{t-j}^{4m} + e_{3t}$$

Where *l* is equal to the number of lags in the model.
To verify the stability of the model, the unit circle of eigenvalues should also be examined:

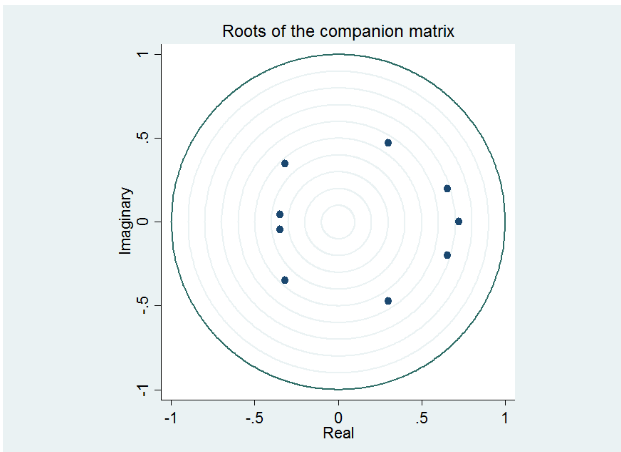

Figure 4: Eigenvalues root test

Here it can be seen that the roots are within the unit circle. Therefore the VAR is stable under this condition.

The first differenced VAR however, does throw away any long term trending relationship. Instead, a Vector Error Correction Model could be used. This would require additional assumptions to be satisfied however. Although a VECM does not require the variables to be stationary, it does require them all to be I(1) and cointegrated. Since one of the variables in our system is I(0), this option is not available to us unless unemployment instead of an unemployment gap is used. Due to the importance of a possible long term equilibrium between the variables, they will be tested via the method shown by Engle and Granger (1987).

The first step, to test the variables individually with the ADF test, was completed above. However, since NAIRU minus U3 was found to be stationary, it is necessary to try to find another I(1) variable instead. U3 by itself is also found to be stationary with the ADF test and 3,5 or 6 lags. Therefore, because there is no way to ensure all three variables are I(1), a VECM should not be used.

than the first. Analysis of this question requires a return to the assumption of stationarity. First differencing the variables is designed to induce stationarity. A visual analysis may help connect this to the idea of structural breaks.

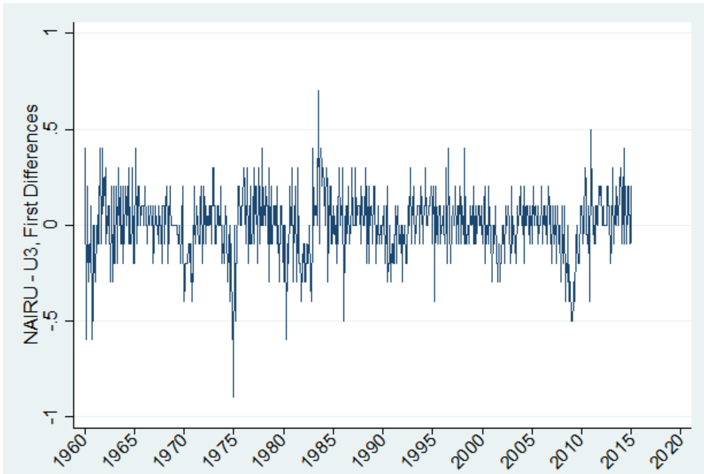

Figure 5: First Differenced Unemployment Gap

There does not appear to be any structural breaks in the first differences of the adjusted unemployment rate. However, the first differences of the federal funds rate do show a violation of the stationarity condition that variance should be constant throughout the series. Three regimes of variance are evident in the time plot of the first differenced rate. This suggests structural breaks in the late 1970s and the early 1990s. Although the ADF tests on the first differences reject the unit root null hypothesis, Ender (2004) recommends the use of the unit root test from Zivot and Andrews (1992) in the presence of possible structural breaks.

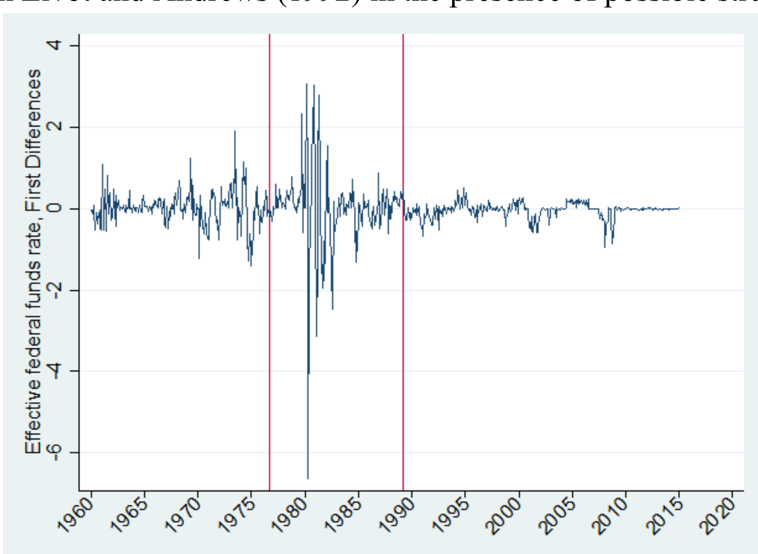

Figure 7 shows that first differenced inflation appears to be stationary, which confirms the finding of the regular ADF test. The Zivot and Andrews (1992) will be used on only the

Federal Funds Rate, with the intuition that because the FFR may have exogenous influences (i.e the Federal Reserve's policy responding to expectations rather than data).

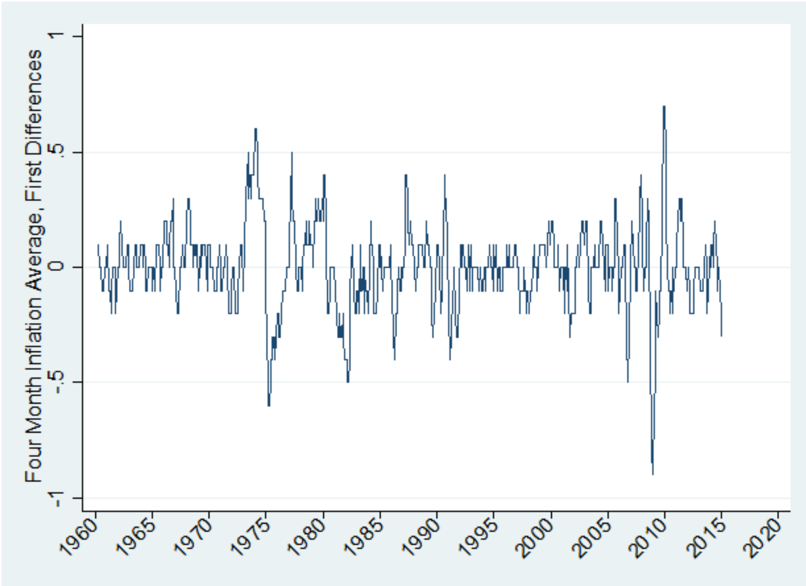

Figure 7: First Differenced Inflation

Following the example of Benhabib et al. (2001), suppose a Fisher equation, with nominal interest i as a function of an interest rate rule $i(rule) = r + \pi$ is the steady state. Given that the monetary policy rule contains inflation as a variable, if the nominal rate is set equal to zero, either both real interest and inflation must be individual equal to zero, or one of the two variables must be negative. If inflation is negative, but real interest is positive, then the nominal rate cannot have any of the intended simulative effects of a lower real interest rate.

Therefore, in order for our monetary policy rule to be useful in explaining when to raise nominal interest, it must first be shown that the economy is not in a state of deflation. To show this, a return to the Clark (2012) is useful.

$$r_t = .8r_{t-1} + .2(2 + \pi_{t,t-4} + .5(\pi_{t,t-4} - 2)) + 2(6 - U_t)$$

Plugging in values to the rule for a zero bound interest rate scenario, with negative inflation of -0.5:

$$0 = .2(2 - .5 + .5(-.5 - 2)) + 2(6 - U)$$

Where U would solve to be 6.05%. This would imply that when the unemployment level reached below 6.05, the Federal Reserve should raise the nominal interest rate. Raising the interest rate to 1% will result in an inflation rate of 8% given an unemployment gap of zero. This shows tremendous inflationary pressure to raising the interest rate off of the zero bound. Compared to VAR analysis, the monetary policy rule may not provide enough time sensitive information to policy makers. A monetary policy rule is very sensitive to its algebraic form.

Additionally, monetary policy rules cannot take into account the effects of past decisions on current ones. Further evidence of the weakness of a simple monetary policy rule will be evident in the discussion of the results of the VAR models.

A more empirical approach can also be used in to show the reaction of inflation to an increase in the federal funds rate. This approach will use the impulse response functions of the VAR model that was derived earlier in this section.

Consider again the VAR in matrix form.

$$\begin{bmatrix} \Delta r_t \\ \Delta \pi_t^{4m} \\ \Delta u^*{}_t \end{bmatrix} = \begin{bmatrix} A_{10}(L) \\ A_{20}(L) \\ A_{30}(L) \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} \Delta r_{t-1} \\ \Delta \pi_{t-1}^{4m} \\ \Delta u^*{}_{t-1} \end{bmatrix} + \begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix}$$

By assigning values to the error vector, exogenous shocks can be simulated. For example if $\begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$ then an impulse of 1% has been placed on the federal funds rate. An impulse response function will then be able to show the response of the other variables to this shock. Even more interesting would be a possible shock to unemployment that could indicate a need to move away from the zero bound of nominal interest. If $\begin{bmatrix} e_{rt} \\ e_{\pi t} \\ e_{u^*t} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$ then the IRF will show the reaction of the system to a 1% movement of the unemployment gap in the positive direction. That is NAIRU – U3 will become more positive by 1%.

VI. Results

The first model was estimated with 2 lags, the second with 5. They all follow the general specification shown above where each variable is in first differences. Each column is one equation of a VAR. For example, the second column of table 1 has FFR on the left side as in the following specification:

$$\Delta r_t = \alpha_{10} + \sum_{j=1}^{l} \alpha_{11} \Delta r_{t-j} + \sum_{j=1}^{l} \alpha_{12} \Delta \pi_{t-j}^{4m} \sum_{j=1}^{l} \alpha_{13} \Delta u^*{}_{t-j} + e_{1t}$$

The results of the two lag model indicate that each variable strongly responds to lags of itself. Federal Reserve policy of late has largely taken advantage of this relationship. Due to the fact that the variables of interest are highly influenced by their own pasts, it is important that decisions about monetary policy take into account the recent past of each variable.

The response of the variables to their own lags also suggests that to some extent, changes in the variables are sticky. If changes in the variables depend mostly on their own pasts, change will on average, occur gradually.

Table 1: Results of VARs

	(1) D.FFR			(2) D.FFR		
	D_FFR	D_INF4M	D_unrate_adj	D_FFR	D_INF4M	D_unrate_adj
LD.FFR	0.397***	0.0168	0.00410	0.374***	0.0178*	0.00952
	(10.22)	(1.96)	(0.29)	(9.38)	(2.10)	(0.69)
L2D.FFR	-0.188***	0.00154	0.00924	-0.196***	-0.00114	-0.0199
	(-4.95)	(0.18)	(0.68)	(-4.64)	(-0.13)	(-1.35)
L3D.FFR				-0.0195	-0.00474	0.0210
				(-0.46)	(-0.52)	(1.40)
L4D.FFR				-0.125**	0.0136	-0.0158
				(-2.96)	(1.52)	(-1.07)
L5D.FFR				-0.0367	0.00820	-0.0210
				(-0.94)	(0.99)	(-1.54)
LD.INF4M	0.380*	0.896***	0.0237	0.408*	0.874***	-0.0103
	(2.15)	(22.91)	(0.37)	(2.27)	(22.84)	(-0.16)
L2D.INF4M	-0.270	-0.105**	-0.0358	-0.466*	0.0929	-0.0457
	(-1.54)	(-2.72)	(-0.57)	(-1.96)	(1.84)	(-0.55)
L3D.INF4M				0.261	-0.161**	0.0752
				(1.11)	(-3.22)	(0.91)
L4D.INF4M				0.0818	-0.255***	-0.0916
				(0.34)	(-5.04)	(-1.10)
L5D.INF4M				-0.0636	0.233***	0.000449
				(-0.36)	(6.18)	(0.01)
LD.unrate_adj	0.590***	0.0204	0.0898*	0.599***	0.00661	-0.00440
	(5.52)	(0.86)	(2.35)	(5.26)	(0.27)	(-0.11)
L2D.unrate_adj	0.0925	0.0380	0.271***	0.126	0.0141	0.216***
	(0.85)	(1.57)	(6.94)	(1.10)	(0.58)	(5.40)
L3D.unrate_adj				0.139	0.0347	0.172***
				(1.21)	(1.42)	(4.30)
L4D.unrate_adj				0.0892	0.00976	0.167***
				(0.78)	(0.40)	(4.19)
L5D.unrate_adj				0.0136	0.0248	0.0932*
				(0.12)	(1.01)	(2.32)
_cons	-0.00298	-0.000447	-0.0000582	-0.00373	-0.000258	-0.00000246
	(-0.16)	(-0.11)	(-0.01)	(-0.20)	(-0.07)	(-0.00)
N	655			652		

t statistics in parentheses

* p<0.05 ** p<0.01 *** p<0.001

The Federal Funds rate for example, which is controlled by the Federal Reserve, is generally held constant except in the presence of strong shocks to the economy. This has been seen as a way to promote price stability. By keeping interest rates predictable, it allows prices in the economy to remain predictable as well. Recently this has meant that without a significant inflation shock, interest rates have been held stable.

Interestingly, the Federal Funds rate responds more significantly to lagged unemployment gap changes than lagged inflation changes. This implies that the Fed considers full employment to be a more important indication of the state of the economy than inflation. It could also indicate that changes in inflation are in general more gradual, and a more gradual response from the Fed is optimal.

Since the main concern of the model is Fed policy, a more detailed discussion of each of the variables will continue by first looking only at the first equation of the first model:

$$\Delta r_t = \alpha_{10} + \sum_{j=1}^{l} \alpha_{11} \Delta r_{t-j} + \sum_{j=1}^{l} \alpha_{12} \Delta \pi_{t-j}^{4m} \sum_{j=1}^{l} \alpha_{13} \Delta u^*{}_{t-j} + e_{1t}$$

Where $\alpha_{10} = -0.00298$, $\alpha_{11} = \begin{bmatrix} 0.397 \\ -0.188 \end{bmatrix}$ (top is lag 1, bottom is lag 2), $\alpha_{12} = \begin{bmatrix} 0.380 \\ -0.270 \end{bmatrix}$, $\alpha_{13} = \begin{bmatrix} 0.590 \\ 0.0925 \end{bmatrix}$.

Both of the first two α_{11} lags are very highly significant in both models. The first lag is positive and the second is negative. This implies that an increase in the FFR last month will coincide with an increase this month. The second lag implies that an increase in the federal funds rate two months ago will lead to a decrease in the FFR this month. These two coefficients are reflective of a gradual approach to monetary policy, where changes to the federal funds rate are adjusted for on a month to month basis in order to keep the rate constant except for in the presence of strong exogenous shocks. Interestingly, in the five lag model, the fourth lag of the federal funds rate is also significant and negative. The explanation for this could lie in the fact that GDP is announced quarterly, and if current GDP is below the last GDP announcement the Fed may choose to react by lowering the federal funds rate if they had raised it at the time of the last GDP announcement. This reaction would be indicative of the Fed attempting to promote economic growth and full employment. Of course, at the zero lower bound none of these relationships are particularly meaningful.

The response of the federal funds rate to inflation reacts mainly to the most recent data on inflation. The Fed likely reacts only to recent data due to their preference for constant ~2% inflation. Reaction to stale data could result in an over adjustment where the inflation rate is pushed below a constant rate of 2%, leading to possible disinflationary effects. In the five lag model, the second lag is also significant but has the opposite sign. This gives further evidence that the Fed attempts on average to maintain a constant inflation rate. If the inflation rate's four month average increased last month, the model suggests that last month, the federal funds rate was raised. But if the four month average inflation rate increased last month and again this month, the implication is that the federal funds rate will rise, but by an amount that takes into account the fact that the rate was raised last month. At the zero lower bound there is no way that the last decision made by the Fed was to raise the FFR. This means that an increase in the four month average inflation rate can only lead to an increase in the federal funds rate.

The current four month average inflation rate does not respond particularly strongly to changes in the federal funds rate's rate of change. Although the first lag of the federal funds rate of change is significant at the 5% level, there are no statistically significant responses in any of the other lags. The variable does respond strongly to lags of itself however, implying that inflation gains momentum from its past changes.

Returning to the federal funds rate equation, which is analogous to a complicated monetary policy interest rate rule, the federal funds rate shows a statistically significant and positive response to an increase in the rate of change of a shrinking of the unemployment gap. The other lags are statistically insignificant.

In addition to the above analysis of the results of the VAR, impulse response functions were generated based on the five lag VAR to analyze the reaction of one of the variables to an increase in another. The IRFs pictured in figures 8, 9, and 10 are cumulative IRFs. They show the accumulated effect of an increase in the impulse variable.

Figure 8 shows several of the results already observed in the VAR statistical output, namely that the federal funds rate responds weakly to the initial impulse of inflation but strongly to unemployment. Changes in the rate of change of the unemployment gap appear to have strong and long lasting effects on the federal funds rate, even 8 months after the initial impulse.

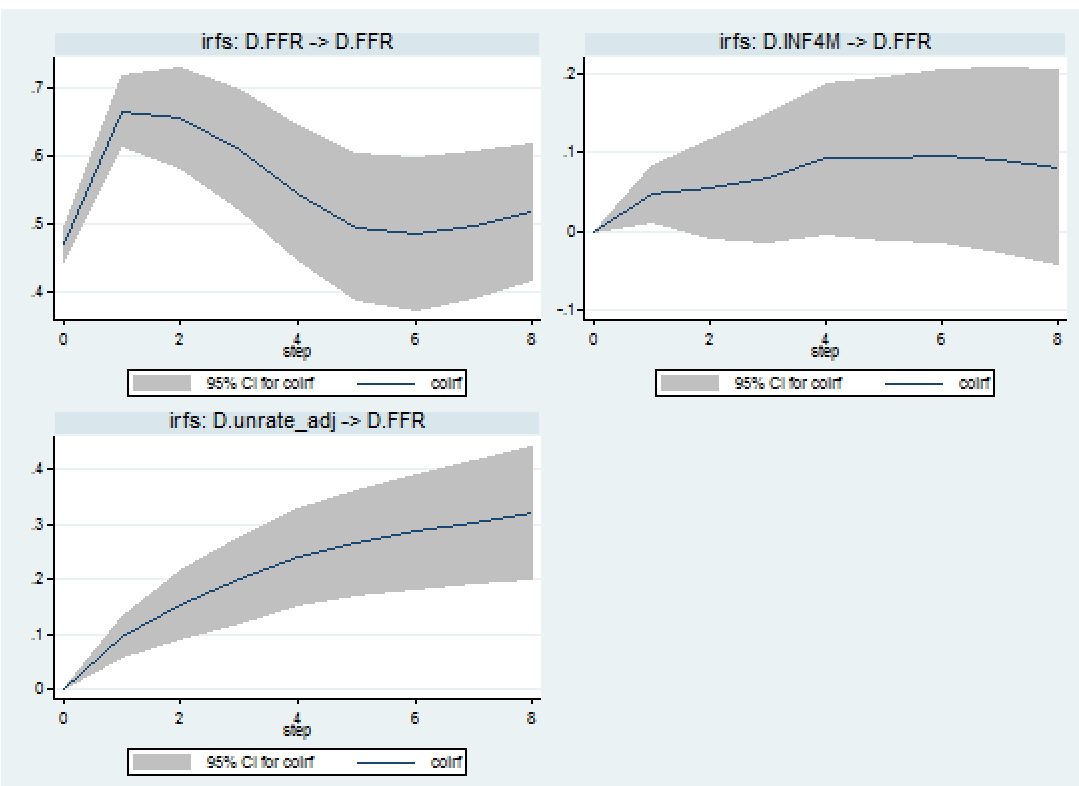

Figure 8: Cumulative IRFs for the Federal Funds Rate as the response variable.

The federal funds rate also appears to have a significant effect on itself. The IRF shows that the Fed's current decisions on the federal funds rate are impacted by their past decisions. This implies that the Fed attempts to make their decisions in a consistent manner in order to manage market expectations.

Figure 9 shows four month average inflation as the response variable. The very tight confidence interval of inflation as both the impulse and response shows that inflation is highly influenced by its own past, almost as if it has momentum. It takes nearly four months for the effects to level off. However, inflation shows a belated response to impulses of the FFR and the unemployment gap. It takes 2 months for a change in the federal funds rate to show up in the inflation rate and 6 for changes in the unemployment gap to even have a small effect on the four month average inflation rate. These results match up with what was observed in the VAR coefficients and provides evidence that reducing inflation through the federal funds rate requires a strong shock.

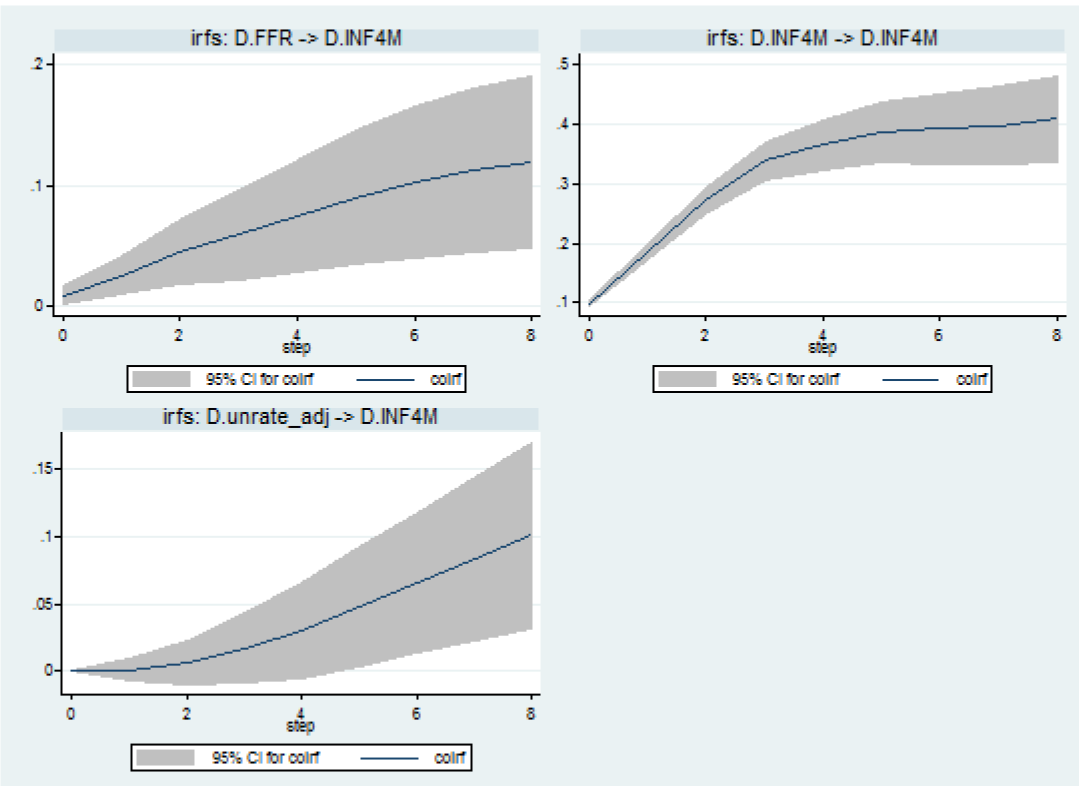

Figure 9: Cumulative IRFs for four month average inflation as the response variable

Figure 10 shows the unemployment gap as the response variable. Again it can be seen that the FFR does not have a strong effect. The cumulative effects after 5 months are statistically insignificant. That the effect of a federal funds rate impulse dies off after only 5 months shows how challenging it was for the Federal Reserve to attempt to use their traditional tool to improve employment conditions. The inflation rate appears to have a negligible effect on the unemployment gap. And much like the other two variables, the unemployment gap is highly sensitive to an impulse of itself.

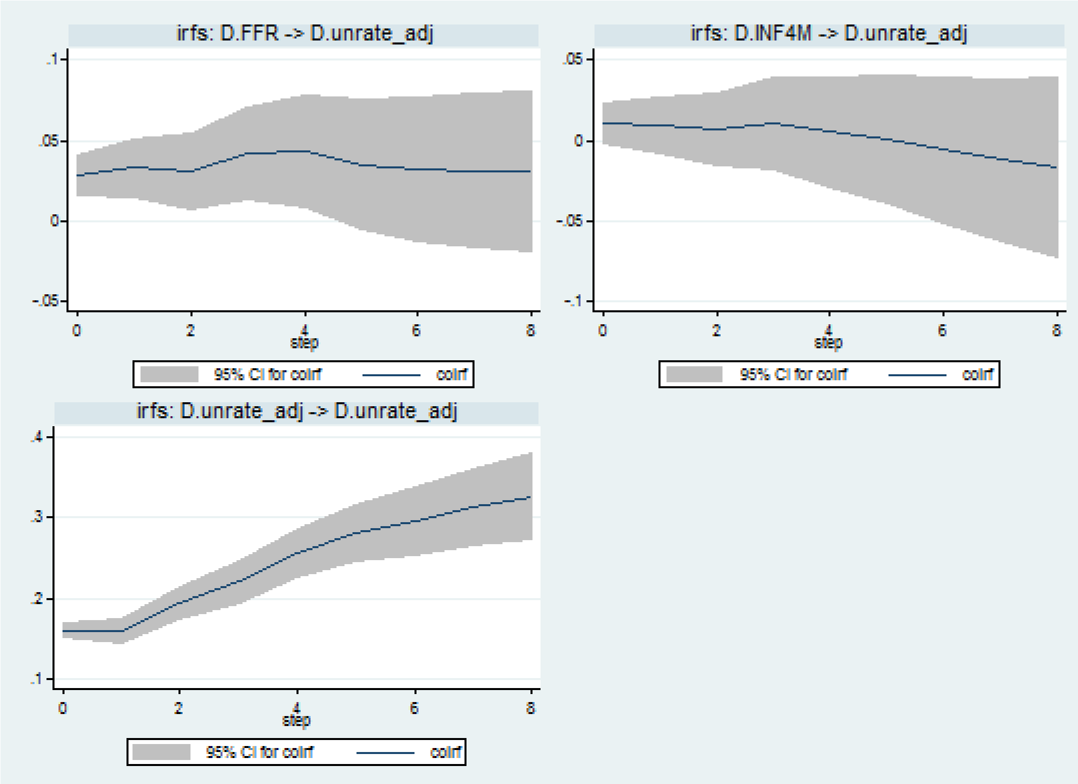

Figure 10: Cumulative IRFs for the Unemployment Gap as the response variable.

From the results of all three figures several conclusions about a possible structure of causality and what it means for monetary policy rules in the zero bound (and monetary policy rules in general) can be proposed. Unemployment and inflation both appear to be mainly determined exogenously to the model and then influence the federal funds rate. The federal funds rate reacts more strongly to employment conditions than price levels, yet it has no statistically significant long term effect on unemployment, and only a minor one on inflation. This perhaps calls into question the feasibility of the Federal Reserve's dual mandate. If the federal funds rate cannot significantly affect the unemployment gap, it seems imprudent to claim that monetary policy can address employment conditions.

Additionally, the results indicate a weak short term tradeoff between unemployment and inflation. The bottom left panel of figure 9 shows that the cumulative effects of a smaller unemployment gap are statistically insignificant until about five months after the initial impulse. The top right panel of figure 10 shows no statistically significant response in unemployment to an impulse of inflation. Since monetary policy rules rely on an assumption of a short term tradeoff between unemployment and inflation, the lack of evidence for such a tradeoff combined with the weak effects of the federal funds in the above results may suggest that monetary policy rules such as Clark (2012) or Taylor(1993) may not be able to effectively promote price stability and full employment. The greatest concern with a monetary policy rule, suggested by the above results, is that it may greatly overweight the importance of employment conditions on monetary policy decisions relative to inflationary pressure. Although the amount of slack in the unemployment gap can provide a good gauge on how much inflationary pressure exists, a sudden spike in inflation may be much more difficult for it to deal with.

Because the results suggest that a monetary policy rule performs slightly better at promoting price stability than full employment, the monetary policy rule will likely not perform any worse than it would otherwise at the zero lower bound. By using the unemployment gap as a guide for when to raise rates should allow a rule to perform well in predicting when to exit the zero bound, while pre-empting strong inflationary pressure.

VII. Conclusions

This research attempts to provide a connection between the existing literature on monetary policy rules with the issue of monetary policy at zero nominal short term interest rates. The evidence presented by the Vector Autoregression model shows the complexities that are faced by monetary policy makers. An oft overlooked challenge of monetary policy is making it transparent enough to have appealing properties for the management of market expectations. Monetary policy rules attempt to address this problem by providing a simple algebraic relationship between monetary policy and indicator variables.

What the results of this research show is that monetary policy rules may overlook the complexities to an unacceptable extent. Importantly, they do not account for the fact that changes in the federal funds rate are unable to affect employment conditions. The VAR model shows only a weak tradeoff between unemployment and inflation, as well as only weak effects of the FFR on inflation, and virtually no effect on unemployment. That said, at the zero lower bound, monetary policy rules may still have a use. Because monetary policy rules react more strongly to changes in unemployment even though they are not able to directly affect unemployment, it is possible that a monetary policy rule may be able to get out ahead of inflationary pressure. Whether or not this can happen before it becomes obvious to policy makers that interest rates should be raised is not directly observable in the results.

In reality, monetary policy makers must tradeoff the amount of information provided by a model with its transparency to the public. Since the current stance of the Federal Reserve tends towards a highly discretionary approach following the use of quantitative easing, it seems unlikely that simple monetary policy rules will return to service in the same fashion that they did during the Greenspan era. Despite the weaknesses of monetary policy rules, there still could be a place for them if they are allowed to account for the inability of the federal funds rate to affect employment conditions.

Overall, the optimal monetary policy strategy likely includes elements of a rules based approach, in tandem with a discretionary approach.

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