The federal funds rate in the post-Volcker era: evidence from Basic VAR

Jamilov, Rustam

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Rustam Jamilov

1466713

Bachelor in International Economics and Management

Università Commerciale Luigi Bocconi

Thesis Supervisor: Dr. Tommaso Monacelli

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Abstract

This paper proposes a comparative analysis of the federal funds rate. The analysis is based on the results of an empirical study, conducted using the econometrics of Vector Auto Regressions. The results are compared across two time periods: 1960-1979 and 1983-2002, the intervals representing the pre and post-Volcker monetary eras. The study examines the degree of exogeneity of the federal funds rate and its power to explain and predict variations in macroeconomic aggregates. The paper concludes that for the post-Volcker era the federal funds rate has become more exogenous; that the federal funds rate has remained a strong economic indicator; that the notion of "lean against the wind" monetary policy continues to be relevant and appropriate; that the "price effect" of the response of inflation to innovations in the federal funds rate has become smaller. The paper also suggests that the Federal Reserve has since the 1980s initiated the practice of countercyclical monetary policy, and that economic cycles have tightened during the post-Volcker era.

Introduction

The initial incentive to undertake this research work comes from the 1992 paper by Bernanke and Blinder: "The Federal Funds Rate and the Channels of Monetary Transmission". This paper was an important one, as it carries a lot of information useful for future research, for reflection on standard economic theory, and for the practical matters of central banking.

Bernanke and Blinder are using the econometric tool of basic Vector Auto Regressions for the majority of their analysis. The models that are directly relevant to this paper consist of two systems, one with and the other without the M2 money supply indicator. Both systems contain the federal funds rate as the main target of analysis, inflation and unemployment as the macroeconomic aggregates. The basic ideas were to establish a connection between the funds rate and the two real-economy variables – inflation and unemployment, and to determine if the funds rate, among other potential economic indicators like M2 or the treasury bills rate, had a stronger connection. The paper had the 1959-1979 period, or the pre-Volcker era, as the time interval. The primary focuses of attention were the forecast error variance decompositions tables and the graphs of impulse response functions.

This paper aims to extend the analysis of Bernanke and Blinder to the post-Volcker era, or to the period of after 1982. In addition, I will add other economic variables to the discussion, such as Gross Domestic Product and the output gap (the differential between the actual real GDP and the potential real GDP). Overall I am pursuing a two-dimensional goal with this work: to perform a comparative analysis of the pre-Volcker and post-Volcker eras to supplement the earlier study by Bernanke and Blinder, and to examine the reactions of the models when GDP and the output gap are inserted. For the latter part, a comparison of the two periods will also be presented.

It is important to mention that the paper by Bernanke and Blinder had several agendas, covered a variety of topics, and included more variables in the core analysis. I am mostly interested in the behavior of the federal funds rate in particular, and such aspects as the interest rate spread will not be examined.

The primary research questions of this paper are on the overall effectiveness of monetary policy during the post-1982 period. I will specifically address the following questions. First, how does the federal funds rate respond to unexpected shocks to unemployment and inflation, and also to GDP and output gap innovations? Second, how has the strength of the federal funds rate as an economic indicator developed since the 60s and 70? Third, are there any fundamental or structural changes in the relationships between the funds rate and the macroeconomic aggregates in the post-Volcker era as opposed to the 1959-1979 period? And if there are some evident changes, what are the potential causes for such differences?

One of the secondary reasons for undertaking this work is to see if and how the historical developments of the early 80s affected the behavior of the federal funds rate in relation to the real economy. At least 3 major potential catalysts are possible: the deregulation of the financial sector in the 1980s, a structural shift in inflation dynamics in the late 1970s, and an elevated public sensitivity to inflation (thus a more fragile inflation expectations component). All these factors could have potentially influenced the conduct of monetary policy; the vise-versa relationship is also possible. Therefore it's important to expand the analysis of the federal funds rate to the most recent years.

Apart from the several historical facts that could have had an exogenous impact on the monetary policy strategizing and/or on the funds rate-macroeconomy interplay, a more simple motivation for this study is that a more recent dataset is necessary. The Bernanke paper deals with old data, and a more contemporary set of figures is desirable. The period of 1983-2002 is therefore appropriate for a comparative analysis of the two studies, as well as for the refreshment of the data.

Methods

This paper is based on an extensive empirical study. The software application used for the econometric analysis is STATA. The data for this study was drawn mostly from the Federal Reserve Bank of St. Louis (FRED) online database. The information source is credible and is considered to be one of the most reliable online sources of economic and statistical information for the US market. There are 6 major variables that are used in this paper. First

– the federal funds rate – is the FRED's "effective federal funds rate". Second – unemployment – is the FRED's "civilian unemployment rate" and is denominated in percentages. Third – inflation – the FRED's "consumer price index", denominated in percentage changes from previous year. Fourth – M2 – the FRED's "M2" indicator for the monetary base. Fifth – GDP – is the FRED's "Real Gross Domestic Product", denominated in percentage changes from previous year. Sixth – GAP – is the syndicated variable representing the output gap: the actual real GDP less the potential real GDP shown as a percentage of the potential real GDP. Finally, there are two time dimensions: each is set monthly, the first from January 1983 to December 2002, the second from January 1960 to December 1979. Both dimensions are equal in length: 19 full calendar years. All the above economic variables are also recorded as month-based.

For this paper I will be employing the econometrics of basic vector autoregressions (VAR). VARs are time series models that use only past values of the variables of interest to make forecasts. For instance, a four-variable VAR system of federal funds interest rates, M2, unemployment, and inflation can be expressed as:

$$R_t=\beta_1 + \sum R_{t-i} + \sum M_{t-i} + \sum U_{t-i} + \sum \pi_{t-i} + \varepsilon_{Rt}$$

$$M_t=\beta_2 + \sum R_{t-i} + \sum M_{t-i} + \sum U_{t-i} + \sum \pi_{t-i} + \varepsilon_{Mt}$$

$$U_t=\beta_3 + \sum R_{t-i} + \sum M_{t-i} + \sum U_{t-i} + \sum \pi_{t-i} + \varepsilon_{Ut}$$

$$\pi_t=\beta_4 + \sum R_{t-i} + \sum M_{t-i} + \sum U_{t-i} + \sum \pi_{t-i} + \varepsilon_{It}$$

Where R, M, U, and π are the federal funds interest rate, M2, unemployment rate, and inflation rate respectively. β is an intercept term, t is a time subscript, and ε is an error term. Thus, each of the three variables is expressed as a linear function of past values of itself and past values of other variables in the system. Unemployment is substitutable by the GDP and the output gap, and considering that there are 2 time intervals, this leads to 6 VAR systems: with unemployment pre and post-Volcker, with GDP pre and post-Volcker, and with the output gap pre and post-Volcker. The funds rate, M2, and inflation remain in all 6 models.

As a quick theoretical note, the estimated error terms from each equation above are correlated so that it is not correct to assume that, for instance, ε_{Ut} represents an independent surprise movement in the unemployment rate. To better interpret the dynamic relationships present in the data, the residuals from the VAR are broken up into linear combinations of independent (orthogonal) shocks. A common orthogonalization is to assume that the VAR system is recursive so that there is a chain of causality among surprises in the variables during any given period. The transformation of the original shocks into recursive, orthogonal shocks is called the Choleski decomposition. Choleski decomposition will be used in this paper for all forecasting purposes such as the impulse response functions.

After running the basic VAR, I will conduct the following tests and post-VAR analytics. First of all, the marginal significance levels of exclusion will be presented. Those are the tests to decide whether, for example, inflation and/or unemployment can be rejected from the model. Also, it helps to see if the lagged values of certain variables help predict the other variables; that would happen if lags of, for instance, the funds rate are statistically significant and thus carry some predictive powers. In total, there will be 6 lags of each variable. In addition, the Granger-Causality test results will be shown. The Granger test establishes "Granger-causality", if any, for the pairs of our variables.

The core analytical segment of this paper will include the Forecast Error Variance Decomposition (FEVD) tables and the Impulse Response Functions (IRF). The FEVD technique essentially creates arbitrary forecasts in the future variations of a particular variable, and decomposes that variance into influences attributable to the shocks of other variables in the system. The FEVD are based on Choleski decomposition.

The IRFs are depicting responses of certain variables to the impulses (unexpected shocks) of other variables in the VAR system. The IRFs in this study will be orthogonolized. The forecast horizon for the FEVDs and the IRFs is 36 periods, which in our case are months. Results will be shown in the 6/12/24/36 months format.

The results of each econometric technique will be discussed independently as well as collectively in the end of the paper. Conclusions and observations will be compared across periods. Essentially, the whole set of tests is performed twice – once for the 1960-1979, the

other for the 1983-2002 period. Primarily, the FEVD and the IRF results will be compared. Should there be any noteworthy differences, those will be noted, and potential explanations for those differences will be proposed. It is important to mention that the period that I identify as "pre-Volcker" differs from the time interval used in the Bernanke and Blinder study: mine is 1960-1979 and Bernanke's was 1959-1979. Therefore, there are some minor discrepancies in the two sets of results.

Analysis and Development

Exclusion Tests

I begin the presentation of results by briefly describing the exclusion statistics of the 6 variables in the VARs. Tables of results will be presented in pairs to highlight the differences across time. Tables 1 and 2 in Appendix A depict the marginal significance levels of exclusion for the first VAR: funds rate, M2, unemployment, inflation.

Three things must be noted about this table. First, the significance levels of the lags of unemployment and inflation in the Funds Rate equation (yellow highlight) indicate that they are doing a worse job in predicting the funds rate for the 1983-2002 period than for 1960-1979. Thus, our first observation is that the funds rate is potentially more independent and exogenous in the post-Volcker era.

Second, the funds rate is showing some early signs of predicting the movements in the values of unemployment and inflation, as depicted by the lags of fundsrate in the unemployment and inflation equations (green highlight). Interestingly, for the pre-Volcker era, the funds rate is better at predicting inflation than for the post-Volcker era. With regards to unemployment, the results are yet inconclusive; both periods suggest some predictive presense. Further testing will build on this early observation of the strength of the funds rate's predictive ability.

Third, M2 is very evidently losing its predictive powers for unemployment as proven by the M2 lags in the unemployment equations. With regards to inflation, M2 is stable over the two periods. However, on both variables, the funds rate is consistently outperforming M2. This is in parallel with the earlier findings of Bernanke and Blinder in 1992. Thus, while the

federal funds rate is not a perfect indicator of macroeconomic aggregates, it is consistently more efficient than its best alternative, M2, for both pre and post-Volcker periods.

The chi-squared test results are also reported in Appendix A.

For our second model, with the output gap instead of unemployment, the tables 3 and 4 report the corresponding exclusion test statistics for the two time periods in the same Appendix A.

The potential pattern of federal funds rate's growing exogeneity with time is getting stronger. As displayed in the tables (yellow highlight), the funds rate is considerably more independent from the influences of the output gap and inflation in the post-Volcker era.

It's interesting that the relationship between the federal funds rate and the output gap has remained basically unchanged over the span of almost 40 years (green highlight). Also noticeable is the fact that M2 is probably more suitable at explaining the output gap than even the funds rate itself (blue highlight). It is apparent that unemployment is not the only possible variable which can be used as a "proxy" for the real economic growth element. It is possible that the output gap could be a more realistic approximation, and any conclusions with regards to the funds rate being a more efficient economic indicator than M2, those reached by Bernanke and Blinder in 1992, could be questioned.

For the final pair of models, with the GDP variable, the appropriate tables are numbers 5 and 6 in Appendix A. The funds rate exogeneity pattern discovered earlier is now solid and consistent across 4 macroeconomic aggregates: unemployment, inflation, output gap, and now GDP as well. The proposition that funds rate is more exogenous in the post-Volcker is now noted and will be tested later in the paper using the FEVDs and IRFs.

Similarly to the model with the output gap, the funds rate is not particularly significant at any lag of the GDP function. But it's important to point out that both for the funds rate and the GDP the first lag is deviating from the rest lags by being a lot more sensitive: in the first lag, GDP is much more significant in the funds rate's function than in any other lag, and the same relationship holds for the funds rate function.

With regards to the predictive powers of M2, it is once again evident that M2 is better at describing a macroeconomic variable (blue highlight), in this case GDP, than the funds rate.

However, because the federal funds rate is so much more significant in the lags of unemployment, any conclusions about the predictive abilities of the two indicators at this stage of the research would be premature. It is probable that more sophisticated forecasting techniques will show which of the two variables is stronger.

Granger-Causality Tests

Interesting implications arise from the Granger-causality test. First of all, for the first VAR with unemployment, regarding the argument for federal funds rate exogeneity, the yellow highlight in Tables 1 and 2 of Appendix B suggests that none of the variables taken together Granger-cause the funds rate in post-Volcker era, which further builds on the proposition that the funds rate is indeed becoming more independent. In contrast, during the 1960-1979 period, the funds rate was almost perfectly endogenous according to this particular VAR model. Also, none of the variables taken *individually* Granger-causes the federal funds rate in the post-Volcker era.

Second, in both time periods, unemployment is Granger-caused by the federal funds rate. The inflation part is a weaker, as shown by the green highlight. M2 is strongly Granger-causing inflation in the post-Volcker era. This is consistent with the earlier observations from the exclusion statistics: the funds rate is excellent at predicting unemployment but weak with inflation, while M2 tends to be more appropriate for inflation in the post-Volcker era. In both periods, however, M2 has no power over unemployment.

For the second VAR with the output gap, the general picture is practically the same. The federal funds rate, endogenous in the pre-Volcker era is strictly exogenous in the 1983-2002 period. The funds rate is strongly Granger-causing the output gap in the post-Volcker era, which is similar to the unemployment relationship. The funds rate is again poor at connecting with inflation, while M2 is again Granger-causing inflation in the post-Volcker era.

The situation is slightly different for the third VAR with GDP. While the federal funds rate is again more exogenous in the post-Volcker era, and M2 is still Granger-causing inflation while the funds rate isn't, GDP doesn't seem to be responding to the funds rate the way the output gap does.

Overall, all three VARs have shown that M2 is Granger-causing inflation, and that the funds rate is more exogenous in the post-Volcker era. Also, the funds rate Granger-causes unemployment and the output gap, but not the GDP. The conclusions of the Granger tests are thus a bit inconclusive about the funds rate being a consistently good policy indicator.

Forecast Error Variance Decompositions

The FEVDs will be presented with specific purpose, to provide evidence for the particular argument in discussion. Overall, there are 3 specific aspects that must be analyzed, and the FEVD tables will be fitting this structure. The first part is on the federal funds rate exogeneity. Second – the funds rate as an indicator of variations in macroeconomic variables. Thirdly, there will be a comparison between pre and post-Volcker eras.

First, we examine the notion of federal funds rate exogeneity. The suiting FEVD would be the one consisting of the funds rate as a response and four macroeconomic variables (unemployment, inflation, output gap, GDP) as the impulses. Table 1 in Appendix C first presents the results for the pre-Volcker era. Every single variable for almost every forecast horizon is in double-digit percentages. This clearly shows that the funds rate was an endogenous variable during the 1960-1979 period.

Table 2 presents the same FEVD picture but for the post-Volcker era. The contrast in numbers is simply remarkable, because now only inflation has some significant influence on the funds rate for the horizons 24 and 36. While almost all others are in low single-digits. The proposition that the funds rate has been exogenous since the Volcker tenure at the Fed is becoming less of a hypothesis and more as an undisputable empirical fact.

The second notion to be analyzed is the predictive power of the federal funds rate: the percentage of forecasted variation in the 4 macroeconomic variables that the funds rate is able to predict. Tables 3 and 4 in Appendix C show the relevant results. While there is no obvious pattern which was in the case with post-Volcker funds rate exogeneity, it is clear that the funds rate has some evident explanatory potential for each of the four variables, and for both time periods. There are 3 distinct observations to point out about this second set of FEVDs.

First, and this is useful for practical purposes of modern central banking, post-Volcker shocks to the federal funds rate explain 40% of forecasted variation in unemployment after

12 months (Table 4, yellow highlight). While the percentages were also high for pre-Volcker, those numbers never reached as high as in the 1983-2002 period.

This observation becomes even more interesting when one looks at the same Table 3, the same forecast horizon of 12 months, but at the GDP column (green highlight). The percentage of explained variation for GDP is also maximized for the 12-month's horizon. Again, while the strength of the federal funds rate's explanatory power is also evident in pre-Volcker as well, the numbers form a noticeable pattern in the post-Volcker table, with clear maximums and hints of some underlying business cycle. The point on business cycles will be brought up again in later parts of the paper.

The third point is on a structural change in inflation prediction between the two periods: one can notice the uniformally stable percentages for the inflation column in the pre-Volcker table (Table 3), and a different pattern of gradually rising and peaking numbers in Table 4 (blue highlight). It is possible that this observation, if taken together with the first point on unemployment and GDP, can signify an underlying shift in the macroeconomic landscape with the start of Volcker's tenure.

All in all, the FEVDs have reinstated the argument for the federal funds rate exogeneity, shown that the funds rate is a good indicator of all four macroeconomic variables, and suggested a possible structural shift in the inflation dynamics that might have occurred in the 80s.

Impulse Response Functions

The same structure that was already established in the previous paragraphs will remain a key guide for this part as well. The IRFs were constructed based on two primary principles: federal funds rate exogeneity, and the funds rate as policy indicator.

The first part is represented by the first set of IRFs, where the funds rate is the response variable, and the four macroeconomic variables play the roles of the impulses. The idea is to illustrate visually the reactions of the federal funds rate to unexpected innovations coming from the real economy.

The second part, on the other hand, is built on the IRFs where the federal funds rate is an impulse, and the four economic variables are the responses. These IRFs help demonstrate

the dynamics of individual as well collective reactions of the variables to sudden movements of the funds rate.

In addition, all IRFs portray both post-Volcker and pre-Volcker functions to add an illustrative comparative element to the whole analysis. As a rule, straight lines represent the 1983-2002 functions, and dashed lines – 1960-1979 functions.

Figures 1, 2, and 3 in Appendix D all represent the first VAR model with unemployment. Figure 3 is particularly interesting, since it draws a parallel between this study and the work by Bernanke and Blinder. Essentially, the dashed lines on this graph are the reproduced version of the 1992's paper, and the two straight lines present the evidence from the post-Volcker era. Since Bernanke and Blinder put a lot of emphasis on this particular angle of analysis: with unemployment and inflation, this graph carries a lot of weight for comparative economic literature. Three important points, some already mentioned and discussed in 1992, must be noted about this graph.

First, as shown in the said Figure 3 of Appendix D, a positive innovation to the pre-Volcker inflation or unemployment would lead to a jump and fall in the funds rate respectively. A positive relationship between the funds rate and inflation, and a negative relationship between the funds rate and unemployment is perfectly consistent with what Bernanke and Blinder already discussed in 1992. The so-called "lead against the wind" monetary policy is clearly visible on this graph; the funds rate rises for any positive inflation innovation both pre and post-Volcker (although more reluctantly in the latter case), and falls for any unexpected spike in unemployment. This suggests that, fundamentally, the overall monetary strategy of the Fed has not changed dramatically in the past several decades.

It is interesting that for the 1960-1979 period the funds rate would stay low in response to an unemployment shock for very extended periods of time. On the other hand, in the post-Volcker era, most certainly because of Volcker's influence in the first place, the funds rate returns to its original level approximately 24 months after the shock. This is actually consistent with an earlier observation from the FEVD tables, the one about potential business cycle tightening and structural economic shifts.

Second, the amplitudes of the lines for the two periods are different. In other words, the funds rate seems to be much more prone to excessive fluctuation in the post-Volcker era, particularly in the first 15 months after an economic shock. This is witnessed by the fact that the straight lines are much closer to the x-axis than the dashed lines.

Figures 4 and 5 reproduce the IRFs with the output gap instead of unemployment. Again supporting the argument for post-Volcker federal funds rate exogeneity, the funds rate is practically irresponsive to an unexpected positive shock to the output gap, while the response is stronger for the 1960-1979 period.

Figure 6, graph of the IRF with GDP, tells a similar story. This is only natural because the output gap is only a syndicated variable of the GDP. Both variables experience same shocks: a rise in GDP, assuming a constant real potential GDP component, automatically implies an increase in the output gap. For the GDP IRF, the lines are practically parallel to the x-axis and are barely detached from it.

Figure 8 is a graph of the combined VAR, with all four economic variables simultaneously influencing the federal funds rate. Several conclusions have been reached from this first set of IRFs. First, "lean against the wind" monetary theory is still a relevant idea and is empirically traceable. Second, the graphs of the post-Volcker lines are systematically closer to the x-axis, suggesting a higher degree of non-responsiveness and thus exogeneity of the federal funds rate. Third, there are again signs of structural differences between the two periods with regards to funds rate-inflation dynamics, witnessed by graphs 3 and 8.

The second set of IRFs represents the reversed relationships: now the federal funds rate is an impulse to which the economic variables respond. We start again with the first VAR with unemployment. Similarly to the previous set, figures 9, 10, 11 of Appendix D are again in parallel with the graphs of Bernanke and Blinder. The 1960-1979 component is essentially a reproduction of their work, while the 1983-2002 is the new addition of this paper.

Figure 11 is similar in its composition to figure 3, except that the impulses and responses have switched. In response to a positive innovation to the federal funds rate, unemployment rises, while inflation falls. There are several very interesting points to be discussed here.

First of all, "lean against the wind" is again traceable from this graph. In other words, in the long-run, inflation is driven down by a positive funds rate innovation, and unemployment begins to rise after several months. While this is perfectly consistent with economic logic and the "lean against the wind" theory, however, there are significant considerations that could potentially cast doubt on the federal funds rate as a policy indicator.

The fact that unemployment experiences a short fall after a positive funds rate shock is intuitive. Unemployment is laggy and requires time to adjust to exogenous economic shocks. It therefore takes time for unemployment and economic growth as such to negatively react to a monetary contraction. Assuming, of course, that a positive funds rate innovation *can* be considered as a monetary contraction. With inflation, the situation is slightly more complicated. Inflation spikes up with an unexpected increase in the federal funds rate. Although it eventually moves downwards, the initial spike is the so-called "price effect". This price effect is exactly the reason why there are some questions over the stability of the funds rate as a policy indicator.

Now, the intriguing part is that the positive jump in inflation in response to a positive funds rate innovation is true for both periods. Bernanke and Blinder had the same presence of the price effect in their findings. However, for the post-Volcker era the price effect is clearly smaller: consider the time interval between when the price effect starts (inflation rises) and when it ends (inflation starts to fall), and compare that interval between the two periods. For 1960-1979 the price effect interval is approximately 20 months, while for the post-Volcker 1983-2002 the interval is almost halved to 10 months.

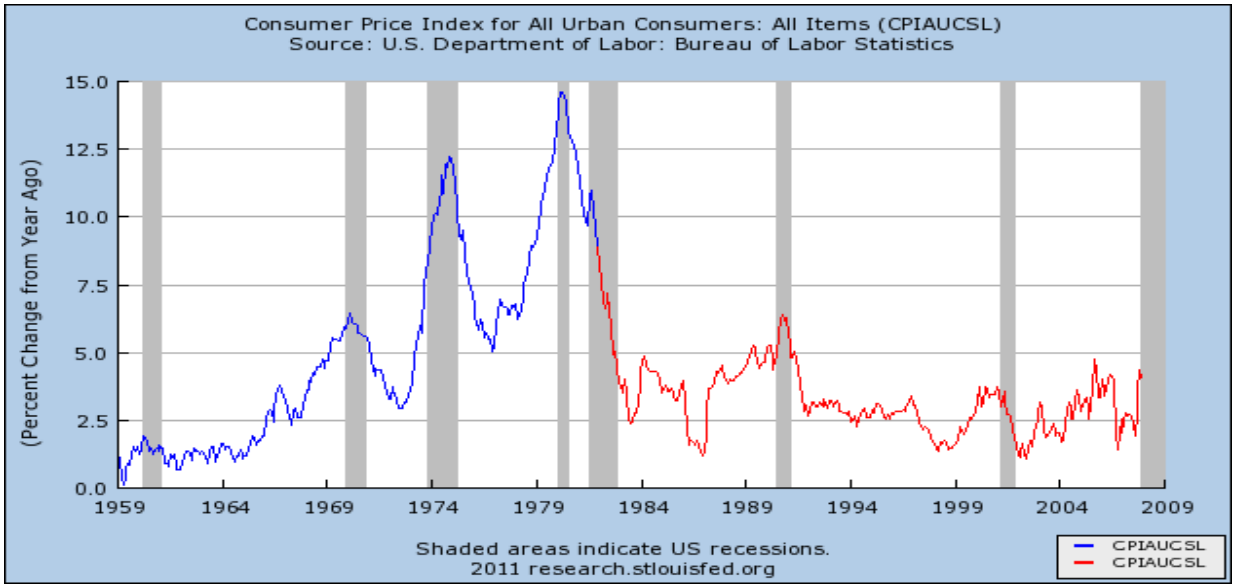
The criticism of the whole funds rate forecasting technique is soothed by the fact that the price effect, which questions the rigidity of the funds rate as an economic indicator, is much smaller in the post-Volcker era. It therefore follows that the funds rate can and should be considered a strong measure for predicting and explaining economic variation, especially for the post-1983 period.

Figures 12, 13 and Figures 14, 15 representing the VARs with the output gap and GDP respectively will be discussed together. Special focus is on the figures 13 and 15 which portray the output and GDP with inflation. On both graphs, there is a dramatic change in the behavior of the real economy variable – output gap and GDP – across the two time

periods. In response to a positive innovation in the federal funds rate, the output gap on graph 13 drops for the 1960-1979 period. The same logic naturally applies to graph 15 with GDP. However, for the post-Volcker 1983-2002 period the relationship is exactly reversed, as both the output gap and the GDP *increase* in response to a positive shock to the funds rate.

There clearly appear to be more fundamental reasons to such transformed dynamics; and not only of the output gap and GDP but also of inflation – the observation mentioned several times in this paper. It is evident that the clue to this shift lies in early 80s, the time when Paul Volcker took control of the Federal Reserve. It's therefore important to look into some historical facts.

Consider below the FRED's graph of consumer price index movement (our proxy for inflation) in the past 50 years. The blue line shows the highly volatile behavior of inflation in the late 60s and 70s. However, as witnessed by the red line, since the 80s inflation has been following a more stable course with much narrower bounds of fluctuation. Essentially we are observing a structural shift in inflation dynamics in the 1980s, a fact which carries important information for this paper's federal funds rate analysis.



There is at least one plausible explanation that could provide an economic rationale for the above phenomena. Highly unstable, inflation of before 1980, was managed primarily pro-

cyclically. In other words, the Federal Reserve would wait for the prices to actually start rising to launch any sort of contractionary measure.

For the post-1982, the situation is fundamentally different. First of all, the public is now apparently much more inflation-aware. Consistently rising prices, or even worse, inconsistent inflation expectations create a terrible investment atmosphere. The Fed now begins a counter-cyclical approach towards controlling inflation. The Fed is itself more inflation aware, in the sense that it predicts rising prices and adjusts the monetary base and the federal funds rate in order to *anticipate* an inflation spike. This is why, in an earlier IRF, the straight line of the inflation response to the funds rate impulses has a smaller amplitude in the post-Volcker era (Figure 11).

Impulses are by definition "innovations", or unexpected movements in the variable. Since the 80s, there *haven't* been many unexpected shocks to the funds rate; all of its movements were either minor and very short-term, or they represented the Fed's deliberate and planned attempts to counteract future inflation. Inflation therefore does not any more respond to unexpected funds rate movements, because there *are* no unexpected funds rate movements.

All in all, a more inflation-aware general public forced the governing central bank to become more inflation-aware itself, which resulted in a counter-cyclical inflation management tactic. A more careful, deliberate strategy caused a structural shift in inflation dynamics, which is demonstrated on the FRED's inflation graph above. Unexpected inflation movements become more short-term, very minor in size, and don't require ad-hoc central bank involvement.

Simultaneously, this explains the reversed relationship between the funds rate and the GDP/output gap. Since economic growth walks parallel with long-run inflation, it is therefore plausible to suggest that a countercyclical inflation management strategy would also result in a countercyclical relationship with the GDP and thus the output gap as well. Thus, when on figures 13 and 15 the output gap and the GDP decrease in response to a positive shock to the funds rate, it is possible that the Fed is actually contracting back a monetary expansion which it had already performed several periods *before* this shock. Keeping the lags of the GDP in mind, the Fed is expecting the economy to respond to the expansion that

it already performed a while ago. The Fed therefore starts to contract to prevent long-run inflation which would be caused by the funds rate being kept too low for too long.

Conclusions

First of all, the federal funds rate has become a much more exogenous monetary instrument in the post-Volcker era.

Second, it has been evident on several occasions that the federal funds rate is a good indicator of macroeconomic aggregates. The funds rate is far more efficient than the alternative measure of M2 with regards to unemployment. However, M2 seems to be better at predicting inflation.

Third, the old notion of "lean against the wind" monetary policy holds true for the post-Volcker era. The funds rate indeed responds negatively to positive innovations in unemployment, and rises for any increase in inflation. While the amplitudes and magnitudes of those relationships have diminished in the past several decades, and despite the "price effect" complications, it seems legitimate and logical to continue applying the "lean against the wind" story in economic literature.

Fourth, the beforementioned price effect has become considerably smaller in the past decades. Thus, the criticism of the funds rate's predictive powers that is based on the said price effect is losing its grounds.

Fifth, on several occasions it was observed in this paper that the economic (or business) cycle has tightened in the 1983-2002 period. This notion comes from the empirical evidence that both the funds rate and the economic aggregates tend to recover from shocks quicker and return to their pre-shock equilibriums faster than in the 1960-1979 period. The question of economic cycles was never among the research questions of this paper. Perhaps future research could expand on this idea.

Finally, the impulse-response interplay between the funds rate, inflation, and the output gap/GDP has led to the discovery of a structural shift of the early 1980s in the whole inflation dynamics. The change is explained by the apparent introduction of countercyclical inflation management by the Volcker's Federal Reserve. The extent to which the reader will

agree to such explanation is naturally uncertain. It is possible and very likely that someone will be able to provide better answers and more extensive explanations to the questions raised in the paper.

Bibliography

Barro, Robert J., "Unanticipated Money Growth and Unemployment in the United," American Economic Review, March 1977, 67, 101-15

Bernanke, Ben S., and Alan S. Blinder (1992), "The Federal Funds Rate and the Channels of Monetary Transmission," American Economic Review 82 (September): 901–21

Friedman, Milton, and Anna J. Schwartz (1963), "A Monetary History of the United States," 1867 –1960 (Princeton, N.J.: Princeton University Press)

Goodfriend, Marvin (1992), "Interest Rate Policy and the Inflation Scare Problem: 1979–1992," Federal Reserve Bank of Richmond 1992 Annual Report, 7–19

Laurent, Robert D. (1988), "An Interest Rate-Based Indicator of Monetary Policy," Federal Reserve Bank of Chicago Economic Perspectives, January/February, 3–14

Sims, Christopher A. (1992), "Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy," European Economic Review 36 (June): 975–1000

Wooldridge, Jeffrey (1992), "Introductory Econometrics: A Modern Approach". 2 edition, South-Western College Pub

Appendix A: Exclusion Tests

VAR1: Funds Rate, M2, Unemployment, Inflation

Marginal Significance levels of exclusion **(1983-2002)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	Unemploym	Infl
L1	0.000	0.779	0.085	0.610
L2	0.040	0.253	0.851	0.236
L3	0.439	0.501	0.421	0.535
L4	0.887	0.47	0.12	0.852
L5	0.282	0.096	0.96	0.203
L6	0.333	0.026	0.476	0.025
M2	Funds Rate	M2	Unemploym	Infl
L1	0.613	0.000	0.000	0.030
L2	0.129	0.456	0.034	0.890
L3	0.02	0.419	0.406	0.366
L4	0.429	0.006	0.513	0.75
L5	0.599	0.064	0.355	0.377
L6	0.973	0.484	0.073	0.125
Unemployment	Funds Rate	M2	Unemploym	Infl
L1	0.059	0.849	0.000	0.001
L2	0.462	0.887	0.065	0.018
L3	0.144	0.572	0.179	0.593
L4	0.093	0.454	0.129	0.399
L5	0.491	0.186	0.39	0.957
L6	0.481	0.574	0.332	0.701
Inflation	Funds Rate	M2	Unemploym	Infl
L1	0.279	0.155	0.650	0.000
L2	0.934	0.225	0.026	0.012
L3	0.33	0.04	0.563	0.806
L4	0.582	0.112	0.121	0.453
L5	0.99	1	0.782	0.036
L6	0.896	0.888	0.66	0.031

	Chi-Squared **(1983-2002)**	
Equation	χ2 (Chi-Squared)	P-Value
Fundsrate	13478	0.00
M2	11802	0.00
Unemployment	13374	0.00
Inflation	4502	0.00

Marginal Significance levels of exclusion **(1960-1979)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	Unemploym	Infl
L1	0.000	0.485	0.044	0.006
L2	0.086	0.271	0.256	0.672
L3	0.067	0.515	0.852	0.77
L4	0.175	0.964	0.635	0.928
L5	0.62	0.553	0.462	0.575
L6	0.048	0.197	0.167	0.52
M2	Funds Rate	M2	Unemploym	Infl
L1	0.268	0.000	0.346	0.009
L2	0.887	0.000	0.228	0.349
L3	0.552	0.427	0.994	0.302
L4	0.902	0.992	0.493	0.799
L5	0.064	0.39	0.017	0.478
L6	0.011	0.181	0.138	0.234
Unemployment	Funds Rate	M2	Unemploym	Infl
L1	0.071	0.123	0.000	0.031
L2	0.195	0.270	0.003	0.039
L3	0.045	0.943	0.171	0.603
L4	0.007	0.881	0.35	0.733
L5	0.429	0.295	0.551	0.524
L6	0.178	0.457	0.244	0.913
Inflation	Funds Rate	M2	Unemploym	Infl
L1	0.182	0.355	0.809	0.000
L2	0.650	0.366	0.567	0.049
L3	0.688	0.387	0.84	0.017
L4	0.384	0.139	0.116	0.048
L5	0.271	0.047	0.678	0.323
L6	0.698	0.083	0.653	0.012

	Chi-squared Tests (1960-1979)	
Equation	χ2 (Chi-Sqaured)	P-Value
Fundsrate	7466.58	0.00
M2	18651.54	0.00
Unemployment	9700.976	0.00
Inflation	19271.29	0.00

VAR 2: Funds Rate, M2, Output Gap, Inflation

Marginal Significance levels of exclusion **(1983-2002)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	GAP	Infl
L1	0.000	0.470	0.529	0.976
L2	0.029	0.147	0.829	0.526
L3	0.55	0.518	0.923	0.789
L4	0.993	0.459	0.806	0.629
L5	0.422	0.159	0.333	0.226
L6	0.332	0.065	0.97	0.046
M2	Funds Rate	M2	GAP	Infl
L1	0.222	0	0.721	0.017
L2	0.398	0.741	0.234	0.513
L3	0.056	0.704	0.008	0.845
L4	0.312	0.005	0.12	0.677
L5	0.259	0.012	0.886	0.833
L6	0.606	0.163	0.971	0.273
Output Gap	Funds Rate	M2	GAP	Infl
L1	0.958	0.352	0.000	0.134
L2	0.320	0.263	0.622	0.689
L3	0.75	0.654	0	0.057
L4	0.772	0.911	0	0.003
L5	0.441	0.507	0.987	0.025
L6	0.169	0.807	0.204	0.286
Inflation	Funds Rate	M2	GAP	Infl
L1	0.146	0.063	0.628	0.000
L2	0.804	0.205	0.589	0.013
L3	0.413	0.064	0.56	0.905
L4	0.592	0.059	0.92	0.405
L5	0.925	0.72	0.693	0.067
L6	0.87	0.982	0.85	0.08

	Chi-squared tests **(1983-2002)**	
Equation	χ2 (Chi-Sqaured)	P-Value
Fundsrate	12822	0.00
M2	11166	0.00
Output Gap	5385	0.00
Inflation	4270	0.00

Marginal Significance levels of exclusion **(1960-1979)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	GAP	Infl
L1	0.000	0.194	0.042	0.015
L2	0.079	0.890	0.935	0.595
L3	0.091	0.231	0.736	0.758
L4	0.283	0.739	0.286	0.871
L5	0.546	0.616	0.559	0.775
L6	0.066	0.362	0.699	0.448
M2	Funds Rate	M2	GAP	Infl
L1	0.287	0	0.832	0.010
L2	0.644	0	0.674	0.311
L3	0.663	0.812	0.015	0.257
L4	0.446	0.648	0.032	0.765
L5	0.062	0.456	0.86	0.24
L6	0.011	0.231	0.372	0.071
Output Gap	Funds Rate	M2	GAP	Infl
L1	0.917	0.350	0.000	0.582
L2	0.555	0.613	0.950	0.898
L3	0.591	0.631	0.001	0.473
L4	0.535	0.423	0.006	0.366
L5	0.787	0.842	0.788	0.573
L6	0.957	0.389	0.96	0.509
Inflation	Funds Rate	M2	GAP	Infl
L1	0.326	0.460	0.127	0.000
L2	0.913	0.307	0.943	0.027
L3	0.678	0.217	0.023	0.016
L4	0.219	0.121	0.648	0.063
L5	0.134	0.108	0.257	0.102
L6	0.35	0.277	0.04	0.002

	Chi-squared tests **(1960-1979)**	
Equation	χ2 (Chi-Sqaured)	P-Value
Fundsrate	7725	0.00
M2	18882	0.00
Output Gap	3370	0.00
Inflation	20590	0.00

VAR 3: Funds Rate, M2, GDP, Inflation

Marginal Significance levels of exclusion **(1983-2002)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	GDP	Infl
L1	0.000	0.944	0.631	0.740
L2	0.016	0.424	0.519	0.437
L3	0.628	0.594	0.639	0.601
L4	0.912	0.473	0.549	0.879
L5	0.528	0.194	0.826	0.379
L6	0.312	0.132	0.448	0.054
M2	Funds Rate	M2	GDP	Infl
L1	0.326	0	0.268	0.036
L2	0.348	0.573	0.846	0.584
L3	0.098	0.678	0.079	0.907
L4	0.382	0.012	0.355	0.789
L5	0.342	0.008	0.161	0.445
L6	0.804	0.204	0.028	0.132
GDP	Funds Rate	M2	GDP	Infl
L1	0.285	0.014	0.000	0.000
L2	0.716	0.009	0.186	0.170
L3	0.488	0.094	0	0.411
L4	0.616	0.918	0	0.021
L5	0.902	0.005	0.313	0.06
L6	0.605	0.137	0.193	0.731
Inflation	Funds Rate	M2	GDP	Infl
L1	0.363	0.075	0.706	0.000
L2	0.964	0.140	0.499	0.012
L3	0.288	0.067	0.263	0.711
L4	0.582	0.076	0.907	0.613
L5	0.851	0.552	0.663	0.159
L6	0.835	0.744	0.269	0.153

	Chi-Squared tests **(1983-2002)**	
Equation	χ2 (Chi-Sqaured)	P-Value
Fundsrate	12779	0.00
M2	11415	0.00
GDP	2101	0.00
Inflation	4352	0.00

Marginal Significance levels of exclusion **(1960-1979)**				
Equation	Lags of			
Fundsrate	Funds Rate	M2	GDP	Infl
L1	0.000	0.376	0.140	0.024
L2	0.055	0.143	0.868	0.613
L3	0.059	0.272	0.629	0.617
L4	0.333	0.769	0.984	0.771
L5	0.57	0.615	0.49	0.575
L6	0.08	0.441	0.684	0.651
M2	Funds Rate	M2	GDP	Infl
L1	0.227	0	0.683	0.022
L2	0.742	0	0.654	0.607
L3	0.752	0.992	0.101	0.16
L4	0.986	0.682	0.115	0.892
L5	0.103	0.434	0.407	0.248
L6	0.036	0.249	0.252	0.06
GDP	Funds Rate	M2	GDP	Infl
L1	0.644	0.024	0.000	0.649
L2	0.774	0.023	0.610	0.329
L3	0.21	0.449	0.081	0.056
L4	0.405	0.571	0.005	0.947
L5	0.215	0.891	0.872	0.733
L6	0.91	0.525	0.839	0.33
Inflation	Funds Rate	M2	GDP	Infl
L1	0.283	0.744	0.001	0.000
L2	0.750	0.289	0.128	0.026
L3	0.594	0.147	0.006	0.001
L4	0.168	0.189	0.489	0.008
L5	0.429	0.264	0.644	0.068
L6	0.864	0.644	0.112	0

	Chi-Squared tests **(1960-1979)**	
Equation	$\chi 2$ (Chi-Sqaured)	P-Value
Fundsrate	7221	0.00
M2	18359	0.00
GDP	1751	0.00
Inflation	22661	0.00

Appendix B: Granger-Causality Tests

VAR 1: Funds rate, M2, Unemployment, Inflation

Granger causality test **(1983-2002)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.269
Fundsrate	Unemployment	0.113
Fundsrate	Inflation	0.225
Fundsrate	ALL	0.127
M2	Fundsrate	0.000
M2	Unemployment	0.002
M2	Inflation	0.000
M2	ALL	0.000
Unemployment	Fundsrate	0.001
Unemployment	M2	0.404
Unemployment	Inflation	0.000
Unemployment	ALL	0.000
Inflation	Fundsrate	0.803
Inflation	M2	0.022
Inflation	Unemployment	0.276
Inflation	ALL	0.007

Granger causality test **(1960-1979)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.293
Fundsrate	Unemployment	0.108
Fundsrate	Inflation	0.009
Fundsrate	ALL	0.004
M2	Fundsrate	0.214
M2	Unemployment	0.160
M2	Inflation	0.147
M2	ALL	0.004
Unemployment	Fundsrate	0.000
Unemployment	M2	0.224
Unemployment	Inflation	0.241
Unemployment	ALL	0.000
Inflation	Fundsrate	0.251
Inflation	M2	0.617
Inflation	Unemployment	0.829
Inflation	ALL	0.252

VAR 2: Funds Rate, M2, Output Gap, Inflation

Granger causality test **(1983-2002)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.267
Fundsrate	Output Gap	0.677
Fundsrate	Inflation	0.441
Fundsrate	ALL	0.461
M2	Fundsrate	0.001
M2	Output Gap	0.034
M2	Inflation	0.007
M2	ALL	0.000
Output Gap	Fundsrate	0.015
Output Gap	M2	0.441
Output Gap	Inflation	0.000
Output Gap	ALL	0.002
Inflation	Fundsrate	0.541
Inflation	M2	0.017
Inflation	Output Gap	0.980
Inflation	ALL	0.056

Granger causality test **(1960-1979)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.567
Fundsrate	Output Gap	0.021
Fundsrate	Inflation	0.028
Fundsrate	ALL	0.001
M2	Fundsrate	0.256
M2	Output Gap	0.094
M2	Inflation	0.091
M2	ALL	0.002
Output Gap	Fundsrate	0.889
Output Gap	M2	0.656
Output Gap	Inflation	0.832
Output Gap	ALL	0.887
Inflation	Fundsrate	0.511
Inflation	M2	0.681
Inflation	Output Gap	0.083
Inflation	ALL	0.027

VAR 3: Funds Rate, M2, GDP, Inflation

Granger causality test **(1983-2002)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.572
Fundsrate	GDP	0.732
Fundsrate	Inflation	0.320
Fundsrate	ALL	0.492
M2	Fundsrate	0.026
M2	GDP	0.011
M2	Inflation	0.019
M2	ALL	0.000
GDP	Fundsrate	0.385
GDP	M2	0.000
GDP	Inflation	0.000
GDP	ALL	0.000
Inflation	Fundsrate	0.826
Inflation	M2	0.057
Inflation	GDP	0.758
Inflation	ALL	0.027

Granger causality test **(1960-1979)**		
Equation	Excluded	Prob>chi2
Fundsrate	M2	0.704
Fundsrate	GDP	0.403
Fundsrate	Inflation	0.043
Fundsrate	ALL	0.016
M2	Fundsrate	0.394
M2	GDP	0.301
M2	Inflation	0.061
M2	ALL	0.008
GDP	Fundsrate	0.246
GDP	M2	0.103
GDP	Inflation	0.269
GDP	ALL	0.025
Inflation	Fundsrate	0.084
Inflation	M2	0.498
Inflation	GDP	0.000
Inflation	ALL	0.000

Appendix C: Forecast Error Variance Decompositions

FEVD Table 1	Funds Rate Exogeneity **(1960-1979)**			
Response: Funds Rate	Percentage of Forecast Error Variance Explained by			
Forecast Horizon	Unemployment	Inflation	Output Gap	GDP
6	3.81%	22.00%	14.43%	4.52%
12	11.36%	36.71%	30.04%	20.08%
24	28.20%	34.60%	48.60%	33.11%
36	40.82%	25.78%	53.92%	35.62%

FEVD Table 2	Funds Rate Exogeneity **(1983-2002)**			
Response: Funds Rate	Percentage of Forecast Error Variance Explained by			
Forecast Horizon	Unemployment	Inflation	Output Gap	GDP
6	7.84%	0.31%	3.32%	0.12%
12	11.02%	0.51%	5.78%	0.28%
24	7.86%	15.08%	7.55%	1.70%
36	5.77%	34.78%	7.13%	4.57%

FEVD Table 3	Funds Rate as Policy Indicator **(1960-1979)**			
Impulse: Funds Rate	Response Variables			
Forecast Horizon	Unemployment	Inflation	Output Gap	GDP
6	12.38%	13.84%	10.17%	2.13%
12	4.92%	23.85%	19.14%	14.63%
24	12.63%	29.06%	29.82%	20.88%
36	28.79%	23.23%	29.34%	18.57%

FEVD Table 4	Funds Rate as Policy Indicator **(1983-2002)**			
Impulse: Funds Rate	Response Variables			
Forecast Horizon	Unemployment	Inflation	Output Gap	GDP
6	28.51%	9.18%	8.10%	11.43%
12	40.75%	24.25%	20.54%	38.18%
24	26.32%	31.37%	14.91%	36.77%
36	16.54%	29.36%	9.35%	30.24%

Appendix D: Impulse Response Functions

Figure 1
VAR: Funds Rate, M2, Unemployment, Inflation
Impulse: Unemployment; Response: Federal Funds Rate

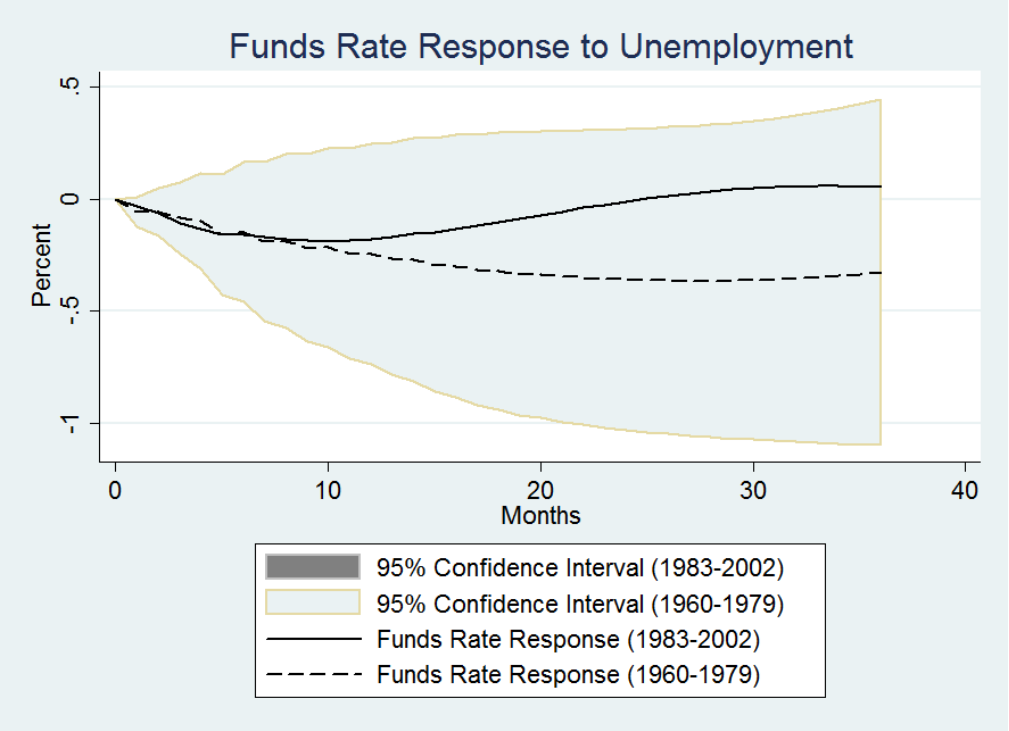


Figure 2
VAR: Funds Rate, M2, Unemployment, Inflation
Impulse: Inflation; Response: Federal Funds Rate

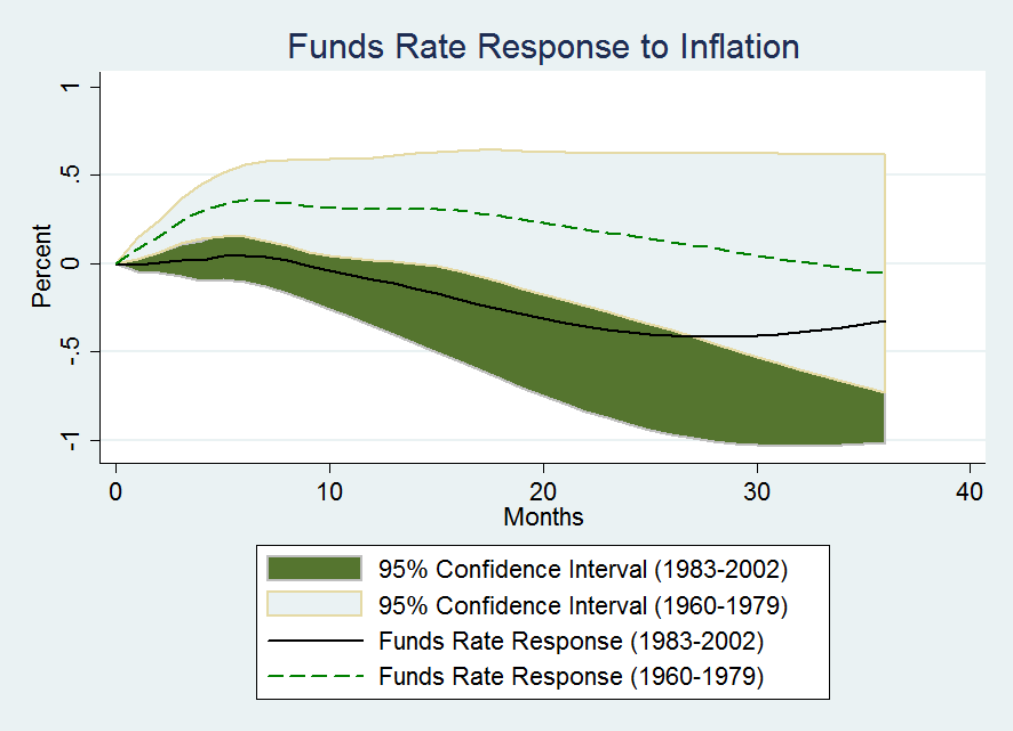


Figure 3
VAR: Funds Rate, M2, Unemployment, Inflation
Impulses: Unemployment, Inflation; Response: Federal Funds Rate

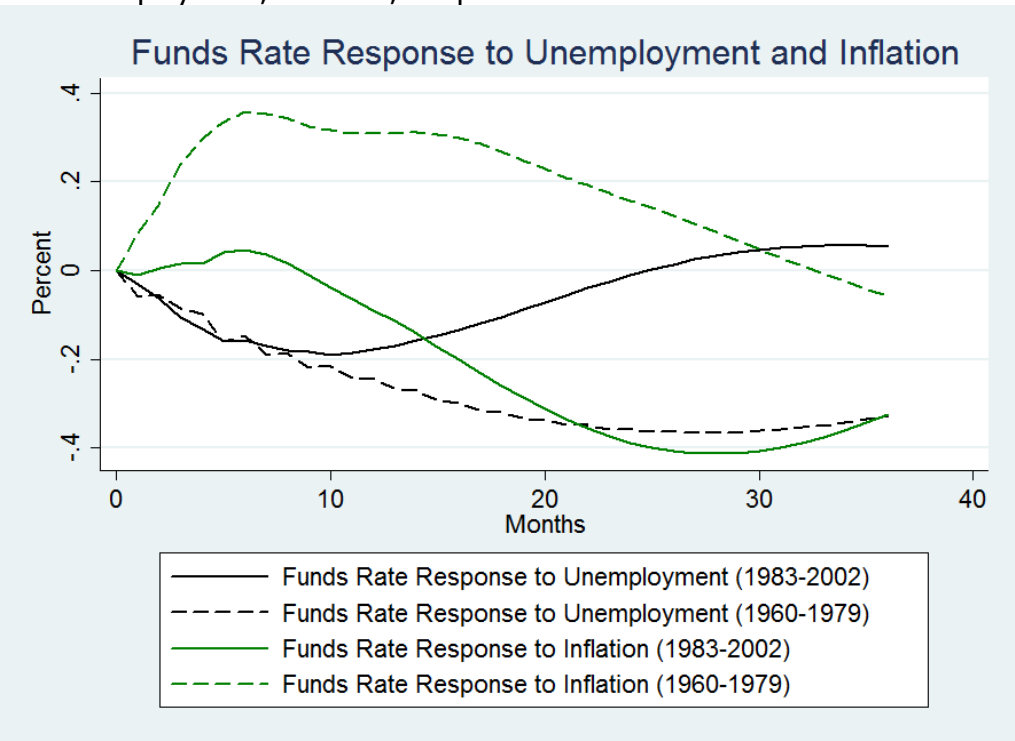


Figure 4
VAR: Funds Rate, M2, Output Gap, Inflation
Impulse: Output Gap; Response: Federal Funds Rate

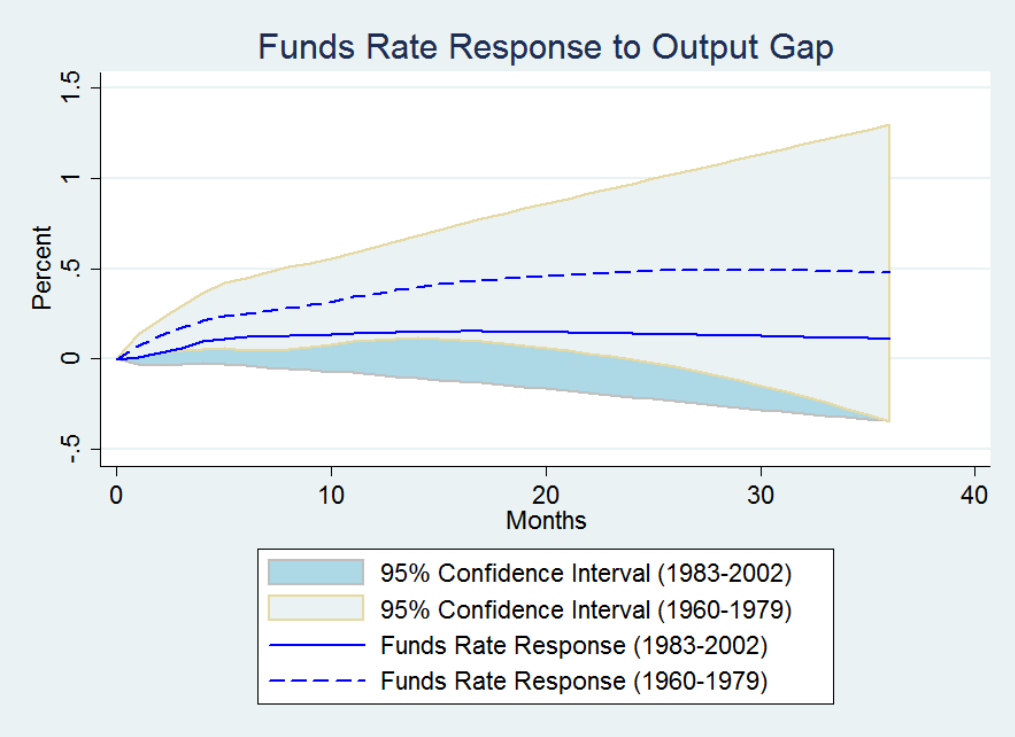


Figure 5
VAR: Funds Rate, M2, Output Gap, Inflation
Impulses: Output Gap, Inflation; Response: Federal Funds Rate

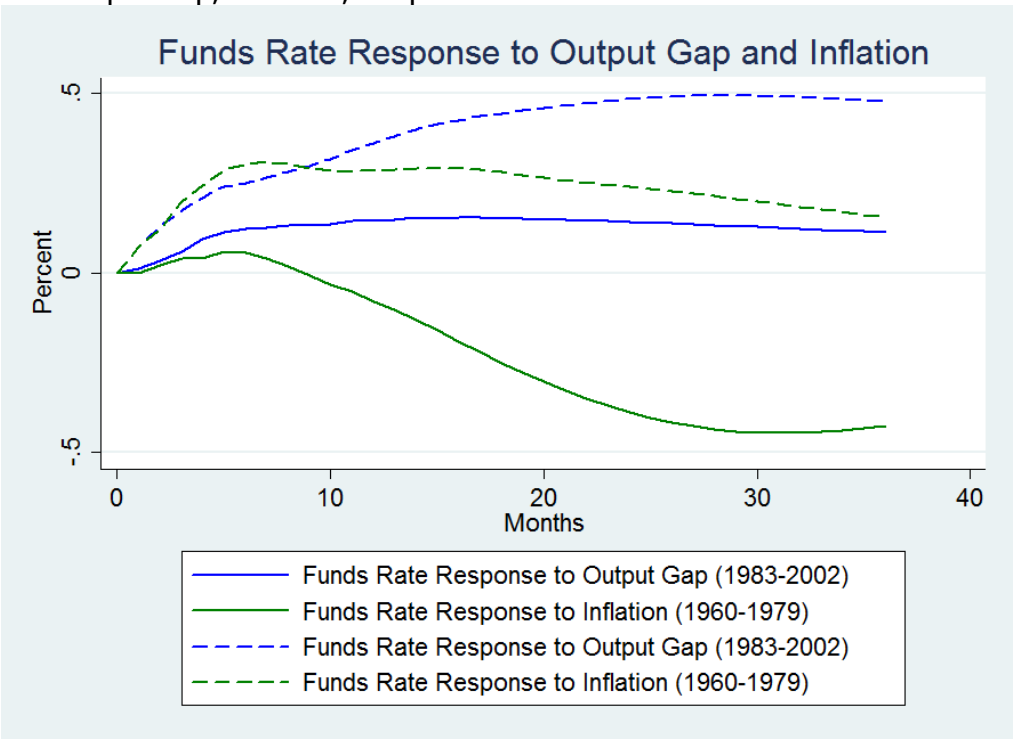


Figure 6
VAR: Funds Rate, M2, GDP, Inflation
Impulse: GDP; Response: Federal Funds Rate

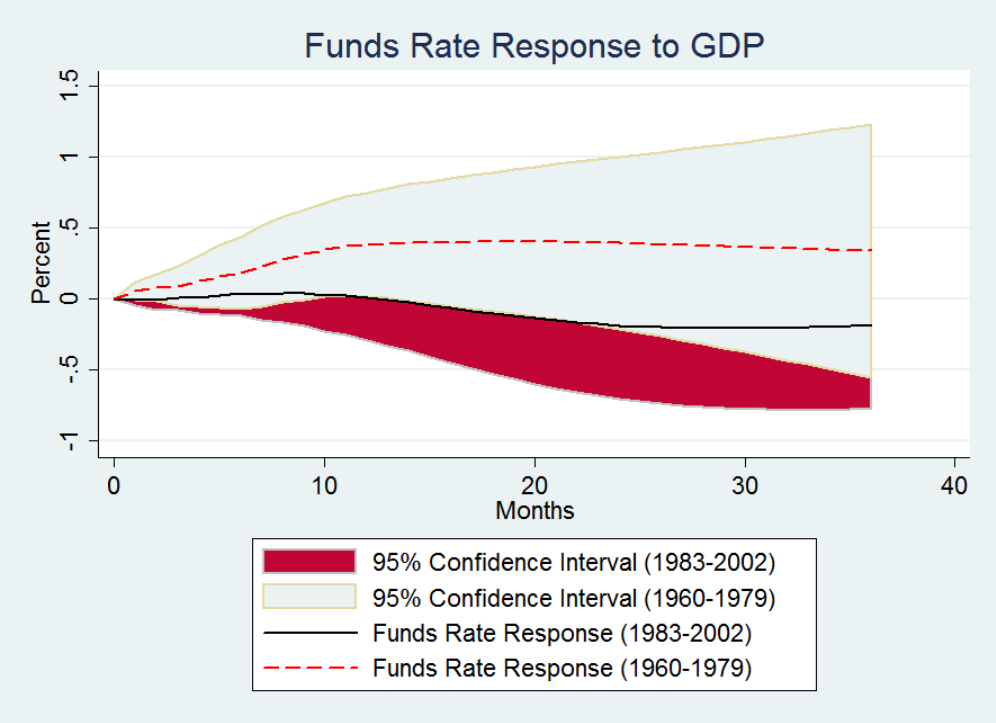


Figure 7
VAR: Funds Rate, M2, GDP, Inflation
Impulse: GDP, Inflation; Response: Federal Funds Rate

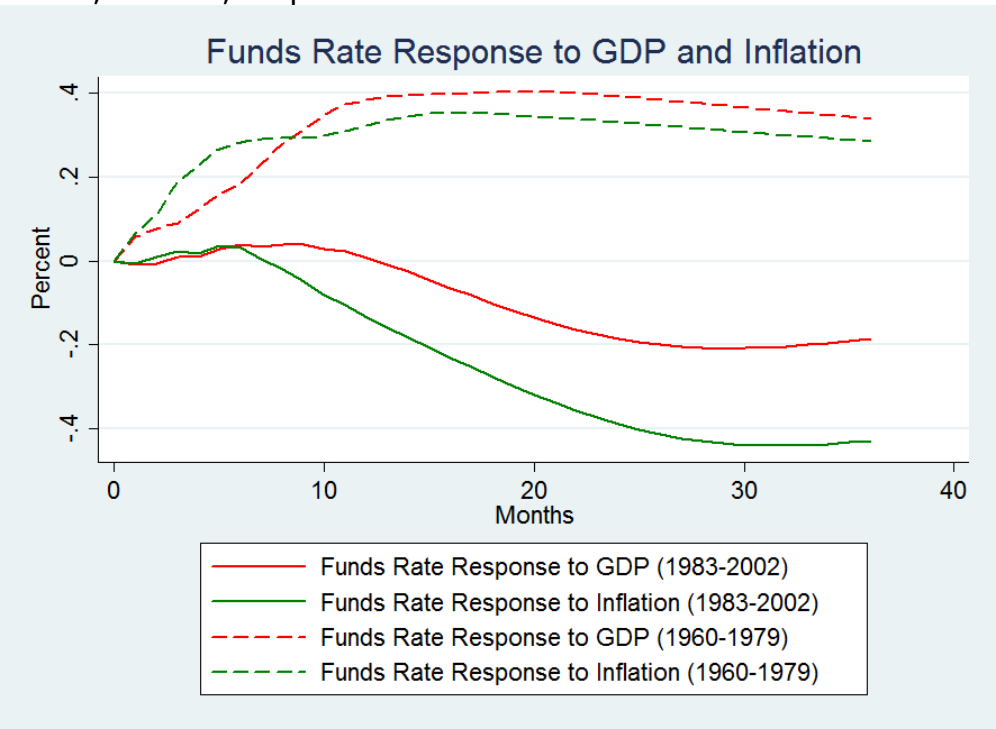


Figure 8
Combined VAR
Impulse: Unemployment, Inflation, Output Gap, GDP; Response: Federal Funds Rate

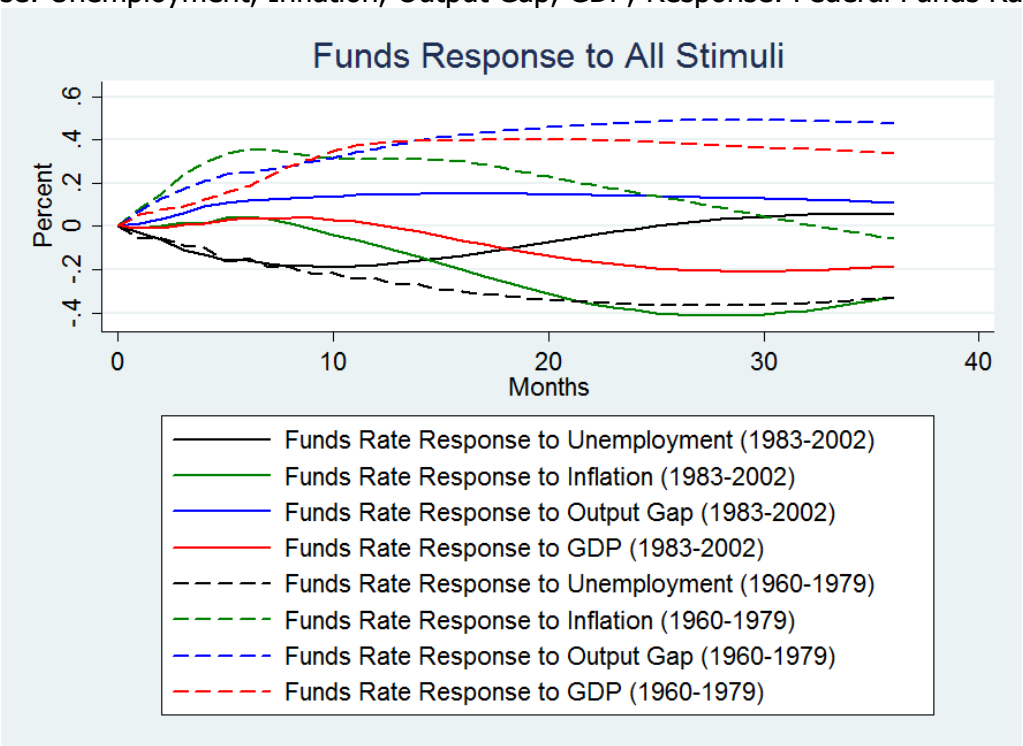


Figure 9
VAR: Funds Rate, M2, Unemployment, Inflation
Impulse: Funds Rate; Response: Unemployment

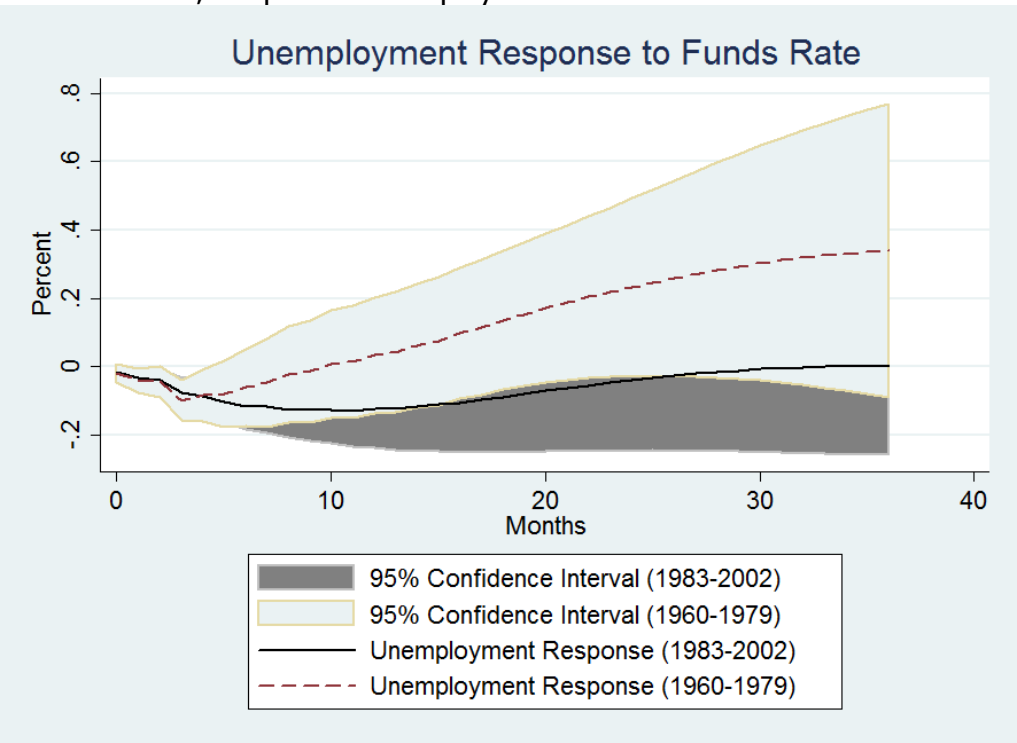


Figure 10
VAR: Funds Rate, M2, Unemployment, Inflation
Impulse: Funds Rate; Response: Inflation

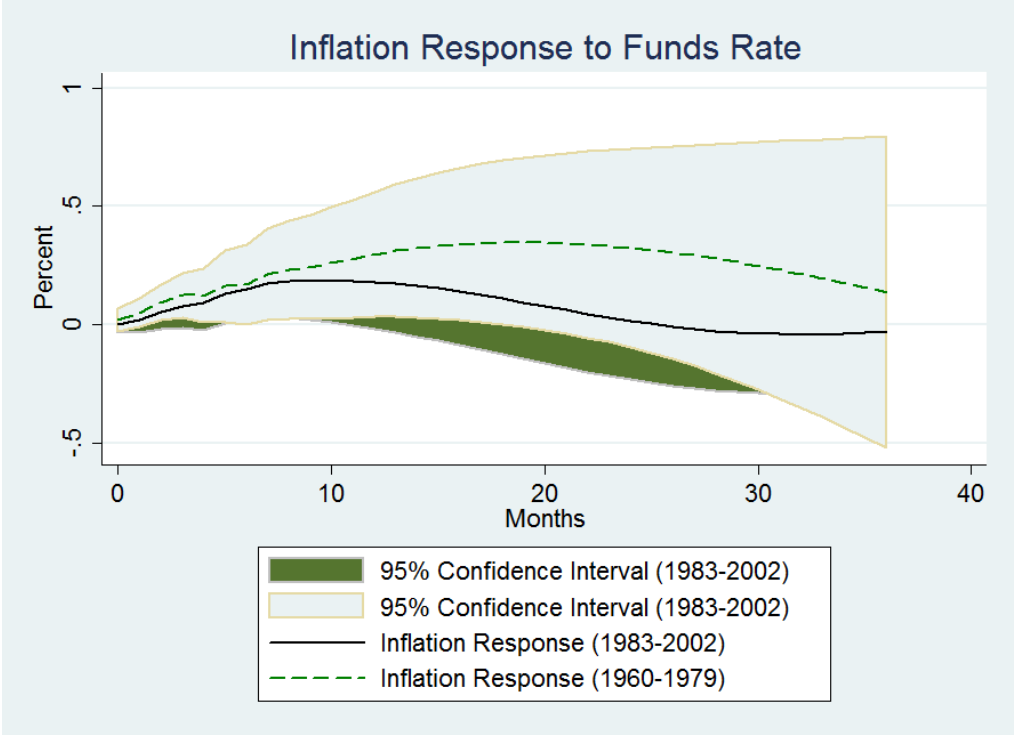


Figure 11
VAR: Funds Rate, M2, Unemployment, Inflation
Impulse: Funds Rate; Response: Unemployment, Inflation

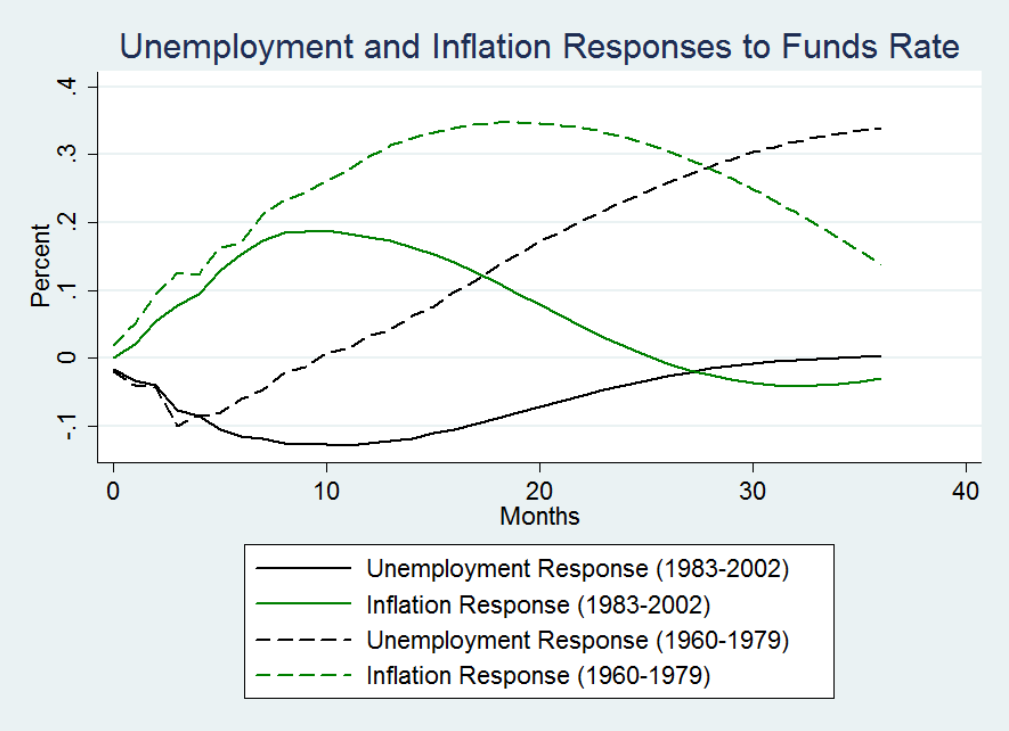


Figure 12
VAR: Funds Rate, M2, Output Gap, Inflation
Impulse: Funds Rate; Response: Output Gap

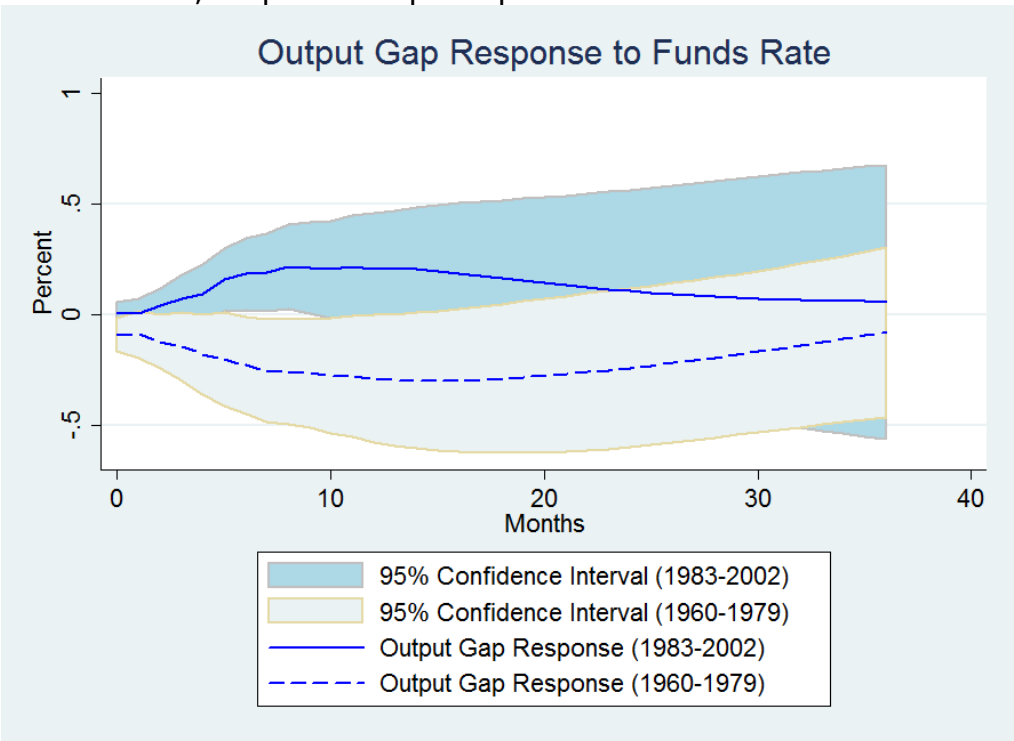


Figure 13
VAR: Funds Rate, M2, Output Gap, Inflation
Impulse: Funds Rate; Response: Output Gap, Inflation

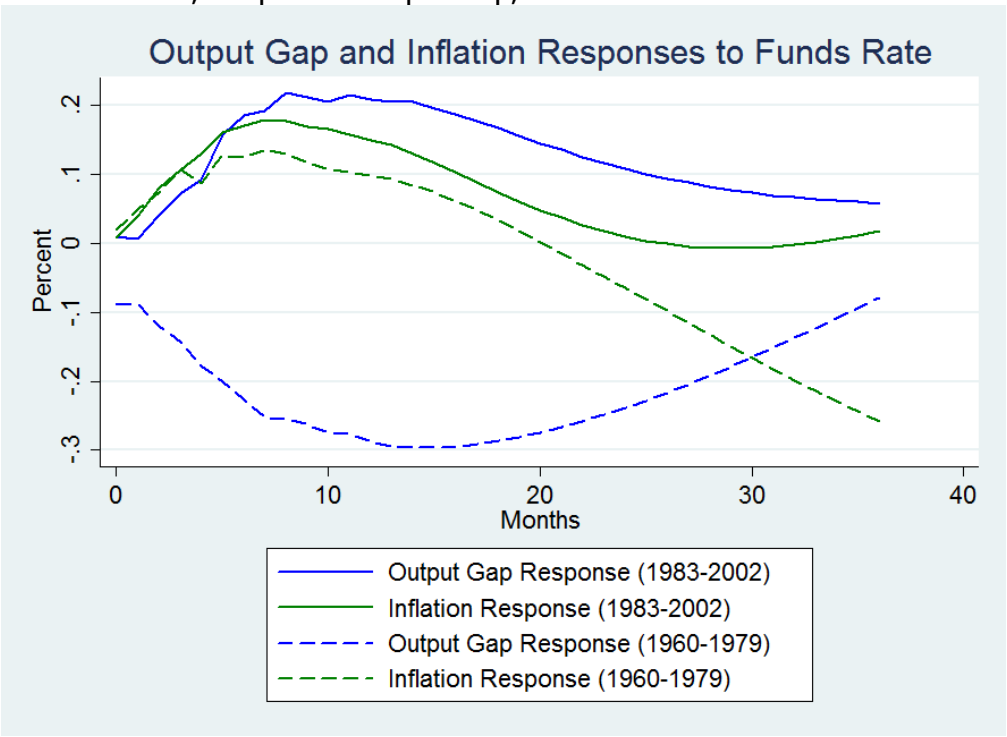


Figure 14
VAR: Funds Rate, M2, GDP, Inflation
Impulse: Funds Rate; Response: GDP

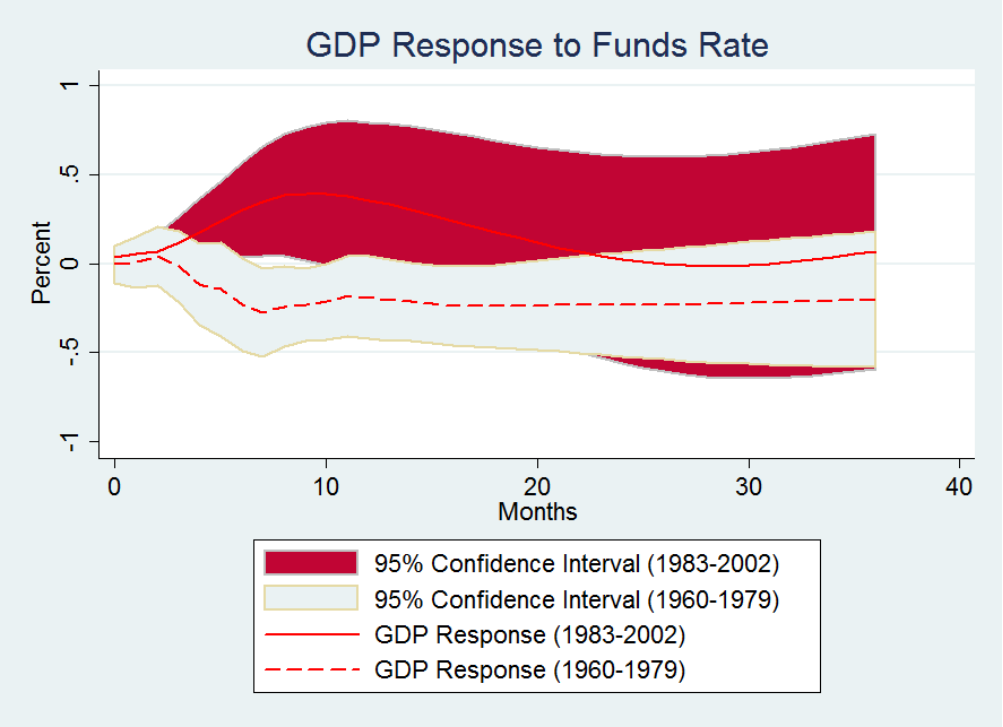


Figure 15
VAR: Funds Rate, M2, GDP, Inflation
Impulse: Funds Rate; Response: GDP, Inflation

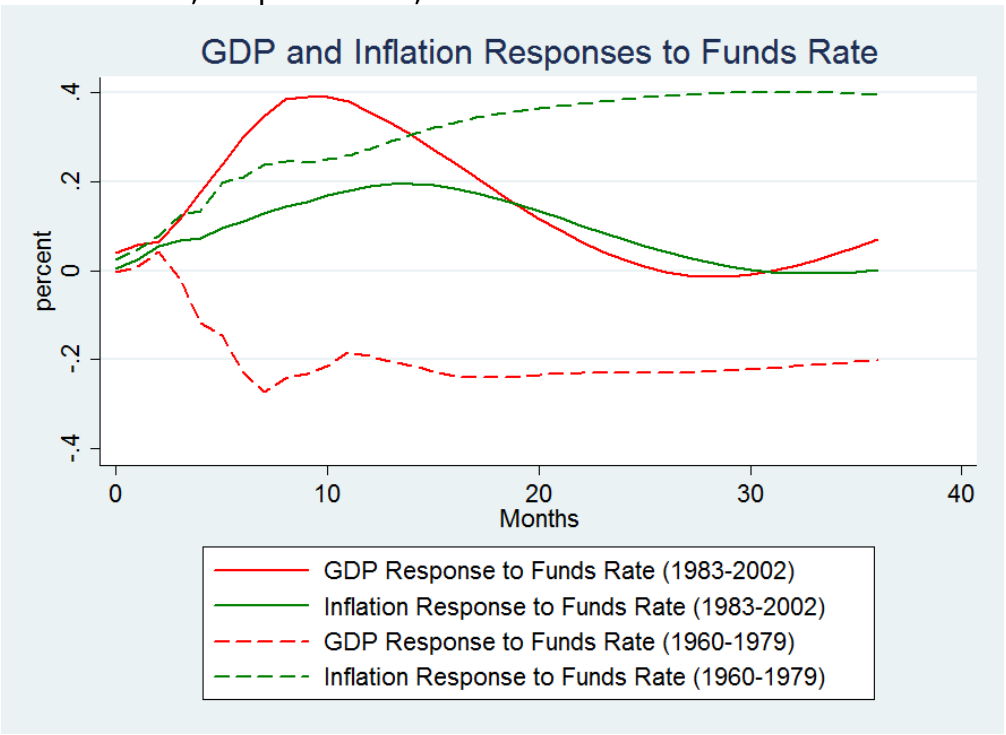


Figure 16
Combined VAR
Impulse: Funds Rate; Response: Unemployment, Inflation, Output Gap, GDP