Does the Fed Respond to Oil Price Shocks?

Lutz Kilian
University of Michigan
CEPR

Logan Lewis
University of Michigan

October 25, 2009

Abstract: Since Bernanke, Gertler and Watson (1997), a common view in the literature has been that systematic monetary policy responses to the inflation triggered by oil price shocks are an important source of aggregate fluctuations in the U.S. economy. We show that there is no evidence of systematic monetary policy responses to oil price shocks after 1987 and that this lack of a policy response is unlikely to be explained by reduced real wage rigidities. Prior to 1987, according to standard VAR models, the Federal Reserve was not responding to the inflation triggered by oil price shocks, as commonly presumed, but rather to the oil price shocks directly, consistent with a preemptive move by the Federal Reserve to counteract potential inflationary pressures. There are indications that this response is poorly identified, however, and there is no evidence that this policy response in the pre-1987 period caused substantial fluctuations in the Federal Funds rate or in real output. Our analysis suggests that the traditional monetary policy reaction framework explored by BGW and incorporated in subsequent DSGE models should be replaced by DSGE models that take account of the endogeneity of the real price of oil and that allow policy responses to depend on the underlying causes of oil price shocks.

JEL: E31, E32, E52, Q43,

Key words: Counterfactual; Oil; Recessions; Systematic monetary policy; Policy response; Temporal instability.

Acknowledgements: We thank Mark Gertler, Ana María Herrera, Elena Pesavento, and seminar participants at the University of Michigan for helpful discussions. Correspondence to: Lutz Kilian, Department of Economics, University of Michigan, 611 Tappan Street, Ann Arbor, MI 48109-1220. Email: lkilian@umich.edu. Phone: (734) 647-5612. Fax: (734) 764-2769.

1. Introduction

Although it is common to attribute the recessions of the 1970s and early 1980s to oil price shocks, it has proved difficult to rationalize such large real effects based on standard macroeconomic models of the transmission of oil price shocks (see Kilian (2008a) for a review). One channel that may help amplify the effects of oil price shocks on real output is the endogenous policy response of the central bank to oil price shocks. Bernanke, Gertler and Watson (1997), henceforth referred to as BGW, stipulated that the Federal Reserve, when faced with potential or actual inflationary pressures triggered by a positive oil price shock, responds by raising the interest rate, amplifying the decline in real output associated with oil price shocks.[1] In assessing the effect of this policy response from VAR models, BGW postulated a counterfactual in which the Federal Reserve holds the interest rate constant. In other words, the Fed is not responding to any of the effects of the oil price shock on the economy. BGW concluded that the Fed's systematic and anticipated response to oil price shocks is the main cause of the recessions that tend to follow oil price shocks and that these recessions could have been avoided (at the cost of higher inflation) by holding the interest rate constant.[2]

BGW's results have not remained unchallenged. For example, Hamilton and Herrera (2004) showed that the estimates in BGW are sensitive to the choice of the VAR lag order. Allowing for additional lags undermines the importance of the policy response. They also demonstrated that implementing a constant interest rate policy would have required policy changes so large to be unprecedented historically and hence not credible in light of the Lucas critique, a point acknowledged by Bernanke, Gertler and Watson (2004). This evidence has done little to diminish the appeal of BGW's results, however.

BGW's empirical results also have motivated a theoretical literature that examines the potential macroeconomic impact of monetary policy responses to oil price shocks using DSGE models. The conclusions reached in this literature very much depend on the specification of the

[1] BGW viewed the monetary policy response to oil price shocks merely as a convenient example in the context of the broader question of how important systematic monetary policy responses are relative to exogenous monetary policy shocks. This example, however, subsequently has received great attention in its own right and it is this aspect of the BGW study that we focus on in this paper.

[2] In the words of BGW, "an important part of the effect of oil price shocks on the economy results not from the change in oil prices, per se, but from the resulting tightening of monetary policy. This finding may help explain the apparently large effects found by Hamilton and many others." (p. 136). They conclude that their results "provide substantial support for the view that the monetary policy response is the dominant source of the real effects of an oil price shock" (p. 124).

DSGE model. Whereas Leduc and Sill (2004), for example, concluded that in their DSGE model monetary policy contributes about 40 percent to the drop in real output following a rise in the price of oil, Carlstrom and Fuerst (2006), found that under alternative assumptions the entire decline in U.S. real output following an oil price shock may be due to oil and none attributable to monetary policy.[3] Thus, the key question remains of how plausible the original empirical estimates in BGW are. In this paper, we re-examine the evidence presented in BGW within the context of the class of VAR models they employed. We build on recent insights as to the specification of these models, we introduce additional data, and we exploit additional econometric tools that aid in the interpretation of the model estimates.

Our analysis of the BGW VAR framework implies that the Federal Reserve during the 1970s and early 1980s responded not to actual inflation triggered by oil price shocks, but rather responded directly to the oil price shocks, consistent with a preemptory move to counteract potential inflationary pressures. There is no evidence, however, that the Fed's policy response prior to 1987 was responsible for substantial fluctuations in the Federal Fund rate or in real output. Moreover, there are indications that the monetary policy response to oil price shocks is not well identified. There is no compelling evidence of the Federal Reserve tightening in response to the 1973/74 oil price shock; in fact, the Federal Reserve lowered the interest rate when oil prices increased sharply in late 1973. As BGW acknowledge, their empirical estimates rest mainly on evidence from 1979. This finding raises the question of whether Volcker raised interest rates in 1979 in response to the oil price shock of 1979 or whether he would have raised interest rates in response to rising inflation even in the absence of oil price shocks, as suggested, for example, in Barsky and Kilian (2002). One way of discriminating between these hypotheses is to focus on the post-Volcker period. Clearly, Greenspan and Bernanke have been rightly credited for putting the inflation objective first in the tradition of Volcker's policies, and there have been enough oil price shocks between 1987 and 2008 to help us identify the Federal Reserve's systematic policy response to oil price shocks. Yet, the type of model proposed by BGW shows no evidence at all of systematic monetary policy responses to oil price shocks after 1987, during the Greenspan-Bernanke era. This evidence is consistent with the view that the response estimates based on the 1979 data have been spurious.

[3] For related work see Blanchard and Gali (2008), Rotemberg (2008), and Harris, Kasman, Shapiro and West (2009), among others.

This finding is not necessarily a puzzle in light of evidence that the Federal Reserve's policy response has been much more sophisticated than BGW's model gives it credit for. We present evidence that the Federal Reserve on average has been responding differently to oil price shocks driven by global demand pressures than to oil price shocks driven by oil supply disruptions, for example. Our analysis suggests that DSGE models of monetary policy responses in particular must account for a variety of structural shocks in the crude oil market, each of which may necessitate a different policy response. For example, the policy response required in dealing with oil price shocks reflecting shifts in the global demand for oil driven by unexpected growth in emerging Asia should look different from the response required in dealing with oil price shocks triggered by oil supply disruptions in the Middle East. A recent example of a stylized DSGE model that formally establishes that it is suboptimal from a welfare point of view for a central bank to respond to oil price shocks rather than the underlying causes of that oil price shock is Nakov and Pescatori (2007).

An alternative explanation of the lack of evidence of a monetary policy response after 1987 that is often cited in the literature is reduced real wage rigidities (see Blanchard and Gali 2008). The argument is that oil price shocks have become less inflationary over time, allowing the policymaker to respond less aggressively to oil price shocks without causing a major recession. We discuss the merits of this explanation and show that the evidence presented in its support is not conclusive. Although there are other possible explanations of the diminished importance of systematic monetary policy responses to oil price shocks, some of which we review, we stress that this recent debate is largely irrelevant because even prior to 1987 monetary policy responses to oil price shocks did not have large cumulative effects on aggregate fluctuations, as measured by historical decompositions. That conclusion is independent of the choice of counterfactual. Our results suggest that the traditional framework of monetary policy reactions to oil price shocks explored by BGW and incorporated in subsequent DSGE models should be replaced by DSGE models that take account of the endogeneity of the real price of oil and allow policy responses to depend on the underlying causes of oil price shocks.

The paper is organized as follows. In section 2, we discuss the rationale of the narrative account presented in BGW. In section 3, we motivate and summarize the innovations in our VAR model specification relative to BGW's original analysis. In section 4, we analyze the responses to oil price shocks over the periods of 1967.5-1987.7 and 1987.8-2008.6. We show

that one interpretation of the temporal instability across these subsamples is that monetary policy responses to oil price shocks for the pre-1987 period are not well identified. In section 5, we examine alternative explanations of this temporal instability including improved monetary policy responses, reduced real wage rigidities, changes in the energy share and a more stable monetary environment. We also discuss implications of changes in the composition of oil price shocks for empirical and theoretical models of the systematic policy reaction to oil price shocks. In section 6, we use historical decompositions to bound the real effects of monetary policy responses to oil price shocks. We conclude in section 7 with a discussion of the relevance of our results for today's policy makers.

2. The Rationale for a Monetary Tightening in Response to Oil Price Shocks

Although few researchers have questioned the narrative in BGW, the rationale for the policy response they stipulated is not self-evident. There are three problems. First, it is widely accepted that the Federal Reserve in the 1970s was as much concerned with maintaining output and employment as it was concerned with containing inflation. In fact, it has been argued that the Federal Reserve was overly concerned with the output objective during this period (see, e.g., Barsky and Kilian 2002). To the extent that oil price shocks are recessionary, in the absence of a policy response one would have expected the Fed to ease rather than tighten monetary policy in response; and even if one were to grant that oil price shocks also have inflationary effects, it would not be obvious that the appropriate policy response on balance would be to raise the interest rate. In fact, BGW's notion of a policymaker responding aggressively to inflationary pressures seems more consistent with the Volcker era than with U.S. monetary policy in the 1970s.

Second, while a robust theoretical finding is that oil price shocks are at least mildly recessionary in the absence of a monetary policy response, it is not clear that oil price shocks are necessarily inflationary. For simplicity suppose that a one-time oil price shock occurs, while everything else is held constant. There are two main channels of transmission. One is the increased cost of producing domestic output (which is akin to an adverse aggregate supply shock); the other is the reduced purchasing power of domestic households (which is akin to an adverse aggregate demand shock). The latter channel of transmission may be amplified by increased precautionary savings and by the increased operating cost of energy-using durables

(see Edelstein and Kilian 2009). Recent empirical evidence suggests that the supply channel of transmission is weak and that the demand channel of transmission dominates in practice (for a review see, e.g., Kilian 2008a). On that basis, one would expect an exogenous oil price shock, if it occurs in isolation, to be recessionary and deflationary, suggesting that there is no reason for monetary policy makers to the raise interest rate at all. In fact, one could make the case that policy makers should lower interest rates to cushion the recessionary impact. Moreover, if both the aggregate demand and the aggregate supply curves shift to the left, as seems plausible, the net effect on the domestic price level is likely to be small, so there is little need for central bankers to intervene under the price stability mandate. Thus, unless a good case can be made for the risk of a wage-price spiral, oil price shocks would not be expected to cause sustained inflation. This analysis shows that BGW implicitly take the rather extreme view that oil price shocks necessarily represent adverse aggregate supply shocks that are both recessionary – if only mildly so because otherwise there would be no need for an amplifier – and inflationary.

The third problem is BGW's premise that innovations to the price of oil are exogenous with respect to the U.S. economy. The recent literature has established that oil price shocks do not take place in isolation, violating the premise of the analysis in BGW. This point matters. For example, Nakov and Pescatori (2007) demonstrate that a welfare-maximizing central banker should not respond to innovations in the price of oil. More generally, Kilian (2008a) observes that policy makers should respond not to the price of oil (which is merely a symptom rather than a cause), but directly to the underlying demand and supply shocks that drive the real price of oil along with other macroeconomic variables. This does not rule out, of course, that policymakers may have chosen to respond to oil price shocks as stipulated in BGW.

3. Innovations in the Model Specification Relative to BGW's Analysis

In light of the caveats discussed in section 2, the empirical success of the model proposed by BGW is by no means a foregone conclusion. Below we reexamine their conclusions bringing to bear additional data as well as additional econometric tools. We do so within the context of the class of models they postulated. In addition to examining a much longer sample period and conducting subsample analyses, we modify the VAR model used by BGW as follows:

First, the impulse response analysis in BGW is mainly based on the nominal net oil price increase measure of Hamilton (1996, 2003). Kilian and Vigfusson (2009) have shown that

censored VAR models of the type estimated by BGW are inconsistent and have a tendency to exaggerate the responses to oil price shocks. Moreover, the hypothesis of symmetric response functions in oil price increases and decreases cannot be rejected even for large oil price shocks, suggesting that standard linear VAR models are adequate for modeling oil price shocks. For that reason we follow an alternative strand of the literature and replace the net oil price increase measure by the real price of oil (see, e.g., Rotemberg and Woodford 1996; Kilian 2009a; Herrera and Pesavento 2009). This approach is consistent with the specification of standard economic models of the transmission of oil price shocks.

Second, BGW relied on an interpolated measure of real GDP. The dangers of interpolating economic data are well known (see, e.g., Angelini, Henry and Marcellino 2006). Since BGW's original analysis, much progress has been made in constructing coincident indicators of monthly real activity. In our analysis, we use a version of the Chicago Fed's National Activity Index (CFNAI), which is based on the leading principal component of a wide range of monthly indicators of U.S. real activity.[4] The effectiveness of the use of principal components and related data dimension reduction methods in the context of VAR models of monetary policy has been demonstrated in Bernanke, Boivin and Eliasz (2005) and Bańbura, Giannone and Reichlin (2008), among others. The CFNAI index produces temporary declines in real activity in response to an unanticipated monetary tightening that persist for less than two years, whereas the interpolated real GDP series of BGW implies much more persistent and hence less plausible effects on real output.[5] In addition, our approach is consistent with the view that central bankers consider a wide range of indicators of real activity in making policy decisions rather than real GDP only (see, e.g., Evans 1999). Figure 1 shows that the CFNAI business cycle fluctuations differ from those in the quarterly real GDP series in amplitude and timing, although there are many commonalities as well. The NBER recessions are shown as shaded areas. Figure 1 illustrates why the CFNAI is considered a credible measure of the business cycle.

[4] The CFNAI is methodologically identical to the index of real economic activity developed in Stock and Watson (1999). It is based five categories of data: (1) output and income (21 series); (2) employment, unemployment, and hours (24 series); (3) personal consumption, housing starts, and sales (13 series); (4) manufacturing and trade sales (11 series); and (5) inventories and orders (16 series). All nominal series are adjusted for inflation.

[5] An alternative approach would have been to conduct the analysis at the quarterly frequency as in Herrera and Pesavento (2009). We do not pursue that possibility because of concerns that the semi-structural recursive identification approach of BGW may not remain valid at quarterly frequency, although we show in section 6 that our substantive conclusions are robust to the use of such models.

Third, rather than expressing all variables in the VAR model in levels we log difference the CPI, consistent with the common view that the price level is I(1). This transformation facilitates the construction of historical decompositions for the inflation rate. The CFNAI real output variable is already stationary by construction and does not require differencing or filtering. In addition, we also difference the real price of oil and the real price of industrial commodities in the baseline specification. This transformation has little effect on the qualitative pattern of the impulse responses. An alternative specification with the real price of oil in levels and the linearly detrended real price of commodities produced similar results; so did a specification allowing for a trending cointegration relationship between the real price of oil and the real price of commodities, reflecting the secular decline in real non-oil commodity prices.[6] We also experimented with dropping the real commodity price index from the baseline model. Again, the qualitative results were robust to this sensitivity analysis.

Finally, we reduced the model to its essentials by dropping the term structure variables ordered below the interest rate in BGW's original models. Those additional variables are not required for our analysis and may be dropped without loss of generality. A similar approach was followed in Leduc and Sill (2004) and Herrera and Pesavento (2009), for example.

4. The Benchmark VAR Model

Our data are monthly and span 1967.5-2008.6. We deliberately exclude the episode of the recent financial crisis from consideration, as standard monetary policy reaction functions would not be expected to apply to that period. Our baseline model focuses on the sample period of 1967.5-1987.7. Although one might be concerned about the inclusion of data prior to 1973, given the institutional changes in global oil markets after 1972, the results are not overly sensitive to the starting date. The starting date of 1967.5 is dictated by the availability of the CFNAI data. It is almost identical to the starting date of 1965.1 in BGW. The ending date of 1987.7 is more natural in our view than the ending date of 1995.12 in BGW, given the transition from Volcker to Greenspan in 1987. This shorter sample period also takes account of Hamilton and Herrera's (2004, p. 267) observation that the 1990/91 oil price shock episode may not fit the narrative in BGW. In any case, we verified that our substantive results are not sensitive to shortening the

[6] Standard tests do not reject the null of no cointegration between the real price of oil and the real price of commodities at conventional significance levels, even allowing for separate trends.

sample in this manner. Using additional data not available to BGW at the time, we will provide a separate analysis of the post-1987.7 period in section 4.4.

The baseline VAR model includes five variables: the percent change in the real price of industrial commodities, the percent change in the real price of imported crude oil, the CFNAI measure of U.S. real activity, the U.S. CPI inflation rate, and the Federal funds rate (in this order). The commodity price index is the spot index provided by the Commodity Research Board (CRB) and excludes the price of crude oil. The nominal spot price is deflated by the U.S. CPI. The oil price series is obtained by extrapolating the U.S. composite refiner's acquisition cost of crude oil backwards at the rate of growth of the U.S. producer price for oil and deflating by the U.S. CPI. The refiner's acquisition cost is provided by the Energy Information Administration as far back as 1974.1. The producer price index is the PW561 series of Hamilton (2003).

The VAR model includes 12 lags and an intercept.[7] The model allows identification of the monetary policy shock as well as the oil price shock based on a recursive ordering. The identification of the oil price shock exploits the conventional assumption of predetermined oil prices (see Kilian and Vega 2008). The real price of commodities is included following BGW because it is widely viewed as an indicator of inflationary pressures that the Federal Reserve responds to (also see Barsky and Kilian 2002, 2004). We order the real price of commodities first in an effort to control for global demand pressures in isolating exogenous oil price shocks. The monetary policy shock is identified as in BGW as the residual of the Federal funds rate after accounting for the contemporaneous feedback from all variables ordered above the Federal funds rate. This approach is standard in the literature (see, e.g., Christiano, Eichenbaum and Evans 1999). The remaining structural shocks in the VAR model are not identified.

4.1. Responses to an Exogenous Monetary Policy Shock

A useful starting point for the analysis is a review of the responses to an exogenous monetary policy shock in the modified VAR model. We consider an exogenous increase of 10 basis points in the Federal funds rate. Figure 2 shows response patterns that are fully consistent with similar VAR models in the literature (see Christiano et al. 1999). A monetary tightening induces a temporary increase in the Federal funds rate and a temporary decline in real output. Real

[7] Hamilton and Herrera (2004) discuss the importance of choosing a lag order that is large enough to capture the effects of oil price shocks. They suggest that choosing a lag order below 12 is likely to undermine the reliability of the impulse response estimates, whereas there is no indication that more than 12 lags are needed in typical monthly VAR models of the transmission of oil price shocks.

industrial commodity prices and the real price of oil fall. There is evidence of the usual price puzzle. Over time, CPI inflation declines significantly, but the effect on the price level is not significant.

Figure 3 illustrates that the implications of our modified VAR model using the CFNAI measure of real output are more economically plausible than those from the same model using interpolated real GDP as in BGW. In particular, the latter model implies an implausibly persistent decline in real output in response to a monetary policy tightening. The real output measure based on interpolated and HP-filtered real GDP as in BGW's analysis returns to its steady state only after four years, compared with one year and a half if real output is measured based on the CFNAI. The inflation and interest rate dynamics are very similar. We conclude that our modified model provides a credible baseline model for further analysis.

4.2. Systematic Policy Responses to an Oil Price Shock during 1967-1987

The main question of interest is how the Federal Reserve responds endogenously to an oil price shock. We consider a 10 percent increase to the real price of oil not related to innovations in global industrial commodity markets. Our initial analysis focuses on 1967.5-1987.7. The results in the left column of Figure 4 are seemingly very much in line with the narrative in BGW. The oil price shock is associated with a persistent increase in the real price of oil. Within two months, CPI inflation sharply spikes. Following the spike in inflation, the Federal funds rate rises temporarily, followed by a temporary drop in real output and a gradual reduction in inflation. Compared with the original BGW results, the interest rate response is somewhat smaller. It only involves a cumulative increase within the first year of 60 basis points rather than 80 basis points. The magnitude of our estimate is consistent with Hamilton and Herrera's (2004, p. 282) preferred response estimate.

4.2.1. What Was the Fed Responding to?

It is useful to examine in more detail what variables the Federal Reserve is responding to in the VAR model of section 4.1 by means of a decomposition of the policy response to the dynamics triggered by an oil price shock. The intuition underlying this procedure is straightforward. In any given period following an exogenous oil price shock, the deviation of the response of the Federal funds rate from the baseline of zero can be written as the sum of the response to its own lagged values and of the responses to lagged values of other variables in the system. This allows us to

decompose which variables are driving the policy response.

Consider the structural VAR(p) representation

$$A_0 y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t,$$

where y_t is the K-dimensional vector of variables, ε_t denotes the vector of structural innovations, the $K \times K$ matrix A_0 is lower triangular, and the intercept has been suppressed for notational convenience. Express this VAR system as

$$y_t = Cy_t + A_1 y_{t-1} + \ldots + A_p y_{t-p} + \varepsilon_t$$

where C is a $K \times K$ dimensional lower triangular matrix with zeroes on the diagonal. Define

$$B \equiv \begin{bmatrix} C & A_1 & \ldots & A_p \end{bmatrix}.$$

The contribution of variable i to the response of the Federal Funds rate at horizon h to an oil price shock at date 0 is given by:

$$d_{FFR,i,h} = \sum_{m=0}^{\min(p,h)} B_{5,mK+i}\theta_{i,2,h-m} \qquad h = 0,1,2,\ldots; i = 1,\ldots.,K,$$

where $\theta_{i,2,h-m}$ refers to the $\{i,2\}$ element of the $K \times K$ impulse response coefficient matrix at horizon $h-m$, denoted by Θ_{h-m}, as defined in Lütkepohl (2005).

The left column of Figure 5 shows the decomposition of the response of the Federal funds rate in the left column of Figure 4 along these lines. To improve the readability of the graph, results are shown in two separate plots. On impact, the response of the Federal funds rate is explained entirely by the Federal Reserve's direct reaction to the oil price shock; there is essentially no contemporaneous response to inflation, real output or industrial commodity prices. For the first three months, the Federal Reserve responds to the oil price shock by lowering interest rates, which is inconsistent with the narrative of BGW. For the next three months, the Federal Reserve responds directly to oil price shocks by raising the interest rate. There is little evidence of the Federal Reserve's policy response working through inflation. That response is negligible for the first three months and small thereafter. The sign of the response to inflation varies across the horizon. Likewise, there is very little reaction to the real output dynamics triggered by oil price shocks. Thus, to a first approximation, almost all of the response of the Federal funds rate after the impact period is accounted for by the own lags of the Federal funds rate.

This analysis is useful in that it shows that the Federal Reserve during the 1970s and early 1980s responded not to actual inflation triggered by oil price shocks, but rather responded directly to the oil price shocks, consistent with a preemptory move against potential inflationary pressures. For example, the Federal Reserve might have been responding to oil price shocks because they were seen as potential causes of wage-price spirals. This interpretation seems plausible in an unstable monetary environment. To the extent that this policy response is successful in preempting the risk of inflation, one would never actually observe wage-price spirals or a large response of inflation to the real price of oil in the data.

4.2.2. Counterfactual Analysis

The decomposition used in section 4.2.1 also is helpful in the construction of explicit counterfactuals. The key contribution of BGW is the inclusion of the price of oil in the monetary policy reaction function. How much of a difference does it make that the Federal Reserve is allowed to respond directly to oil price shocks? The relevant counterfactual in answering this question is not one in which the Federal Reserve holds the interest constant in response to an oil price shock, as postulated by BGW, but a counterfactual in which the Federal Reserve reacts to fluctuations in other macroeconomic state variables (such as inflation and real output) as it normally would with only the direct response to the real price of oil being shut down. Below we contrast the construction and implications of these two counterfactuals.

Under the counterfactual of only shutting down the direct response to the real price of oil, we construct a sequence of hypothetical shocks to the Federal funds rate that offsets the contemporaneous and lagged effects of including the real price of oil in the policy reaction function. This sequence of shocks is:

$$\varepsilon_{FFR,h} = -B_{5,2}x_{2,h} - \sum_{m=1}^{\min(p,h)} B_{5,mK+2}z_{2,h-m}, \quad h = 0,1,2,...$$

where $x_{i,0}, i = 1,...,K,$ denotes the contemporaneous response of variable i to the oil price shock in the absence of a counterfactual policy intervention. The change in variable i in response to the oil price shock after the counterfactual policy response is denoted by:

$$z_{i,0} = x_{i,0} + \theta_{i,5,0}\varepsilon_{FFR,0} / \sigma_5,$$

where σ_5 denotes the standard deviation of the exogenous monetary policy shock. The corresponding values for $h > 0$ can be generated recursively, starting with $i = 1$ from:

$$x_{i,h} = \sum_{m=1}^{\min(p,h)} \sum_{j=1}^{K} B_{i,mK+j} z_{i,h-m} + \sum_{j<i} B_{i,j} x_{j,h}$$

and

$$z_{i,h} = x_{i,h} + \theta_{i,5,0} \varepsilon_{FFR,h} / \sigma_5,$$

where $j = 1,...,K$.

In contrast, for the original BGW counterfactual, which BGW refer to as the Sims-Zha counterfactual based on a proposal in Sims and Zha (2006), one simply constructs a hypothetical path of the shock $\varepsilon_{FFR,t}$ that offsets all endogenous dynamics in the Federal funds rate such that the Federal funds rate remains unchanged over time. In our notation, this can be expressed as:

$$\varepsilon_{FFR,h} = -\sum_{j=1}^{K} B_{5,j} x_{j,5} - \sum_{m=1}^{\min(p,h)} \sum_{j=1}^{K} B_{5,mK+j} z_{j,h-m}, \quad h = 0,1,2,...,$$

building on the same recursion as in the construction of the alternative counterfactual described above. For an alternative description of the BGW counterfactual see Hamilton and Herrera (2004).

Figure 6 compares these counterfactuals with the unconstrained responses in the VAR model. Shutting down the direct response to oil price shocks has virtually no effect on inflation and little effect on real output. The Federal Reserve still would have raised interest rates by a roughly similar number of basis points in response to exogenous oil price shocks, but the bulk of that response would have occurred three months later. This evidence casts serious doubt on the narrative in BGW. For completeness we also include the original counterfactual computed as in BGW in Figure 6. In that case, the Federal funds rate remains constant by construction. This policy would have had essentially no effect on inflation and real output would have been only slightly higher, if at all.

An interesting question is what policy surprises each counterfactual would have involved compared with actual policy choices. Figure 7 shows that under the new counterfactual interest rates would have unexpectedly risen by about 17 basis points on impact, would have fallen by about 33 basis points in month 4 after the oil price shock and would have risen again by about 25 basis points in month 6, relative to actual policy choices. This sequence of policy surprises is somewhat different from that under the BGW counterfactual. One way of assessing how reasonable the implied departures from actual policy outcomes would have been is to focus on

the magnitude of actual policy changes in the past; given that we are interested in unanticipated policy changes, however, a better approach is to compare these implied changes to historical policy shocks in the fitted VAR model. The largest policy surprises in the structural VAR model are 446 and -662 basis points and occurred in 1980. About 30 percent of all policy shocks in the sample period exceed 30 basis points and a further 32 percent are below -30 basis points. By that standard, the policy changes required to implement the counterfactuals in Figure 7 do not seem unreasonable.

A closely related concern is that constructing any counterfactual is subject to the Lucas critique (see Hamilton and Herrera 2004; Bernanke, Gertler and Watson 2004; Sims and Zha 2006). Rather than provide a comprehensive analysis of this issue, we follow Hamilton and Herrera (2004) in analyzing BGW's approach on its own terms. We follow the common assumption in this literature of assuming that the policy changes contemplated are small enough not to affect the structure of the economy materially. This assumption is more credible in our context than in the original analysis in BGW because the counterfactuals in Figure 7 do not involve a surprise change in interest rates relative to actual policy outcomes in the same direction "for 36 months in succession" (Hamilton and Herrera 2004, p. 269). In fact, the time path of the Federal Funds rate in Figure 7 does not look noticeably different from plots of the actual policy surprises implied by the model one could construct for a period of similar length. Hence, it is not evidently unreasonable to presume that the model structure is stable with respect to policy interventions.

4.3. Does the Narrative Account in BGW Match Actual Policy Decisions?

Although our estimates – unlike the original estimates in BGW – pass the tests proposed by Hamilton and Herrera (2004), there is reason to be skeptical of BGW's interpretation of the evidence. It is instructive to focus on the relationship of the narrative account in BGW with the actual evolution of the U.S. Federal funds rate during the two oil price episodes of the 1970s. Although the Federal Reserve was not following an interest rate rule at the time, we follow the literature in postulating that the Federal funds rate effectively was controlled by the Federal Reserve.[8] The left panel of Figure 8 covers the first oil price shock episode of late 1973 and early 1974. A striking feature of these data is that the Federal Reserve had been raising interest rates

[8] For related accounts of U.S. monetary policy in the 1970s see Barsky and Kilian (2002) and Kozicki and Tinsley (2009).

steadily from early 1972 until mid-1973. This finding is consistent with evidence from Federal Reserve policy statements. The Fed by its own account was responding to rising industrial commodity prices when it continuously raised interest rates long before the oil price shock of late 1973. The observed rapid increases in global industrial commodity prices in 1972/73 were an indication of an overheating global economy, consistent with the analysis in Barsky and Kilian (2002). In contrast, when the oil price shocks did occur in late 1973, the Federal Reserve lowered interest rates for the first time in more than a year, consistent with the interpretation of oil price shocks as adverse aggregate demand shocks. The decline of interest rates continued into 1974, even after oil prices doubled again in January of 1974. Only in March of 1974, interest rates began to rise again, reaching a peak in July, before gradually receding to about 6 percentage points by early 1975.

This response is clearly different from the narrative account in BGW of a generic oil price shock episode and BGW readily conceded that "the 1974-75 decline in real output is generally not well explained by the oil price shock. The … major culprit was (non-oil) commodity prices. Commodity prices … rose very sharply before this recession and stimulated a sharp monetary policy response of their own." (p. 121). Thus, BGW's evidence in favor of a monetary policy response to oil price shocks rests squarely on the 1979 episode covered in the right panel of Figure 8. Given that both the Federal funds rate and the real price of oil began to increase in May of 1979, it is not surprising that date from this episode tends to dominate estimates of the contemporaneous correlation of oil price shocks and interest rate changes. This fact is troublesome because we do not know whether Paul Volcker raised interest rates in response to the oil price shock of 1979 or in response to rising inflation driven by domestic policies. Given that both interest rates and oil prices moved at about the same time, it is difficult to separate correlation from causation. In short, there is reason to suspect an identification problem.

4.4. Systematic Policy Responses to an Oil Price Shock during 1987-2008

The discussion in section 4.3 suggests that the monetary policy response to oil price shocks is not well identified. Much depends on whether we interpret the rise in interest rates in 1979 under Paul Volcker as a response to the oil price shocks of that year or as a shift in the policy regime away from the employment objective that would have taken place even in the absence of the oil price shocks of 1979. One way of discriminating between these hypotheses is to focus on the

pre-Volcker period 1967.5-1979.7. Estimates for this period (which are not shown to conserve space) indicate that in response to an oil price shock the Federal fund rate initially declines below its mean, then rises substantially above its mean (with a peak after 7 months), and finally drops substantially below its mean (with a trough after 17 months), before returning to its mean. This pattern roughly matches the evolution of the Federal funds rate after late 1973 in the left panel of Figure 8. The estimated responses of the Federal funds rate are statistically significant based on one-standard error bands. Clearly, this response pattern differs from the narrative in BGW who did not envision that the Federal Reserve would lower the interest rate in response to an oil price shock in the short run or, for that matter, in the second year following the oil price shock. These estimates are not dispositive, however, because there is reason to doubt that the Federal Reserve prior to Paul Volcker was committed to the price stability objective.

We also estimated the same model for the Volcker period of 1979.8-1987.7 for comparison (with pre-sample observations from the pre-Volcker period). Interestingly, the estimated responses provide no support for the notion that Volcker raised interest rates in response to oil price shocks and thereby caused a recession, although we hasten to add that this sample is likely to be too small to allow meaningful inference. A better way of assessing whether there is an identification problem in 1979 is to focus on the post-Volcker period. Clearly, Greenspan and Bernanke have been rightly credited for putting the inflation objective first in the tradition of Volcker's policies, and there have been enough oil price shocks between 1987 and 2008 to help us identify the Federal Reserve's systematic policy response to oil price shocks.

The right column of Figure 4 shows that there is no evidence at all of systematic monetary policy responses to oil price shocks after 1987, during the Greenspan-Bernanke era. Although the response of the real price of oil to an oil price shock is quite similar to that in the first subsample, there is almost no increase in the Federal funds rate or in real output and the path of inflation shows no evidence of significant price pass-through even in the absence of a policy reaction. Only on impact and twelve months later are there small spikes in inflation. The right column in Figure 5 decomposes the rather small response of the Federal funds rate further. The positive impact response reflects a direct response to the oil price shock; subsequent Fed funds rate movements are merely responses to own lags. Finally, the right column in Figure 6 illustrates that the counterfactual departures from the actual policy outcomes would have made essentially no difference for the inflation and real output responses. In light of that finding, the

implication of Figure 7 (right column) that the original BGW counterfactual (unlike the alternative counterfactual proposed in this paper) would have involved positive policy surprises for at least three years in a row, which hardly seems plausible, is a moot point. On the basis of these results, there clearly is no reason to include the real price of oil in the policy reaction function of the VAR model after 1987.

5. Explaining the Temporal Instability since 1987

A challenge for macroeconomists is to explain why oil price shocks were not followed by sharp recessions ever again after the 1970s and in particular why the economy has remained remarkably resilient to the sustained real oil price increases of 2003-mid 2008. In light of the findings in section 4.4, one interpretation of the temporal instability of monetary policy reactions to oil price shocks is that policy response estimates for the pre-1987 period simply are not well identified and overstate the response of policymakers. In other words, were it not for this identification problem, the response estimates would be quite similar for pre-1987 and post-1987 data. There are several other potential explanations of the temporal instability of policy reactions, however, that are reviewed below.

5.1. Improved Monetary Policy?

For example, Carlstrom, Fuerst and Paustian (2009), among others, have suggested that central banks have responded more aggressively to inflationary pressures in recent decades. If that were the case, in the context of the endogenous monetary policy response to oil price shocks, this would imply, if anything, a stronger interest rate response to oil price shocks than in the 1970s and hence a deeper recession. The problem with that interpretation is that the data do not show a significant recession between 2003 and mid-2008, for example, notwithstanding a sustained and largely unanticipated surge in the real price of oil, nor is there evidence of aggressive policy responses to oil price shocks in the VAR estimates. An alternative and more plausible explanation is that oil price shocks are no longer as inflationary as they used to be, allowing the central bank to respond less aggressively to a given oil price shock. This alternative explanation involves several elements.

5.2. The Role of Reduced Real Wage Rigidities, Changes in the Energy Share, and Changes in the Composition of Oil Price Shocks

For example, Blanchard and Galí (2008) recently made the case that the U.S. economy has

become much more flexible since the 1980s and that the real wage rigidities that are thought to have characterized the U.S. economy in the 1970s have been greatly reduced. In this view the reason that the Federal Reserve needed to respond strongly to oil price shocks in the 1970s was that such shocks might set in motion wage-price spirals. Given the much more stable monetary environment starting in the 1980s and perhaps due to weaker unions, these concerns have dissipated, enabling the Federal Reserve to remain passive in the face of oil price shocks.

In light of our evidence of diminished policy responses, it is useful to investigate the hypothesis that reduced real-wage rigidities help explain the diminished importance of oil price shocks for U.S. real output and inflation. The notion of real wage rigidities was originally designed to explain high European unemployment (see Bruno and Sachs 1982). The idea was that strong unions tend to resist cuts in real wages associated with increases in the price level. To the extent that higher oil prices are passed on to consumers, unions insist on raising the nominal wage to preserve the real wage level. Excessively high real wages in turn cause unemployment. While this explanation may sound vaguely plausible for European economies, it seems less appealing for the United States. Clearly, U.S. real wages fell in response to oil price shocks even in the 1970s and 1980s (see, e.g., Rotemberg and Woodford 1996). Moreover, while the real wage response shows some variability over time, it does not show a tendency towards a larger response since the mid-1980s. Recently, Blanchard and Galí (2008) therefore have refined the argument. Since the response of unemployment to the same shock has declined dramatically over time, they suggest that the decrease in real wages, which required a large increase in unemployment in the 1970s, today is achieved with barely any increase in unemployment, consistent with a reduction in real wage rigidities.

It is not clear that this argument is valid, however, since the composition of oil demand and supply shocks underlying the innovations to the real price of oil has changed over time. The structural VAR estimates in Kilian (2009a) suggest that different oil demand and oil supply shocks involve different responses of U.S. real output and unemployment. As a consequence, the estimated responses of these aggregates to oil price innovations will evolve with changes in the composition of oil demand and oil supply shocks. To the extent that global aggregate demand shocks have increased in importance in recent years, one naturally would expect precisely the diminished unemployment response documented by Blanchard and Galí (2008), even in the absence of structural changes in labor markets. In fact, this is one of the central implications of

Kilian (2009a). Such a structural model can fully account for the diminished importance of oil price shocks in 2002-2007 compared with 1979-1982, for example, even in the absence of structural change. This does not preclude that real wages may have become more flexible, as conjectured by Blanchard and Galí (2008), but it says that no direct evidence has been presented that supports that hypothesis.

We can, however, use cross-country evidence to assess the plausibility of the real-wage rigidity argument. For example, it is uncontroversial that real-wage rigidities in continental Europe (and in the U.K. prior to Margaret Thatcher) must have been higher than in the U.S. If real wage rigidities were the primary explanation of the severity of real output response to oil price shocks, we would expect these countries to have performed worse than the U.S. during major oil price surges. Table 1 shows the economic performance of the G7 countries during selected oil price shock episodes. The data show that no G7 country experienced as steep a decline in real GDP growth (relative to average growth) following the 1973/74 and 1979/80 oil price shocks as the United States, contradicting the real wage rigidity hypothesis.

It may seem that perhaps differences in energy intensity across countries could also explain that pattern of results. If the U.S. were more energy intensive than Europe and Japan, then, not controlling for energy intensity, U.S. economic performance following oil price shocks may look worse than other countries' economic performance. While time series data on energy intensity by country are not readily available, an additional comparison suggests that this alternative explanation is unlikely. It seems reasonable to presume that the degree of real wage rigidity in any one country was approximately constant between 1973/74 and 1979/1980. Table 1 shows that Germany, Italy, and Japan all experienced below average real GDP growth following the first oil crisis, yet these same countries experienced above average growth following the second oil crisis. Even granting some improvement in energy efficiency over this time period, this sign reversal cannot be explained by changes in energy intensity or changes in real wage rigidities. It is consistent, however, with the view that Japan, for example, conducted very different monetary policies during the first and the second oil price shock (see Bohi 1989).

It is important to stress that not only are reduced real-wage rigidities not a plausible explanation of the diminished importance of oil price shocks since the mid-1980s, but neither are fluctuations in the energy share by themselves. One observation that is sometimes overlooked is that the U.S. energy share is primarily driven by the price of oil and has rebounded sharply in

recent years. Moreover, while it is true that fluctuations in the energy share have affected the transmission of energy price shocks, even controlling for the evolution of energy expenditures there is strong evidence for the reduced importance of energy price shocks (see Edelstein and Kilian 2009).

Although there is no compelling evidence of reduced real wage rigidities, there is some evidence that the monetary environment after 1987 was more stable than in the 1970s. Figure 9 plots U.S. survey inflation expectations, allowing us to contrast the experience of the 1970s and 2000s, two periods characterized by major oil price shocks. Figure 9 shows that U.S. inflation expectations remained remarkably stable as late as 2008.I.[9] Just when it appeared that inflation expectations might become unhinged after all, in mid-2008 the oil and commodity price boom collapsed, along with the global economy, rendering concerns over inflation expectations moot. This evidence is consistent with the interpretation that a more stable monetary environment reflecting the Federal Reserve's commitment to price stability may have allowed the Federal Reserve to respond less aggressively to the oil price shocks after 2002 than in the 1970s. Such an increased commitment to price stability could arise in the form of evolving response coefficients within the same policy reaction function as discussed in Herrera and Pesavento (2009). The data in Figure 9, however, are equally consistent with a shift from one policy regime to another, neither of which includes a direct response to oil price shocks, as in the monetary explanation of the Great Inflation proposed in Barsky and Kilian (2002). Again the data are not dispositive.

5.3. Changes in the Composition of Oil Price Shocks

Perhaps the most obvious reason for the temporal instability of responses to oil price shocks, in light of the earlier discussion about the endogeneity of oil price innovations, is that not all oil price shocks are the same. Oil price shocks are best viewed as symptoms of deeper structural shocks in oil markets. One would expect the Federal Reserve to respond differently to oil price shocks associated with, say, unexpected booms in global demand, than oil supply disruptions. An unexpected demand boom driven by the global business cycle, for example, will stimulate the U.S. economy in the short run, whereas an unanticipated oil supply disruption will not, calling for different policy responses depending on the composition of the oil demand and oil supply

[9] While the survey data used here only relates to one-year horizons, alternative measures of inflation expectations paint a very similar picture. For example, the 2-year and 5-10-year inflation expectations reported by Consensus Economics are flat in early 2008, notwithstanding an increase in the 1-year expectation. Likewise, the TIPS breakeven inflation rate (BEIR) for 5-10 years ahead shows only a slight upward drift in early 2008.

shocks underlying the oil price shock. For that reason one would not expect monetary policy rules involving oil price shocks or for that matter the response of the economy to oil price shocks to be the same at each point in time.[10]

Figure 10 investigates this point by adding the Federal funds rate as the fourth variable to the recursively identified VAR model utilized in Kilian (2009a).[11] We trace out the effects on the Federal funds rate of unanticipated oil supply disruptions ("oil supply shocks"), unexpected positive innovations to the global business cycle ("aggregate demand shocks") and demand shocks that are specific to the oil market ("oil-market specific demand shocks"). Figure 10 shows that the Federal Reserve tends to respond to positive oil demand shocks by raising the interest rate, whereas it tends to lower the interest rate in response to oil supply disruptions. The positive response to aggregate demand shocks in particular is consistent with the Fed's decision to raise interest rates long before the oil price shock of late 1973. The negative response to unanticipated oil supply disruptions is consistent with the view that the Federal Reserve views the resulting oil price increases as adverse aggregate demand shocks. Interpreting the positive response to demand shocks in this context is more difficult, as higher oil prices are but one of many consequences of such demand shocks.

Although the responses shown in Figure 10 correctly represent historical averages; it is not clear whether the Federal Reserve did consistently make a distinction between different oil demand and oil supply shocks in setting interest rates and whether embedding such a modified policy reaction function in the BGW model and estimating this VAR model on historical data would make sense. Indeed, it would be surprising if the Federal Reserve pursued a consistent policy over time. Moreover, the methodology underlying Figure 10 requires long samples with sufficient variation in all oil demand and oil supply shocks to ensure identification. Thus, the idea of embedding oil demand and oil supply shocks within a monetary policy reaction function, while perhaps natural, is not practical.

This caveat does not apply, however, to theoretical studies of the optimal monetary policy response to oil demand and oil supply shocks. Such studies require a different class of structural models than are customarily used by policy makers and macroeconomists.

---

[10] Note that this source of instability is different from the other potential explanations in that it does not involve changes in the unconditional distribution of the economy.

[11] The assumption that the price of oil and hence that oil demand and supply shocks are predetermined with respect to the interest rate is consistent with evidence in Kilian and Vega (2009).

Recent advances in the DSGE modeling of endogenous oil price shocks are a step in that direction. For example, Bodenstein, Erceg and Guerrieri (2007) model oil-market specific demand shocks, and Balke, Brown, and Yücel (2009) model the dependence of oil demand on global macroeconomic conditions. In related work, Nakov and Pescatori (2007) explicitly model the endogeneity of oil production decisions. While none of these papers provides a comprehensive analysis of all relevant aspects of the relationship between oil prices and the macro economy, a new class of models is beginning to emerge. In addition, future work will have to incorporate in more detail the external transmission of oil demand and oil supply shocks (see Kilian, Rebucci and Spatafora 2009) as well as the nexus between crude oil prices and retail energy prices (see Edelstein and Kilian 2009). DSGE models also may allow economists to distinguish between alternative causes of fluctuations in the global demand for industrial commodities, and to simulate the impact of alternative policy choices.

6. Historical Decompositions

While the search for alternative explanations of the diminished importance of endogenous monetary policy responses to oil price shocks is inconclusive, as the discussion in section 5 illustrates, more importantly there is evidence that it this search is moot. Although there are various pieces of evidence that could potentially help explain a smaller monetary policy response to oil price shocks after 1987, the literature has taken for granted that monetary policy responses had large cumulative effects on real activity prior to 1987. Figure 11 shows that there is no basis for this implicit premise. The cumulative contribution of oil price shocks through time on U.S. real output in particular is negligible. Figure 11 plots the actual (demeaned) real output and inflation data and the fluctuations in the same variable explained by the direct effect of oil price shocks and the endogenous policy response combined. It is evident that oil price shocks overall had little impact on observed U.S. real activity and inflation even in the first subsample. Likewise, we see that oil price shocks had little effect on the Federal Funds rate not only in 1973/74, but more importantly under Volcker in 1979/80.

Because the indirect effect on U.S. real activity associated with the monetary policy response and the direct effect of oil price shocks on U.S. real activity are of the same sign, an immediate implication of Figure 11 is that central bankers' monetary policy responses to oil price shocks cannot have been a major contributor to the U.S. recessions of the 1970s and the

early 1980s.[12] This result is quite powerful in that it does not depend on any counterfactual and is in striking contrast to BGW's original analysis. Despite BGW's failure to explain the 1974/75 recession based on the Federal Reserve's reaction to the oil price shock and despite their limited success in explaining subsequent recessions based on policy reactions to oil price shocks, BGW concluded that the data overall were supportive of a dominant role for monetary policy reactions. The historical decomposition of real output in Figure 11 does not support that view. There is no indication that U.S. real activity would have been much different under alternative policy scenarios, even in the late 1970s and early 1980s, despite the fact that our results pass standard tests of whether the counterfactual is reasonable, as discussed in section 4.2.1. This conclusion is much more in line with the theoretical results in Carlstrom and Fuerst (2006) of the impotence of systematic monetary policy than with BGW's original results, although unlike Carlstrom and Fuerst we do not find any evidence of large direct effects of oil price shocks on the U.S. economy.

It is interesting to compare our findings to the analysis in Herrera and Pesavento (2009). As part of a comprehensive study of potential causes of the Great Moderation, Herrera and Pesavento (2009) examined the extent to which systematic monetary policy responses had dampened fluctuations in real activity during the 1970s. Unlike our model, theirs was based on quarterly data. Here we consider a simplified version of their model. Figure 12 presents historical decompositions for quarterly U.S. real GDP growth and GDP deflator inflation. The recursively identified model includes the percent change in the real price of oil, the percent growth rate of real GDP, GDP deflator inflation and the Federal funds rate (in that order).[13] The results shown are based on the same sample period of 1967.II-1987.II. Essentially identical results would be obtained using Herrera and Pesavento's original sample period. Figure 12 contrasts the actual demeaned data with the cumulative effect of oil price shocks on real GDP growth and deflator inflation. Notwithstanding important differences in the sample period, model specification and data, the empirical results are fully consistent with our earlier analysis. In particular, the

[12] A very similar result applies to the second subsample (but is not shown to conserve space). The model provides no evidence that a monetary policy response to oil price shocks played a dominant role in the recessions of 1990, 2001, or late 2007, for example.

[13] We follow Herrera and Pesavento in fitting a VAR(4) model. Unlike Herrera and Pesavento we order the percent change in the real price of oil first in line with the results in Kilian and Vega (2009) and we drop the growth rate of potential output. These changes do not materially alter the results of the historical decomposition, nor does the exclusion of industry level variables that do not relate to our analysis. Our results for real GDP growth are substantively identical with those in Herrera and Pesavento (2009, Figure 7) for the larger quarterly model.

historical decompositions of real GDP growth based on the quarterly model in Figure 12 substantively agree with our historical decompositions of the CFNAI measure of real output in Figure 11. Regardless of the model adopted, there is no evidence that oil price shocks indirectly through the monetary policy reaction or directly were a major contributor to the recessions of 1974/75, 1980 or 1981-83.

7. Conclusion

Since BGW (1997), a common view in the literature has been that systematic monetary policy responses to the actual or potential inflationary pressures triggered by oil price shocks are an important source of aggregate fluctuations in the U.S. economy. Notwithstanding the popularity of this view, doubts remain about the empirical strategy used in support of that proposition. Using improved model specifications, additional data, and additional econometric tools that aid in the interpretation of the model estimates, we documented that there is no empirical support for an important role of monetary policy responses in amplifying the effects of oil price shocks. This finding is not completely surprising. We observed that the narrative underlying BGW's analysis of the 1970s is not self-evident in light of economic theory and at odds with recent empirical and theoretical work accounting for the endogeneity of the price of oil. Moreover, actual policy actions during the two oil price shock episodes of the 1970s do not fit well with the narrative account in BGW.

It is useful to put our results in perspective relative to earlier studies of the BGW model. Hamilton and Herrera (2004) aimed to show that the monetary policy response to oil price shocks in BGW's model was implausibly large. They made the case that the counterfactual constructed in BGW was not credible because it evidently violated the Lucas critique. Based on our analysis of the same sample period, using the same criteria employed in Hamilton and Herrera, the economically more relevant counterfactual proposed in this paper of shutting down the response to oil price shocks appear credible. Nevertheless, there is no evidence that the monetary policy response had large effects on U.S. real activity or CPI inflation. The latter conclusion is independent of the choice of counterfactual. Thus, our results differ from BGW's, but for different reasons than Hamilton and Herrera's.

Hamilton and Herrera (2004) also made the case that the direct effects of oil price shocks on the U.S. economy were substantial, making it less important to consider mechanisms of amplifying the effects of oil price shocks such as endogenous monetary policy responses.

In contrast, we found that the combined direct and indirect effect of oil price shocks on the U.S. economy has been negligible. This result is driven mainly by the specification of the oil price shock measure. The censored VAR model used in BGW's and in Hamilton and Herrera's (2004) analysis has been shown to yield inconsistent impulse response estimates (see Kilian and Vigfusson 2009). Given the lack of evidence of asymmetric response functions, documented in Kilian and Vigfusson, our analysis relies on more conventional specifications that are consistent with standard macroeconomic models of the transmission of oil price shocks and can be consistently estimated using standard estimation methods.

A potential concern with all monetary policy VAR models is the possibility of breaks in the policy reaction function associated with the transition from one chairman of the Federal Reserve to the next. Our subsample analysis addressed this issue within the constraints imposed by the data. In addition to reexamining the analysis of BGW on data for the 1967.5-1987.7 period (as well as the Volcker and pre-Volcker era within that period), we examined in detail policy responses to oil price shocks during the Greenspan-Bernanke era of 1987.8-2008.6. Ours is not the first study to find important differences in policy responses after 1987. For example, as part of a comprehensive study of potential causes of the Great Moderation, Herrera and Pesavento (2009) concluded that systematic monetary policy responses had dampened fluctuations in real activity during the 1970s, but had virtually no effect after the mid-1980s. Their conclusion appears to have been based on impulse response analysis and forecast error variance decompositions. Indeed, notwithstanding important differences in the sample period, model specification and data, our empirical analysis supported their conclusions, as far as impulse response analysis is concerned. The difference is in the emphasis. Whereas Herrera and Pesavento (2009) stressed differences in average volatility and in the magnitude of impulse responses across the two samples, we are more specifically concerned with the ability of systematic monetary policy responses to explain specific recessions in the 1970s and early 1980s. We showed that, even before the mid-1980s, systematic monetary policy responses were not a dominant source of the real effects of oil price shocks. Our analysis showed that historical decompositions of real GDP growth based on Herrera and Pesavento's quarterly model substantively agree with our historical decompositions of the CFNAI measure of monthly real output. Regardless of the model adopted, there is no evidence that oil price shocks indirectly through the monetary policy reaction or directly were a major contributor to the recessions of

1974/75, 1980 or 1981-83.

An important question in the recent literature has been what explains the apparent absence of a monetary policy response after the mid-1980s. We stressed that the evidence in favor of policy responses to oil price shocks in the 1970s and early 1980s is heavily influenced by the episode of 1979, yet it is unclear whether Volcker raised interest rates in 1979 in response to the 1979 oil price shock or whether he would have raised interest rates in response to rising inflation even in the absence of oil price shocks. To the extent that there was no causal link between from the oil price shock of 1979 to rising interest rates, the disappearance of this dynamic correlation in subsequent data is not surprising. A popular alternative view in the literature has been that diminished real wage rigidities in the U.S. are the primary explanation of the temporal instability of the BGW model (see Blanchard and Gali 2008). We showed that there is little evidence in support of that view. Not only is the evidence provided in Blanchard and Gali consistent with alternative explanations based on changes in the composition of oil price shocks, but cross-country data seem at odds with an important role for real wage rigidities. Nor are fluctuations in the energy share alone a plausible explanation. Likewise, evidence that the monetary environment has been much more stable after the mid-1980s with inflation expectations remaining firmly anchored throughout recent oil price shocks is open to different interpretations. Although we did not provide a definitive answer to this question, we showed that the ongoing debate about the cause of diminished monetary policy reactions to oil price shocks is largely moot, given our evidence that even during the 1970s and early 1980s systematic monetary policy responses to oil price shocks did not cause large cumulative fluctuations in real output.

Although the underlying reasons are still debated, there is little disagreement that the Federal Reserve has not been responding much to oil price shocks in recent decades. Much of the discussion in this paper instead has been about whether there were large real effects from Fed responses to oil price shocks in the 1970s and early 1980s. It may seem that this question should be primarily of interest to economic historians. This interpretation would be a mistake. Not only is this question central in designing theoretical models of the transmission of oil price shocks, but recent work by Harris et al. (2009), for example, has suggested that the Federal Reserve after 2005 may have been too passive in dealing with the determinants of high asset and oil prices. The question of how to respond to higher oil prices is likely to take on a new urgency, as the

world economy recovers from the current crisis. Moreover, the policy environment of 2009 in many ways resembles that at the beginning of the 1970s (see Kilian 2009b). Understanding the monetary policy regimes in that era, to what extent they were successful, and to what extent they can be improved upon is crucial for monetary policy makers as the global recovery unfolds.

Our analysis suggests that the traditional monetary policy reaction framework explored by BGW and incorporated in subsequent DSGE models has outlived its usefulness. There is growing, but not yet universal, awareness that it would be a mistake for policy makers to respond to oil price shocks rather than its underlying determinants. Rather than respond to relative price shocks that often are merely symptoms of broader global macroeconomic developments, central banks must identify and respond to the deeper causes of oil price shocks. This requires a different class of structural models than are customarily used by policy makers. It calls for DSGE models that take account of the endogeneity of the real price of oil and that allow policy responses to depend on the underlying causes of oil price shocks. Recent advances in the DSGE modelling of oil price shocks have made important strides in that direction, although more remains to be done to make these models operational for policy use.

References

Angelini, E., Henry, J., and M. Marcellino (2006), "Interpolation and Backdating with a Large Information Set," *Journal of Economic Dynamics and Control*, 30, 2693-2724.

Balke, N.S., S.P.A. Brown, and M.K. Yücel (2009), "Oil Price Shocks and U.S. Economic Activity: An International Perspective," mimeo, Federal Reserve Bank of Dallas.

Bańbura, M., Giannone, D., and L. Reichlin (2008), "Large Bayesian VARs," Working Paper No. 966, European Central Bank.

Barsky, R.B., and L. Kilian (2002), "Do We Really Know that Oil Caused the Great Stagflation? A Monetary Alternative," in: *NBER Macroeconomics Annual 2001*, B.S. Bernanke and K. Rogoff (eds.), MIT Press: Cambridge, MA, 137-183.

Barsky, R.B., and L. Kilian (2004), "Oil and the Macroeconomy Since the 1970s," *Journal of Economic Perspectives*, 18(4), 115-134.

Bernanke, B.S., Boivin, J., and P. Eliasz (2005), "Measuring the Effects of Monetary Policy: A Factor Augmented Vector Autoregressive (FAVAR) Approach," *Quarterly Journal of Economics*, 120, 387-422.

Bernanke, B.S., Gertler, M., and M.W. Watson (1997), "Systematic Monetary Policy and the Effects of Oil Price Shocks," *Brookings Papers on Economic Activity*, 1, 91-157.

Bernanke, B.S., Gertler, M., and M.W. Watson (2004), "Reply to Oil Shocks and Aggregate Economic Behavior: The Role of Monetary Policy," *Journal of Money, Credit and Banking*, 36, 287-291.

Blanchard, O.J., and J. Galí (2008), "The Macroeconomic Effects of Oil Shocks: Why are the 2000s so Different from the 1970s?" Forthcoming in: J. Galí and M. Gertler (eds.), *International Dimensions of Monetary Policy*, University of Chicago Press: Chicago, IL.

Bodenstein, M., Erceg, C.J., and L. Guerrieri (2007), "Oil Shocks and U.S. External Adjustment," mimeo, Federal Reserve Board.

Bohi, D.R. (1989), *Energy Price Shocks and Macroeconomic Performance*, Resources for the Future: Washington, DC.

Bruno, M., and J. Sachs (1982), "Input Price Shocks and the Slowdown in Economic Growth: The Case of U.K. Manufacturing," *Review of Economic Studies*, 49, 679-705.

Carlstrom, C.T., and T.S. Fuerst (2006), "Oil Prices, Monetary Policy, and Counterfactual Experiments," *Journal of Money, Credit and Banking*, 38, 1945-1958.

Carlstrom, C.T., Fuerst, T.S., and M. Paustian (2009), "Inflation Persistence, Monetary Policy, and the Great Moderation," *Journal of Money, Credit and Banking*, 41, 767-786.

Christiano, L.J., Eichenbaum, M., and C.L. Evans (1999), "Monetary Policy Shocks: What Have We Learned and to What End?" *Handbook of Macroeconomics*, 1, Chapter 2, Elsevier Science, 65-148.

Edelstein, P., and L. Kilian (2009), "How Sensitive are Consumer Expenditures to Retail Energy Prices?" *Journal of Monetary Economics*, 56, 766-779.

Evans, C.L. (1999), "If You Were the Central Banker, How Many Data Series Would You Watch? An Empirical Analysis." mimeo, Federal Reserve Bank of Chicago.

Gonçalves, S., and L. Kilian**.** (2004), "Bootstrapping Autoregressions with Conditional Heteroskedasticity of Unknown Form," *Journal of Econometrics*, 123(1), 89-120.

Hamilton, J. D. (1996). "This is What Happened to the Oil Price–Macroeconomy Relationship," *Journal of Monetary Economics*, 38, 215–220.

Hamilton, J. D. (2003) "What is an Oil Shock?" *Journal of Econometrics*, 113, 363–398.

Hamilton, J.D., and A.M. Herrera (2004), "Oil Shocks and Aggregate Economic Behavior: The Role of Monetary Policy," *Journal of Money, Credit and Banking*, 36, 265-286.

Harris, E.S., Kasman, B.C., Shapiro, M.D., and K.D. West (2009), "Oil and the Macroeconomy: Lessons for Monetary Policy," mimeo, University of Wisconsin.

Herrera, A.M., and E. Pesavento (2009), "Oil Price Shocks, Systematic Monetary Policy, and the 'Great Moderation'," *Macroeconomic Dynamics*, 13, 107-137.

Kilian, L. (2008a), "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature*, 46(4), 871-909.

Kilian, L. (2008b), "A Comparison of the Effects of Exogenous Oil Supply Shocks on Output and Inflation in the G7 Countries," *Journal of the European Economic Association*, 6, 78-121.

Kilian, L. (2009a), "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market," *American Economic Review*, 99(3), 1053-1069.

Kilian, L. (2009b), "Oil Price Shocks, Monetary Policy and Stagflation," forthcoming in: Fry, R., Jones, C., and C. Kent (eds.), *Inflation in an Era of Relative Price Shocks*, Sydney, 2009.

Kilian, L., A. Rebucci and N. Spatafora (2009), "Oil Shocks and External Balances," *Journal of International Economics*, 77, 181-194.

Kilian, L., and C. Vega (2008), "Do Energy Prices Respond to U.S. Macroeconomic News? A Test of the Hypothesis of Predetermined Energy Prices," mimeo, University of Michigan.

Kilian, L., and R. Vigfusson (2009), "Pitfalls in Estimating Asymmetric Effects of Energy Price Shocks," mimeo, Department of Economics, University of Michigan.

Kozicki, S., and P.A. Tinsley (2009), "Perhaps the 1970s' FOMC Did What It Said It Did?" forthcoming: *Journal of Monetary Economics*.

Leduc, S., and K. Sill (2004), "A Quantitative Analysis of Oil Price Shocks, Systematic Monetary Policy, and Economic Downturns," *Journal of Monetary Economics*, 51, 781-808.

Lütkepohl, H. (2005), *New Introduction to Multiple Time Series Analysis*, Springer: Berlin.

Nakov, A., and A. Pescatori (2007), "Inflation-Output Gap Trade-Off with a Dominant Oil Supplier," mimeo, Federal Reserve Bank of Cleveland.

Rotemberg, J. (2008), "Comment on Blanchard-Gali: The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so different from the 1970's?" Forthcoming in: J. Galí and M. Gertler (eds.), *International Dimensions of Monetary Policy*, University of Chicago Press: Chicago, IL.

Rotemberg, J., and M. Woodford (1996), "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," *Journal of Money, Credit, and Banking*, 28, 550-77.

Sims, C.A., and T. Zha (2006), "Does Monetary Policy Generate Recessions?" *Macroeconomic Dynamics*, 10, 231-272.

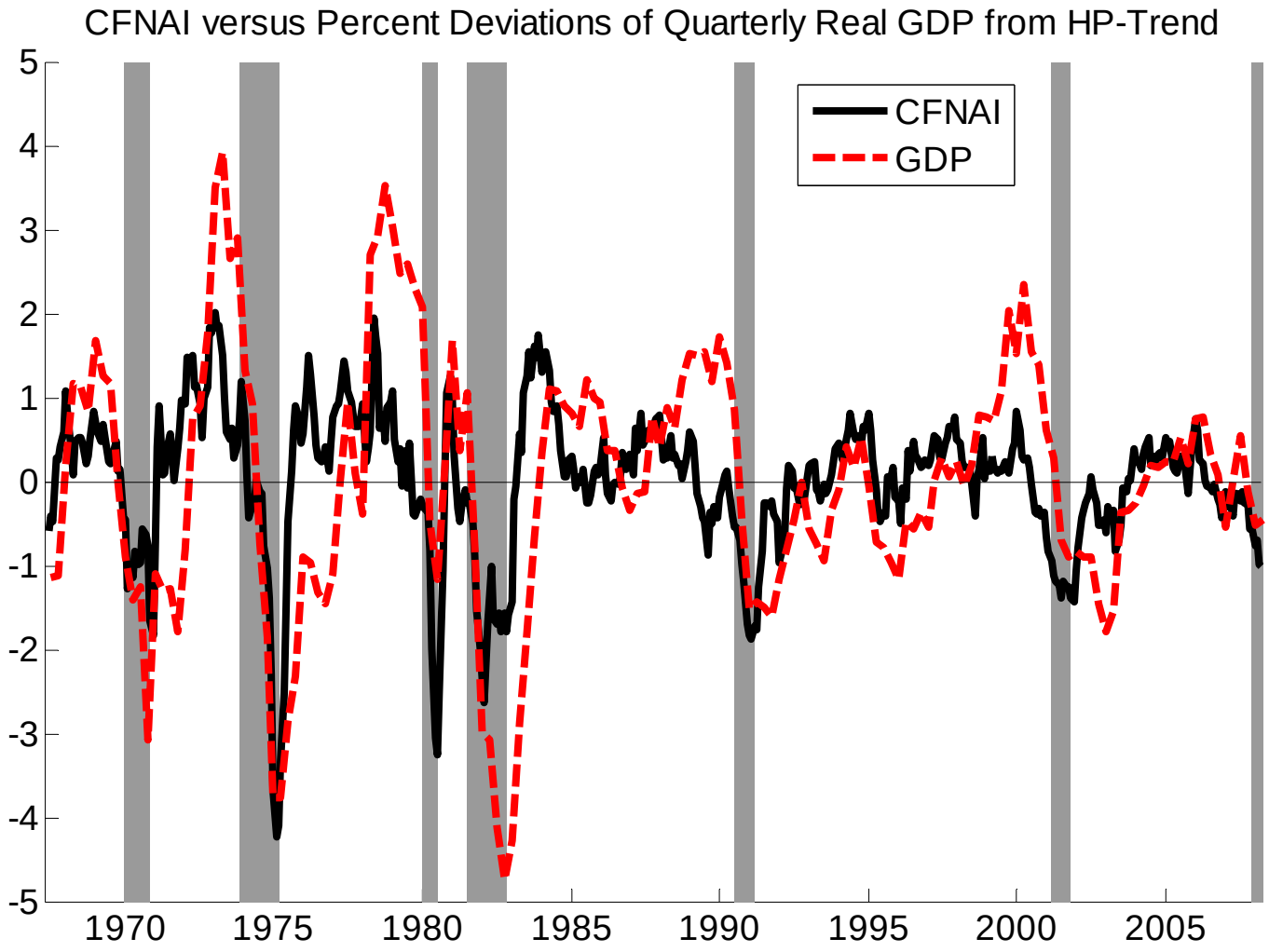
Stock, J.H., and M.W. Watson (1999), "Forecasting Inflation," *Journal of Monetary Economics*, 44, 293-335.

Table 1: Real GDP Growth Rates Relative to Long-Run Average in the G7 Countries Selected Episodes of Oil Price Shocks

	1973.IV-1975.II	1978.IV-1980.III	1980.IV-1983.I	1990.III-1993.III
United States	-3.84	-2.64	-1.87	-1.30
Italy	-2.01	2.10	-1.66	-1.96
France	-1.06	-0.24	-0.37	-1.72
Germany	-3.38	0.15	-2.01	2.33
U.K.	-3.50	-2.45	-1.14	-2.02
Canada	-0.24	-0.41	-2.56	-2.71
Japan	-1.75	1.00	0.17	-1.19

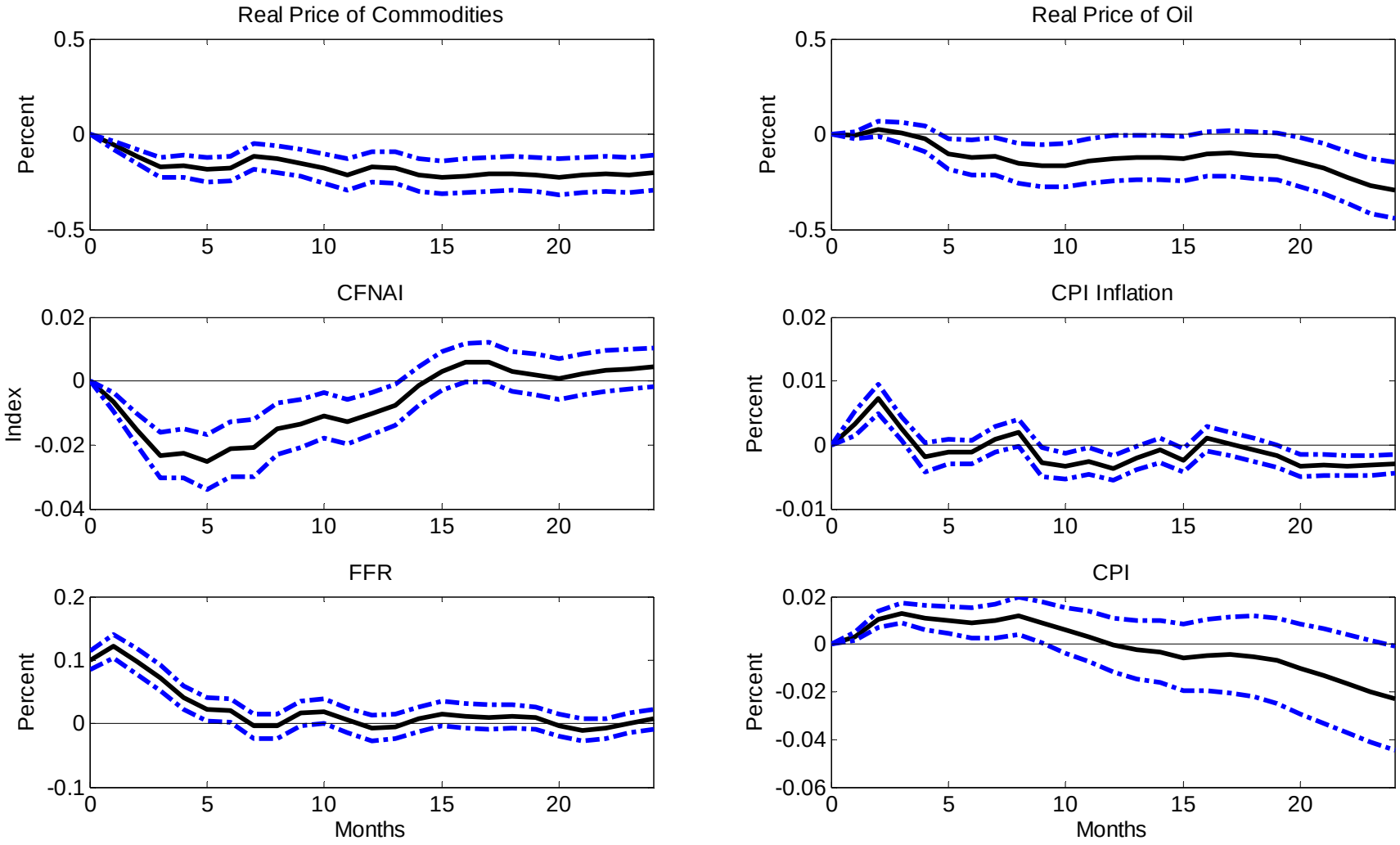
SOURCE: Kilian (2008b).

Figure 1: Alternative Measures of the Business Cycle in U.S. Real Output



Notes: Three-month moving average of the Chicago Fed National Activity Index (CFNAI) and HP-filtered log real U.S. GDP in percent deviationa from trend. NBER recessions are shown as shaded areas.

Figure 2: Responses to a 10 Basis Points Exogenous Increase in the Federal Funds Rate (with 1-Standard Error Bands) 1967.5-1987.7



Notes: The error bands were constructed using the recursive-design wild bootstrap method of Goncalves and Kilian (2004).

Figure 3: Responses to a 10 Basis Points Exogenous Increase in the Federal Funds Rate
1967.5-1987.7

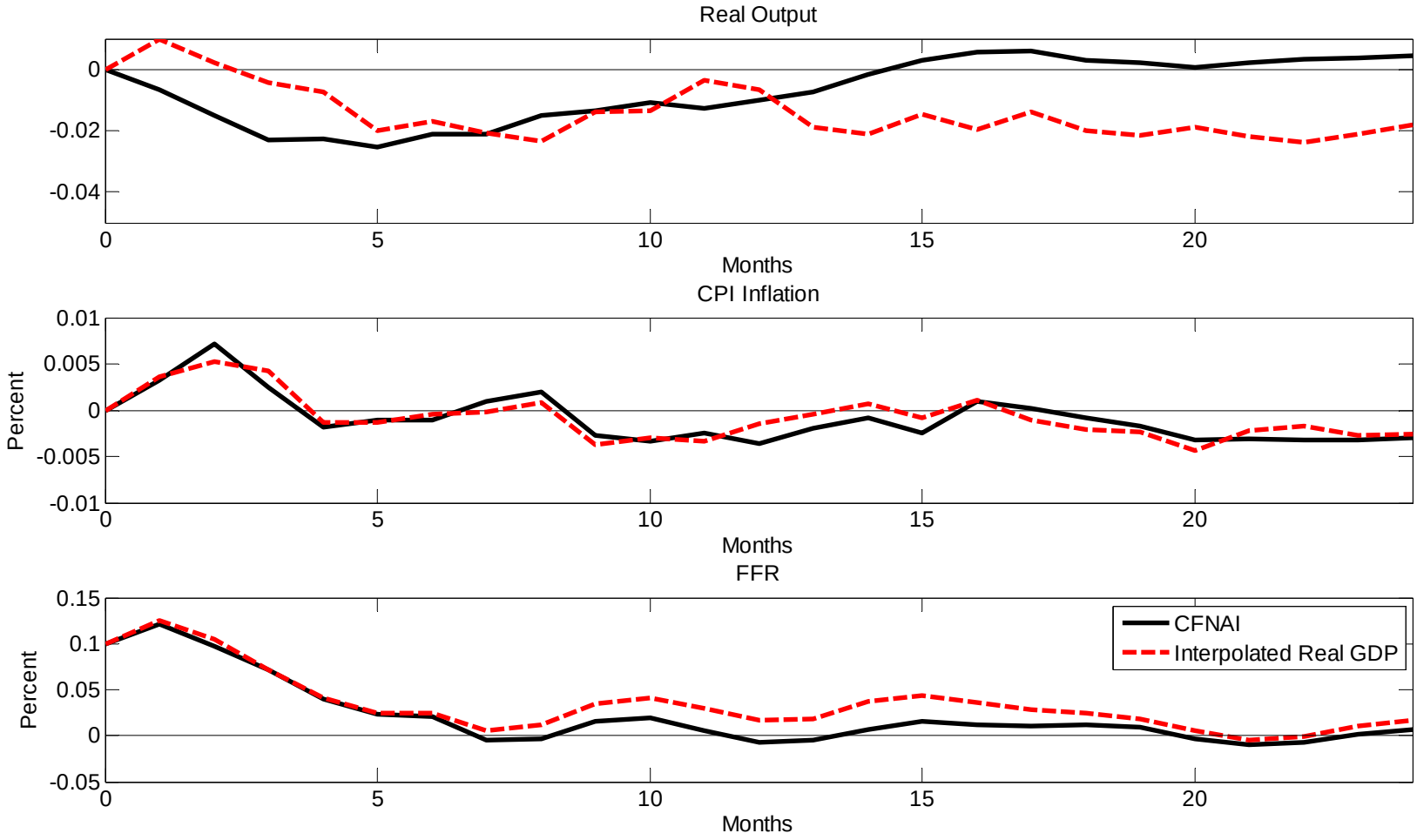
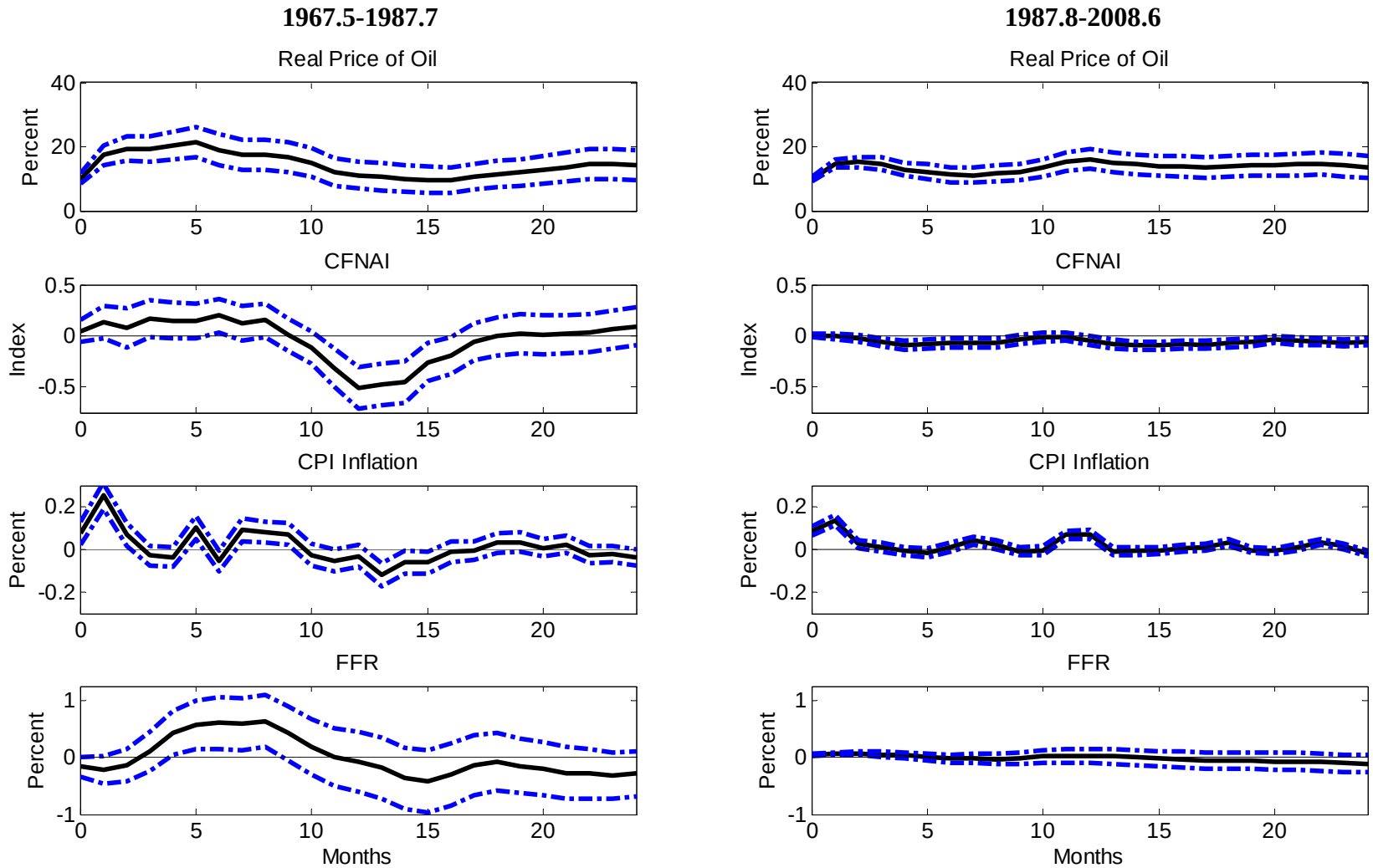
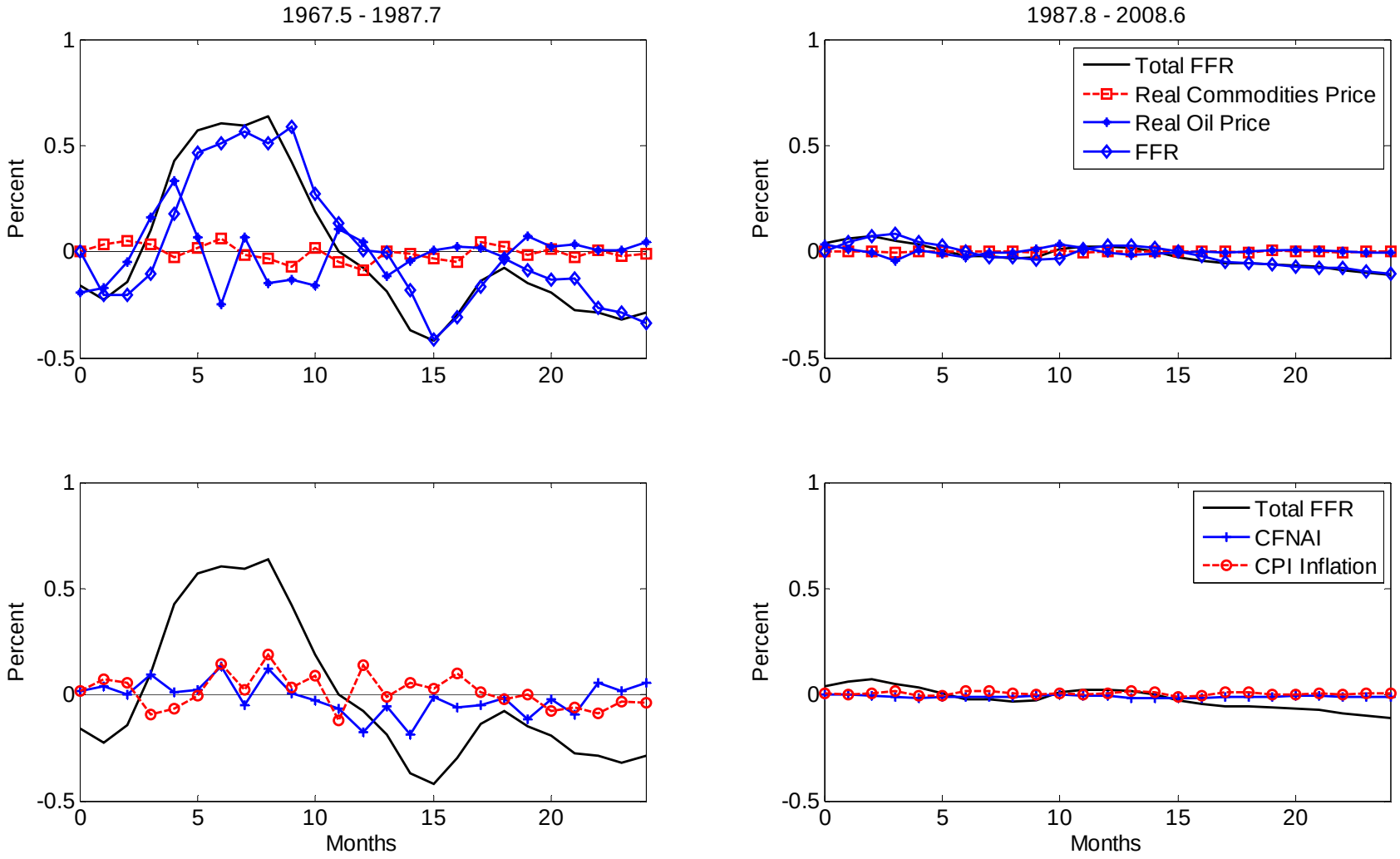


Figure 4: U.S. Responses to a 10 Percent Real Oil Price Shock (with One-Standard Error Bands)



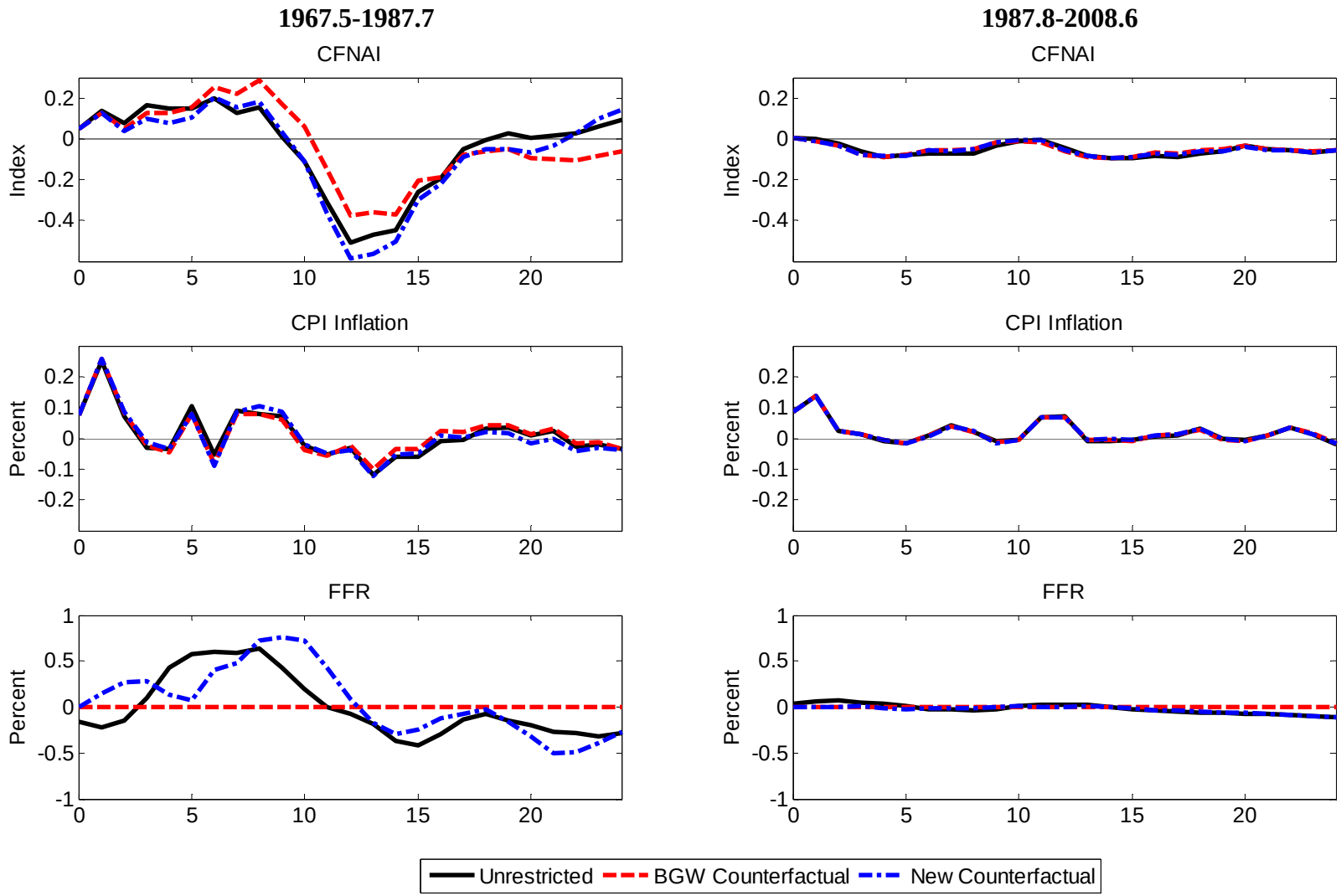
Note: Estimates based on recursively identified VAR(12) model for the percent change in real CRB commodity prices, the percent change in the real price of oil, CFNAI, CPI inflation and the Federal funds rate.

Figure 5: Decomposition of the Response of the Federal Funds Rate to a 10 Percent Real Oil Price Shock



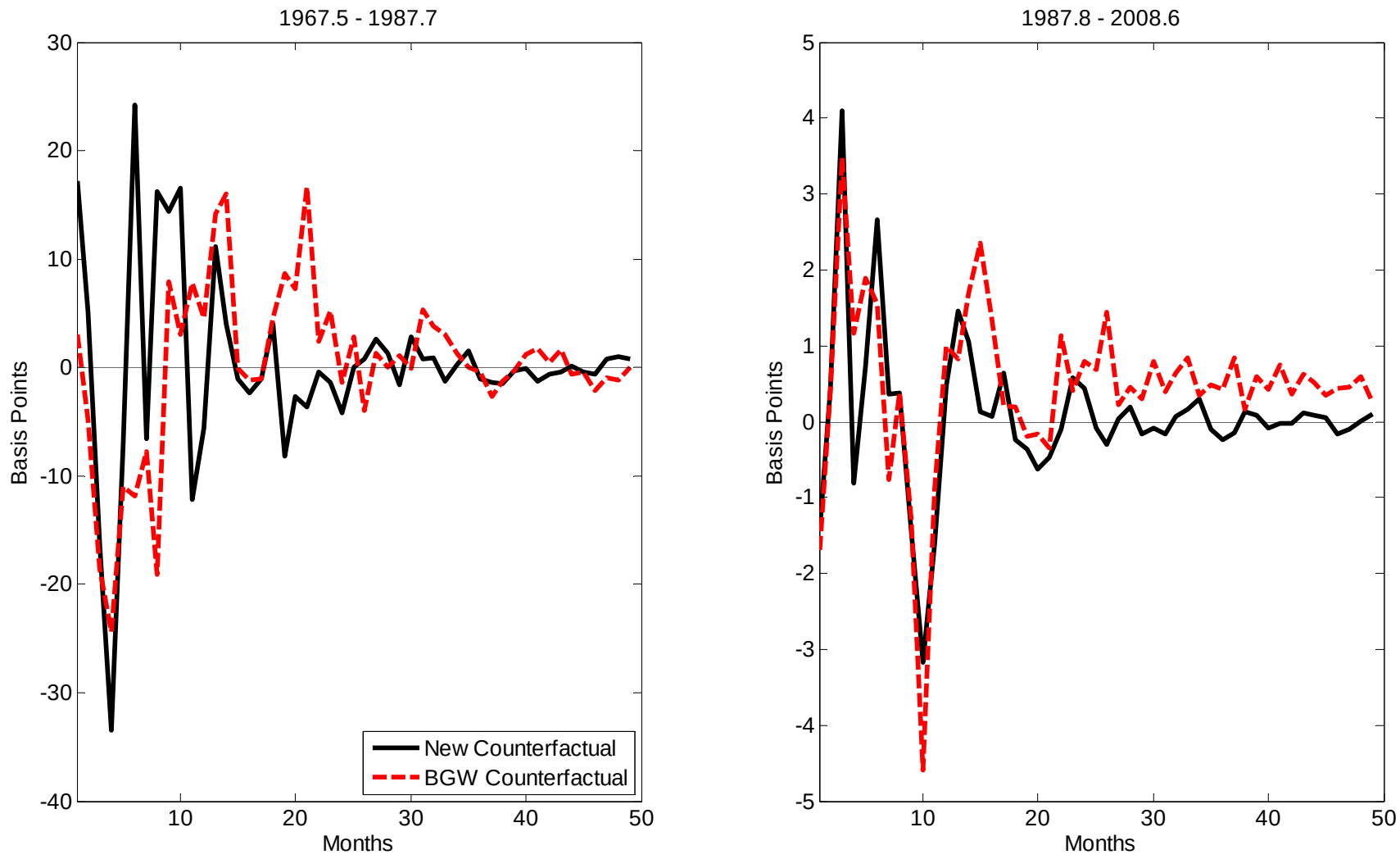
Notes: The decomposition underlying this figure is described in section 4.2.1.

Figure 6: Counterfactual Simulations



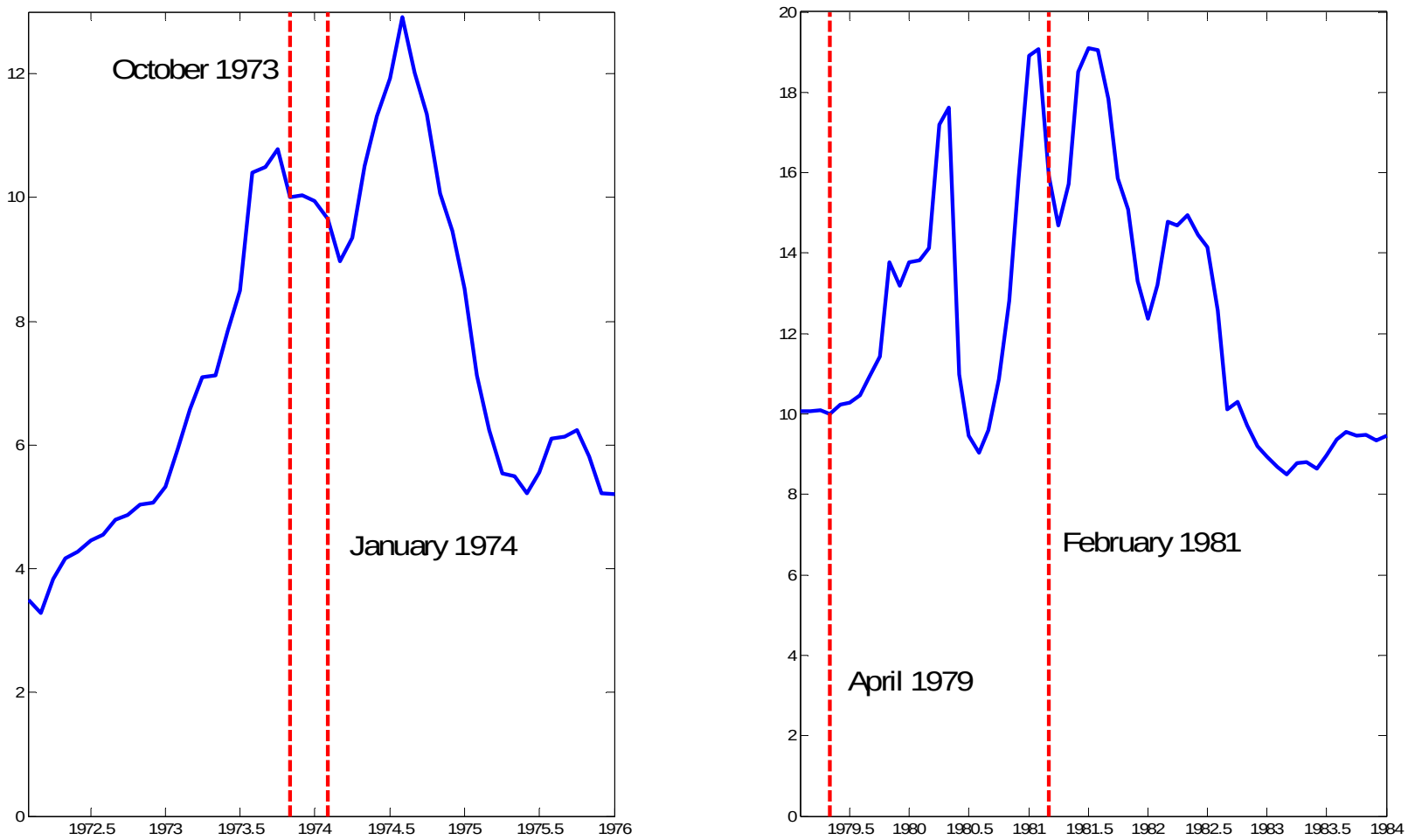
Notes: BGW Counterfactual refers to the counterfactual of holding constant the interest; New Counterfactual refers to the counterfactual of shutting down the direct monetary policy response to oil price shocks in the policy reaction function.

Figure 7: Policy Shocks Required for the Implementation of the Counterfactual



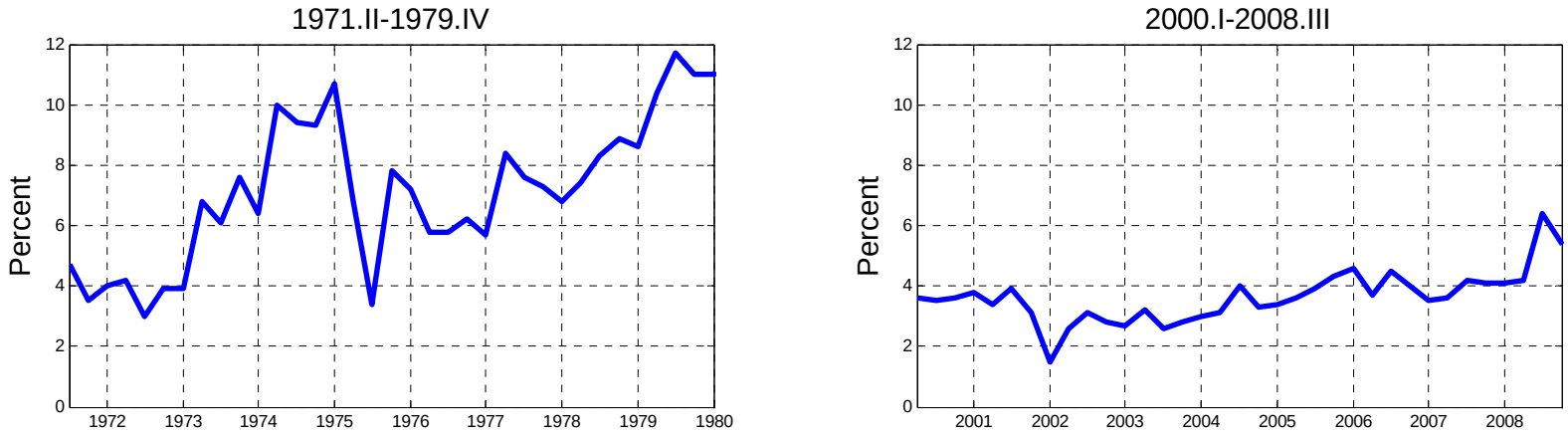
Notes: BGW Counterfactual refers to the counterfactual of holding constant the interest; New Counterfactual refers to the counterfactual of shutting down the direct monetary policy response to oil price shocks in the policy reaction function.

Figure 8: The Evolution of the Federal Funds Rate during the Oil Price Shocks of the 1970s and Early 1980s



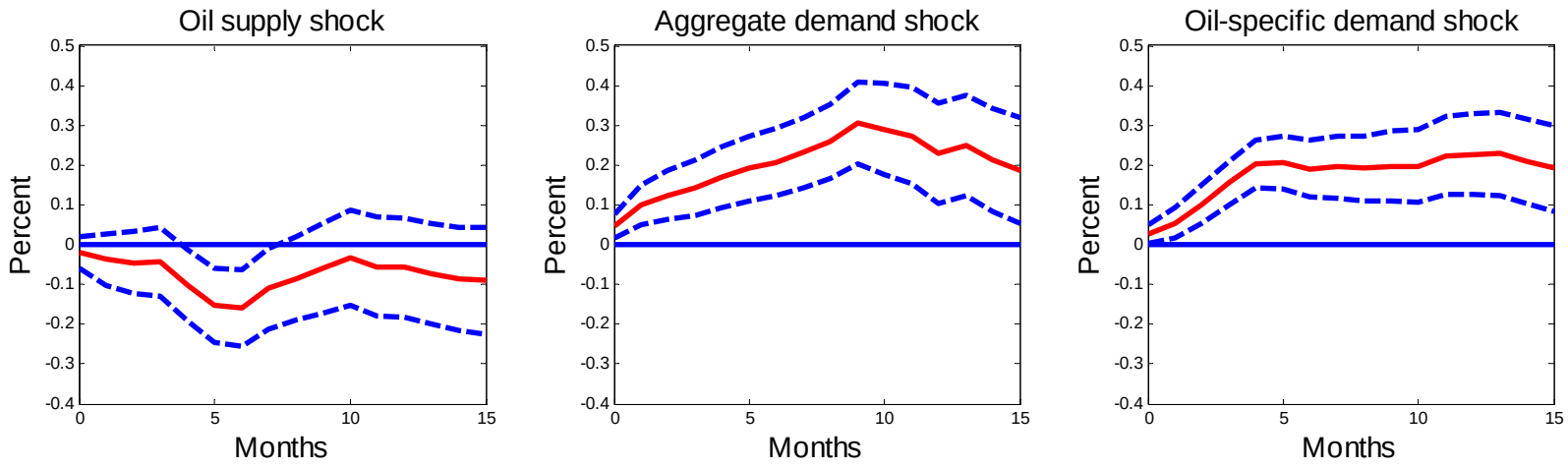
NOTES: In October of 1973 and January of 1974 the price of oil doubled. April 1979 marks the beginning of the 1979 oil price surge; in February of 1981 the price of imported crude oil peaks.

Figure 9: U.S. Inflation Expectations



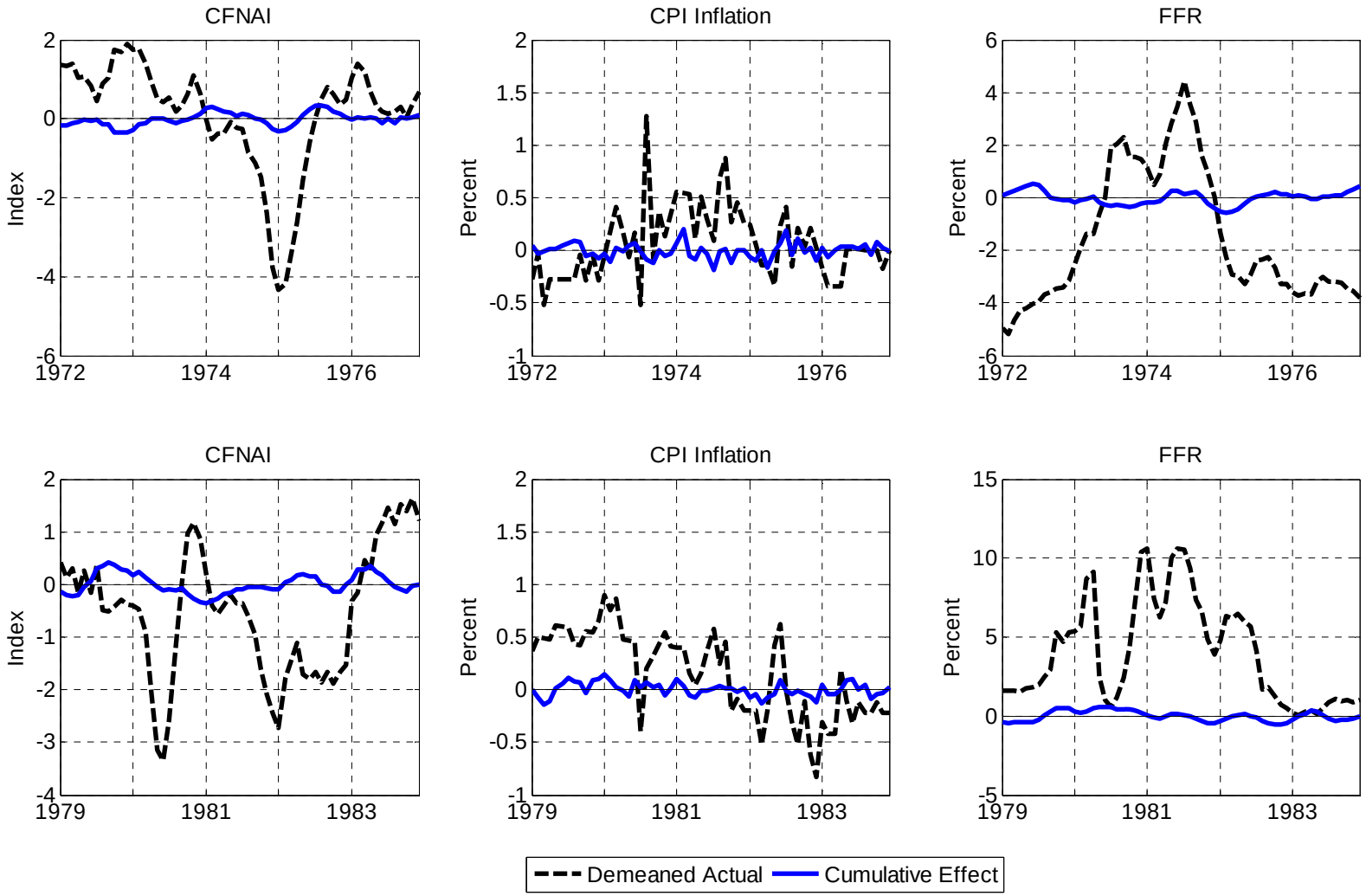
Note: Inflation expectations are 1-year-ahead inflation expectations as of the date shown from the Michigan Survey of Consumers.

Figure 10: Response of the Effective Federal Funds Rate to Oil Demand and Oil Supply Shocks (with One-Standard Error Bands)



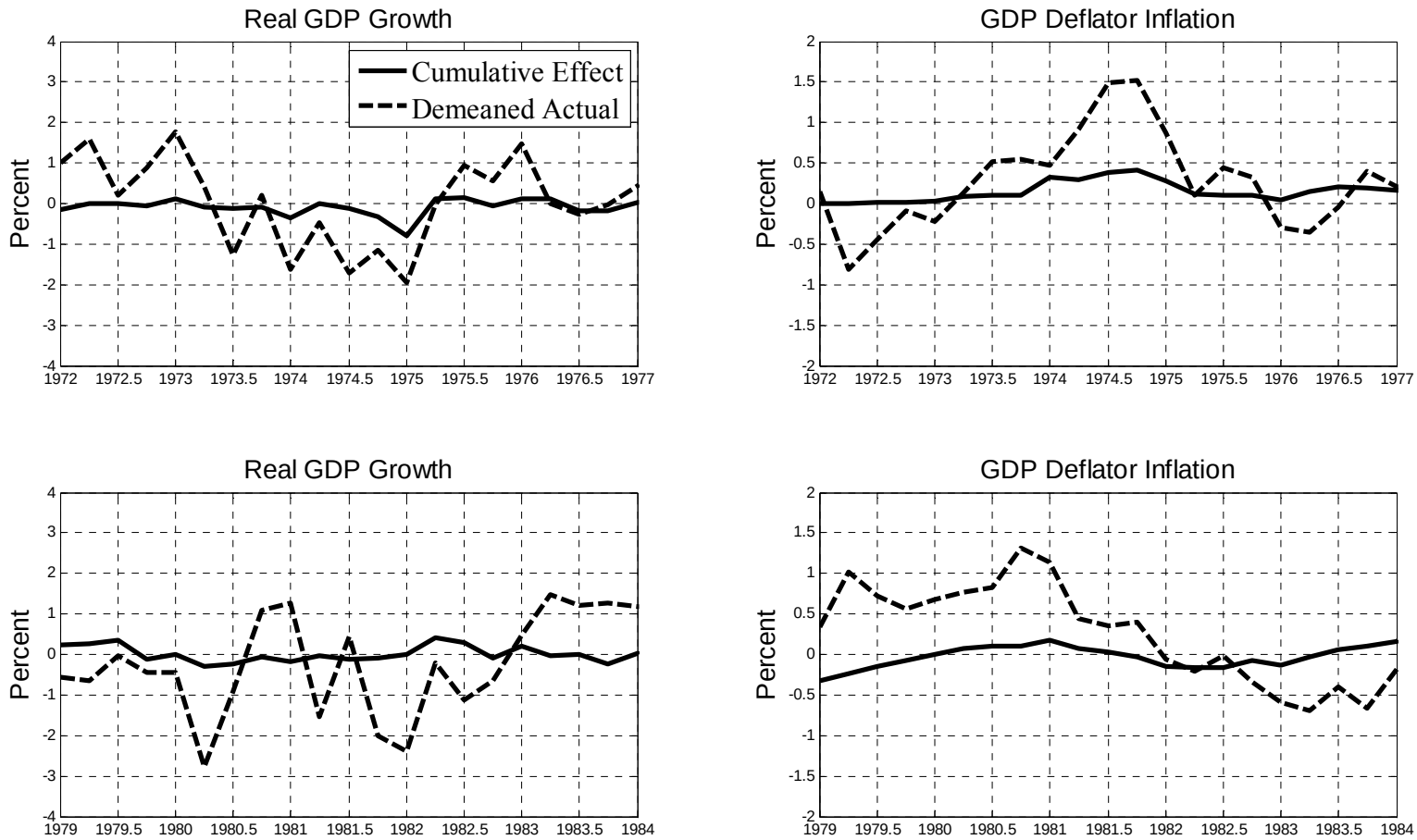
Notes: Estimates from a recursively identified oil-market VAR model based on Kilian (2009a) augmented by the change in the Federal funds rate as the fourth variable. The sample period is 1973.2-2008.6. All shocks have been normalized to imply an increase in the real price of oil. Aggregate demand shocks refer to shocks that increase global demand for all industrial commodities (including crude oil); oil-specific demand shocks are shocks that increase the demand for crude oil only; oil supply shocks represent unexpected disruptions of the global production of crude oil.

Figure 11: Cumulative Effect of Real Oil Price Shocks on U.S. Real Output, Inflation and Interest Rates: Selected Episodes Baseline Model



Notes: Historical decompositions constructed from monthly model underlying Figure 4.

Figure 12: Cumulative Effect of Real Oil Price Shocks on U.S. Real Output and Inflation: Selected Episodes Quarterly VAR Model



Notes: Estimates based on macroeconomic block and oil block of the quarterly VAR model of Herrera and Pesavento (2009). Unlike Herrera and Pesavento we order the percent change in the real price of oil first in line with the results in Kilian and Vega (2009) and we drop the growth rate of potential output. These changes do not materially alter the results. The results shown are based on the same sample period as our earlier estimates. Essentially identical results for the upper row would be obtained using Herrera and Pesavento's original sample period.