Oil Price Shocks, Systematic Monetary Policy and the 'Great Moderation'

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September, 2007

Abstract

The U.S. economy has experienced a reduction in volatility since the mid 1980's. In this paper we investigate the changes in the response of the economy to an oil price shock and the role of the systematic monetary policy response in accounting for changes in the response of output, prices, inventories, sales and the overall decline in volatility. Our results suggest a smaller and more short-lived response of most macro variables during the Volcker-Greenspan period. It also appears that while the systematic monetary policy response has dampened fluctuations in economic activity during the 1970s, it has had virtually no effect after the 'Great Moderation'.

Key words: GDP variance, structural break, VAR, oil price shocks, systematic monetary policy.

JEL Classification: E32, E50.

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1 Introduction

To policy makers, oil price shocks pose the difficult challenge of balancing the trade-off between higher inflation and higher unemployment. Work by Bernanke, Gertler and Watson (1997, 2004) suggests that monetary policy makers have historically leaned towards keeping inflation at bay, at the cost of a greater slowdown in economic activity. That is to say, the systematic component of monetary policy accounted for a large portion of the decline in GDP growth following an oil price shock. Although the magnitude of this systematic component is a matter of debate (see Hamilton and Herrera, 2004 and Bernanke, Gertler and Watson, 2004), the current investigation into the sources of the 'Great Moderation' suggests two questions that call for further analysis. One is whether changes in the dynamic response of the economy to observable shocks, such as an oil price increase, can account for the decline in volatility. The second question is the role of systematic monetary policy in accounting for changes in the response of output, prices, inventories and sales to these shocks. The aim of this paper is to address these issues and to examine the contribution of better monetary policy and oil price shocks to the widespread decline in volatility.

Since Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) documented a decline in output volatility in the mid 1980s, various studies have indicated that this reduction extends to other variables such as all the major components of GDP (McConnell, Mosser, and Perez-Quiros, 1999), aggregate unemployment (Warnock and Warnock, 2000), aggregate consumption and income (Chauvet and Potter, 2001), wages and prices (Sensier and Van Djik, 2004; Stock and Watson, 2002). Broadly, explanations for this structural break fall in three categories: better technology, better policy and good luck. The proponents of the first hypothesis emphasize the role of changes in the structure of the economy related to better inventory holding techniques (McConnell and Perez-Quiros, 2000; Kahn, McConnell and Perez-Quiros, 2001; Irvine and Schuh, 2002), and innovations in financial markets (Blanchard and Simon, 2001). Those attributing the decline in output volatility to "better policy" contend that a significant change in the monetary policy rule during the Volcker-Greenspan period was the main source of this dramatic change in economic outcomes (Clarida, Gali, and Gertler, 2000; Boivin and Giannoni, 2005; Favero and Rovelli, 2003). For instance, Ramey and Vine's

(2004) study of the automobile industry suggests that the decline in output volatility stems from a change in the data generating process for sales which, in turn, could be associated with monetary policy. A third explanation ("good luck") suggests that, even though improved monetary policy may account for part of the decline in output volatility, the majority of the moderation can be explained by a reduction in the size of shocks hitting the economy during the last two decades (Ahmed, Levin and Wilson, 2004; Stock and Watson, 2002). As for the source of this "good luck", there appears to be no consensus in the literature. Several authors have tried to pin down the contribution of various shocks by focusing on the structural innovations of VAR models. For instance, Kim, Morley and Piger (2004) posit that aggregate supply shocks, and not demand shocks, are the source of "good luck", whereas Stock and Watson (2002) suggest monetary policy, commodity prices and productivity shocks contributed to moderating output volatility.

In this paper we address the contribution of "better policy" and "good luck" from a different perspective. Using a modified VAR system, in the spirit of Sims and Zha (2006), we ask whether the reaction of monetary policy to a specific shock (oil prices) contributed to the 'Great Moderation'. Although other types of shocks (e.g., fiscal or technology shocks) constitute an interesting research area, we focus on oil price shocks for two reasons.

First, oil price increases have been put forward as a possible cause for the increased volatility of the U.S. economy during the 1970s, especially for the heightened inflation and the decline in output growth (Hamilton, 1983). Second, periods of oil price increases are somewhat easier to identify than other structural shocks. Since, as emphasized by Barsky and Kilian (2002), Parkin (1993), Ireland, (1999), and Orphanides (2002) among others, monetary policy is another possible explanation for the changes in the behavior or macroeconomic variables, we focus our attention to the contribution of the monetary policy response to oil price shocks and its role in the 'Great Moderation'.

We find that the magnitude and the duration of the response of output, and especially prices, to an oil price shock has diminished during the Volcker-Greenspan era. Of interest is the significantly smaller contribution of systematic monetary policy to the dynamic response of most macro variables during the post-1984 period. We estimate that a one-year delay in the systematic monetary policy response would have lowered the variance of GDP growth by 27% and 8% in the pre-1980 period and post-1984 periods. Regarding manufacturing, our estimation results suggest a somewhat smaller and shorter-lived response to oil price shocks during the post-1984 years. After the 'Great Moderation', a one-year delay in the monetary policy response would have resulted in a slight reduction in the volatility of sales and work-in-process inventories and roughly no effect on the volatility of finished goods and materials and supplies inventories.

The remainder of this paper is organized as follows: section 2 describes the recent literature on the debate between the proponents of the good luck hypothesis and better policy hypotheses, sections 3 and 4 describe the industry level data and the VAR specification used; section 5 addresses the effect of oil price shocks and systematic monetary policy, and the last section provides some concluding remarks.

2 Good Luck and Better Policy

The proponents of the "good luck" hypothesis have argued that a reduction in the size of the shocks hitting the economy have accounted for a large proportion of the decline in U.S. output volatility. Ahmed, Levin and Wilson (2004) identify smaller shocks with a reduction in the high frequency range of the spectrum of GDP growth, and monetary policy with the business cycle frequencies. They find that most of the reduction in the volatility of output can be explained by a reduction in the size of the innovations (i.e. a smaller contribution of the high frequency range). However, they recognize that this behavior can also be consistent with "better monetary policy" that has acted to eliminate sun spot equilibria. Similarly, Stock and Watson (2002) find some role both for identifiable shocks -less volatile money, commodity prices, and productivity shocks-, and improved monetary policy in the decline of U.S. output growth volatility. However, they conclude that *"to the extent that improved policy gets some of the credit, then one can expect at least some of the moderation to continue as long as the policy regime is maintained. But because most of the reduction seems to be due to good luck in the form of smaller economic disturbances, we are left with the unsettling conclusion that the quiescence of the past fifteen years could well be a hiatus before a return to more turbulent economic times."*

The idea that monetary policy can be a major source of business cycle fluctuations is by no means new. In fact, a large body of literature in macroeconomics and monetary economics has been devoted to obtaining plausible measures of the contribution of monetary policy to business cycle fluctuations. One one hand the VAR literature has provided important insights into the effect of unanticipated monetary policy shocks (Christiano, Eichenbaum and Evans, 1999) reaching a broad consensus that they account for only a small proportion of the volatility of aggregate output and even less of the fluctuations in the aggregate price level. On the other hand works that do not distinguish between the anticipated and unanticipated components suggest monetary policy plays an important role in explaining business cycle fluctuations (Romer and Romer, 1989). Thus, it seems reasonable that if we want to investigate the role of monetary policy on the 'Great Moderation' we should concentrate our attention to its systematic component.

To be able to compare the systematic monetary policy component before and after the decline in volatility, we need to pick a macroeconomic shock to which monetary policy is likely to respond. As we mentioned in the introduction, we focus on oil price shocks for two reasons. First, oil price shocks have been put forward as a possible explanation for the increased inflation and the recessions of the 1970s. Second, periods of oil price shocks are somewhat easier to identify than other structural shocks of interest, such as technology shocks. Furthermore, a change in the relationship between oil price increases and monetary policy appears to have taken place during the post-1984 years. This point is illustrated in Figure 1, which plots the monthly federal funds rate and the percentage change in the oil price for the 1959-2006 period. Notice how in the pre-Volcker period, significant monetary tightening in the U.S. appears to have coincided with major oil price shocks. These relationship is less apparent in the Volcker-Greenspan era. In fact, whereas the correlation for the 1959-79 sample is positive and significant (0.33), the correlation in the 1985-2006 sample is not significantly different from zero (-0.07).

Certainly, focusing on the role of oil prices has also some disadvantage. As Table 1 illustrates, whereas the volatility of the real oil price experienced a significant increase[1], the volatility of output growth and

[1] The unconditional volatility of nominal oil prices, measured by the net oil price increase, was 14%.

inflation declined (76% and 89%, respectively). Similar declining patterns are observed for manufacturing sales and inventories at different stages of production, especially for inventories of materials and supplies where volatility declined by 75%. Hence, some "good luck" must have taken the form of smaller shocks (other than oil prices) not analyzed in this paper (e.g., technology shocks). It is also conceivable that the response of monetary policy to other shocks hitting the economy differed between the pre-Volcker and the Volcker-Greenspan-Bernanke periods. For instance, Clarida, Gali and Gertler (2000) find evidence that the monetary policy rule during the Volcker-Greenspan era was more effective in terms of mitigating the effect of any shock and in stabilizing changes in expected inflation. To the extent that this result is likely to hold for an extended sample including the last Greenspan years and the beginning of the Bernanke period, "better policy" in response to shocks, other than oil prices, may have played an important role in the 'Great Moderation'. Although beyond the scope of this paper, exploring the role of other shocks –possibly using similar tools to those employed in this paper– may shed additional light on the "good luck" or "better policy" controversy.

All in all, our aim is first to establish the contribution of oil price shocks to the variance of GDP, inflation, manufacturing sales and inventories across subsamples, and, second, to evaluate whether the role of monetary policy in moderating the effect of this shock varied between the pre-Volcker and the Volcker-Greenspan era. Finally, we investigate whether the response of monetary policy accounts for the reduction in the volatility of other series such as manufacturing sales and inventories.

3 Econometric Specification

Bernanke, Gertler and Watson (1997) argue that the systematic component of monetary policy accounts for a large portion of the decline in GDP growth that follows an oil price shock. Although the debate on the magnitude of the systematic component is still active (see Hamilton and Herrera, 2004, and Bernanke, Gertler and Watson, 2004), there is no doubt that identifying the effect of systematic monetary policy is central to understanding the dynamic response of the economy. Thus, we extend the modified VAR framework of

Bernanke, Gertler, and Watson (2004) to analyze the effect of oil price shocks and the role of the monetary policy response before and after the 'Great Moderation'.[2]

We estimate a quarterly structural VAR describing the behavior of the vector y_t, which contains three blocks of variables. The first block includes the following macroeconomic variables: the log growth of potential output (y_N), the log growth of GDP (y_{GDP_t}), the log of the GDP deflator $(y_{P,t})$, and the log growth of real oil prices $(y_{OIL,t})$. The following block contains the federal funds rate $(ff_{,t})$, our indicator of monetary policy. The last block is an industry block, which includes sales $(y_{S,t})$ and inventories by stages of production (finished goods, y_{FIt}, work-in-process, y_{WIt}, and materials $y_{MI,t}$). We assume that the structural VAR for $\mathbf{y}_t$ has a linear moving average representation

$$y_t = B(L)\, u_t, \qquad B(0) = B_0 \tag{1}$$

where $B(L)$ is an infinite order matrix lag polynomial, and $u_t = [u_{n,t}, u_{gdp,t}, u_{p,t}, u_{ot}, u_{ff,t}, u_{s,t}, u_{fi,t}, u_{wi,t}, u_{mi,t}]'$ is a vector of white noise structural innovations. We identify the response function $B(L)$ and the structural disturbances u_t by placing restrictions on certain elements of B_0. The restrictions are given by

$$b_{n,gdp}(0) = b_{n,p}(0) = b_{n,o}(0) = b_{n,ff}(0) = 0 \tag{2a}$$

$$b_{gdp,p}(0) = b_{gdp,o}(0) = b_{gdp,ff}(0) = 0 \tag{2b}$$

$$b_{p,o}(0) = b_{p,ff}(0) = 0 \tag{2c}$$

$$b_{o,ff}(0) = 0. \tag{2d}$$

The identification restrictions in (2) are common in the VAR literature on the effects of monetary policy. Ordering the federal funds rate last in the macro block follows the conventional assumption that monetary policy cannot instantaneously affect potential output growth, output growth, prices and oil prices.

[2] Note that this treatment differs from Bernanke, Gertler and Watson (1997) and Hamilton and Herrera (2004), who estimate the VAR using the whole sample and, then, employ those estimates to carry out the counterfactual analysis for three historical oil price shock episodes.

Note that our specification of the macro block differs from that of Bernanke, Gertler and Watson (2004) and Hamilton and Herrera (2004), in that we include a measure of potential output and we exclude the commodity price index. As noted by Giordani (2006) among others, the traditional approach of including commodity prices in the VAR is not enough to avoid the price puzzle, particularly in the second period of our sample. Following his suggestion, we include the log growth of potential output in the VAR before the log growth of GDP. (See also Giordani (2006) page 26 and 27). In addition, instead of measuring oil prices by the net oil price increase, we use the growth rate of real oil prices.[3]

The ordering of the real oil price growth after the macroeconomic variables and before the federal funds rate imposes the reasonable restriction that the oil price does not contemporaneously affect output growth and prices, while it contemporaneously affects the monetary policy equation. Some authors have argued that –at least until the late 1990's– major oil price shocks were caused by political disruptions in the Middle East that were exogenous to the U.S. economy (Hamilton, 1983, 1996; Bernanke, Gertler and Watson, 1997). However, others have argued that since 1973 –when the Middle East countries became the dominant supplier of crude petroleum– oil prices have become increasingly responsive to demand conditions (Barsky and Kilian, 2002; Kilian, 2005 and 2006). In this paper we deal with the endogeneity of oil prices by treating them as predetermined with respect to the federal funds rate. That is, we assume no contemporaneous feedback from monetary policy to oil prices. While we cannot test this assumption, we can show that the correlation between the VAR innovations to the oil price measure and to the federal funds rate is rather low (less than 0.001).

The restrictions in (2) suffice to identify the effect of oil price shocks and the systematic monetary policy response on the industry block. However, because we do not attempt to attain identification at the interior of the industry block (i.e. sales, finished goods, work-in-process, and materials and supplies inventories), no restrictions are imposed on the off-diagonal elements of B_0 corresponding to the industry equations.[4]

[3] While we think that this is a reasonable specification to avoid the prize puzzle, our results are robust to using the standard specification with GDP and commodity prices. Similarly, our results are robust to using the net oil price increase (Hamilton, 2003) instead of the real oil price.

[4] While partial identification is enough for the impulse response analysis, we need to fully identify the model for the variance

In addition, we impose the following restrictions on the elements of $B(L)$

$$b_{i,s}(l) = b_{i,fi}(l) = b_{i,wi}(l) = b_{i,mi}(l) = 0 \text{ for all } l \text{ and } i = n, gdp, p, o, ff, \tag{3}$$

where $b_{i,j}(l)$ denotes the i, j element at lag l of $B(L)$. Under the restrictions (2) and (3) the industry specific variables are constrained to affect the macro variables only indirectly through their effect on the aggregate economy. Thus, our estimated VARs can be described as a near-VAR specification that guarantees that the effects of oil price and monetary policy shocks, as well as the other unspecified macro shocks, are identical across manufacturing aggregates. Thus, even though we estimate separate VARs for durable and nondurable manufactures, the implied effects of the shocks of interest on the macro variables are identical. At the same time this specification allows the response of sales and inventories to vary freely across durable and nondurable manufacturing goods.

4 Data

In this paper we use quarterly data, in the spirit of Bernanke, Gertler and Watson (2004), instead of the monthly data used by Hamilton and Herrera (2004) and Bernanke, Gertler and Watson (1997). In this manner we are able to include 4-quarterly lags in our VAR specification, which is consistent with previous literature on the effect of oil price shocks (see for instance Hamilton, 1983; Mork, 1989; Raymond and Rich, 1997, and Hamilton, 2003), and reduce the number of parameters to be estimated relative to the monthly model. This is of particular relevance given that we split the sample in two smaller subperiods. In addition, using quarterly data allows us to make our results comparable to previous literature on output volatility.

The data comprise both macroeconomic variables and industry level series from the first quarter of 1959 to the fourth quarter of 2006. As we mentioned before, the macroeconomic variables include the log growth of potential output, the log growth of real GDP, the log of the GDP deflator, the log growth of the real

decomposition. We will then assume lower triangularity of B_0 also for the industry block.

oil price, and the federal funds rate. Data for real GDP, the GDP deflator and the federal funds rate were obtained from the FRED database of the Federal Reserve Bank of St. Louis. We follow Giordani (2006) and compute potential output as $[log(GDP) - \ capacity * 0.5/100]$, where capacity is the series of capacity utilization for manufacturing (SIC) computed by the Federal Reserve Board. The real oil price is computed by deflating the Refiners Acquisition Cost for composite crude oil (reported by the Department of Energy) by the Consumer Price Index.

One may argue, however, that the measure of oil price shock should be based on a non-linear transformation of the nominal oil price rather than on the real price, as it is sometimes done in the related literature (e.g. Bernanke, Gertler and Watson, 1997, 2004; Hamilton and Herrera, 2004). Furthermore, it has been suggested that differences between nominal and real oil price shocks may have lead to different conclusions regarding the contribution of oil price shocks and systematic monetary policy to fluctuations in GDP growth and the aggregate price level. In unreported results we also estimate our near-VARs by replacing the rate of growth of the real oil price with the nominal oil price increase (Hamilton, 2003). Our results are robust to this change in the measure of oil prices.

At the industry level we use sales and inventories series for total manufacturing, as well as nondurable and durable manufacturing goods from the Bureau of Economic Analysis. The inventory data are disaggregated by stages of production into materials, work-in-process and finished goods inventories. The data are seasonally adjusted and measured in chained dollars of 1996. The original series are available at a monthly frequency, and we transform them into quarterly data by aggregating monthly sales and using end of quarter inventories.

5 VAR Analysis

As initially documented by Kim and Nelson (1999) and McConnell and Perez-Quiros (2000), there is strong evidence of a structural break in the volatility of GDP growth at the beginning of 1984. More recent work has confirmed the presence of a break anywhere between the fourth quarter of 1982 and the third quarter of 1984 with 67% probability (Stock and Watson, 2002).[5] Therefore, in our analysis we divide the sample in two sub-samples: 1959:1-1979:4 and 1985:1-2006:4.[6] We have two reasons to split the sample at those particular dates. First, because we want to study whether the economy's response to an oil price shock has changed, we need to eliminate the period in which the structural break is possibly located. Second, this particular split eliminates the nonborrowed reserve targeting experiment from the second sample (see also Boivin and Giannoni, 2005). The exclusion of the possible break provides the additional advantage of not having to model a structural break in the variance covariance matrix during the estimation of our VAR.

For each manufacturing aggregate we estimate the nine equations in (1) by OLS, equation by equation, which differ in the sample period (1959:1-1979:4 or 1985:1-2006:4) and the industry (total, non durables or durables manufacturing). We fix the lag length p to 4 in accordance with previous studies on the effects of oil price shocks that suggest the effect of oil prices on aggregate economic activity only shows up significantly after a year (see Hamilton and Herrera, 2004).[7]

5.1 Impulse Response Analysis

To study changes in the dynamic response to oil price shocks we calculate the effect of an exogenous 10% increase in the real oil price for both the entire sample and the split samples. We compute confidence intervals robust to possible presence of conditional heteroskedasticity using a recursive design wild bootstrap, as suggested by Gonçalves and Kilian (2004). We either report the corresponding 68% and 95% confidence bands or we use symbols on the response function to denote points in the impulse response that are statistically significant.

[5] Similarly, Herrera and Pesavento (2005) estimate the 90% confidence interval for a break in the conditional variance of GDP to be 1982:4-1989:1.

[6] Evidence suggests major structural changes also in the early 1970s. Due to the limited data span and the dimension of the VAR, we cannot divide the data in three subsamples. We therefore ignore the possibility of breaks other than in the early 1980s. We acknowledge that our results are subject to this assumption.

[7] The choice of a lag length of four is not an obvious choice. Estimates of lag length with Information Criteria as suggested by Ivanov and Kilian (2005) and an upper bound of 8 suggest smaller than four lags for all three inventories specification. To be on the safe side given that we have quarterly data we chose to include four lags.

5.1.1 Oil Price Shocks

The left panel of Figure 2 plots usual response functions for the entire sample. That is, the total effect which combines the direct effect of an oil price increase plus the indirect effect through the systematic monetary policy response. As previously reported in the literature, an unexpected increase in the price of crude oil results in a slowdown in economic activity about four quarters after the shock. The VAR also predicts a tighter monetary policy reflected in an increase in the federal funds rate, possibly aimed at curbing inflation. In Figure 3 we plot the responses for the two subsamples (solid lines). The responses for the pre-1980 period are plotted in the left panel, while the right panel displays the responses for the post-1984 period. Symbols on the impulse response functions indicate points that are outside the 68% and 95% bootstrap confidence interval. In the 1959:1-1979:4 sample, after two years, the cumulative change in output is -0.6% and 276 basis points in the federal funds rate. In contrast, during the post-1984 period, the same percentage increase in oil prices results in a smaller (-0.05%) and shorter-lived drop in output, and a smaller increase in the federal funds rate (55 basis points). In the first period, the contractionary effect of the oil price shock reaches a through a year after the shock, whereas the through is reached after only two quarters in the post-1984 period.

An interesting result is the change in the response of prices across subsamples. Note that in the pre-Volcker era the oil price shock generates an increase in the price level and a slowdown in output growth.[8] During the second period, the shock still generates a slowdown in GDP growth but the increase in prices is considerably smaller. Although the responses of the price level are not precisely estimated, the change in the magnitude suggests that the less accommodative monetary policy of the Volcker-Greenspan era may has been more effective in controlling the expectations of higher inflation that follow an oil price shock.[9]

Figures 4-6 report the total responses (solid lines) of manufacturing sales and inventories. Each set of responses are obtained by running a VAR with the same macro variables and a different industry block

[8] See the lower panel of Figure A.3 in the appendix for the response of the inflation rate.
[9] See Hooker(2002) for similar finidings using a Phillips curve framework.

for each manufacturing aggregate (total manufacturing, non durables and durables). Comparing the left and right panels of Figures 4-6 reveals differences across periods and across industries in the response of manufacturing sales and inventories to the oil price shock.

The responses of total manufacturing to an oil price shock (Figure 3) are in general larger in the first period for both sales and inventories. For instance, sales show a trough of -0.9% after the first year in the pre-1980 period but a shorter-lived and smaller decline (-0.06%) in the post-1984 period. The cumulative response at the trough is -1.6% and -0.08% in the pre-1980 and post-1984 periods, respectively. Similarly the plots for inventories by stages of production reveal a smaller response in the second period.

The disaggregated results (Figures 5 and 6) suggests that the dampening of the sales' response took place both for the nondurable and the durables industries. For instance, the cumulative effect on non durables (durables) reaches a trough at -1.1% (-1.9%) in the first period and at -0.1% (-0.4%) in the second period. In contrast, the change in the behavior of inventories is mostly limited to durable manufactures, and to some degree in durables inventories of materials and supplies. These patterns in the response of inventories suggest that better inventory holding techniques could have contributed to the smoother and faster adjustment of input inventories to oil price shocks. However, the smoother response of sales may also be consistent with a structural break in the data generating process for sales as posited by Ramey and Vine (2004).

5.1.2 Systematic Monetary Policy

Is this change in the dynamics a result of a shift in the monetary policy rule? To address this issue we employ the methodology proposed by Sims and Zha (2006)[10] to separate the effects of the systematic (or anticipated) and unsystematic portion of monetary policy: We use the historical data summarized by the VARs to analyze what would have happened if the tightening response of the monetary policy would have been delayed. As in Bernanke, Gertler, and Watson (2004), the counterfactual scenario we analyze is one in which exogenous monetary policy is aimed at maintaining the federal funds rate unchanged for one year in

[10] For a discussion on the advantages and disadvantages of this methodology see Bernanke, Gertler and Watson (1997), Hamilton and Herrera (2004) and Bernanke, Gertle and Watson (2004).

face of an oil price shock. We interpret this scenario as the direct response obtained by shutting down the (indirect) response of systematic monetary policy. We calculate the consequences of this policy by computing the value of $u_{FED,t+s}$ that would keep the value of $y_{FED,t+s}$ at zero for four quarters, and add this shock in at horizons $s = 1, 2, 3, 4$ before calculating the response of the industry block to the oil price shock.[11] It seems plausible that if the deviation of the monetary policy from the expected path is not large and purely transitory (we impose it to last only for one year) agents should not be able to react immediately and significantly affect the structure of the economy thus protecting our exercise from the Lucas critique.

Before investigating possible shifts in the monetary policy response across periods, we take a look at the response estimated using the full 1959-2006 sample. The right panel of Figure 2 plots the impulse response to an oil price shock when the systematic monetary policy response is delayed one year. Our results are consistent with Hamilton and Herrera's (2004) finding that the potential of monetary policy to avert the contractionary consequences of an oil price shock is moderate and smaller than reported by Bernanke, Gertler and Watson (1997). Yet, by addressing the price puzzle following Giordani (2006) rather than using the commodity price index, we obtain a smaller contribution of the systematic monetary policy to the increase in the price level than reported by Bernanke, Gertler and Watson (1997, 2004) and Hamilton and Herrera (2004).

We now proceed to study the direct response for the pre-1980 and post-1984 subsamples. The dashed lines in Figures 3 to 6 plot the response of the economy to a 10% oil price shock, when the systematic monetary policy response is shut down for one year, for the two periods of interest. As before the solid line represents the total impulse response function (combined direct and indirect effect), thus the difference between the solid and the dotted lines can be interpreted as the indirect effect of the systematic monetary policy. Since the parameters governing the response of the macro variables in each subsample are left unchanged, the difference between the solid and the dotted lines are due simply to differences in the responses of the anticipated monetary policy and not to differences in the response of the economy.

[11] Figure A.1 in the appendix reports the sequence of federal funds rate innovations implied by such a delay in the response of monetary policy.

Figure 3 shows that, if the monetary policy had not responded to the oil price shock for one year, the pre-Volcker period would have experienced a slightly smaller drop in output and a considerable smaller increase in prices. In contrast, the contribution of systematic monetary policy during the post-1984 period has been very moderate, as illustrated by the smaller difference between the solid and dotted lines.[12] It appears that not only the response of the economy to monetary policy innovations has changed as documented by Boivin and Giannoni (2005), but also the systematic response to exogenous shocks. In fact, the contribution of systematic monetary policy to the response of output growth and prices to oil price shocks appears to have been negligible during the Volcker-Greenspan era.

As in the case of the macro variables, the more substantial differences between the total and direct response (solid and dotted lines) in Figures 4-6 are in the pre-1980 period, particularly for sales and work-in-process inventories. A comparison of the graphs for manufacturing and its components suggests that durable manufactures are mostly responsible for these differences.

Taken all together the results from Figures 3-6 suggest that changes in the monetary policy rule may have played a small role in accounting for the difference in response both of macro and industrial variables across the sub-samples. The evidence is stronger for output growth, prices, sales, and durables inventories, in particular for input inventories. In brief, both at the aggregate and the industry level, the negative effect of a 10% increase in the real oil price would not have been reinforced by the systematic monetary policy in the post-1984 period.

5.2 Historical decomposition

As Kilian (2005) argues, impulse response functions convey only limited information regarding the effect of historical oil price shocks. In particular, whereas the impulse responses trace the effect of a one-time increase in the price of oil, historically oil price shocks have not been a one-time event but a sequence of shocks that can take on positive and negative values. Thus, to evaluate the cumulative effect of these sequence of

[12] Figure A.2. in the Appendix reports the responses of the macro variables to a monetary policy shocks.

shocks we compute the historical decomposition of the shocks to the real oil price on the aggregate and manufacturing variables. As in the previous sections, we split the sample in two periods and compute the cumulative effect using the VAR estimates for the sub-sample under analysis. Figures 7-10 plot the actual value of the series (dotted line), the estimates when the monetary policy is allowed to respond to the oil price shock (solid line) and the estimate when we shut down the monetary policy response for a year (dashed line).

The contribution of oil prices to the fluctuation of output growth, inflation, the federal funds rate, sales and inventories by stages of production, was considerably larger in 1959-1979 (left panel) than in 1985-2006 (right panel). At a first glance, it is not clear whether shutting down the monetary policy response during the first period would have resulted in smaller or greater fluctuations in output growth and inflation. Yet the variances of the total contribution to output growth and inflation are 1/3 and 1/10 smaller (respectively) than the variances for the direct contribution, thus suggesting systematic monetary policy aid to smooth the fluctuations. Similarly, for most manufacturing variables, shutting down the monetary policy response results in larger fluctuations.

Of interest in the first period is the large contribution of oil prices to the recession following the onset of the Arab-Israel War (October 1973). On average, oil price fluctuations explained 51% and 16% of the fluctuations in output growth and inflation. Of the contributions to output growth and inflation, 35 and 7 percentage points can be attributed to the monetary policy response. Oil prices also contributed to fluctuations in the federal funds rate (17%). As for the manufacturing variables, oil prices accounted for a considerable proportion of the decline in sales, the accumulation of finished goods inventories and the liquidation of inventories of materials and supplies. The systematic monetary policy response mitigated the volatility of output growth, as well as manufacturing inventories and sales, at the cost of exacerbating the volatility of inflation. Note how, for these real variables, the direct contribution (without systematic response) is larger than the total contribution.

The 1985-2006 period is characterized by a smaller volatility, a reduced contribution of oil prices to aggregate and manufacturing fluctuations, and a decline in the contribution of the systematic monetary policy response. Note how, with the only exception of work-in-process inventories of non durables, the magnitude of the actual fluctuations (dotted line) covered a smaller range during the post-1984 period, reflecting a smaller volatility. Furthermore, the contribution of oil price fluctuations decreased in the late 1990s, but might have increased slightly during 2006. Finally, differences between the contribution with and without the systematic monetary policy response became indistinguishable during the second period. For instance, the variances of the total contribution to output growth and inflation are only 2% and 5% smaller than the variances for the direct contribution.

Focusing on the year following Iraq's invasion of Kuwait (August 1990) reveals a significant but smaller contribution of oil price fluctuations to the volatility of output growth (21% for 1990:IV-1991:I) and inflation (14%). Similarly, fluctuations in the price of oil resulting from the Persian Gulf War contributed to the volatility of manufacturing sales and inventories, especially for durable goods. In contrast with the response during the Arab-Israel War, during this event the contribution of oil prices to the fluctuations in the federal funds rate was zero or slightly negative as the actual interest rate declined during 1990 and 1991.

While recent increases in the price of oil did not contribute much to the fluctuations in output growth, higher crude oil prices in 2006 contributed to the increase in inflation and particularly to the decline in manufacturing sales and the accumulation of finished goods inventories. Even though the federal funds rate increased during 2005-2006, the contribution of oil prices to this hike appears to have been minimal.

Summarizing, the historical decomposition suggests an important contribution of oil prices to economic fluctuations, particularly during two periods of political disruptions in the Middle East (i.e., the Arab-Israel War and the Persian Gulf War). This contribution declined in the late 1990s, but appears to have increased somewhat during 2006. As for the contribution of systematic monetary policy, while delaying the monetary policy response for one year could have amplified economic fluctuations during the 1970s, no effect would have been observed in the period following the 'Great Moderation'.

5.3 Volatility and Variance Decomposition

The impulse responses (Figures 3-6) and the historical decomposition (Figures 7-10) evidence two important changes in the role played by oil price shocks and systematic monetary policy in explaining economic fluctuations. First, since the 'Great Moderation', oil price shocks account for a smaller proportion of the variability of both macro and manufacturing variables. Second, anticipated monetary policy played a smaller role in dampening fluctuations in real economic activity during the Volcker-Greenspan period.

Because our main interest is in understanding the reduction in the variance since 1980s, we now estimate some measures of volatility from the mean square error of the 30 periods-ahead forecast, and of the contribution of the oil price shock to the mean square error (MSE) of our variables as implied by our estimated VAR. Given that the mean square error at a long horizon can be interpreted an approximation of the unconditional variance, the variance decomposition provides an estimate of the contribution of oil prices to the volatility of each variable in the system. By comparing the MSE across sub-samples we can assess changes in volatility while, by comparing the MSE across alternative scenarios (i.e., with and without systematic response) but within the same period, we can assess the role of monetary policy.

To compute the variance of the industry block we now need to identify the VAR completely, thus we impose the following causal ordering for the industry data: sales, finished goods, work-in-process and material and supplies. As in the previous section we report our estimates for the two periods under consideration with and without a systematic response of the monetary policy. Table 2 reports the variance of each variable as estimated from the parameters of the VAR.[13] The first three columns of the table report the results from the standard structural VAR for the entire sample and the two subsamples under consideration.[14] The last three columns report the decomposition when we shut down the systematic monetary policy response for one year.

As documented in the literature almost all the variables show a significant drop in the unconditional

[13] We report the estimated variance multiplied by 100 for all variables except oil and federal funds rates.

[14] Given the short time span and the large dimension of the VAR the estimated variance in the two subsamples should be taken with caution due to large uncertainty.

variance after 1984. Sales in all three cases show a decline in the variance between 71% and 79% which is remarkably close to the 78% decline in GDP growth. The decline in inventories varies across stages of production and level of aggregation ranging from 17% for work-in-process inventories of non durables to 78% for material and supplies inventories of durables. The considerable decline in the latter is not without importance for the 'Great Moderation' as, on average, input inventories are twice as large as output inventories, three times more volatile, and particularly important in the durable goods industries (see Humphreys, Maccini and Schuh, 2001). Furthermore, these results are consistent with the findings in Herrera and Pesavento (2005) that materials and supplies inventories account for most of the reduction in the volatility of total inventories.

Shutting down the systematic response of monetary policy lowers the estimated variances in most cases. For the macro block, when we look at the entire 1959-2006 period the differences in the variances estimated with and without immediate systematic response of the policy maker are not very large, with the exception of the federal funds rate. Splitting the sample in two reveals different dynamics in the two samples. Whereas the variance of prices drops 74% in the pre-1980 period, it does not change in the later period. As for the contribution of the systematic policy to output volatility, a one-year delay results in a 27% drop in the variance of output growth in the pre-1980 period and a 8% decrease in the later period.[15]

Changes in the role of monetary policy can also be observed in the disaggregate data. Declines in volatility are evident for sales and work-in-process inventories. The only exceptions are finished goods and materials and supplies inventories for which the variance either remains unchanged or slightly increases. It is interesting that materials and supplies, which show the largest percentage decline in the variance across the two sub-samples, is also the group that is less affected by the systematic monetary policy. Differences in the behavior of materials and supplies and work-in-process inventories suggest that: improvements in inventory holding techniques may have influenced both types of input inventories in a similar manner, but fluctuations in interest rates linked to changes in the systematic monetary policy response may have affected

[15] Although computed with a different approach our results are consistent with Stock and Watson (2002) estimates of a 10%-25% contribution of monetary policy.

the purchase and usage of input inventories differently.[16]

For each variable in the VAR, table 3 reports the percent of the total variance after 7 1/2 years due to an oil price shock. The results for the full sample show that the contribution of an oil price shock to the variability of GDP is around 3.7%. When we don't allow the policy maker to systematically respond, the oil price shock contributes 1.2% of the total variance. The contribution to the variance of prices is around 0.02% in both scenarios.

Looking at total manufacturing, the larger differences in the contribution of the oil price shock (with and without systematic response) can be found in sales and work-in-process inventories for which the contribution is almost half the size. Given that the unconditional variance (the denominator in the variance decomposition) of the macro series does not vary across policy scenarios, we can conclude that what changed was the response of the variables to the oil price shock.

Splitting the sample in the two periods also reveals some interesting results. For the macro variables, the systematic response lowers the contribution of oil prices in the first period but leaves it almost unchanged in the second. In the pre-Volcker period the contribution of the oil price shock to the variance of GDP is 23.52% and 34.85% with and without systematic monetary policy response, respectively. That is, about 32% of the contribution is explained by the by the systematic response (11.33 percentage points of the 37.85%). The systematic monetary policy response contributed to a lesser role of the oil price shocks in the variance of federal funds rate, some of which is accounted for by the smaller overall variance (Table 2). Regarding the manufacturing series, the contribution of the oil price shock to the variance of sales and inventories is higher when we only consider the pre-Volcker period. When we delay the monetary policy response, the variance decomposition almost doubles for sales and is five times higher for total and durables work-in-process inventories.

On the whole, the data suggests that the impact of the systematic monetary policy in mitigating the effect of an oil price shock is much smaller after the 'Great Moderation'. The only case in which it still has

[16] Studying the effects of good luck, better policy, and better technology in a model that accounts for stage-of-fabrication linkages is the object of ongoing research.

a marginal effect is in sales and durables inventories.

Finally, Table 4 reports the percent of the variance reduction explained by better monetary policy, good luck, and oil price shocks. To compute these participations, here we follow a method similar to Stock and Watson (2002). That is, we consider the baseline variance estimated from the post-1984 VARs and compute the counterfactual by replacing the policy equation or the variance of the structural shocks by their pre-1980 values. Better monetary policy explains a significant proportion of the decline in the variance of output growth (28.65%) and the price level (49.12%), whereas the proportion explained by good luck is an order of magnitude larger. Yet, good luck seems to have taken a form other than smaller oil price shocks. Note that the contribution of oil prices is minimal. A similar pattern is observed for the manufacturing variables where the ratio of the variance reduction explained by good luck relative to that explained by better policy ranges from 1/3 to 9, and oil price shocks marginally increase the variance.

6 Final Remarks

In this paper we analyze the contribution of oil prices shocks and systematic monetary policy to the 'Great Moderation'. We find that a one-time 10% increase in the real oil prices had a larger and longer-lived effect on output growth, the aggregate price level, manufacturing sales' growth and inventory investment in the pre-Volcker period. In addition, the historical decomposition suggests an important contribution of oil prices to economic fluctuations, particularly during the years following the Arab-Israel War and the Persian Gulf War. The contribution declined in the late 1990s, but appears to have increased somewhat during 2006.

Regarding the role of the systematic monetary policy response, it appears to have dampened fluctuations in economic activity during the 1970s, but to have had virtually no effect after the 'Great Moderation'. The impulse responses indicate that preventing a change in the fed funds rate (in response to the oil price increase) would have resulted in a lower price level and a milder recession during the pre-Volcker period. Similarly, this counterfactual scenario results in larger contribution of oil price shocks to the variance of GDP growth, inflation and manufacturing sales and work-in-process inventories. These results are also supported by the historical decomposition, which suggest that delaying the monetary policy response for one year would have amplified the contribution of oil price shocks to the economic fluctuations in the pre-1980 sample.

During the Volcker-Greenspan years, both the impulse response functions and the variance decomposition suggest a reduced role of monetary policy in dampening the effects of oil price shocks. It appears that even if the monetary authority had not responded (for one year) to a 10% increase in real oil prices, changes in the structure of the economy would still have kept inflation at a much lower level than in the 1970s. Both the impulse responses and the variance decomposition suggests that, after the 'Great Moderation', the role of monetary policy in mitigating the effect of an oil price shock is considerably smaller. Only, in 2006, does the contribution of systematic monetary policy seem to play a significant role in explaining the contribution of oil price shocks to economic fluctuations.

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Table 1: Unconditional Volatility

	1959-1979	1985-2006
GDP growth	18.76	4.56
Inflation	9.04	1.01
GDP deflator	1.52	0.40
Real oil price growth	35.87	294.08
Federal funds rate	8.49	4.93
Total manufacturing		
Sales	91.50	25.36
Finished goods	25.76	16.93
Work-in-process	41.23	28.30
Materials and supplies	65.46	16.45
Non durables		
Sales	48.52	18.37
Finished goods	38.30	18.99
Work-in-process	46.51	47.95
Materials and supplies	41.02	16.57
Durables		
Sales	189.81	51.37
Finished goods	59.54	29.34
Work-in-process	52.99	41.58
Materials and supplies	158.48	34.69

Note: Estimated variances for all variables except real oil price increase and federal funds rates are multiplied by 100.

Table 2: Variance of each variable as implied by the VAR estimates.

	With Systematic Response			No Systematic Response		
	1959-2006	1959-1979	1985-2006	1959-2006	1959-1979	1985-2006
Change in output gap	31.37	53.21	14.74	28.08	42.39	10.53
GDP growth	13.08	21.07	4.54	11.78	15.33	4.16
GDP deflator	0.05	0.03	0.01	0.05	0.01	0.01
Real oil price growth	154.16	34.06	260.46	153.76	27.83	254.13
Federal funds rate	8.25	6.21	2.77	1.60	1.86	0.14
Total manufacturing						
Sales	66.93	121.77	27.04	65.16	88.40	21.05
Finished goods	22.91	27.51	17.44	20.12	29.23	13.09
Work-in-process	36.55	60.28	37.65	35.10	40.55	29.97
Materials and supplies	35.10	65.17	15.83	37.63	68.69	14.10
Non durables						
Sales	36.79	61.49	18.04	33.37	48.48	15.38
Finished goods	37.90	41.71	18.45	34.17	43.92	13.97
Work-in-process	48.34	54.74	45.53	45.85	49.34	42.70
Materials and supplies	26.95	55.40	13.96	25.82	54.45	13.19
Durables						
Sales	129.56	209.72	56.11	126.88	159.09	48.61
Finished goods	41.57	72.73	30.70	37.05	68.54	25.96
Work-in-process	47.26	80.79	55.30	43.56	49.74	44.03
Materials and supplies	77.97	146.98	32.79	81.72	150.80	29.55

Note: See Table 1.

Table 3: Contribution of an oil price shock to the variance of each variable for both scenarios and various periods.

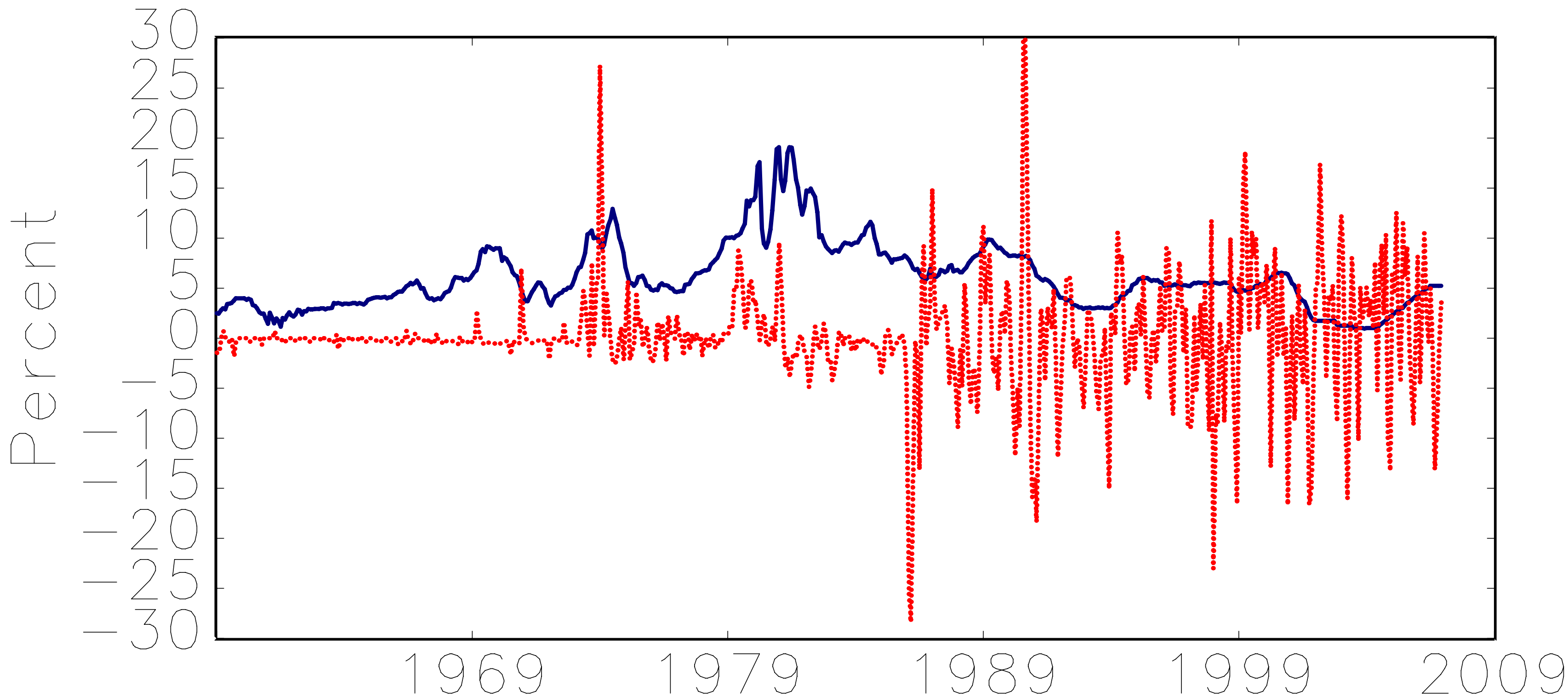
	With Systematic Response			Without Systematic Response		
	1959-2006	1959-1979	1985-2006	1959-2006	1959-1979	1985-2006
Change in output gap	7.87	128.12	5.46	2.51	146.33	7.72
GDP growth	3.75	23.52	1.33	1.21	34.85	1.48
GDP deflator	0.02	0.02	0.00	0.02	0.01	0.01
Real oil price growth	142.00	22.45	209.23	142.56	23.69	212.97
Federal funds rate	0.18	0.86	0.09	0.01	1.69	0.01
Total manufacturing						
Sales	27.77	254.22	25.71	12.71	355.93	26.69
Finished goods	7.99	79.39	8.44	6.24	107.28	7.68
Work-in-process	7.03	35.96	6.38	2.47	100.81	11.25
Materials and supplies	12.94	134.36	11.54	11.82	204.40	11.08
Non durables						
Sales	27.02	121.79	13.16	17.39	167.65	12.42
Finished goods	13.32	86.55	13.83	11.04	125.49	9.05
Work-in-process	18.11	71.85	29.90	14.74	82.63	36.00
Materials and supplies	9.65	97.64	5.63	7.11	112.10	5.75
Durables						
Sales	39.11	344.08	59.65	22.33	522.23	77.53
Finished goods	20.52	218.53	6.97	15.71	254.49	8.66
Work-in-process	13.23	47.00	10.86	4.19	161.20	16.36
Materials and supplies	32.52	175.44	15.66	31.06	343.20	19.43

Table 4: Effect of Monetary Policy, Good Luck and Oil Price Shocks

	Historical Variances		Percent of variance reduction explained by		
	1959-1979	1985-2006	Systematic monetary policy	Good luck	
				All shocks	Only oil price shocks
GDP growth	22.16	4.59	28.65	40.32	-0.19
GDP deflator	0.07	0.01	49.12	24.56	-1.75
Total manufacturing					
Sales	128.90	26.66	60.19	30.24	-2.39
Finished goods	28.54	18.24	1126.03	190.97	-7.47
Work-in-process	63.43	40.06	1933.38	148.43	-2.59
Materials and supplies	65.91	15.24	75.26	43.27	-2.07
Non durables					
Sales	65.76	18.90	66.29	40.36	-2.58
Finished goods	41.87	19.26	450.70	101.18	-5.39
Work-in-process	56.88	48.03	1629.44	321.53	-27.25
Materials and supplies	54.85	14.56	35.63	50.88	-1.22
Durables					
Sales	221.17	53.13	52.31	34.95	-3.38
Finished goods	72.54	30.70	411.45	85.28	-1.50
Work-in-process	86.56	59.47	907.14	141.38	-3.39
Materials and supplies	152.96	32.70	82.12	36.66	-1.21

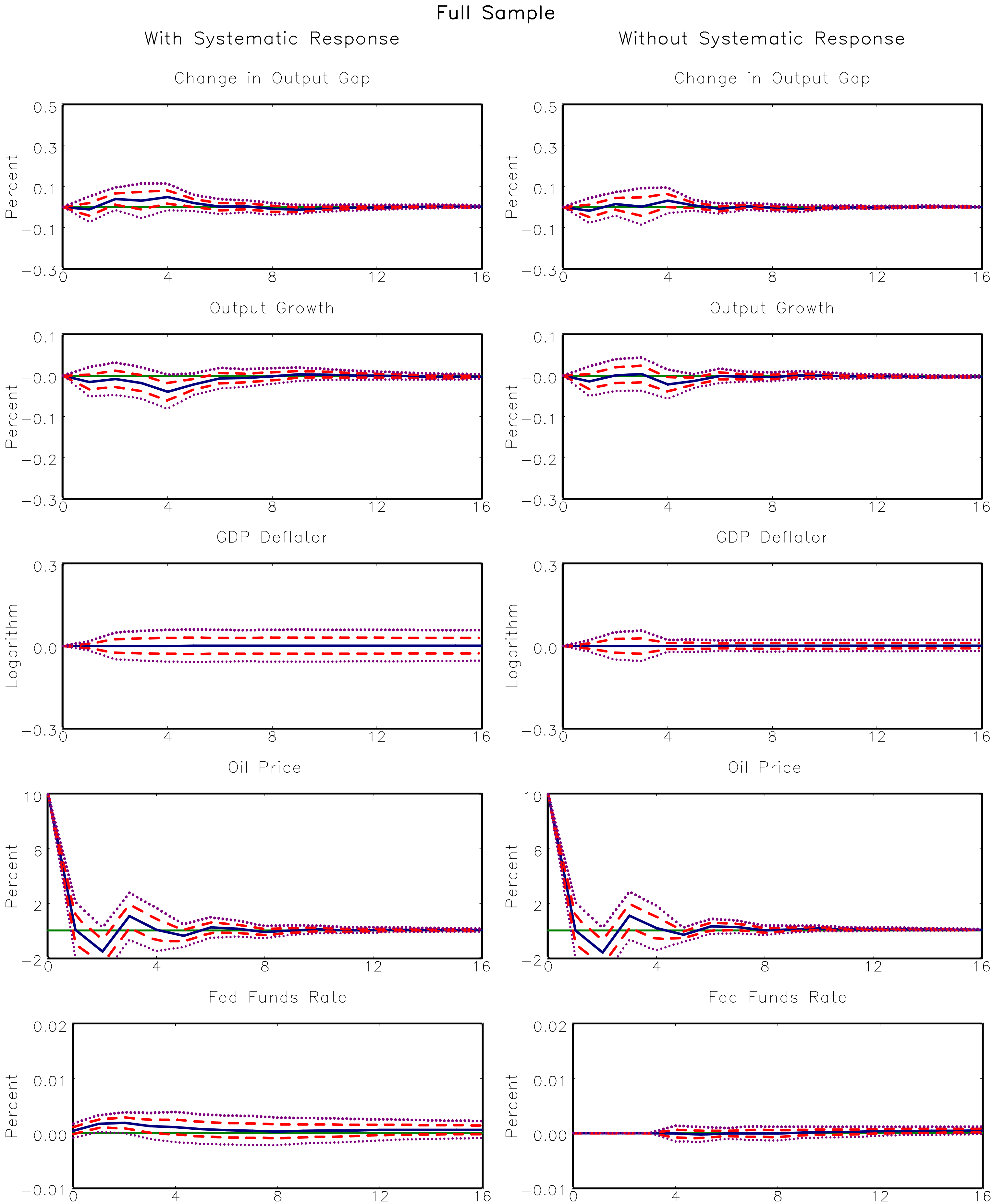
Note: Historical variances estimated from the VAR (multiplied by 100). The counterfactual for monetary policy is calculated by replacing the coefficients in the post-1984 Fed funds rate equation with the pre-1980 coefficients. The counterfactual for good luck is calculated by replacing the post-1984 variance for the all structural shocks with the pre-1980 variance. The counterfactual for oil price shocks is calculated by replacing the post-1984 oil price shocks with the pre-1980 oil price shocks.

Figure 1. Federal Funds Rate and Real Oil Price Growth



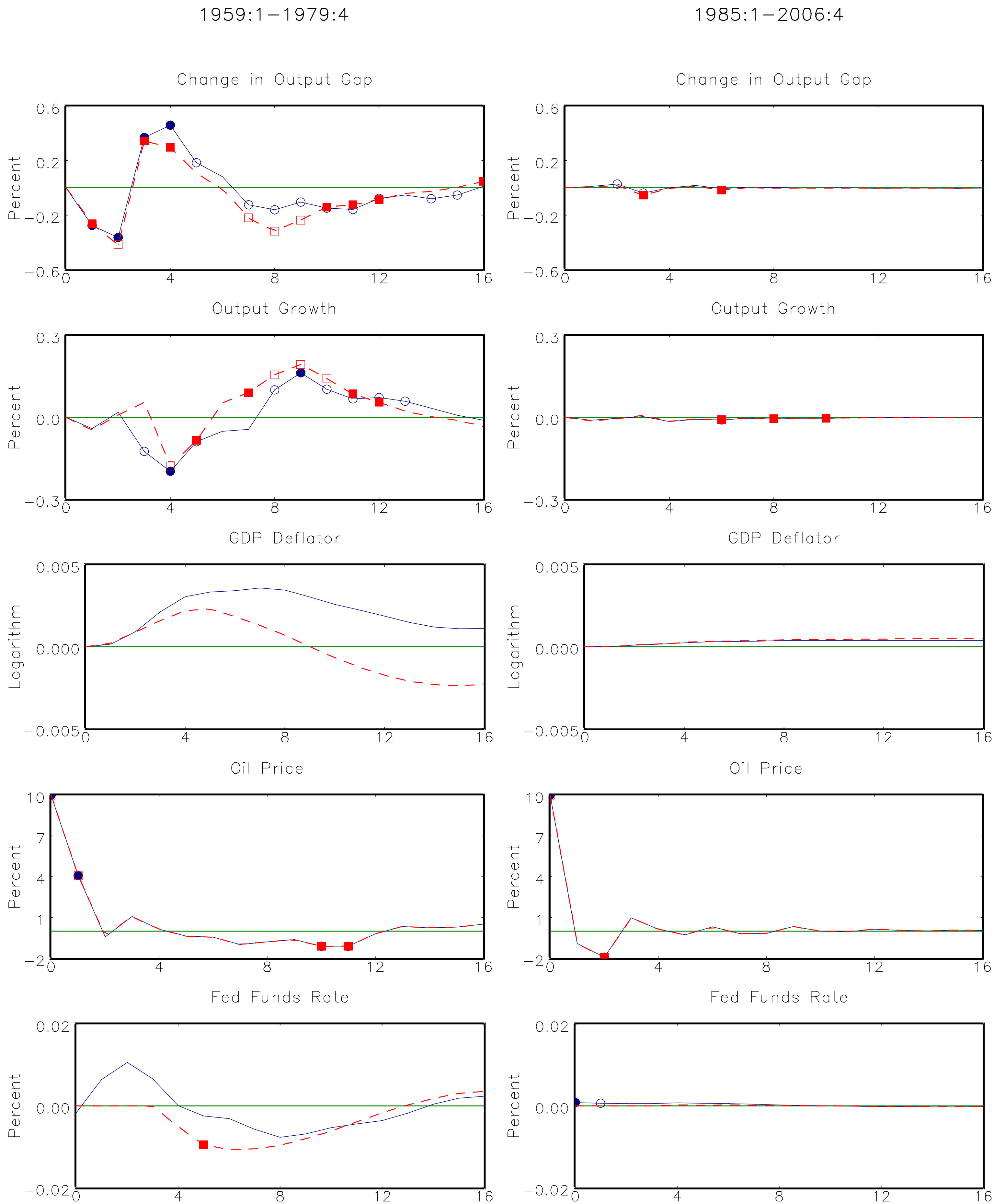
NOTES: Solid line is the Federal Funds Rate.
Dotted line is the Percentage Change in the Real Oil Price.

Figure 2. Impulse—response functions for effect of a 10% oil price increase



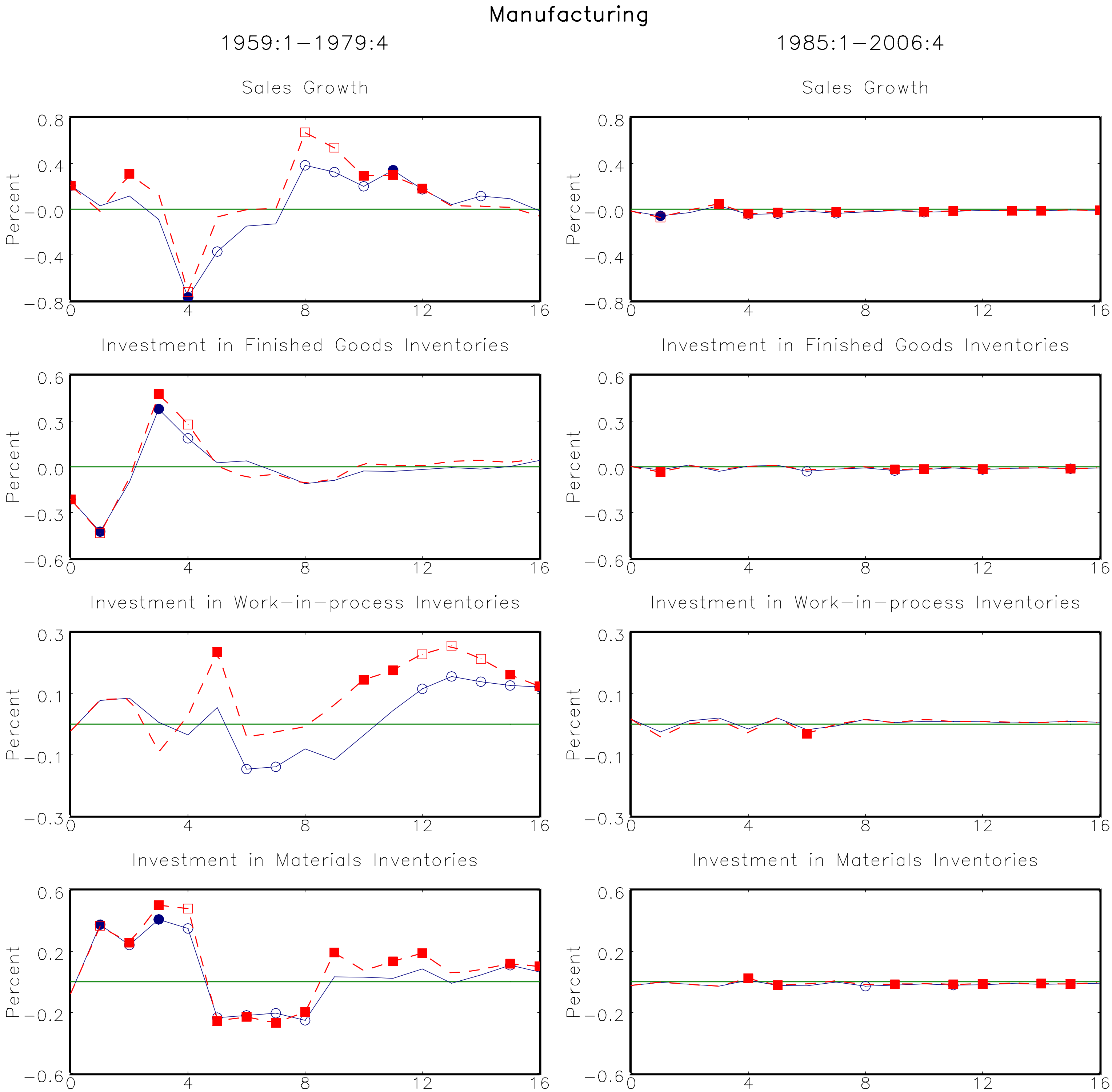
NOTES: Solid line is the impulse response function. Dashed and dotted lines are the 68% and 95% confidence intervals, respectively.

Figure 3. Impulse–response functions for effect of a 10% oil price increase



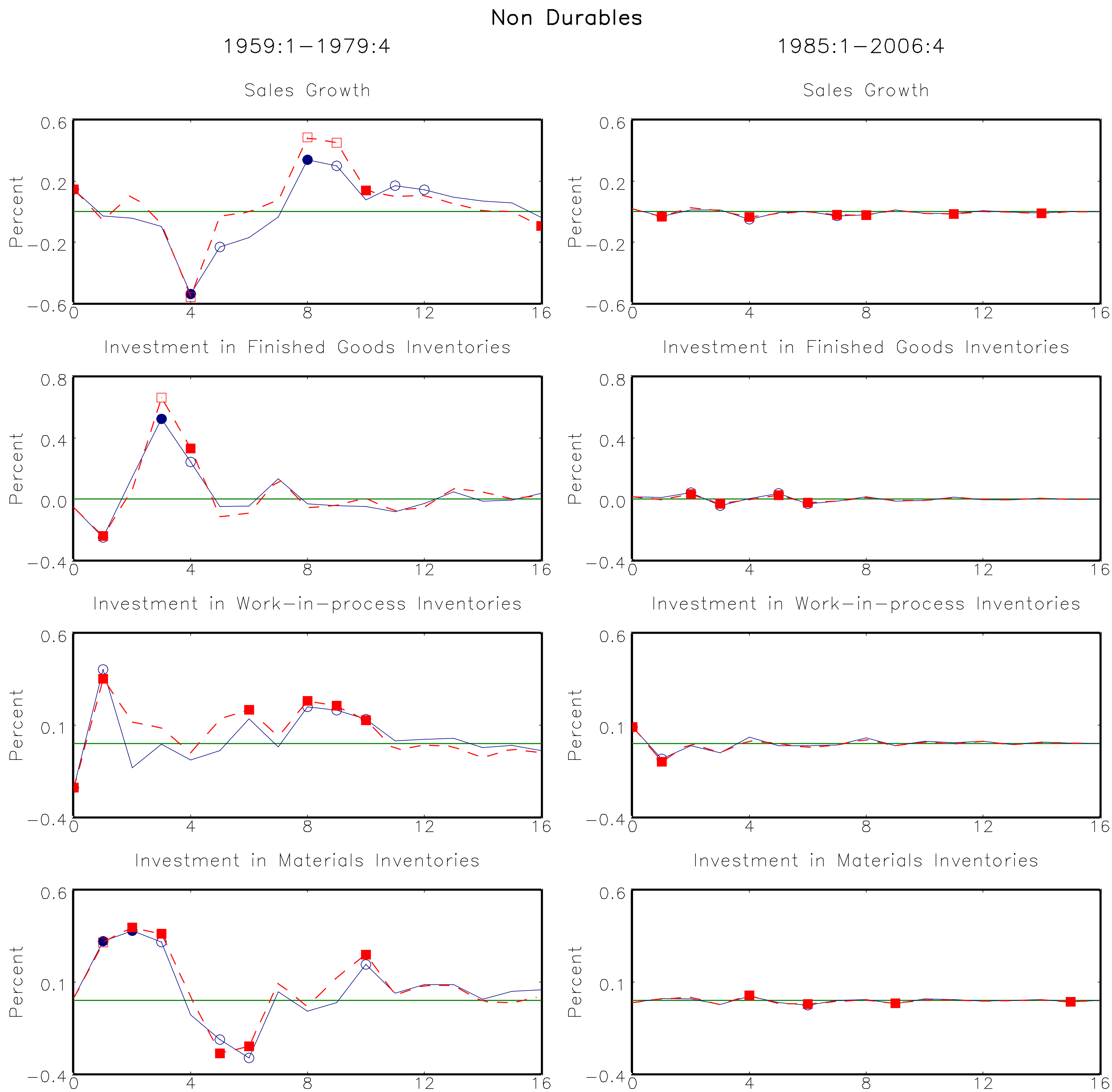
NOTES: Solid line is the total response (direct plus indirect through monetary policy). Dashed line is the direct response (shutting down the systematic monetary policy response). Filled and empty symbols represent significance at a 5% and 32% level, respectively.

Figure 4. Impulse–response functions for effect of a 10% oil price increase



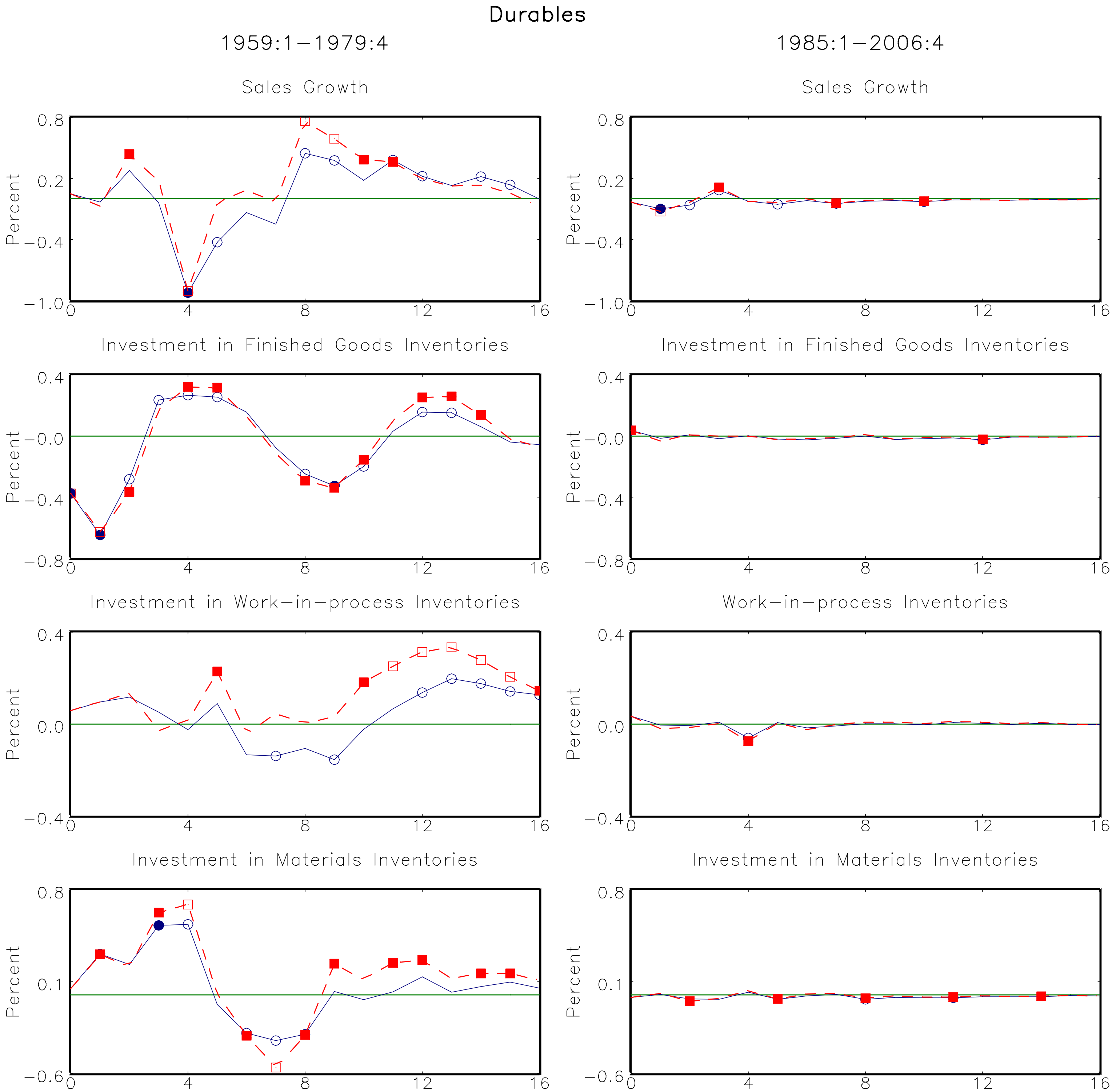
NOTES: Solid line is the total response (direct plus indirect through monetary policy). Dashed line is the direct response (shutting down the systematic monetary policy response). Filled and empty symbols represent significance at a 5% and 32% level, respectively.

Figure 5. Impulse–response functions for effect of a 10% oil price increase



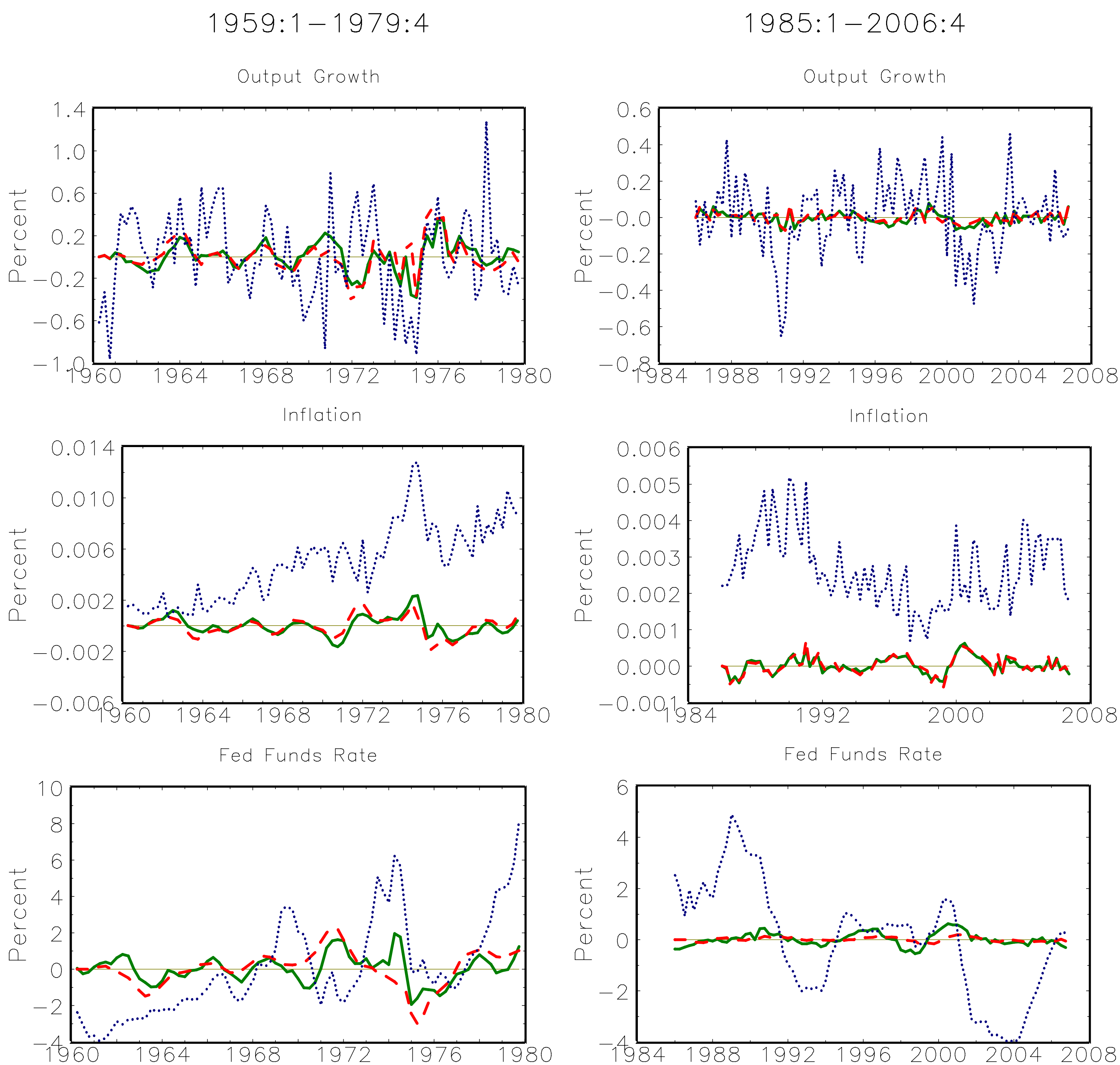
NOTES: Solid line is the total response (direct plus indirect through monetary policy). Dashed line is the direct response (shutting down the systematic monetary policy response). Filled and empty symbols represent significance at a 5% and 32% level, respectively.

Figure 6. Impulse-response functions for effect of a 10% oil price increase



NOTES: Solid line is the total response (direct plus indirect through monetary policy). Dashed line is the direct response (shutting down the systematic monetary policy response). Filled and empty symbols represent significance at a 5% and 32% level, respectively.

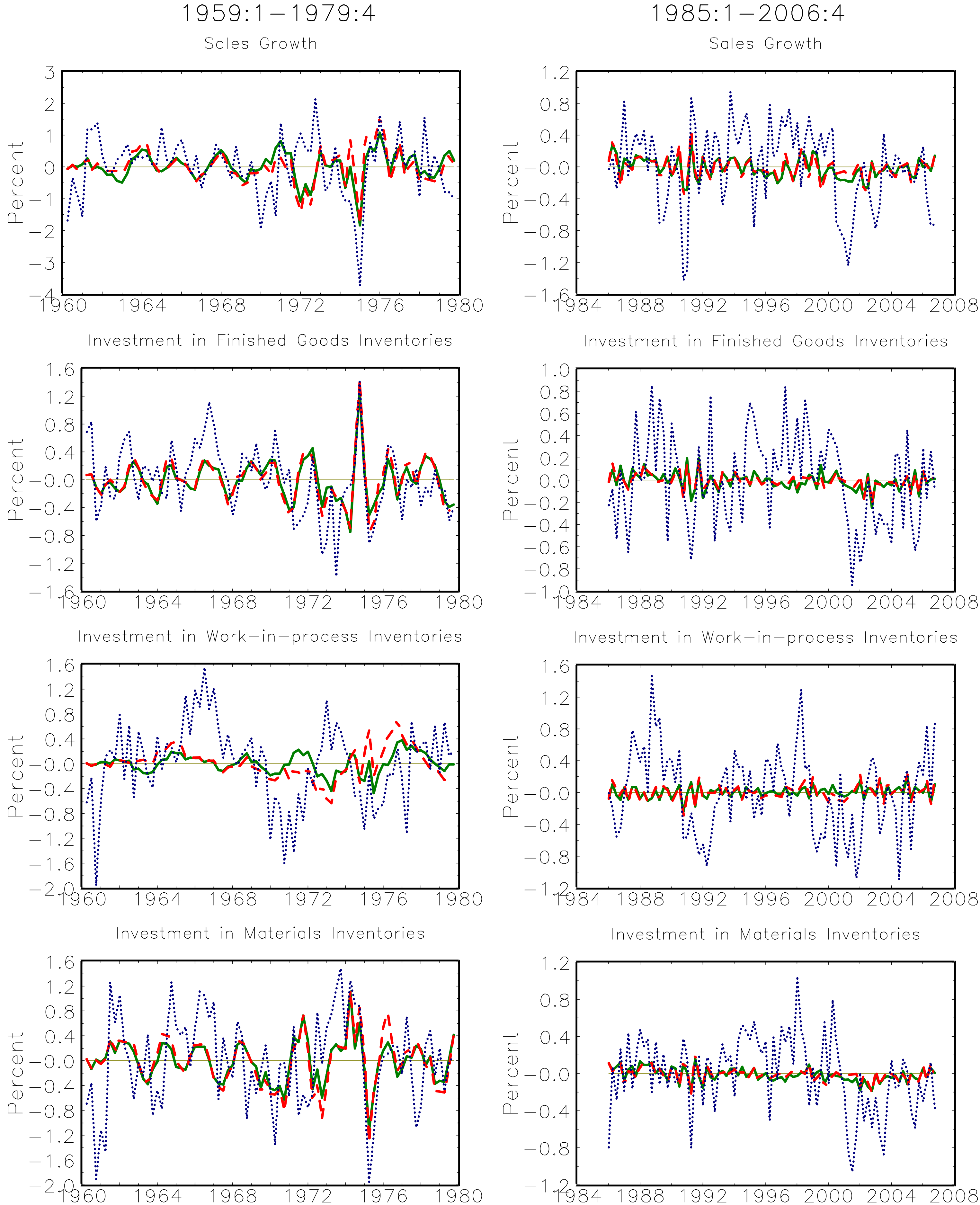
Figure 7. Historical decomposition – Contribution of oil price shocks



NOTES: Estimates based on near–VAR(4) described in the paper. Solid line is the total effect (direct plus indirect through monetary policy). Dashed line is the direct effect (shutting down systematic monetary policy). Dotted line is historical evolution.

Figure 8. Historical decomposition – Contribution of oil price shocks

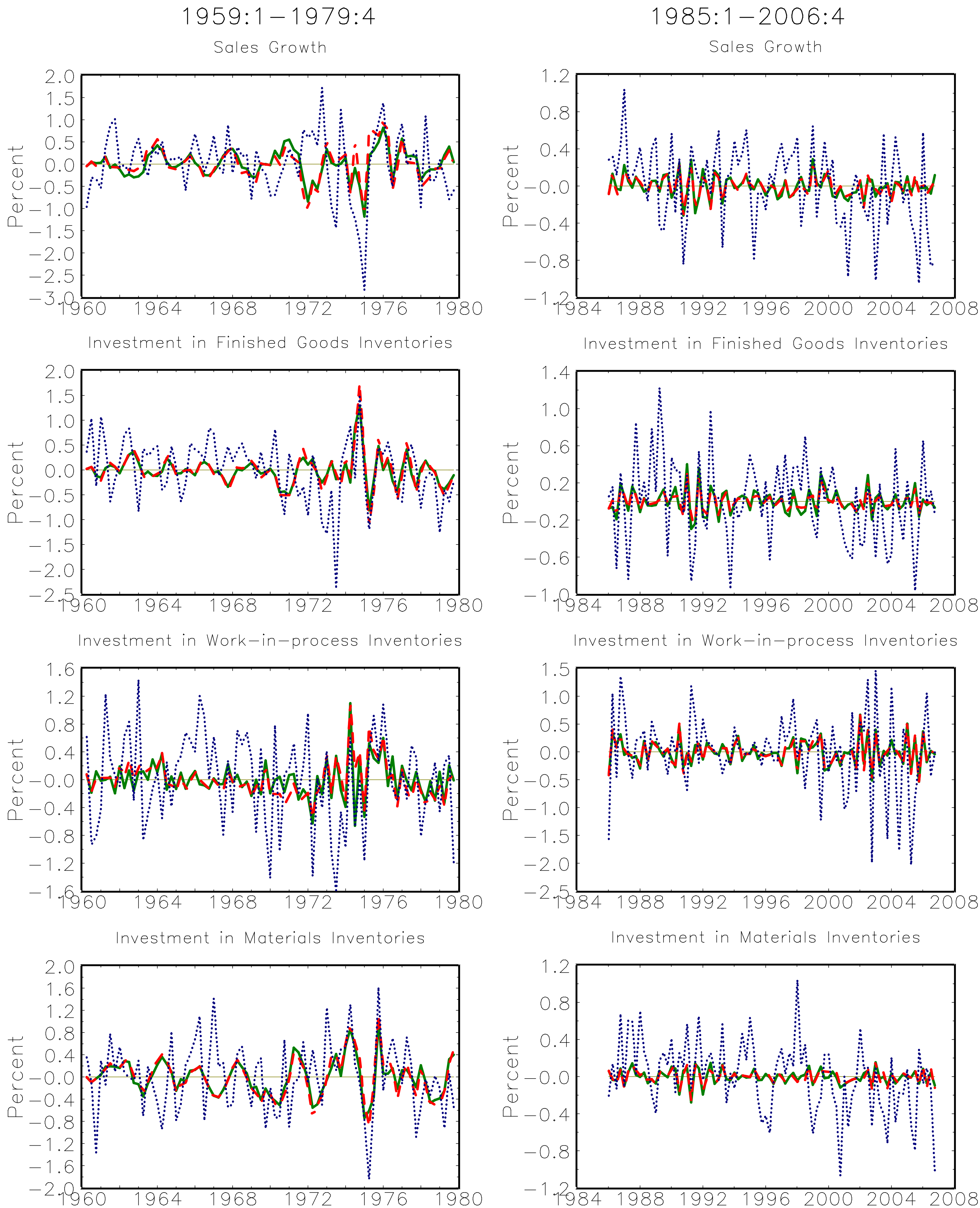
Manufacturing



NOTES: Estimates based on near-VAR(4) described in the paper. Solid line is the total effect (direct plus indirect through monetary policy). Dashed line is the direct effect (shutting down systematic monetary policy). Dotted line is historical evolution.

Figure 9. Historical decomposition — Contribution of oil price shocks

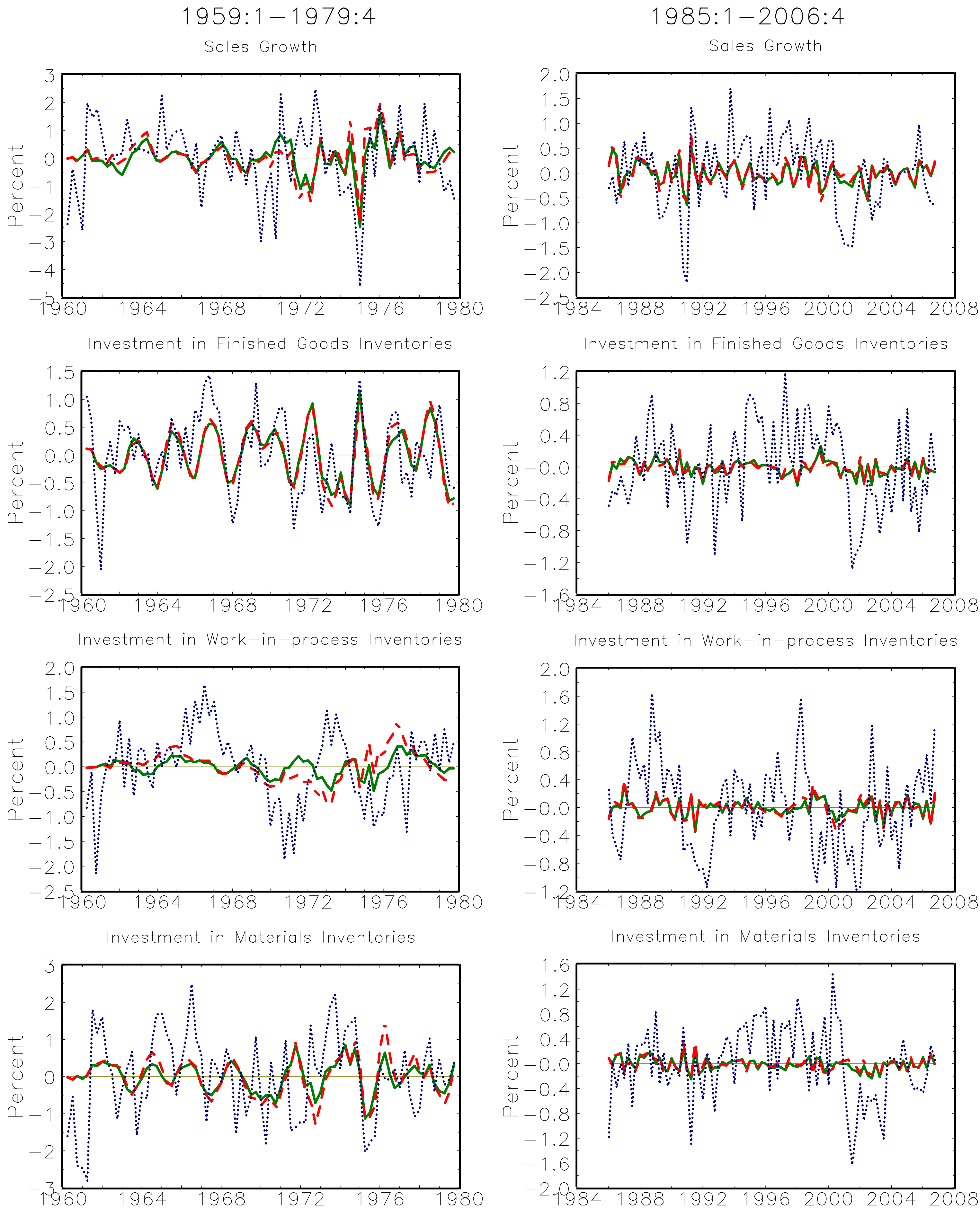
Non Durables



NOTES: Estimates based on near-VAR(4) described in the paper. Solid line is the total effect (direct plus indirect through monetary policy). Dashed line is the direct effect (shutting down systematic monetary policy). Dotted line is historical evolution.

Figure 10. Historical decomposition — Contribution of oil price shocks

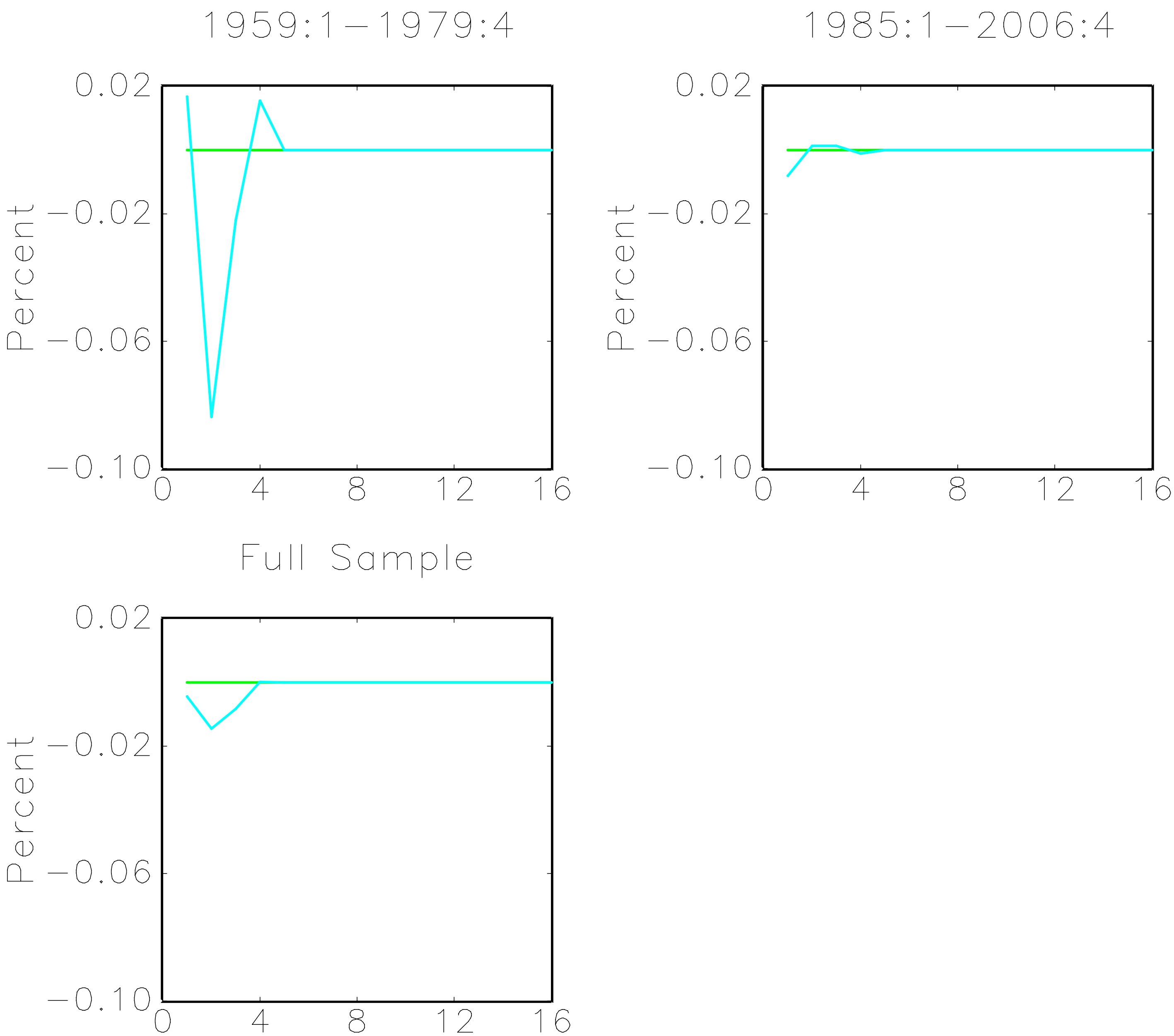
Durables



NOTES: Estimates based on near-VAR(4) described in the paper. Solid line is the total effect (direct plus indirect through monetary policy). Dashed line is the direct effect (shutting down systematic monetary policy). Dotted line is historical evolution.

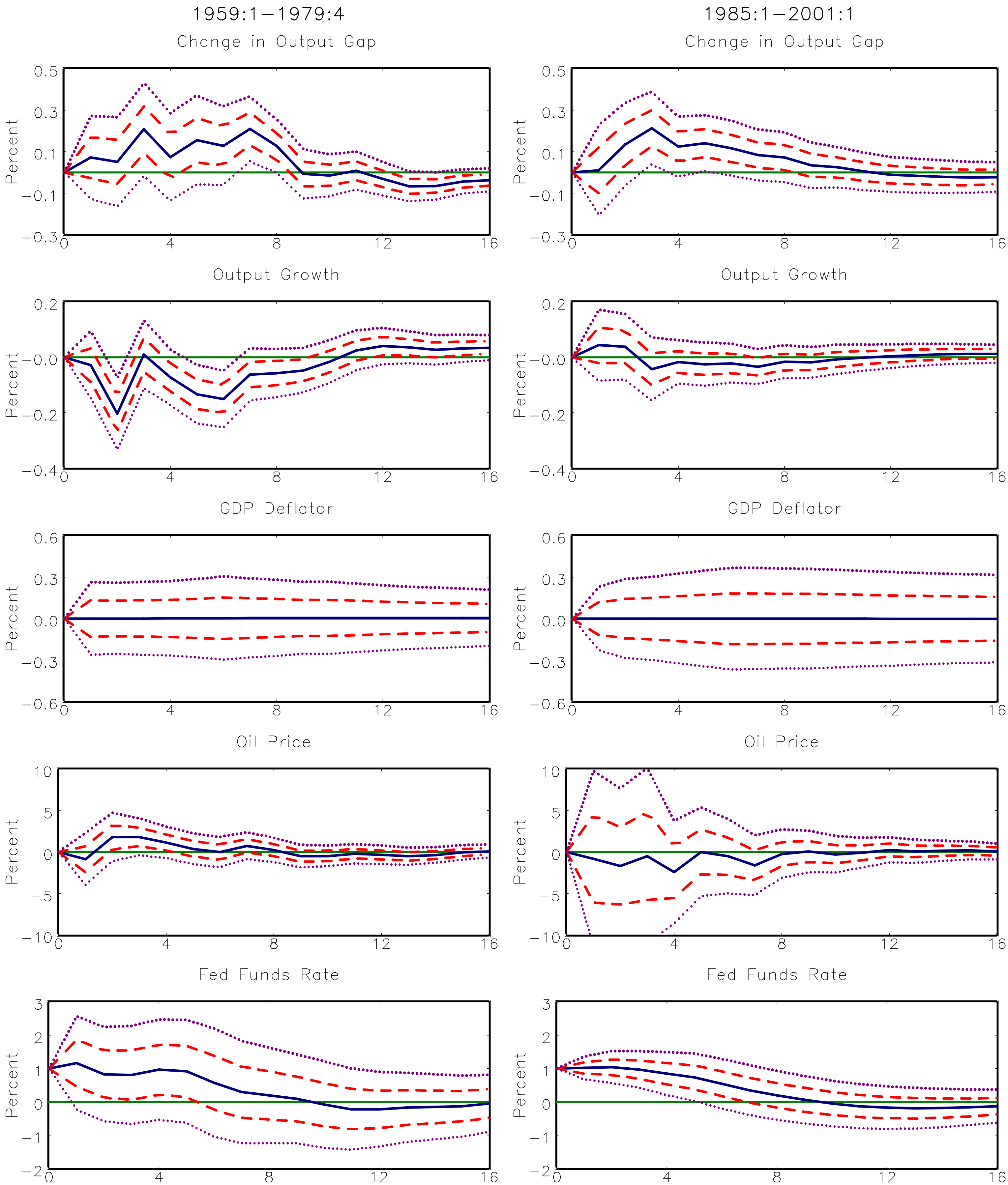
Appendix

Figure A.1. Policy Innovations



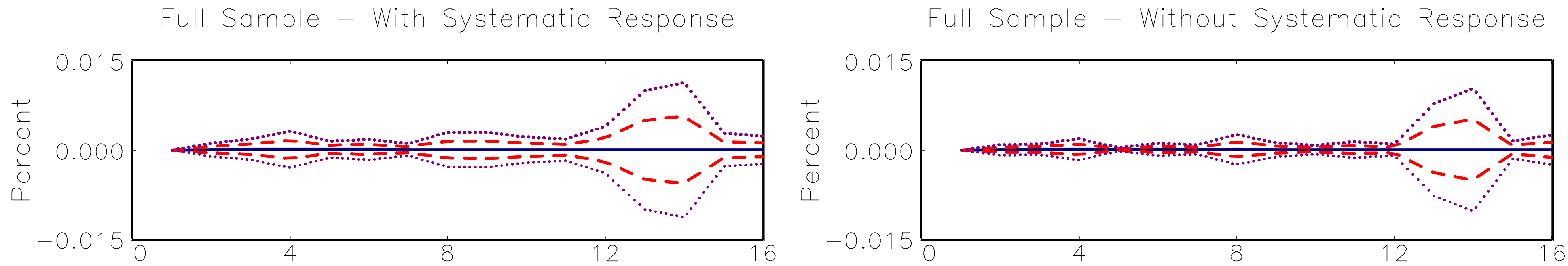
NOTES: Solid line is the shock required to shut down the systematic monetary policy response to a 10% oil price increase.

Figure A.2. Impulse–response functions for effect of a 1% increase in the fed funds rate

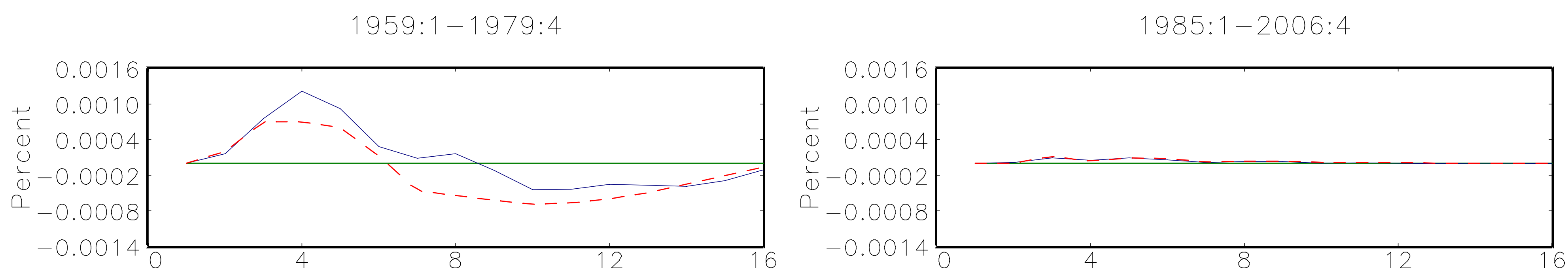


NOTES: Solid line is the impulse response function. Dashed and dotted lines are the 68% and 95% confidence intervals, respectively.

Figure A.3. Impulse–response functions for effect of a 10% oil price increase on inflation



NOTES: Solid line is the impulse response function. Dashed and dotted lines are the 68% and 95% confidence intervals, respectively.



NOTES: Solid line is the total response (direct plus indirect through monetary policy). Dashed line is the direct response (shutting down the systematic monetary policy response). Filled and empty symbols represent significance at a 5% and 32% level, respectively.