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The Macroeconomic Effects of Oil Price Shocks
Why Are the 2000s so Different from the 1970s?

Olivier J. Blanchard and Jordi Galí

7.1 Introduction

Since the 1970s, and at least until recently, macroeconomists have viewed changes in the price of oil as an important source of economic fluctuations, as well as a paradigm of a global shock, likely to affect many economies simultaneously. Such a perception is largely due to the two episodes of low growth, high unemployment, and high inflation that characterized most industrialized economies in the mid and late 1970s. Conventional accounts of those episodes of stagflation blame them on the large increases in the price of oil triggered by the Yom Kippur war in 1973, and the Iranian revolution of 1979, respectively.[1]

The events of the past decade, however, seem to call into question the relevance of oil price changes as a significant source of economic fluctuations. The reason: since the late 1990s, the global economy has experienced two oil shocks of sign and magnitude comparable to those of the 1970s but, in contrast with the latter episodes, both gross domestic product (GDP) growth

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1. Most undergraduate textbooks make an unambiguous connection between the two oil price hikes of 1973 and 1974 and 1979 and 1980 and the period of stagflation that ensued. (See, e.g., Mankiw [2007, 274].)

and inflation have remained relatively stable in much of the industrialized world.

Our goal in this chapter is to shed light on the nature of the apparent changes in the macroeconomic effects of oil shocks, as well as on some of their possible causes. Disentangling the factors behind those changes is obviously key to assessing the extent to which the episodes of stagflation of the 1970s can reoccur in response to future oil shocks and, if so, to understanding the role that monetary policy can play in order to mitigate their adverse effects.

One plausible hypothesis is that the effects of the increase in the price of oil proper have been similar across episodes, but have coincided in time with large shocks of a very different nature (e.g., large rises in other commodity prices in the 1970s, high productivity growth, and world demand in the 2000s). That coincidence could significantly distort any assessment of the impact of oil shocks based on a simple observation of the movements in aggregate variables around each episode.

In order to evaluate this hypothesis one must isolate the component of macroeconomic fluctuations associated with exogenous changes in the price of oil. To do so, we identify and estimate the effects of an oil price shock using structural Vector Autoregression (VAR) techniques. We report and compare estimates for different sample periods and discuss how they have changed over time. We follow two alternative approaches. The first one is based on a large VAR, and allows for a break in the sample in the mid-1980s. The second approach is based on rolling bivariate VARs, including the price of oil and one other variable at a time. The latter approach allows for a gradual change in the estimated effects of oil price shocks, without imposing a discrete break in a single period.

Two conclusions clearly emerge from this analysis: first, there were indeed other adverse shocks at work in the 1970s; the price of oil explains only part of the stagflation episodes of the 1970s. Second, and importantly, the effects of a given change in the price of oil have changed substantially over time. Our estimates point to much larger effects of oil price shocks on inflation and activity in the early part of the sample; that is, the one that includes the two oil shock episodes of the 1970s.

Our basic empirical findings are summarized graphically in figure 7.1 (we postpone a description of the underlying assumptions to section 7.3). The left-hand graph shows the responses of U.S. (log) GDP and the (log) consumer price index (CPI) to a 10 percent increase in the price of oil, estimated using pre-1984 data. The right-hand graph displays the corresponding responses, based on post-1984 data. As the figure makes clear, the response of both variables has become more muted in the more recent period. As we show following, that pattern can also be observed for other variables (prices and quantities) and many (though not all) other countries considered. In sum, the evidence suggests that economies face an improved

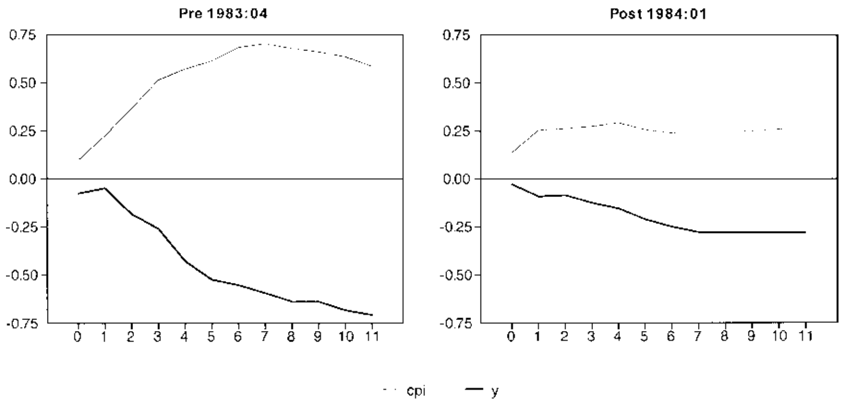


Fig. 7.1 U.S.—Impulse response to an oil price shock

trade-off in the more recent period, in the face of oil price shocks of a similar magnitude.

We then focus on the potential explanations for these changes over time. We consider three hypotheses, not mutually exclusive. First, real wage rigidities may have decreased over time. The presence of real wage rigidities generates a trade-off between stabilization of inflation and stabilization of the output gap. As a result, and in response to an adverse supply shock and for a given money rule, inflation will generally rise more and output will decline more, the slower real wages adjust. A trend toward more flexible labor markets, including more flexible wages, could thus explain the smaller impact of the more recent oil shocks.

Second, changes in the way monetary policy is conducted may be responsible for the differential response of the economy to the oil shocks. In particular, the stronger commitment by central banks to maintaining a low and stable rate of inflation, reflected in the widespread adoption of more or less explicit inflation targeting strategies, may have led to an improvement in the policy trade-off that would make it possible to have a smaller impact of a given oil price increase on both inflation and output simultaneously.

Third, the share of oil in the economy may have declined sufficiently since the 1970s to account for the decrease in the effects of its price changes. Under that hypothesis, changes in the price of oil have increasingly turned into a sideshow, with no significant macroeconomic effects (not unlike fluctuations in the price of caviar).

To assess the merits of the different hypotheses we proceed in two steps. First, we develop a simple version of the new-Keynesian model where (imported) oil is both consumed by households and used as a production input by firms. The model allows us to examine how the economy's response to an exogenous change in the price of oil is affected by the degree of real wage rigidities, the nature and credibility of monetary policy, and the share of oil in production and consumption. We then look for more direct evidence pointing to the relevance and quantitative importance of each of those hypotheses. We conclude that all three are likely to have played an important role in explaining the different effects of oil prices during the 1970s and during the last decade.

The chapter is organized as follows. Section 7.1 gives a short summary of how our chapter fits in the literature. Section 7.2 presents basic facts. Section 7.3 presents results from multivariate VARs. Section 7.4 presents results from rolling bivariate VARs. Section 7.5 presents the model. Section 7.6 uses the model to analyze the role of real rigidities, credibility in monetary policy, and the oil share. Section 7.7 concludes.

7.1 Relation to the Literature

Our chapter is related to many strands of research. The first strand is concerned with the effects of oil price shocks on the economy. The seminal work in that literature is Bruno and Sachs (1985), who were the first to analyze in depth the effects of oil prices of the 1970s on output and inflation in the major industrialized countries. They explored many of the themes of our chapter, the role of other shocks, the role of monetary policy, and the role of wage setting.

On the empirical side, Hamilton showed in a series of contributions (see, in particular, Hamilton [1983, 1996]) that most of U.S. recessions were preceded by increases in the price of oil, suggesting an essential role for oil price increases as one of the main causes of recessions. The stability of this relation has been challenged by a number of authors, in particular Hooker (1996). Our finding that the effects of the price of oil have changed over time is consistent with the mixed findings of this line of research.

On the theoretical side, a number of papers have assessed the ability of standard models to account for the size and nature of the observed effects of oil price shocks. Thus, Rotemberg and Woodford (1996) argued that it was difficult to explain the sheer size of these effects in the 1970s. They argued that something else was going on; namely, an endogenous increase in the markup of firms, leading to a larger decrease in output. Finn (2000) showed that effects of the relevant size could be generated in a perfectly competitive real business cycle (RBC) model, by allowing for variable capital utilization. Neither mechanism would seem to account for the depth of the effects of the 1970s and not in the 2000s. The latter observation motivates our focus on the role of real wage rigidities, and the decline in these rigidities over time, an explanation we find more convincing than changes in either the behavior of markups or capacity utilization over time. In following this line, we build on our earlier work on the implications of real wage rigidities and their interaction with nominal price stickiness (Blanchard and Galí 2007).

A second strand of research related to the present chapter deals with the possible changes over time in the effects of oil shocks. Of course, that strand is in turn related to the literature on the "Great Moderation," a term used to refer to the decrease in output fluctuations over the last thirty years (e.g., Blanchard and Simon 2001; Stock and Watson 2003). The latter literature has tried to assess to what extent the declines in volatility have been due to "good luck" (i.e., smaller shocks) or changes in the economy's structure (including policy changes). In that context, some authors have argued that the stagflations of the 1970s were largely due to factors other than oil. Most prominently, Barsky and Kilian (2002) argue that they may have been partly caused by exogenous changes in monetary policy, which coincided in time with the rise in oil prices. Bernanke, Gertler, and Watson (1997) argue that much of the decline in output and employment was due to the rise in interest rates, resulting from the Fed's endogenous response to the higher inflation induced by the oil shocks.

While our evidence suggests that oil price shocks can only account for a fraction of the fluctuations of the 1970s, our findings that the dynamic effects of oil shocks have decreased considerably over time, combined with the observation that the oil shocks themselves have been no smaller, is consistent with the hypothesis of structural change.

We know of four papers that specifically focus, as we do, on the changing impact of oil shocks. Hooker (2002) analyzes empirically the changing weight of oil prices as an explanatory variable in a traditional Phillips curve specification for the U.S. economy. He finds that pass-through from oil to prices has become negligible since the early 1980s, but cannot find evidence for a significant role of the decline in energy intensity, the deregulation of energy industries, or changes in monetary policy as a factor behind that lower pass-through. De Gregorio, Landerretche, and Neilson (2007) provide a variety of estimates of the degree of pass-through from oil prices to inflation, and its changes over time, for a large set of countries. In addition to estimates of Phillips curves along the lines of Hooker (2002), they also provide evidence based on rolling VARs, as we do in the present chapter, though they use a different specification and focus exclusively on the effects on inflation. Their paper also examines a number of potential explanations, including a change in the response of the exchange rate (in the case of non-U.S. countries), and the virtuous effects of being in a low inflation environment. In two recent papers, developed independently, Herrera and Pesavento (2007) and Edelstein and Kilian (2007) also document the decrease in the effects of oil shocks on a number of aggregate variables using a VAR approach. Herrera and Pesavento, following the approach of Bernanke, Gertler, and Watson (1997), explore the role of changes in the response of monetary policy to oil shocks in accounting for the more muted effects of those shocks in the recent period. Their answer is largely negative: their findings point to a more stabilizing role of monetary policy in the 1970s relative to the recent period. Edelstein and Kilian focus on changes in the composition of U.S. automobile production, and the declining importance of the U.S. automobile sector. Given that the decline in the effects of the price of oil appears to be present in a large number of Organization for Economic Cooperation and Development (OECD) countries, this explanation appears perhaps too U.S.-specific.

7.2 Basic Facts

Figure 7.2 displays the evolution of the price of oil since 1970. More specifically, it shows the quarterly average price of a barrel of West Texas Intermediate, measured in U.S. dollars.[2] The figure shows how a long spell of stability came to an end in 1973, triggering a new era characterized by large and persistent fluctuations in the price of oil, punctuated with occasional sharp run-ups and spikes, and ending with the prolonged rise of the past few years. The shaded areas in the figure correspond to the four large oil shock episodes discussed following.

Figure 7.3 displays the same variable, now normalized by the U.S. GDP deflator, and measured in natural logarithms. This transformation gives us a better sense of the magnitude of the changes in the real price of oil. As the figure makes clear, such changes have often been very large, and concentrated over relatively short periods of time.

It is useful to start with descriptive statistics associated with the large oil shocks visible in the previous figures. We define a large oil shock as an episode involving a cumulative change in the (log) price of oil above 50 percent, sustained for more than four quarters. This gives us four episodes, starting in 1973, 1979, 1999, and 2002, respectively. Exact dates for each run-up are given in table 7.1 (given our definition, the largest price changes need not coincide with the starting date, and, indeed, they do not). For convenience we refer to those episodes as O1, O2, O3, and O4, respectively. Note that this criterion leaves out the price rise of 1990 (triggered by the Gulf War), due to its quick reversal. We also note that O3 is somewhat different, since it is preceded by a significant price decline.

Table 7.1 lists, for each episode: (a) the run-up period; (b) the date at which the cumulative log change attained the 50 percent threshold (which we use as a benchmark date in the following); and (c) the percent change from trough to peak (measured by the cumulative log change), both in nominal

2. The description of the stylized facts discussed following is not altered significantly if one uses alternative oil price measures, such as the PPI index for crude oil (used, e.g., by Hamilton [1983] and Rotemberg and Woodford [1996]) or the price of imported crude oil (e.g., Kilian 2006).

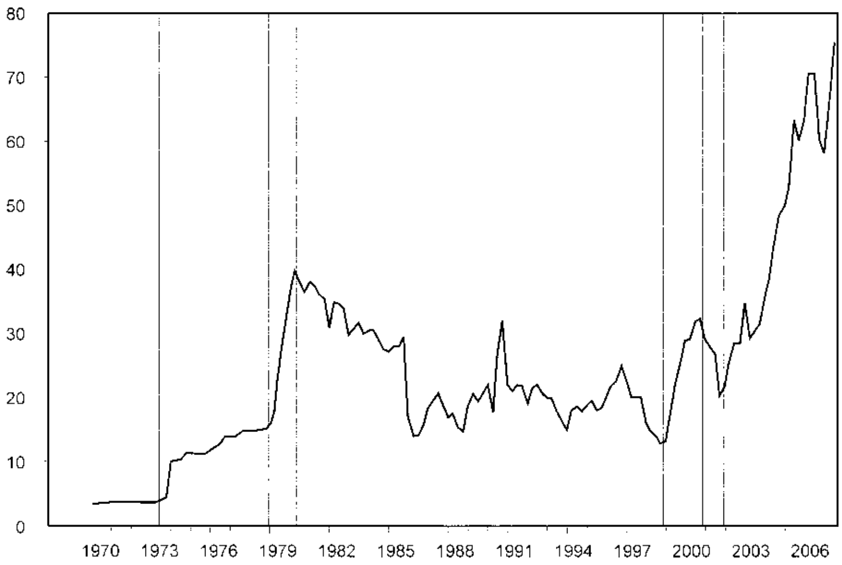


Fig. 7.2 Oil price ($ per barrel)

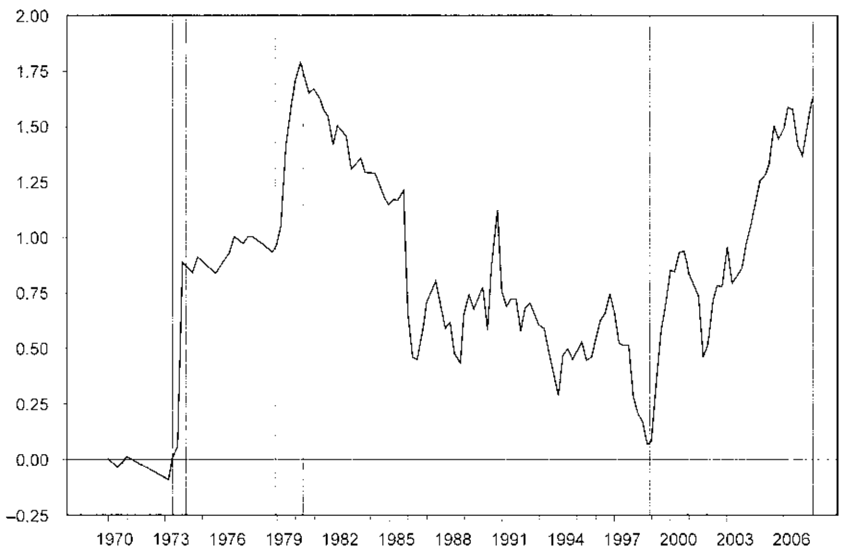


Fig. 7.3 Log real oil price

Table 7.1 **Postwar oil shock episodes**

	Run-up period	50% rise date	Max log change ($) (%)	Max log change (real) (%)
O1	1973:3–1974:1	1974:1	104	96
O2	1979:1–1980:2	1979:3	98	85
O3	1999:1–2000:4	1999:3	91	87
O4	2002:1–2007:3	2003:1	125	110

and real terms. The duration of the episodes ranges from three quarters (O1) to twenty quarters (O4).[3]

Interestingly, the size of the associated nominal price rise is roughly similar across episodes—around 100 percent. A similar characterization emerges when we use the cumulative change in the real price of oil (with the price normalized by the GDP deflator), except for O2, where the rise is somewhat smaller because of the high rate of inflation during that episode. In short, the four episodes involve oil shocks of a similar magnitude. In particular, the numbers do not seem to justify a characterization of the two recent shocks as being milder in size than the shocks of the 1970s.

In spite of their relatively similar magnitude, these four oil shock episodes have been associated with very different macroeconomic performances. Figures 7.4 and 7.5, which show, respectively, the evolution of (annual) CPI inflation and the unemployment rate in the United States over the period 1970:1 through 2007:3, provide a visual illustration.

Each figure shows, in addition to the variable displayed, the (log) real price of oil and the four shaded areas representing our four oil shock episodes. Note that the timing of O1 and O2 coincide with a sharp increase in inflation, and mark the beginning of a large rise in the unemployment rate. In each case, both inflation and unemployment reached a peak a few quarters after the peak in oil prices (up to a level of 11.3 percent and 13.4 percent, respectively, in the case of inflation; 8.8 percent and 10.6 percent for the unemployment rate). The pattern of both variables during the more recent oil shock episodes is very different. First, while CPI inflation shows a slight upward trend during both O3 and O4, the magnitude of the changes involved is much smaller than that observed for O1 and O2, with the associated rises in inflation hardly standing out relative to the moderate size of fluctuations shown by that variable since the mid-1980s. Second, the variation in the unemployment rate during and after O3 and O4 is much smaller in size than that observed in O1 and O2. The timing is also very different:

3. While our sample ends in 2007:3, it is clear that episode (04) has not ended yet. The price of oil has continued to increase, in both 2007:4 and 2008:1.

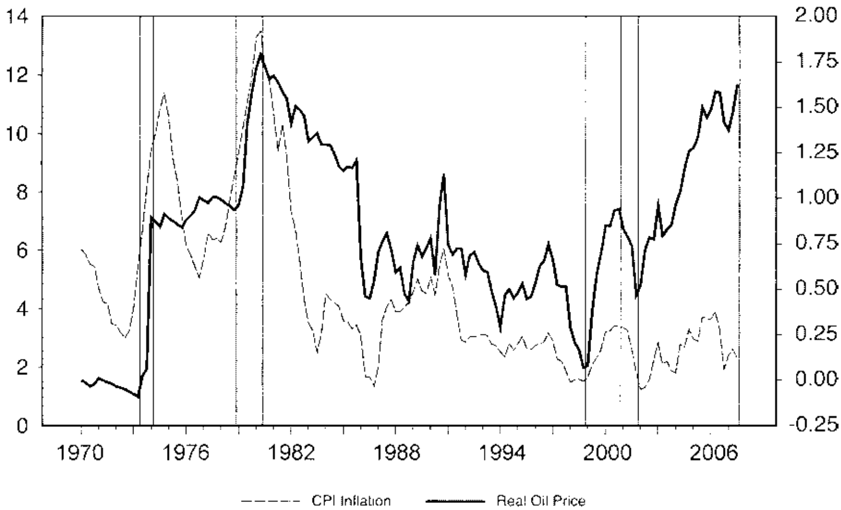


Fig. 7.4 Oil shocks and CPI inflation

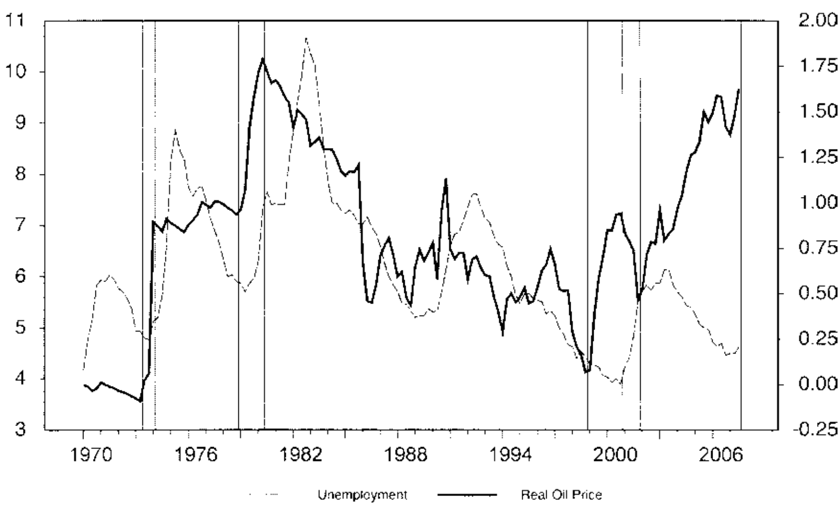


Fig. 7.5 Oil shocks and unemployment

while O1 and O2 lead to a sharp rise in unemployment, the latter variable keeps declining during the length of the O3 episode, with its rebound preceding O4. Furthermore, after a persistent (though relatively small) increase, unemployment starts declining in the midst of O4; that is, while the price of oil is still on the rise.

Tables 7.2 and 7.3 provide related evidence for each of the G7 countries as well as for three aggregates (the G7, the euro-12, and the OECD

Table 7.2 **Oil shock episodes: Change in inflation**

	O1	O2	O3	O4	AVG (1,2)	AVG (3,4)
Canada	4.7	1.8	2.2	0.5	3.3	1.4
Germany	0.1	2.6	1.1	–0.2	1.4	0.4
France	5.4	3.1	1.3	0.5	4.2	0.9
U.K.	10.2	4.3	0.0	0.5	7.3	0.3
Italy	7.7	5.6	1.0	–0.1	6.6	0.4
Japan	7.9	1.0	–1.7	0.9	4.4	–0.4
U.S.	4.9	4.0	1.7	–0.2	4.5	0.7
G7	4.8	1.9	0.3	0.0	3.3	0.2
Euro12	4.3	2.7	1.3	–0.5	3.5	0.4
OECD	4.9	1.8	0.1	–0.5	3.4	–0.2

Table 7.3 **Oil shock episodes: Cumulative GDP change**

	O1	O2	O3	O4	AVG (1,2)	AVG (3,4)
Canada	–8.3	–1.0	–1.5	3.2	–4.6	0.8
Germany	–9.6	–3.5	1.3	–2.5	–6.6	–0.6
France	–7.6	–4.4	0.6	1.2	–6.0	0.9
U.K.	–16.4	–9.2	0.4	2.5	–12.8	1.4
Italy	–8.6	0.4	3.0	–2.0	–4.1	0.5
Japan	–16.1	–4.4	7.6	3.3	–10.3	5.4
U.S.	–13.3	–11.8	–3.7	7.1	–12.5	1.7
G7	–12.6	–7.7	–0.2	3.9	–10.2	1.8
Euro12	–9.1	–2.9	1.0	–0.4	–6.0	0.3
OECD	–11.2	–6.5	0.1	4.1	–8.9	2.1

countries).[4] More specifically, table 7.2 displays, for each country and episode, the average rate of inflation over the eight quarters following each episode's benchmark date (at which the 50 percent threshold oil price rise is reached) *minus* the average rate of inflation over the eight quarters immediately preceding each run-up. Note that the increase in inflation associated with O1 is typically larger than the one for O2. The most striking evidence, however, relates to O3 and O4, which are typically associated with a change in inflation in their aftermath of a much smaller size than that following O1 and O2.[5] The last two columns, which average the inflation change for O1–O2 and O3–O4, makes the same point in a more dramatic way.

The evidence on output across episodes is shown in table 7.3, which reports for each country and episode (or averages of two episodes in the

4. We use quarterly data from OECD's Economic Outlook Database. For the purpose of this exercise, inflation is the annualized quarter-to-quarter rate of change in the CPI. These two tables have not been updated, and use data up to the end of 2005 only.

5. Even for Canada and Germany, the largest change in inflation occurs in either O1 or O2.

case of the last two columns) the cumulative GDP gain or loss over the eight quarters following each episode's benchmark date, relative to a trend given by the cumulative GDP growth rate over the eight quarters preceding each episode. The pattern closely resembles that shown for inflation: O1 and O2 are generally associated with GDP losses that are much larger than those corresponding to O3 and O4 (with the latter involving some small GDP gains in some cases). When averages are taken over pairs of episodes the pattern becomes uniform, pointing once again to much larger output losses during and after the oil shocks of the 1970s.

The evidence previously presented is consistent with the hypothesis that the macroeconomic effects of oil price shocks have become smaller over time, being currently almost negligible (at least in comparison with their effects in the 1970s). But it is also consistent with the hypothesis that other (non-oil) shocks have coincided in time with the major oil shocks, either reinforcing the adverse effects of the latter in the 1970s, or dampening them during the more recent episodes. In order to sort out those possibilities we turn next to a more structured analysis of the comovements between oil prices and other variables.

7.3 Estimating the Effects of Oil Price Shocks Using Structural VARs

In this section we provide more structural evidence on the macroeconomic effects of oil price shocks, and changes over time in the nature and size of those effects. We provide evidence for the United States, France, Germany, the United Kingdom, Italy, and Japan, using a six-variable VAR. In the next section we turn to a more detailed analysis of the U.S. evidence, using a battery of rolling bivariate VARs.

Our baseline VAR makes use of data on the nominal price of oil (in dollars), three inflation measures (CPI, GDP deflator, and wages) and two quantities (GDP and employment). By using a multivariate specification, we allow for a variety of shocks in addition to the oil shock that is our focus of interest. We identify oil shocks by assuming that unexpected variations in the nominal price of oil are exogenous relative to the contemporaneous values of the remaining macroeconomic variables included in the VAR. In other words, we take the oil shock to correspond to the reduced form innovation to the (log) nominal oil price, measured in U.S. dollars.

This identification assumption will clearly be incorrect if economic developments in the country under consideration affect the world price of oil contemporaneously. This may be either because the economy under consideration is large, or because developments in the country are correlated with world developments. For example, Rotemberg and Woodford (1996), who rely on the same identification assumption as we do when studying the effects of oil shocks on the U.S. economy, restrict their sample period to end in 1980 on the grounds that variations in the price of oil may have a significant endogenous component after that date. We have therefore explored an alternative assumption; namely, letting the price of oil react contemporaneously to current developments in the two quantity variables (output and employment), while assuming that quantity variables do not react contemporaneously to the price of oil. Because the contemporaneous correlations between quarterly quantity and oil price innovations are small, the results are nearly identical, and we do not report them in the text.

Another approach would be to use, either in addition or in substitution to the oil price, a more exogenous variable to proxy for oil shocks. This is the approach followed by Kilian (2008), who constructs and uses a proxy for unexpected movements in global oil production. What matters, however, to any given country is not the level of global oil production, but the price at which firms and households can purchase oil, which in turn depends also on world demand for oil. Thus, if the price of oil rises as a result of, say, higher Chinese demand, this is just like an exogenous oil supply shock for the remaining countries. This is indeed why we are fairly confident in our identification approach: the large residuals in our oil price series are clearly associated either with identifiable episodes of large supply disruptions or, in the more recent past, with increases in emerging countries' demand. These observations largely drive our estimates and our impulse response functions.

For each of the six countries, we estimate a VAR containing six variables: the dollar price of oil (expressed in log differences), CPI inflation, GDP deflator inflation, wage inflation, and the log changes in GDP and employment.[6] We use the dollar price of oil rather than the real price of oil to avoid dividing by an endogenous variable, the GDP deflator. For the same reason, we do not convert the price of oil into domestic currency for non-U.S. countries. For the United States, the data are taken from the USECON database, and cover the sample period 1960:1 to 2007:3. For the remaining countries, the data are drawn from OECD's Economic Outlook database, with the sample period being 1970:1 to 2007:3. Our three inflation measures are quarter-to-quarter, expressed in annualized terms. Each equation in our VAR includes four lags of the six aforementioned variables, a constant term, and a quadratic trend fitted measure of productivity growth.

Some of the oil price changes, and by implication, some of the residuals in the price of oil equation, are extremely large. The change in the price of oil for 1974:1, for example, is equal to eight times its standard deviation over the sample. Such large changes are likely to lead to small sample bias when estimating the oil price equation: the best ordinary least squares (OLS) fit is achieved by reducing the size of these particular residuals; thus, by spuri-

6. For the United States we use nonfarm business hours instead of employment, and the wage refers to nonfarm business compensation per hour. For simplicity we use the term employment to refer to both hours (in the case of the United States) and employment proper (for the remaining countries).

ously linking these very large realizations to movements in current or past values of the other variables in the regression. This in turn overstates the endogenous component of the price of oil, and understates the size of the true residuals. We deal with this issue by estimating the oil price equation using a sample that excludes all oil price changes larger than three standard deviations. (These large changes in oil prices are clearly essential in giving us precise estimates of the effects of oil prices on other variables. Thus, we use the complete sample when estimating the other equations.)

7.3.1 Impulse Responses

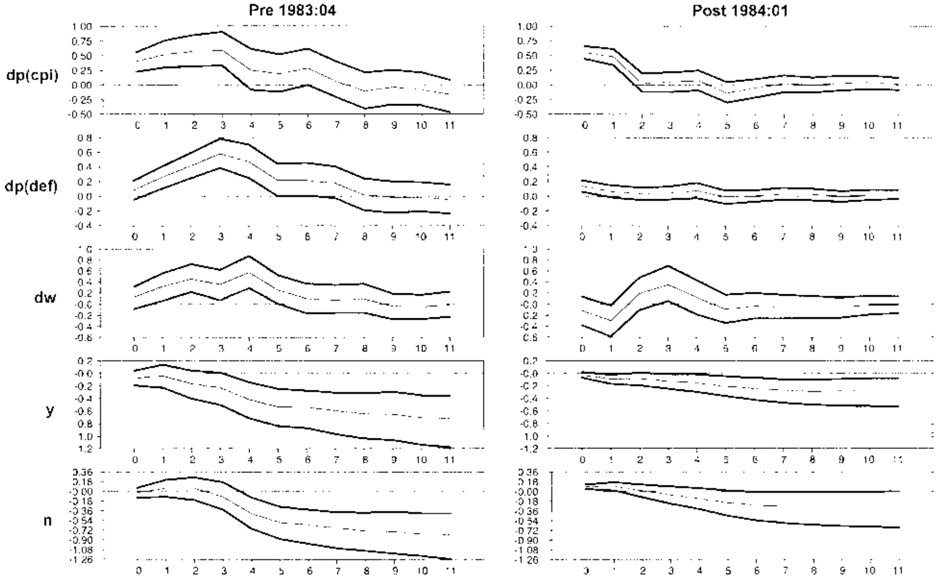
Figure 7.6, panels A through F, display the estimated impulse response functions (IRFs) for the different variables of interest to an oil price shock where, as discussed previously, the latter is identified as the innovation in the oil price equation. Estimates are reported for two different sample periods: 1970:1 to 1983:4 (1960:1 to 1983:4 for the United States) and 1984:1 to 2007:3 (1984:1 to 2005:4 for Germany and Italy). The break date chosen corresponds roughly to the beginning of the Great Moderation in the United States, as identified by several authors (e.g., McConnell and Pérez-Quirós (2000). Note that each subperiod contains two of the four large oil shock episodes identified in the previous section.

One standard deviation confidence intervals, obtained using a Monte Carlo procedure, are shown on both sides of the point estimates. The estimated responses of GDP and employment are accumulated and shown in levels. The size of the shock is normalized so that it raises the price of oil by 10 percent on impact. This roughly corresponds to the estimated standard deviations of oil price innovations for the two subsamples, which are very similar.[7] In all cases, the real price of oil shows a near-random walk response (not shown here); that is, it jumps on impact, and then stays around a new plateau.

The estimates for the United States, shown in panel A of figure 7.6, fit pretty well the conventional wisdom about the effects of a rise in oil prices. (figure 7.1, presented in the introduction, corresponds to panel A, with the results for the CPI shown in levels rather than rates of change.) For the pre-1984 period, CPI inflation shifts up immediately, and remains positive for a protracted period. The response of GDP inflation and wage inflation is similar, though more gradual. Output and employment decline persistently, albeit with a lag. Most relevant for our purposes, the responses of the same variables in the post-1984 period are considerably more muted, thus suggesting a weaker impact of oil price shocks on the economy. The only exception to this pattern is given by CPI inflation, whose response on impact is very similar across periods (though its persistence is smaller in the second period).

7. The estimated standard deviation of oil price innovations is 9.4 percent in the pre-1984 period, 12.4 percent in the post-1984 period.

A



B

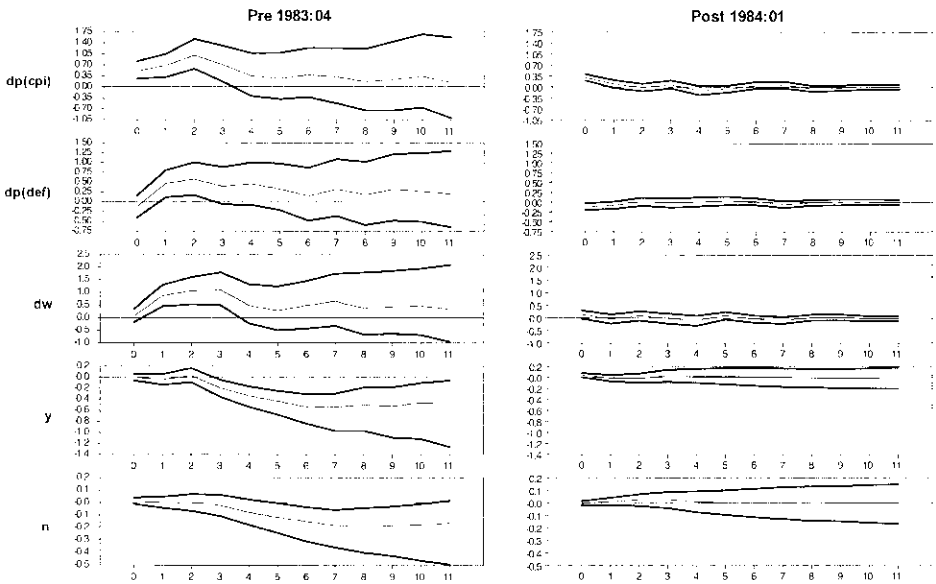
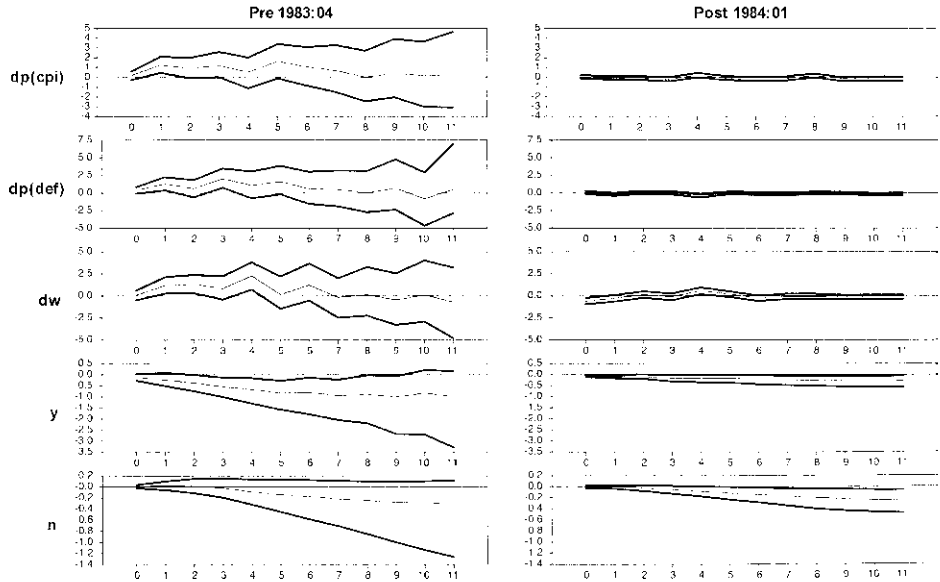


Fig. 7.6 Impulse response to an oil price shock *A*, United States; *B*, France; *C*, United Kingdom; *D*, Germany; *E*, Italy; *F*, Japan

C



D

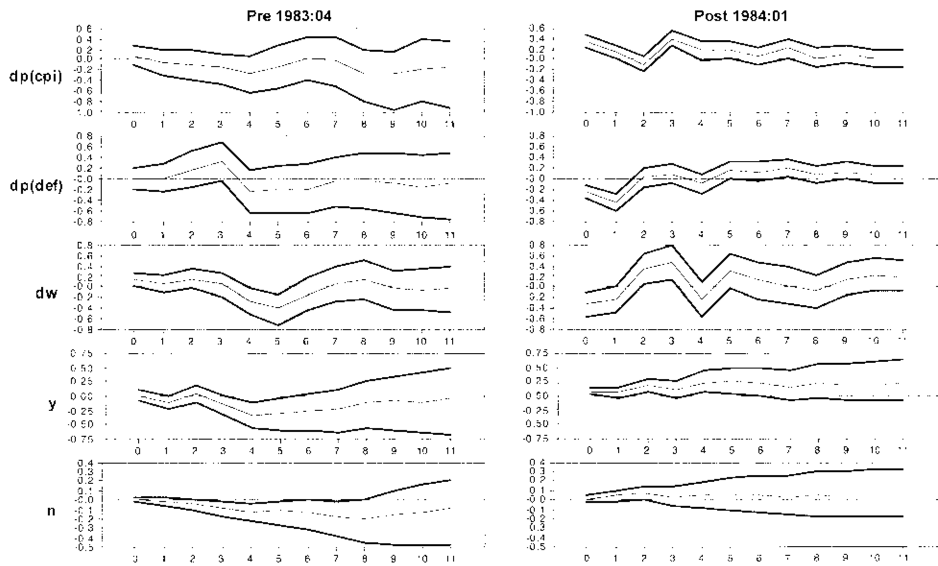
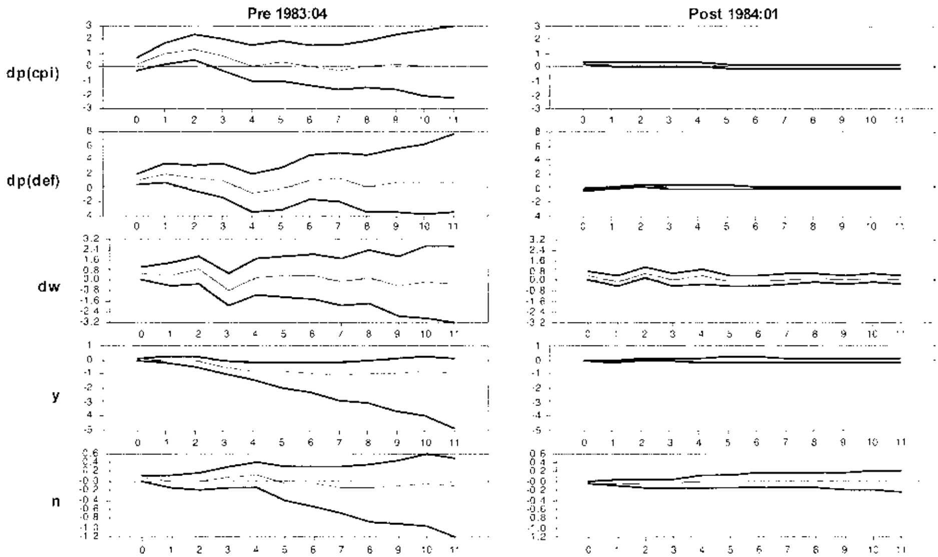


Fig. 7.6 (cont.)

E



F

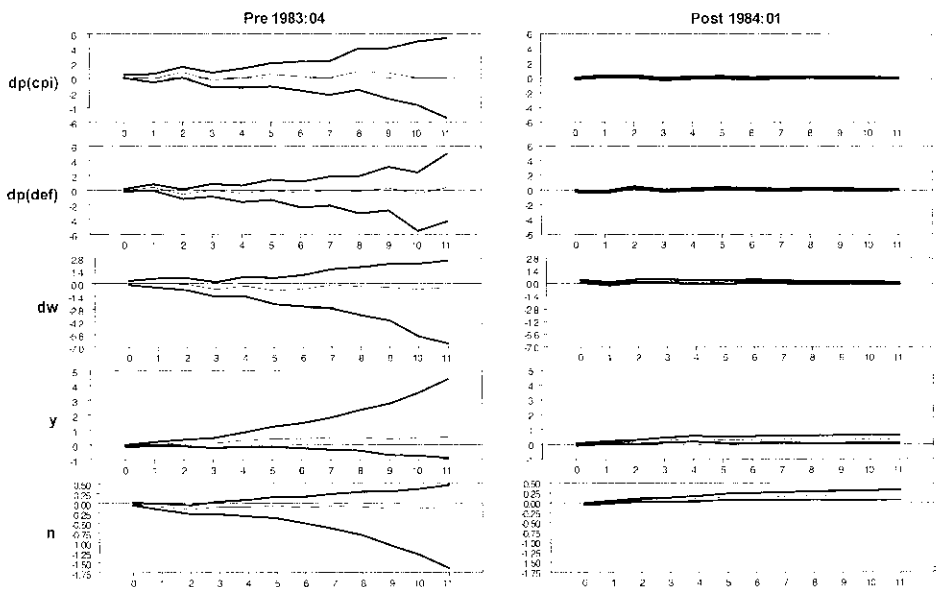


Fig. 7.6 (cont.) Impulse response to an oil price shock *A*, United States; *B*, France; *C*, United Kingdom; *D*, Germany; *E*, Italy; *F*, Japan

This may not be surprising since part of the increase in oil prices is reflected mechanically in the oil component of the CPI.

The estimates for France and the United Kingdom show a pattern very similar to that of the United States. In the case of France, the contrast between the early and the late periods is particularly strong, both in terms of the size and the persistence of the effects, and for both prices and quantities. In the case of the United Kingdom, the response of inflation variables is almost nonexistent in the latter period, though in contrast with France, there is some evidence of a decline in output and employment (albeit smaller than in the first sample period).

Some of the estimated responses for Germany and Italy fit conventional wisdom less well. The inflation measures in Germany hardly change in response to the rise in oil prices in either period, though the impact on output and employment is more adverse in the pre-1984 period. This is consistent with a stronger anti-inflationary stance of the Bundesbank, relative to other central banks. The slight increase in employment and output in the post-1984 period goes against conventional wisdom. In the case of Italy, there is barely any employment response in the pre-1984 period. Still, for both countries the sign of most of the responses accord with conventional wisdom, and the responses are smaller in the post-1984 period.

The story is different for Japan. The sign of many of the responses to the rise in oil prices is often at odds with standard priors. Also, the uncertainty of the estimates is much larger, as reflected in the wider bands. The effect on inflation is weak and does not have a clear sign in either period. There is a (slight) rise in output in both periods, and of employment in the post-1984 period.

In short, except for Japan (and to some extent, for Germany), most of the responses fit conventional wisdom rather well: an increase in the price of oil leads to more wage and price inflation, and to a decrease in employment and output for some time. In all cases, however, the effects on both inflation and activity are considerably weaker in the second subsample than in the first.

7.3.2 Variance and Historical Decompositions

How important are oil shocks in accounting for the observed fluctuations in inflation, output, and employment in the U.S. economy? Table 7.4 and figure 7.7 answer this question by using the decomposition associated with the estimated six-variable VAR, with data starting in 1960. For each variable and sample period, they compare the actual time series with the component of the series that results from putting all shocks, except the identified oil price shocks, equal to zero. Series for GDP and employment are accumulated, so the resulting series are in log-levels. All series are then Hodrick-Prescott (HP)-filtered so that the series can be interpreted as deviations from a slowly moving trend. Table 7.4 provides statistics for the role

Table 7.4 The contribution of oil shocks to U.S. economic fluctuations, 1960:1–2007:3

	Conditional standard deviation			Conditional SD / Unconditional SD	
	60:1–83:4	84:1–07:3	Ratio	60:1–83:4	84:1–07:3
Oil price (real)	12.9	15.4	1.19	0.82	0.88
CPI inflation	0.89	0.74	0.83	0.43	0.55
GDP inflation	0.71	0.15	0.24	0.50	0.25
Wage inflation	0.69	0.56	0.81	0.41	0.23
GDP	0.59	0.28	0.48	0.34	0.31
Hours	0.76	0.43	0.57	0.42	0.30

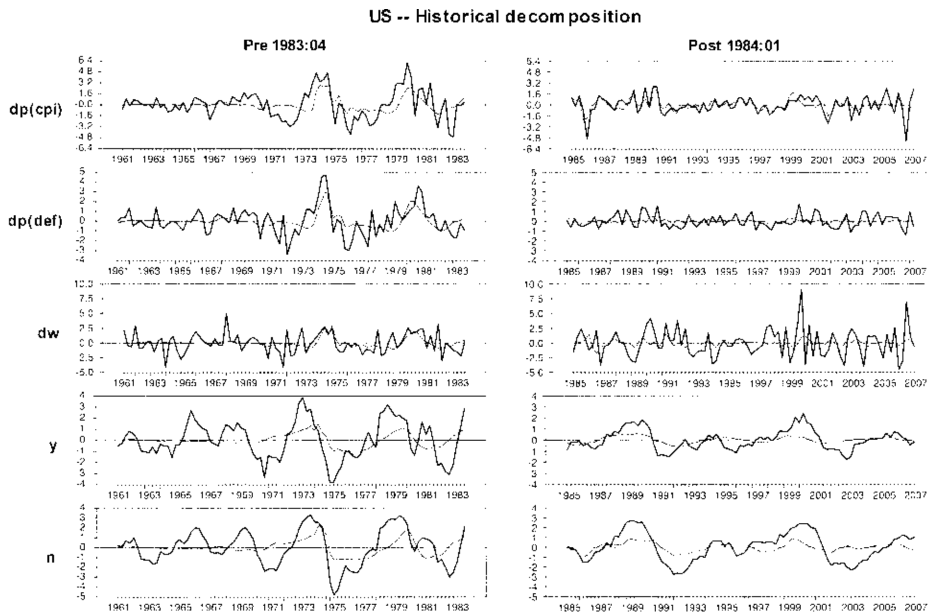


Fig. 7.7 The role of oil price shocks

of oil shocks as a source of fluctuations, including its percent contribution to the volatility of each variable (including the real price of oil, measured relative to the GDP deflator), both in absolute and relative terms. Figure 7.7 plots the series over time.

The estimated standard deviations of the oil-driven component of the different variables ("conditional standard deviations"), given in the first three columns of table 7.4, show that the volatility of fluctuations caused by oil shocks has diminished considerably for all variables, except for the real price of oil itself. In fact, the standard deviation of the exogenous component of the latter variable is about 20 percent larger in the second sample period. This can be explained to a large extent by the limited variation in the real price of oil before the 1973 crisis, and despite the two large spikes in that year and during 1979 and 1980.

This evidence reinforces our earlier Impulse response function (IRFs)-based findings of a more muted response of all variables to an oil shock of a given size. Thus, the change in the way the economy has responded to oil shocks has contributed to the dampening of economic fluctuations since the mid-1980s, the phenomenon known as the Great Moderation. Interestingly, our estimates suggest that this has been possible in spite of the slightly larger volatility of oil prices themselves.

The next two columns of table 7.4 give the relative contribution of oil shocks to movements in the various variables, measured as the ratio of the conditional to the unconditional standard deviation. The estimates suggest that the relative contribution of oil shocks to fluctuations in quantity variables (GDP and employment) has remained roughly unchanged over time, at around one-third. In the case of wage inflation and GDP deflator inflation, the contribution of oil shocks has declined to one-fourth in both cases, from a level close to one-half. In contrast, the contribution of oil shocks to CPI inflation has increased in the recent period. Note that this is consistent with a relatively stable core CPI, with oil price changes being passed through to the energy component of the CPI, and accounting for, according to our estimates, as much as 60 percent of the fluctuations in overall CPI inflation.

Figure 7.7 allows us to focus on the contribution of oil prices to the 1973 to 1974 and 1979 to 1981 episodes. It shows the substantial but nonexclusive role of exogenous oil shocks during each of the two episodes. In particular, while for our three inflation variables the oil price shocks seem to have accounted for the bulk of the increases in 1973 to 1974 and 1979 to 1981, no more than a half of the observed decline in employment and output during those episodes can be attributed to the oil shocks themselves. Thus, our findings suggest that other shocks played an important role in triggering those episodes.

Within our six-variable VAR, our partial identification approach does not allow us to determine what those additional underlying shocks may have been. Yet when we replace the price of oil by the broader producer price index (PPI) for crude materials in our six-variable VAR, the estimates of GDP and employment driven by exogenous shocks to that broader price index track more closely the movements of the actual time series themselves in the pre-1984 period, including the two large oil shock episodes contained in that period, as shown in figure 7.8. In particular, those shocks account for more than half of the fluctuations in all variables over the pre-1984 period. On the other hand, such broader supply shocks play a very limited role in accounting for the fluctuations in output and employment in the post-1984 period (though they play a more important one in accounting for variations in CPI inflation, in a way consistent with earlier evidence).

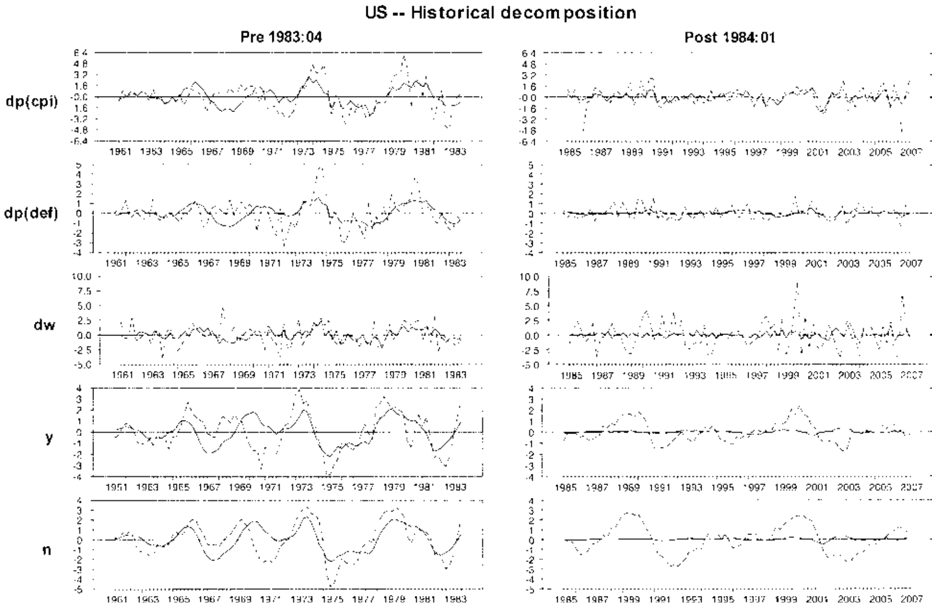


Fig. 7.8 The role of shocks to crude materials prices

7.4 U.S. Evidence Based on Rolling Bivariate Regressions

So far, we have analyzed the macroeconomic effects of oil price shocks and their change over time under the maintained assumption of a discrete break sometime around the mid-1980s. While the findings reported previously are largely robust to changes in the specific date of the break, some of the potential explanations (discussed following) for the change in the effects of oil price shocks are more likely to have been associated with a more gradual variation over time. This leads us to adopt a more flexible approach, and estimate rolling IRFs to oil price shocks, based on a simple dynamic equation linking a variable of interest to its own lags and the current and lagged values of the change in the (log) oil price. We do this using a moving window of 40 quarters, with the first moving window centered in 1970.

More specifically, letting y_t and p_t^o denote the variable of interest and the price of oil, respectively, we use OLS to estimate the regression:

$$y_t = \alpha + \sum_{j=1}^{4} \beta_j y_{t-j} + \sum_{j=0}^{4} \gamma_j \Delta p_{t-j}^o + u_t$$

and use the resulting estimates to obtain the implied dynamic response of y_t (or a transformation thereof) to a permanent 10 percent (log) change in the price of oil, thus implicitly assuming in the simulation that Δp_t^o is an i.i.d. process (which is roughly consistent with the random walk-like response of the price of oil obtained using our multivariate model).

Relative to the multivariate model analyzed in the previous section, correct identification of oil price shocks is obviously more doubtful in the present bivariate model, given the lower dimension specification of the economy's dynamics. This shortcoming must be traded-off with the possibility of estimating the VAR with much shorter samples and, hence, being able to obtain our rolling IRFs. In order to check the consistency with our earlier results, we first computed the average IRFs across moving windows within each of the subperiods considered earlier (pre-1984 and post-1984), and found the estimated IRFs (not shown) to be very similar to the ones obtained earlier. In particular, both the inflation variables, as well as output and employment, show a more muted response in the more recent period.

Figure 7.9, panels A through E, display the rolling IRFs for our three inflation measures, output, and employment. Several features stand out in the figure.

Consumer price index inflation appears quite sensitive to the oil shock over the entire sample period, but particularly in the late 1970s, when inflation is estimated to rise more than 1 percentage point two/three quarters after a 10 percent rise in the oil price. The response becomes steadily more muted over time and, perhaps as important, less persistent, especially in the more recent period (in a way consistent with our earlier evidence based on the six-variable VAR). The evolution over time in the response of GDP deflator inflation to an oil price shock is similar to that of CPI inflation, but shows a more dramatic contrast, with the response at the end of our sample being almost negligible. The response of wage inflation is rather muted all along, except for its large persistent increases in the late 1970s and early 1980s, and a similar spike in the 1990s.

The most dramatic changes are in the responses of output and employment (see figure 7.9, panels D and E). In the early part of the sample, output is estimated to decline as much as 1 percent two years after the 10 percent change in the price of oil. The estimated response, however, becomes weaker over time, with the point estimates of that response becoming slightly positive for the most recent period. A similar pattern can be observed for employment.

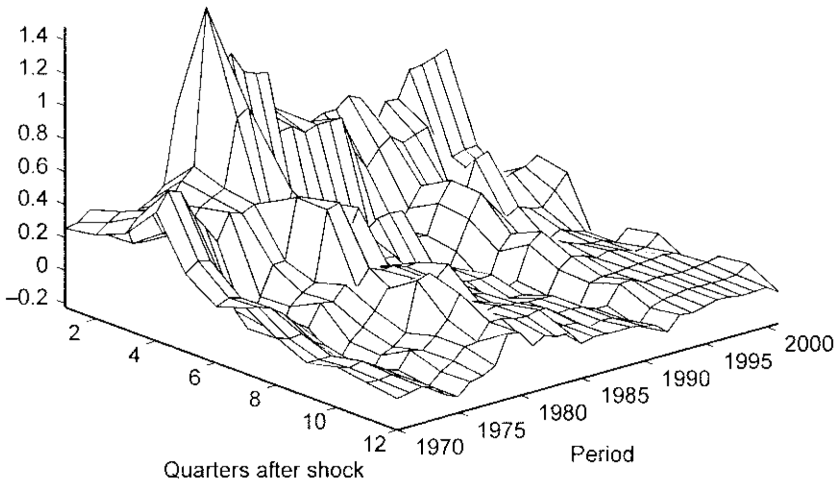
The previous evidence thus reinforces the picture that emerged from the earlier evidence, one which strongly suggests a vanishing effect of oil shocks on macroeconomic variables, both real and nominal. In the next section we try to uncover some of the reasons why.

7.5 Modeling the Macroeconomic Effects of Oil Price Shocks: A Simple Framework

We now develop a simple model of the macroeconomic effects of oil price shocks. Our focus is on explaining the different response of the economy to oil price shocks in the 1970s and the 2000s. With this in mind, we focus on three potential changes in the economy.

A

Response of CPI Inflation



B

Response of GDP Deflator Inflation

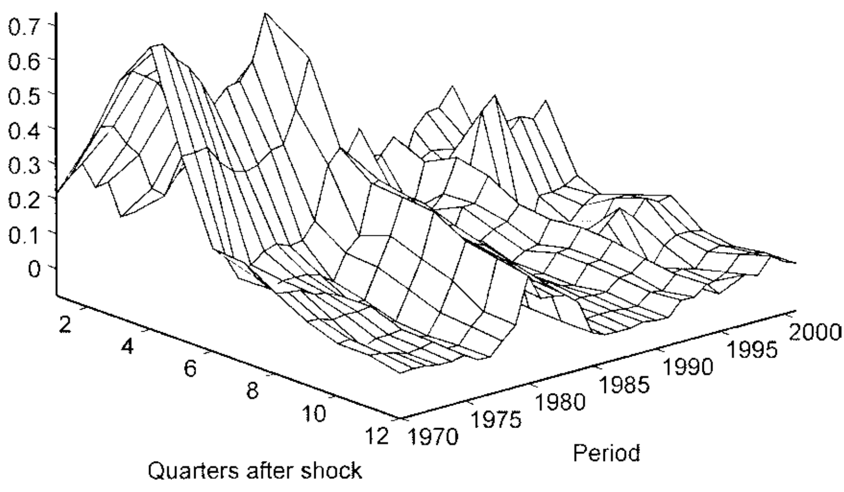
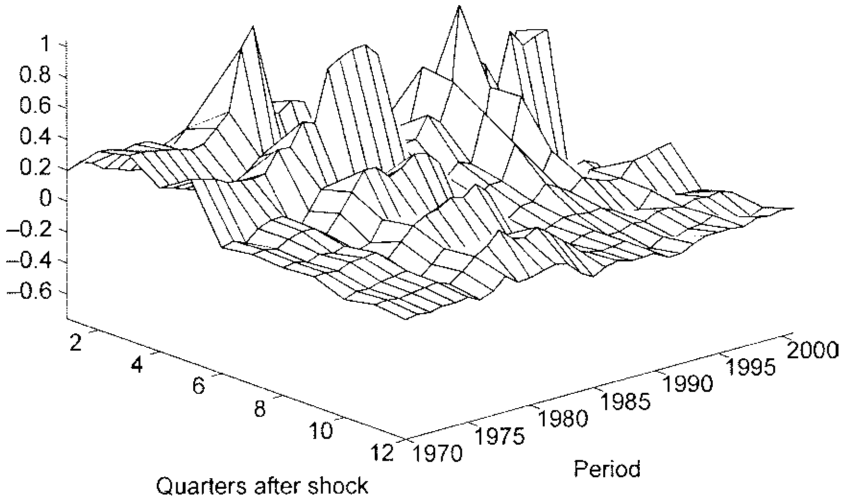


Fig. 7.9 Response of inflation, GDP, and employment

C

Response of Wage Inflation



D

Response of GDP

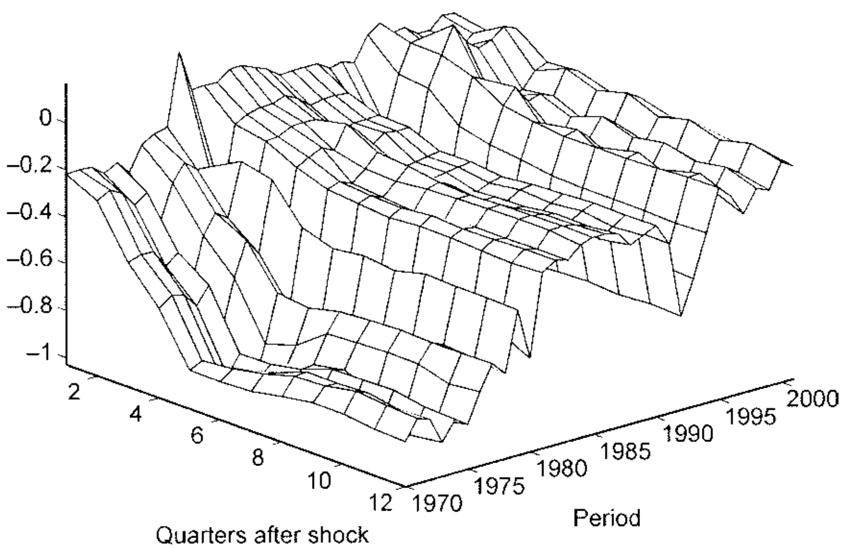


Fig. 7.9 (cont.)

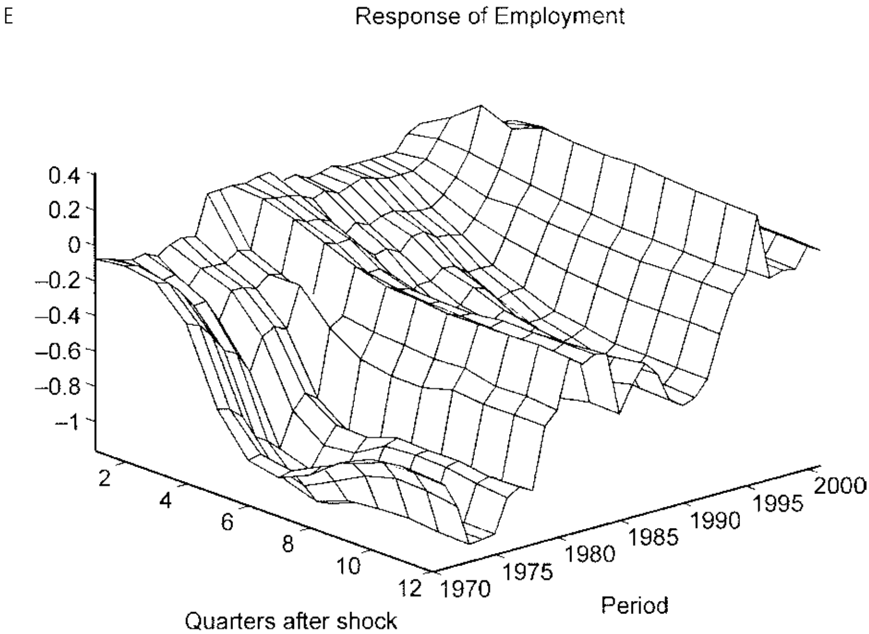


Fig. 7.9 (cont.)

First, the behavior of wages. To us, this looks a priori like the most plausible candidate. The 1970s were times of strong unions and high wage indexation. In the 2000s, unions are much weaker, and wage indexation has practically disappeared.

The second potential change is the role of monetary policy. Faced with a new type of shock, the central banks of the 1970s did not know at first how to react, policy mistakes were made, and central bank credibility was low. In the 2000s, supply shocks are no longer new, monetary policy is clearly set, and credibility is much higher.

Third, and trivially, is the quantitative importance of oil in the economy. Increases in the price of oil have led to substitution away from oil, and a decrease in the relevant shares of oil in consumption and in production. The question is whether this decrease can account for much of the difference in the effects of oil prices in the 1970s and the 2000s.[8]

We start from the standard new-Keynesian model and introduce two modifications. First, we introduce oil both as an input in consumption and as an input in production. We assume the country is an oil importer, and that

8. Some observers have suggested another factor—an increase in hedging against oil price shocks by oil users. What is known about hedging by airlines suggests, however, that while hedging is more prevalent than in the 1970s, its extent remains limited, with few hedges going beyond a year. See, for example, Carter, Rogers, and Simkins (2006a, 2006b).

the real price of oil (in terms of domestic goods) follows an exogenous process. Second, we allow for real wage rigidities, along the lines of our earlier work (Blanchard and Galí 2007). We present only log-linearized relations in the text, leaving the full derivation to appendix A. Lower case letters denote logarithms of the original variables, and for notational simplicity, we ignore all constants.

7.5.1 The Role of Oil

Oil is used both by firms in production and by consumers in consumption. Production is given by

$$q_t = a_t + \alpha_n n_t + \alpha_m m_t,$$

where q_t is (gross) domestic output; a_t is an exogenous technology parameter; n_t is labor; m_t is the quantity of imported oil used in production; and $\alpha_n + \alpha_m \leq 1$.[9]

Consumption is given by

$$c_t \equiv (1 - \chi)\, c_{q,t} + \chi\, c_{m,t},$$

where c_t is consumption; $c_{q,t}$ is the consumption of domestically produced goods (gross output); and $c_{m,t}$ is the consumption of imported oil.

In this environment, it is important to distinguish between two prices, the price of domestic output $p_{q,t}$, and the price of consumption $p_{c,t}$. Let $p_{m,t}$ be the price of oil, and $s_t \equiv p_{m,t} - p_{q,t}$ be the real price of oil. From the definition of consumption, the relation between the consumption price and the domestic output price is given by

$$p_{c,t} = p_{q,t} + \chi\, s_t. \tag{1}$$

Increases in the real price of oil lead to an increase in the consumption price relative to the domestic output price.

7.5.2 Households

The behavior of households is characterized by two equations. The first is an intertemporal condition for consumption:

$$c_t = E_t\{c_{t+1}\} - (i_t - E_t\{\pi_{c,t+1}\}), \tag{2}$$

where i_t is the nominal interest rate, and $\pi_{c,t} \equiv p_{c,t} - p_{c,t-1}$ is CPI inflation.

The second condition characterizes labor supply. If the labor market was perfectly competitive, labor supply would be implicitly given by

$$w_t - p_{c,t} = c_t + \phi\, n_t,$$

9. We use a Cobb-Douglas specification for convenience. It has the counterfactual implication that the share of oil in output remains constant. So, in our framework, when looking at changes in the share over time, we must attribute it to a change in the parameter α_m. For our purposes, this appears innocuous.

where w_t is the nominal wage, and n_t is employment. This is the condition that the consumption wage must equal the marginal rate of substitution between consumption and leisure; ϕ is the inverse of the Frisch elasticity of labor supply.

We formalize real wage rigidities by modifying the previous equation to read

$$w_t - p_{c,t} = (1 - \gamma)(c_t + \phi n_t), \tag{3}$$

where we interpret the parameter $\gamma \in [0, 1]$ as an index of the degree of real wage rigidities. While clearly ad-hoc, equation (3) is meant to capture in a parsimonious way the notion that real wages may not respond to labor market conditions as much as implied by the model with perfectly competitive markets. We have explored the implications of a dynamic version of equation (3), in which the wage adjusts over time to the marginal rate of substitution. This alternative is more attractive conceptually, and gives richer dynamics. However, it is also analytically more complex, and we have decided to present results using the simpler version presented earlier.

7.5.3 Firms

Given the production function, cost minimization implies that the firms' demand for oil is given by $m_t = -\mu_t^p - s_t + q_t$, where μ_t^p is the price markup. Using this expression to eliminate m_t in the production function gives a reduced-form production function

$$q_t = \frac{1}{1 - \alpha_m}(a_t + \alpha_n n_t - \alpha_m s_t - \alpha_m \mu_t^p). \tag{4}$$

Output is a decreasing function of the real price of oil, given employment and technology.

Combining the cost minimization conditions for oil and for labor with the aggregate production function yields the following factor price frontier:

$$(1 - \alpha_m)(w_t - p_{c,t}) + (\alpha_m + (1 - \alpha_m)\chi)\, s_t + (1 - \alpha_n - \alpha_m)\, n_t - a_t + \mu_t^p = 0. \tag{5}$$

Given productivity, an increase in the real price of oil must lead to one or more of the following adjustments: (a) a lower consumption wage, (b) lower employment, and (c) a lower markup. Under our assumed functional forms, it can be shown that with flexible prices and wages, the entire burden of the adjustment in response to an increase in s_t falls on the consumption wage, with employment and the markup remaining unchanged. But, as we discuss next, things are different when we allow the markup to vary (as a result of sticky prices), and wages to respond less than their competitive labor markets counterpart.

Firms are assumed to set prices à la Calvo (1983), an assumption that yields the following log-linearized equation for domestic output price inflation (domestic inflation for short)

$$\pi_{q,t} = \beta\, E_t\{\pi_{q,t+1}\} - \lambda_p\, \mu_t^p, \tag{6}$$

where $\lambda_p \equiv [(1-\theta)(1-\beta\theta)/\theta][(\alpha_m + \alpha_n)/(1 + (1-\alpha_m + \alpha_n)(\varepsilon - 1))]$, where θ denotes the fraction of firms that leave prices unchanged, β is the discount factor of households, and ε is the elasticity of substitution between domestic goods in consumption.

Note that this specification assumes a constant desired markup of firms. By doing so, we rule out a mechanism examined by Rotemberg and Woodford (1996) who argue that, to explain the size of the decline in output observed in response to oil shocks, one must assume countercyclical markups. We do so not because we believe the mechanism is irrelevant, but because we do not think that variations in the degree of countercyclicality of markups are likely to be one of the main factors behind the differences between the 1970s and the 2000s.

7.5.4 Equilibrium

The real wage consistent with household choices (cum real wage rigidities) is given by equation (3), and depends on consumption and employment.

The real wage consistent with the firms' factor price frontier is given by equation (5) and depends on the real price of oil, the markup, and employment.

Together, these two relations imply that the markup is a function of consumption, employment, and the real price of oil. Solving for consumption by using the condition that trade be balanced gives:

$$c_t = q_t - \chi\, s_t + \eta\, \mu_t^p, \tag{7}$$

where $\eta \equiv \alpha_m/(\mathcal{M}^p - \alpha_m)$, with $\mathcal{M}^p$ denoting the steady-state gross markup (now in levels). Combining this equation with the reduced-form production function gives consumption as a function of employment, productivity, the real price of oil, and the markup

$$c_t = \frac{1}{1-\alpha_m} a_t + \frac{\alpha_n}{1-\alpha_m} n_t - \left(\chi + \frac{\alpha_m}{1-\alpha_m}\right) s_t + \left(\eta - \frac{\alpha_m}{1-\alpha_m}\right) \mu_t^p.$$

If the steady-state markup is not too large, the last term is small and can safely be ignored. Replacing the expression for consumption in equation (3) for the consumption wage and then replacing the consumption wage in the factor price frontier gives an expression for the markup

(8) $$\mu_t^p = -\Gamma_n n_t - \Gamma_s s_t + \Gamma_a a_t,$$

where

$$\Gamma_n \equiv \frac{(1 - \alpha_n - \alpha_m)\gamma + (1 - \alpha_m)(1 - \gamma)(1 + \phi)}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0$$

$$\Gamma_a \equiv \frac{\gamma}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0$$

$$\Gamma_s \equiv \frac{\gamma\,(\alpha_m + (1 - \alpha_m)\chi)}{1 - (1 - \gamma)(\alpha_m - (1 - \alpha_m)\eta)} \geq 0.$$

Using this expression for the markup in equations (6) and (2) gives the following characterization of domestic inflation

(9) $$\pi_{q,t} = \beta\, E_t\{\pi_{q,t+1}\} + \lambda_p \Gamma_n n_t + \lambda_p \Gamma_s s_t - \lambda_p \Gamma_a a_t.$$

Under our assumptions, the first best level of employment can be shown to be invariant to the real price of oil—substitution and income effects cancel.[10] If $\gamma = 0$; that is, if there are no real wage rigidities, then Γ_a and Γ_s are both equal to zero, and domestic inflation only depends on employment. Together, these two propositions imply that stabilizing domestic inflation is equivalent to stabilizing the distance of employment from first best—a result we have called elsewhere the "divine coincidence."

Positive values of γ lead instead to positive values of Γ_a and Γ_s. The higher γ, or the higher $(\alpha_m + (1 - \alpha_m)\chi)$—an expression that depends on the shares of oil in production and in consumption—the worse the trade-off between stabilization of employment and stabilization of domestic inflation in response to oil price shocks.

7.5.5 Implications for GDP and the GDP Deflator

Note that the characterization of the equilibrium did not require introducing either value added or the value-added deflator. But these are needed to compare the implications of the model to the data.

The value-added deflator, $p_{y,t}$, is implicitly defined by $p_{q,t} = (1 - \alpha_m)\, p_{y,t} + \alpha_m p_{m,t}$. Rearranging terms gives

(10) $$p_{y,t} = p_{q,t} - \frac{\alpha_m}{1 - \alpha_m} s_t,$$

thus implying a negative effect of the real price of oil on the value-added deflator, given domestic output prices.

10. To see this, we can just determine equilibrium employment under perfect competition in both goods and labor markets, corresponding to the assumptions $\mu_t = 0$ for all t and $\gamma = 0$, respectively.

The definition of value added, combined with the demand for oil, yields the following relation between value added and output:

(11) $$y_t = q_t + \frac{\alpha_m}{1 - \alpha_m} s_t + \eta\, \mu_t^p.$$

This in turn implies the following relation between value added and consumption:

(12) $$y_t = c_t + \left(\frac{\alpha_m}{1 - \alpha_m} + \chi\right) s_t.$$

An increase in the price of oil decreases consumption given value added both because (imported) oil is used as an input in production, and used as an input in consumption.

Under the same approximation as before; that is, $(\eta - \alpha_m/(1 - \alpha_m))\, \mu_t^p \simeq 0$, equations (4) and (11) imply the following relation between value added and employment:

(13) $$y_t = \frac{1}{1 - \alpha_m} (a_t + \alpha_n n_t).$$

Note that, under this approximation, the relation between value added and employment does not depend on the real price of oil.

7.5.6 Quantifying the Effects of Oil Price Shocks

Equations (1), (2), (9), (12), and (13) describe the equilibrium dynamics of prices and quantities, given exogenous processes for technology and the real price of oil, and a description of how the interest rate is determined (i.e., an interest rate rule). We now use these conditions to characterize the economy's response to an oil price shock.

Assume that $a_t = 0$ for all t (i.e., abstract from technology shocks). It follows from (13) and the previous discussion that the efficient level of value added is constant (and normalized to zero) in this case. Assume further that the real price of oil follows an AR(1) process

(14) $$s_t = \rho_s s_{t-1} + \varepsilon_t.$$

We can then summarize the equilibrium dynamics of value added and domestic inflation through the system:

(15) $$\pi_{q,t} = \beta\, E_t\{\pi_{q,t+1}\} + \kappa\, y_t + \lambda_p \Gamma_s s_t$$

(16) $$y_t = E_t\{y_{t+1}\} - (i_t - E_t\{\pi_{q,t+1}\}) + \frac{\alpha_m(1 - \rho_s)}{1 - \alpha_m} s_t,$$

where $\kappa \equiv \lambda_p \Gamma_n (1 - \alpha_m)/\alpha_n$.

These two equations must be complemented with a description of monetary policy. Assume an interest rate rule of the form

$$i_t = \phi_\pi \pi_{q,t}, \tag{17}$$

where $\phi_\pi > 1$. Note that in our model, $\pi_{q,t}$ corresponds to core CPI inflation, a variable that many central banks appear to focus on as the basis for their interest rate decisions.

We can then solve for the equilibrium analytically, using the method of undetermined coefficients. This yields the following expressions for domestic inflation and output:

$$\pi_{q,t} = \Psi_\pi s_t$$
$$y_t = \Psi_y s_t$$

where

$$\Psi_\pi = \frac{(1 - \rho_s)(\kappa \alpha_m/(1 - \alpha_m) + \lambda_p \Gamma_s)}{(1 - \rho_s)(1 - \beta\rho_s) + (\phi_\pi - \rho_s)\kappa}$$

and

$$\Psi_y = \frac{\alpha_m/(1 - \alpha_m)(1 - \rho_s)(1 - \beta\rho_s) - (\phi_\pi - \rho_s)\lambda_p \Gamma_s}{(1 - \rho_s)(1 - \beta\rho_s) + (\phi_\pi - \rho_s)\kappa}.$$

Domestic inflation and GDP follow AR(1) processes with the same first-order coefficient as the real price of oil. Their innovations are proportional to the innovation in the real price of oil, with the coefficient of proportionality depending on the parameters of the model.

Expressions for CPI inflation and employment can be obtained using (1) and (13), respectively:

$$\pi_{c,t} = \Psi_\pi s_t + \chi \Delta s_t$$
$$n_t = \Psi_y \frac{1 - \alpha_m}{\alpha_n} s_t.$$

With these equations, we can turn to the discussion of the potential role of the three factors we identified earlier—real wage rigidities, monetary policy, and the quantitative importance of oil in the economy—in explaining the differences between the 1970s and the 2000s. In all cases we use the evidence we presented earlier for the United States as a benchmark.

7.6 Three Hypotheses on the Changing Effects of Oil Price Shocks

In order to assess quantitatively the potential for oil price shocks to generate significant macroeconomic fluctuations, we first need to calibrate our model. We assume the following parameter values:

The time unit is a quarter. We set the discount factor β equal to 0.99. We set the Calvo parameter, θ, to 0.75. We choose the elasticity of output with respect to labor, α_n, equal to 0.7. We assume $\phi = 1$, thus implying a unitary Frisch labor supply elasticity.

As discussed in previous sections, changes in the volatility of the real price of oil are unlikely to lie behind the changes in the size of the effects of oil shocks. Thus, for simplicity, we assume an unchanged process for the real price of oil. Based on the conditional standard deviation of the price of oil for the period 1984:1 to 2005:4, we assume $var(s_t) = (0.16)^2$. We set $\rho_s = 0.97$.[11] Also, and unless otherwise noted, we set the shares of oil in production and consumption (α_m and χ) to equal 0.017 and 0.012, respectively, which correspond to their values in 1997.[12]

Most of the aforementioned parameters are kept constant across all the simulations presented following. The exceptions, as well as our treatment of the remaining parameters, varies depending on the hypothesis being considered in each case.

7.6.1 Changes in Real Wage Rigidities

In the previously mentioned framework, the presence of some rigidity in the adjustment of real wages to economic conditions is a necessary ingredient in order to generate significant fluctuations in measures of inflation and economic activity. Figure 7.10 illustrates this point by showing the range of volatilities of CPI inflation (annualized, and expressed in percent) and GDP implied by our calibrated model under the assumption of perfectly competitive labor markets ($\gamma = 0$), and under two alternative calibrations. The first calibration assumes a relatively favorable environment, with the two shares of oil at their "low" values prevailing in 1997, and no credibility gap in monetary policy ($\delta = 0$; the discussion of credibility and the definition of δ will be given following). The second calibration assumes a less favorable environment, with the shares of oil at their "high" values prevailing in 1973 (see appendix B), and the presence of a credibility gap in monetary policy ($\delta = 0.5$). For each calibration, the figure plots the standard deviations of CPI inflation and value added, as the coefficient on inflation in the Taylor rule, ϕ_π, varies from 1 to 5, a range of values that covers the empirically plausible set (conditional on having a unique equilibrium). The exercise yields two conclusions.

First, the slope of the relation between the standard deviation of GDP and the standard deviation of CPI inflation is positive. This should not be surprising: in the absence of real wage rigidities, there is no trade-off between inflation and value-added stabilization. Hence, a policy that seeks

11. The price of oil would be better characterized as nonstationary. But we would then have to extend our formalization of real wage rigidities to allow the wage to eventually converge to the marginal rate of substitution. Thus, we assume the value of ρ to be high, but less than one.

12. See appendix B for details of construction. We thank Carlos Montoro for pointing out an error in the computation of the oil shares in earlier versions of the chapter.

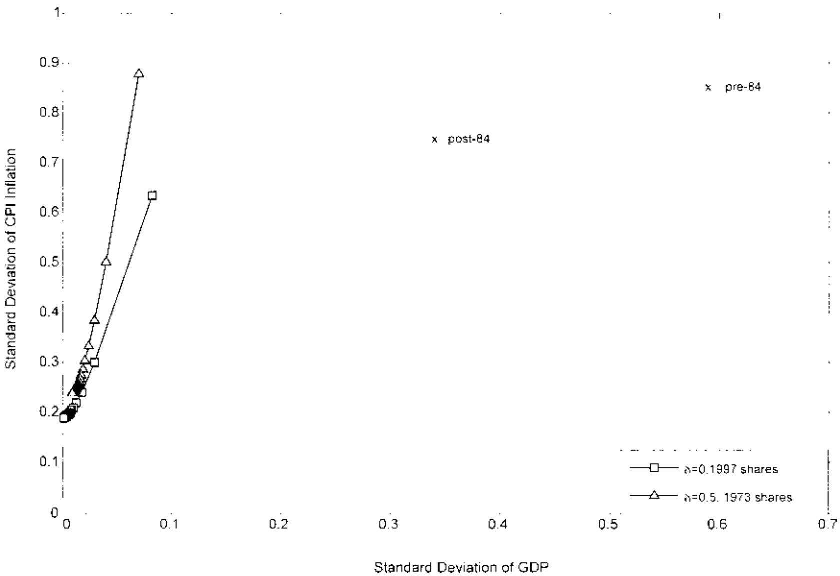


Fig. 7.10 Volatility ranges under flexible wages

to stabilize domestic inflation more aggressively also stabilizes value added. In fact, one can reduce the volatility of both variables by choosing ϕ_π to be arbitrarily large (this is what we called the "divine coincidence" in an earlier chapter). Under the assumed rule, on the other hand, CPI inflation faces a lower bound to its volatility, since it is affected directly by any change in the price of oil, in proportion to the share of oil in the consumption basket.

Second, the model has a clear counterfactual implication. While finite values of ϕ_π yield positive standard deviations for both GDP and CPI inflation, they also imply a positive response of both GDP and CPI inflation to an increase in the price of oil, an implication obviously at odds with the data.

Figure 7.11 shows that the introduction of real wage rigidities alters that picture substantially. It plots three loci, corresponding to three different values of the real wage rigidity parameter: $\gamma = 0.0$, $\gamma = 0.6$, and $\gamma = 0.9$. In the three cases, we assume an otherwise favorable environment, with the 1997 oil shares and full credibility of monetary policy. As before, each locus is obtained by varying ϕ_π from 1 to 5. Several results are worth pointing out.

First, the trade-off generated by the presence of real wage rigidities is apparent in the negative relationship between inflation volatility on the one hand and GDP volatility on the other when γ is positive.

Second, while the introduction of real wage rigidities raises the volatility of all variables (for any given ϕ_π), the model's predictions still fall short of

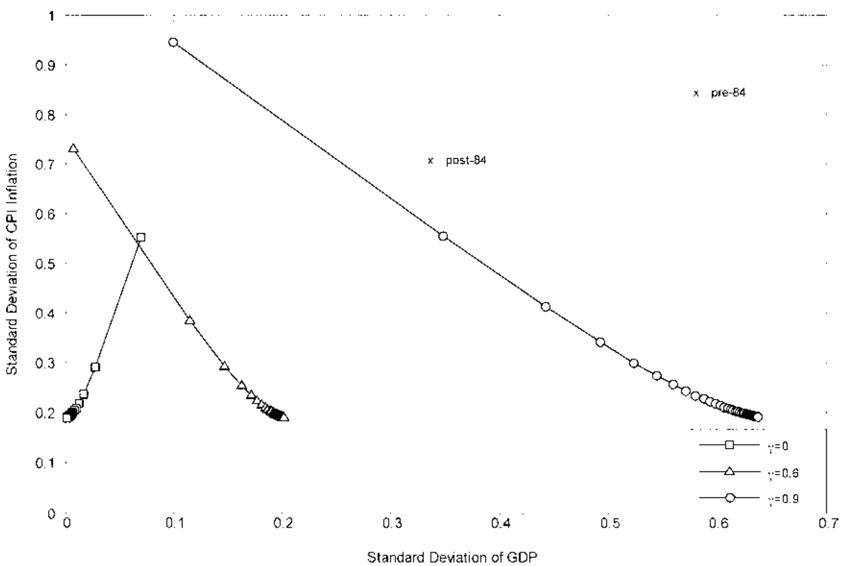


Fig. 7.11 Real wage rigidities and policy trade-offs

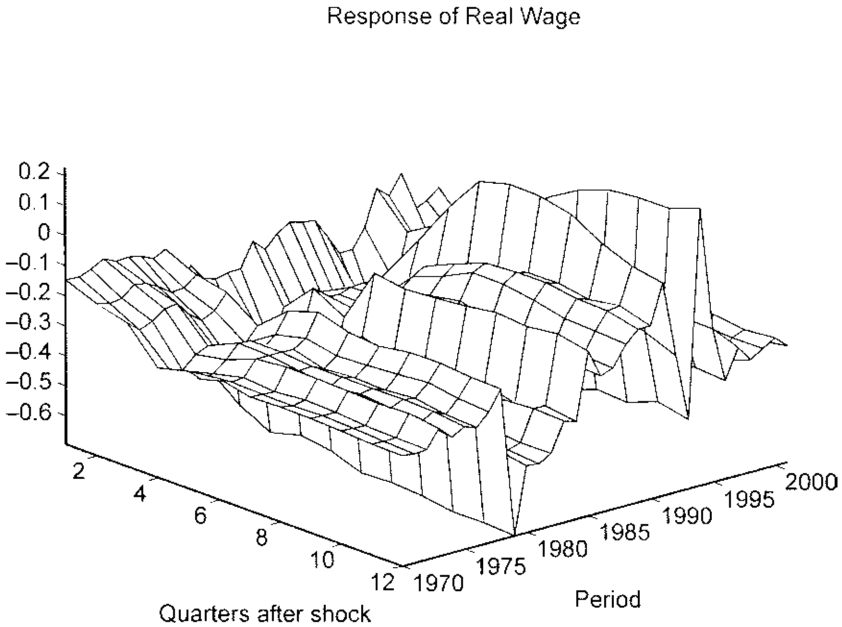
matching the (conditional) standard deviations of CPI inflation and GDP in our two samples, represented by the two crosses.

Finally, and that shortcoming notwithstanding, the figure also makes clear that a moderate reduction in the degree of real wage rigidities (e.g., a shift of γ from 0.9 to 0.6) can account for a substantial improvement in the policy trade-off and hence on a simultaneous reduction in the volatility of inflation and GDP resulting from oil price shocks (or supply shock, more generally).

To what extent a reduction in the degree of real wage rigidities may have been a factor behind the more muted effects of oil shocks in recent years? We rely again on the bivariate rolling VAR approach used earlier to try to answer this question, by seeking evidence of faster wage adjustment in recent years. In particular, we use this approach to estimate the responses of the real consumption wage, the unemployment rate, and the wage markup, defined as the gap between the (log) consumption wage, $w_t - p_{c,t}$, and the (log) marginal rate of substitution, $c_t + \phi n_t$, with $\phi = 1$, as in our baseline calibration. In response to a rise in the real price of oil, we would expect this markup to increase in the presence of real wage rigidities, which in turn should be associated with a rise in unemployment.

Figure 7.12, panels A through C, display the relevant IRFs representing, as before, the estimated response of each variable to a permanent 10 percent increase in the dollar price of oil. Panel A shows that the consumption wage tends to decline in response to the oil shock. While the response shows some variability over time, it does not show a tendency

A



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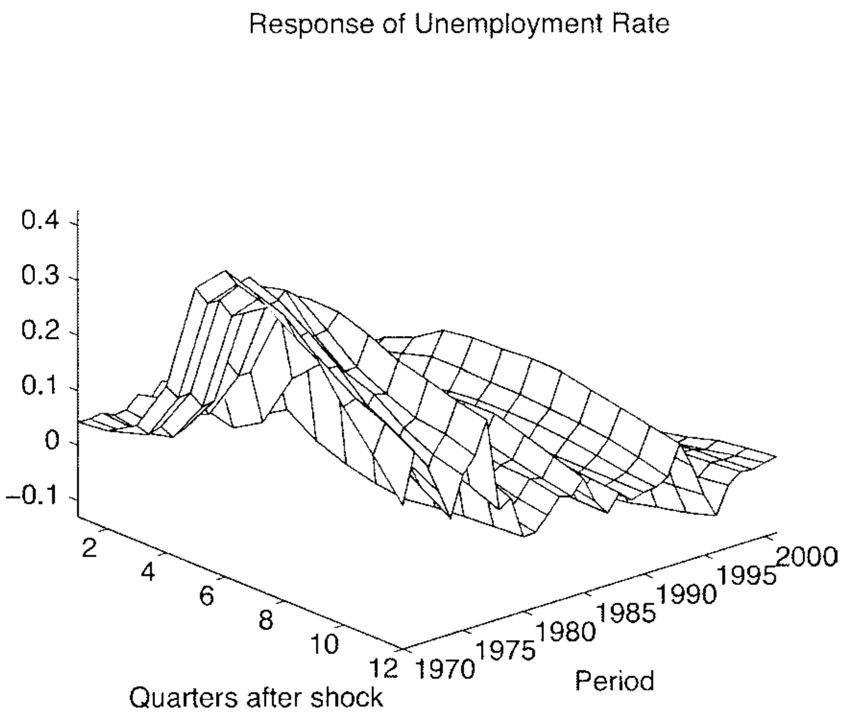


Fig. 7.12 Response of real wage, unemployment rate, and wage markup

C

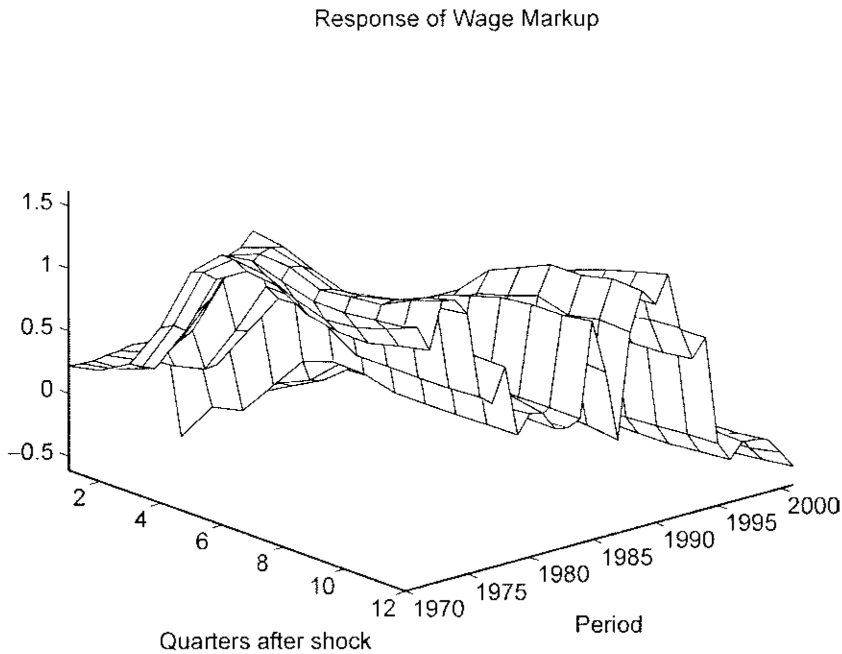


Fig. 7.12 Response of real wage, unemployment rate, and wage markup

toward a larger response of the consumption wage over time. Panel B shows that unemployment tends to increase in response to the oil shock. It also shows that this response has declined dramatically over time. An interpretation of these two evolutions is that the decrease in real wages, which required a large increase in unemployment in the 1970s, is now achieved with barely any increase in unemployment today. This suggests, in turn, a decrease in real wage rigidities. Another way of making the same point, within the logic of the model, is to look at the evolution of the wage markup. This is done in panel C. An increase in the oil price leads to an increase in the wage markup; that is, the decrease in the consumption wage is smaller than the decrease in the marginal rate of substitution. The effect has become, however, steadily smaller over time, very rapidly so in the more recent period. This suggests that the real consumption wage moves today much more in line with the marginal rate of substitution than it did in the 1970s.[13]

7.6.2 Changes in Monetary Policy

A number of studies (e.g., Clarida, Galí, and Gertler 2000) have provided evidence of a stronger interest rate response to variations in inflation over the

13. At least from a qualitative point of view, the previous evidence is robust to variations in the calibration of parameter ϕ within a plausible range (which we take to be given by the interval [0.5, 5]).

past two decades, relative to the 1960s and 1970s. It should be clear, however, from the simulations of our previously presented model that, other things equal, a stronger anti-inflationary stance should have reduced the volatility of inflation, but increased that of GDP. In other words, that evidence cannot explain—at least by itself—the lower volatility of both inflation and economic activity in response to oil price shocks.

In addition to this change in behavior, captured by the literature on empirical interest rate rules, there is also widespread agreement that central banks' commitment to keeping inflation low and stable has also become more credible over the past two decades, thanks to improved communications, greater transparency, the adoption of more or less explicit quantitative inflation targets, and ultimately, by the force of deeds. In this section we use the framework developed earlier to study the role that such an improvement in credibility may have had in accounting for the reduced impact of oil shocks.

We model credibility as follows: as in our baseline model, we assume that the central bank follows an interest rate rule

$$i_t = \phi_\pi \pi_{q,t}.$$

The public, however, is assumed to perceive that interest rate decisions are made according to

$$i_t = \phi_\pi(1 - \delta)\,\pi_{q,t} + v_t,$$

where $\{v_t\}$ is taken by the public to be an exogenous i.i.d monetary policy shock, and $\delta \in [0, 1]$ can be interpreted as a measure of the credibility gap. In the following, we restrict ourselves to calibrations that guarantee a unique equilibrium, which requires that the condition $\phi_\pi\,(1 - \delta) > 1$ be met.[14]

In addition to the prior actual and perceived policy rules, the model is exactly as the one developed previously, with the dynamics of value added, domestic inflation, and the real price of oil summarized by equations (14) through (16). Solving the model for domestic inflation and value added gives:

$$\pi_{q,t} = a\, s_t + b v_t,$$

$$y_t = c\, s_t + d v_t,$$

where a, b, c, and d are given by:

$$a = \frac{(1 - \rho_s)(\kappa\alpha_m(1 - \alpha_m)^{-1} + \lambda_p\Gamma_s)}{(1 - \rho_s)(1 - \beta\rho_s) + (\phi_\pi(1 - \delta) - \rho_s)\kappa} > 0$$

14. The hypothesis of an indeterminate equilibrium (and, hence, the possibility of sunspot fluctuations) in the first part of the sample could also potentially explain the greater volatility in both inflation and GDP, as emphasized by Clarida, Galí, and Gertler (2000). We choose to pursue an alternative line of explanation here, which does not rely on multiplicity of equilibria.

$$b = -\frac{\kappa}{1 + \phi_\pi(1-\delta)\kappa} < 0$$

$$c = \frac{\alpha_m(1-\alpha_m)^{-1}(1-\rho_s)(1-\beta\rho_s) - (\phi_\pi(1-\delta)-\rho_s)\lambda_p\Gamma_s}{(1-\rho_s)(1-\beta\rho_s) + (\phi_\pi(1-\delta)-\rho_s)\kappa}$$

$$d = -\frac{1}{1 + \phi_\pi(1-\delta)\kappa}.$$

Imposing $v_t = \delta\phi_\pi\pi_{H,t}$ into the solution (so that the central bank actually adheres to its chosen rule) we get

$$\pi_{q,t} = \frac{a}{1 - b\delta\phi_\pi} s_t,$$

thus implying that CPI inflation is

$$\pi_{c,t} = \frac{a}{1 - b\delta\phi_\pi} s_t + \chi\, \Delta s_t.$$

Value added is then given by:

$$\begin{aligned} y_t &= c\, s_t + d\phi_\pi\delta\, \pi_{q,t} \\ &= \left(c + \frac{da\phi_\pi\delta}{1 - b\delta\phi_\pi}\right) s_t. \end{aligned}$$

Figure 7.13 displays the loci of standard deviations of CPI inflation and GDP associated with $\delta = 0$ and $\delta = 0.5$; that is, corresponding to a full

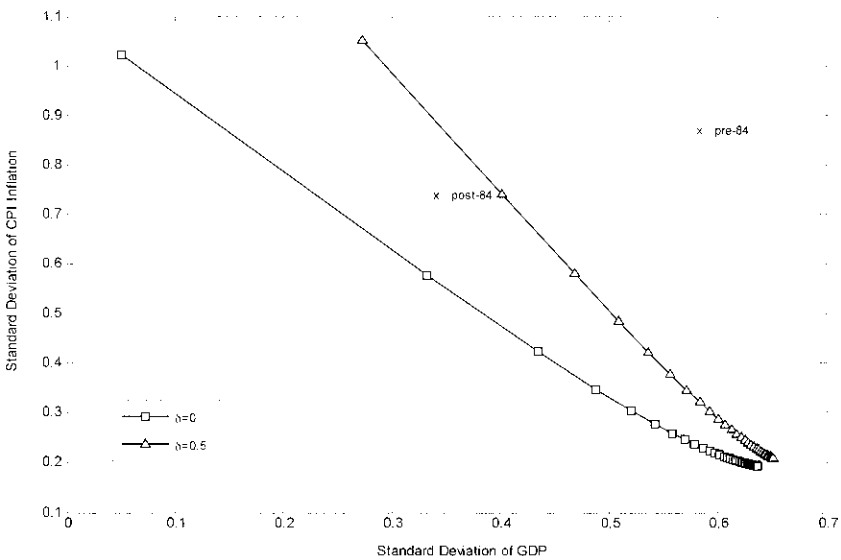


Fig. 7.13 Credibility and policy trade-offs

credibility and a low credibility environment, respectively. In both cases we restrict ϕ_π to values above two in order to guarantee a unique equilibrium. We set γ equal to 0.9, and calibrate the oil shares to their 1997 values. Two points are worth noting.

First, allowing for both real wage rigidities and poor credibility, the model's predictions come closer but still fall somewhat short of matching the (conditional) standard deviations of CPI inflation and GDP in the pre-1984 sample. Given the primitive nature of the model, this may not be overly worrisome.

Second, credibility gains can improve the trade-off facing policymakers significantly. The quantitative gains, however, do not seem sufficient to account, by themselves, for the observed decline in macro volatility in the face of oil shocks, documented earlier in the chapter. But they show that improved credibility may certainly have contributed to that decline.

Figure 7.14, panels A through C, provides some evidence of the changes in the Fed's response to oil price shocks, as well as an indicator of potential changes in its credibility. The rolling IRFs displayed are based on estimated bivariate VARs with the price of oil and, one at a time, a measure of inflation expectations over the next twelve months from the Michigan Survey, the three-month Treasury Bill rate, and the real interest rate (measured as the difference between the previous two variables).

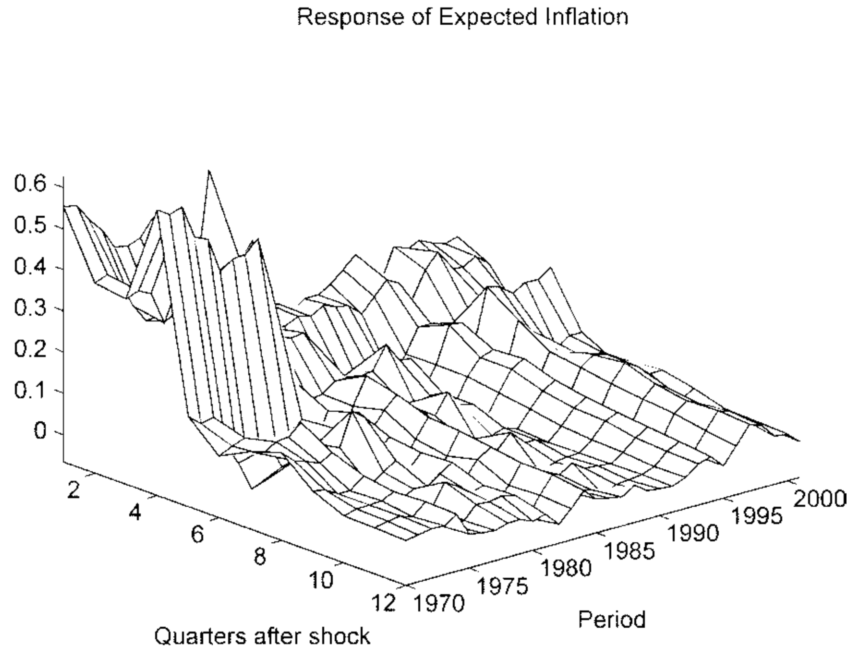
First, and most noticeable, the response of expected inflation to an oil price shock of the same size (normalized here to 10 percent rise) has shrunk dramatically over time, from a rise of about 50 basis points in the 1970s, to about 20 basis points since the mid-1980s, and has remained remarkably stable after that.

Second, and perhaps surprisingly, the strength of the response of the nominal interest rate has not changed much across sample periods. The shrinking response of expected inflation implies, however, that the response of the real rate to an oil price shock has become stronger over time. In fact, the real rate appears to decline significantly in response to an oil price shock in the 1970s, an observation consistent with the (unconditional) evidence in Clarida, Galí, and Gertler (2000). This decline may have contributed to the large and persistent increase in inflation. It also suggests that had the Fed pursued a stronger anti-inflationary policy (keeping credibility unchanged) the adverse effects on output and inflation would have been even larger.[15]

To summarize the lessons from the previous analysis: while the weak

15. Note that, for the most recent period, the real interest rate shows very little change in response to an oil price shock. There are several explanations for this finding. First, as shown before, several measures of inflation (including expected inflation and GDP deflator inflation) hardly change in response to the oil price rise. If the Fed responds to those measures, the required adjustment in the nominal and real rates will be relatively small. Secondly, the Fed may also adjust rates in response to measures of economic activity. The decline in GDP and employment may thus have induced an interest rate movement in the opposite direction, with the net effect being close to zero.

A



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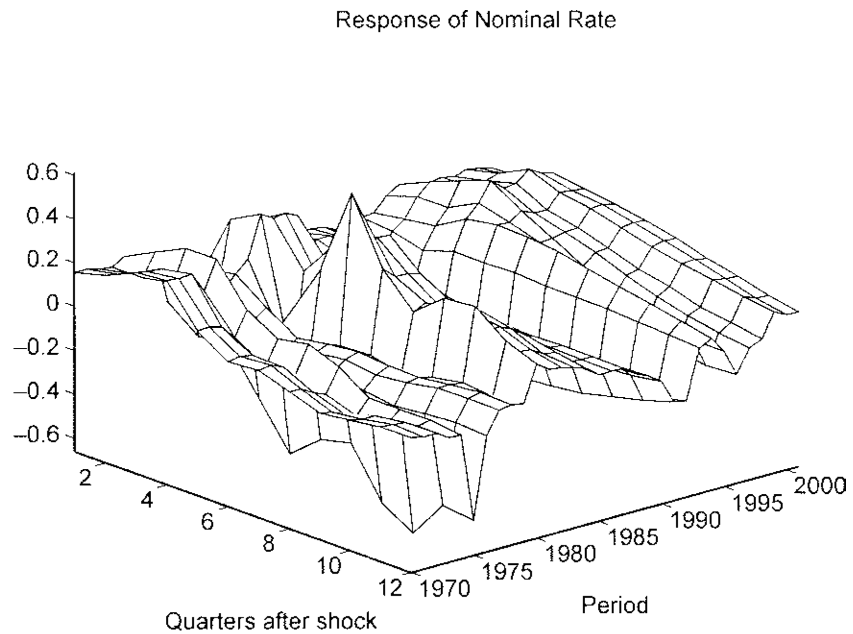

Fig. 7.14 Response of expected inflation, nominal rate, and real rate

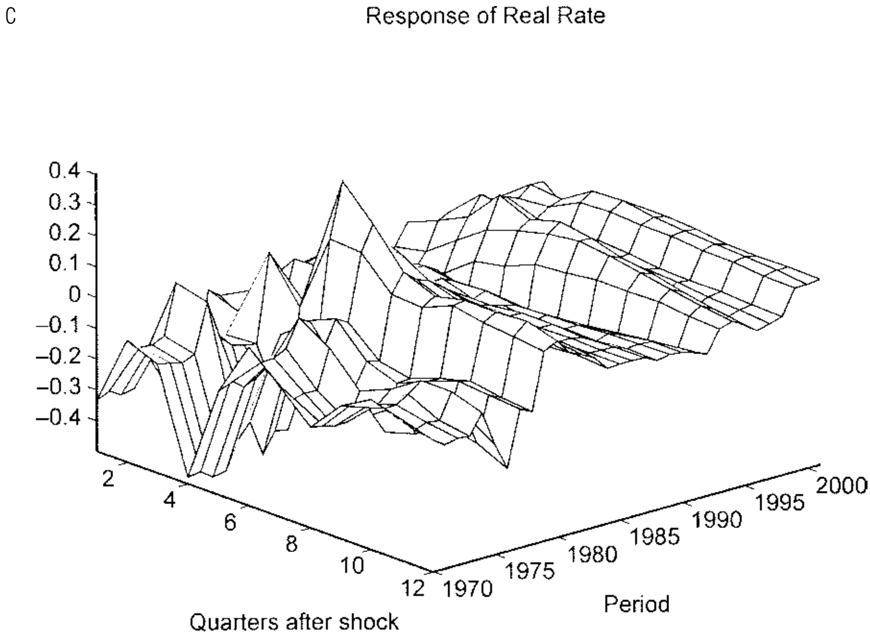

Fig. 7.14 (cont.)

response of inflation to oil price shocks in recent years is often interpreted as a consequence of a stronger anti-inflation stance by the Fed (a higher ϕ_π, in the context of our model), the evidence of a smaller decline in employment and GDP suggests that an enhanced anti-inflation credibility may also have played a role. The sharp decline in the response of inflation expectations to an oil price shock is certainly consistent with this view.

7.6.3 Declining Oil Shares

A third hypothesis for the improved policy trade-off is that the share of oil in consumption and in production is smaller today than it was in the 1970s. To examine the possible impact of these changes we simulate two alternative versions of our model, with α_m and χ calibrated using 1973 and 1997 data on the share of oil in production costs and consumption expenditures (see appendix B for details of construction). In light of this evidence we choose $\alpha_m = 2.3$ percent and $\chi = 1.5$ percent (1973 data) for the 1970s, and $\alpha_m = 1.7$ percent and $\chi = 1.2$ percent (based on data for 1997) for our two calibrations.

Figure 7.15 displays CPI inflation and GDP volatility for the two calibrations, keeping the index of real wage rigidities unchanged at $\gamma = 0.9$ (and $\delta = 0$). The conclusion is similar to those reached for the other two candidate

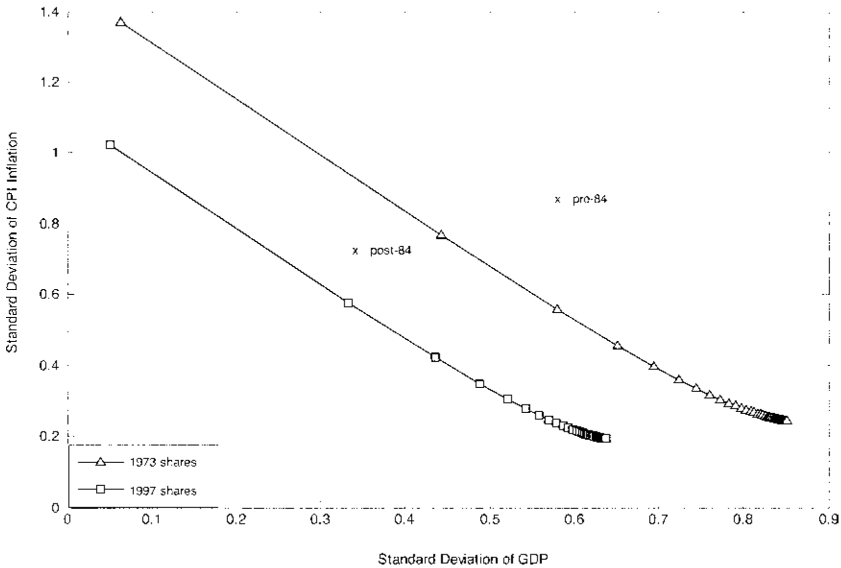

Fig. 7.15 Changing oil shares and policy trade-offs

explanations. The reduction in the oil shares in consumption and production cannot account for the full decline in volatility, but it clearly accounts for part of it. (The values of α_m and χ in 1977, thus after the first but before the second oil shock, were 3.6 percent and 1.8 percent, respectively. This suggests that, other things equal, the second oil shock should have had larger effects than the first. As we saw earlier, the opposite appears to be true.)

The previous analysis has examined the effects on CPI inflation and GDP volatility of changes in one parameter at a time. Figure 7.16 shows the combined effect of a simultaneous change in the three parameters. The first calibration, which is meant to roughly capture the 1970s environment, assumes strong wage rigidities ($\gamma = 0.9$), limited central bank credibility ($\delta = 0.5$), and the 1973 oil shares. The second calibration assumes milder wage rigidities ($\gamma = 0.6$), full credibility ($\delta = 0$), and the 1997 oil shares. The figure shows that the combination of the three changes in the environment we have focused on can in principle more than account for the improvement in the trade-off observed in the data.

7.7 Concluding Comments

We have reached five main conclusions. First is that the effects of oil price shocks must have coincided in time with large shocks of a different nature. Given our partial identification strategy, we have not identified these other

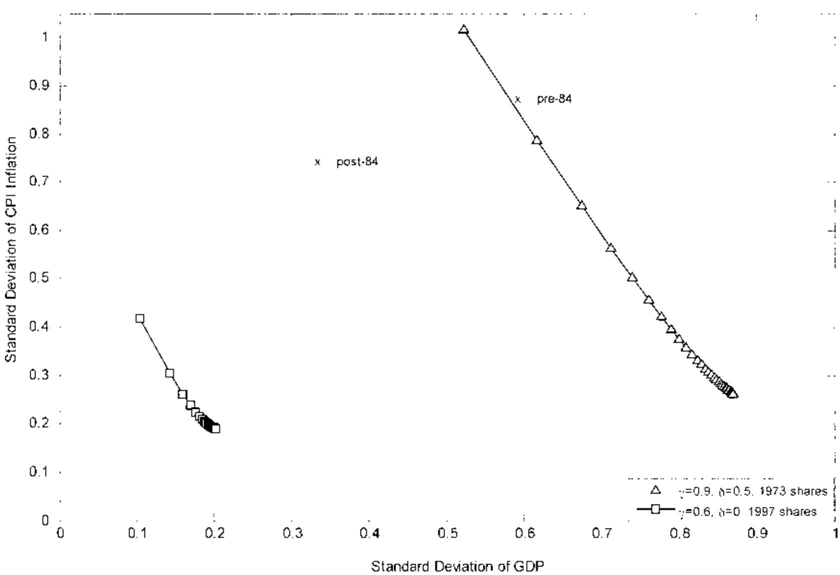

Fig. 7.16 Combined effects

shocks. We have given some evidence that increases in other commodity prices were important in the 1970s. We have not identified the other shocks for the 2000s.

Second, the effects of oil price shocks have changed over time, with steadily smaller effects on prices and wages, as well as on output and employment.

The third conclusion is that a first plausible cause for these changes is a decrease in real wage rigidities. Such rigidities are needed to generate the type of large stagflation in response to adverse supply shocks such as those that took place in the 1970s. We have shown that the response of the consumption wage to the marginal rate of substitution, and thus to employment, appears to have increased over time.

Fourth is that a second plausible cause for these changes is the increased credibility of monetary policy. We have offered a simple formalization of lack of credibility and its effect on the volatility frontier. We have shown that the response of expected inflation to oil shocks has substantially decreased over time.

And finally, the fifth conclusion is that a third plausible cause for these changes is simply the decrease in the share of oil in consumption and in production. The decline is large enough to have quantitatively significant implications.

Despite the length of the chapter, we are conscious, however, of the limitations of our arguments. Some of the evidence—for example, the IRF evidence for Japan—does not fit our story. The model we have developed is too primitive in many dimensions, and its quantitative implications must be taken with caution. The development of a richer model, at least with respect to the specification of production, and of real wage rigidities and its estimation, seem the natural next steps to check the conclusions reached previously. The different implications of the various candidate hypotheses for the shape of impulse response functions in response to changes in the price of oil makes us hopeful that structural estimation can succeed in identifying their respective importance.

Appendix A

A New-Keynesian Model for an Oil-Importing Economy

The present appendix describes in more detail the model used in section 7.5 and derives the equilibrium conditions underlying the simulations in the main text.

Households

We assume a continuum of identical infinitely-lived households. Each household seeks to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, N_t),$$

where

$$C_t \equiv \Theta_\chi \, C_{m,t}^{\chi} \, C_{q,t}^{1-\chi},$$

and where $C_{m,t}$ denotes consumption of (imported) oil, $C_{q,t} \equiv (\int_0^1 C_{q,t}(i)^{1-1/\varepsilon} di)^{\varepsilon/(\varepsilon-1)}$ is a CES index of domestic goods, N_t denotes employment or hours worked, and $\Theta_\chi \equiv \chi^{-\chi}(1-\chi)^{-(1-\chi)}$.

We assume that period utility is given by

$$U(C_t, N_t) \equiv \log C_t - \frac{N_t^{1+\phi}}{1+\phi}.$$

The period budget constraint, conditional on optimal allocation of expenditures among different domestic goods (not derived here) is given by:

$$P_{q,t}C_{q,t} + P_{m,t}C_{m,t} + Q_t^B \, B_t = W_t N_t + B_{t-1} + \Pi_t,$$

where $P_{q,t} \equiv (\int_0^1 P_{q,t}(i)^{1-\varepsilon} \, di)^{1/(1-\varepsilon)}$ is a price index for domestic goods, $P_{m,t}$ is the price of oil (in domestic currency), and W_t is the nominal wage. The price of a one-period nominally riskless domestic bond Q_t^B, paying one unit of domestic currency; B_t denotes the quantity of that bond purchased in period t. For simplicity, we assume no access to international financial markets.

The optimal allocation of expenditures between imported and domestically produced good implies

$$P_{q,t}C_{q,t} = (1 - \chi)\, P_{c,t}C_t$$

$$P_{m,t}C_{m,t} = \chi\, P_{c,t}C_t,$$

where $P_{c,t} \equiv P^{\chi}_{m,t}\, P^{1-\chi}_{q,t}$ is the CPI index. Note that χ corresponds, in equilibrium, to the share of oil in consumption. Note also that $P_{c,t} \equiv P_{q,t}\, S^{\chi}_t$, where $S_t \equiv P_{m,t}/P_{q,t}$ denotes the real price of oil, expressed in terms of domestically produced goods. Taking logs,

$$p_{c,t} = p_{q,t} + \chi\, s_t,$$

where $s_t \equiv p_{m,t} - p_{q,t}$ is the log of the real price of oil (measured in terms of domestic goods).

Furthermore, and conditional on an optimal allocation between the two types of goods, we have $P_{q,t}C_{q,t} + P_{m,t}C_{m,t} = P_{c,t}C_t$, which can be substituted into the budget constraint. The resulting constraint can then be used to derive the household's remaining optimality conditions. The intertemporal optimality condition is given by:

$$Q^B_t = \beta\, E_t\left\{\frac{C_t}{C_{t+1}}\,\frac{P_{c,t}}{P_{c,t+1}}\right\}.$$

Under the assumption of perfect competition in labor markets (to be relaxed following), the household's intratemporal optimality condition is given by

$$\frac{W_t}{P_{c,t}} = C_t\, N^{\phi}_t \equiv M\, RS_t,$$

which is the perfectly competitive labor supply schedule. The log-linearized version of the previous two equations, found in the text, are given by:

$$c_t = E_t\{c_{t+1}\} - (i_t - E_t\{\pi_{c,t+1}\} - \rho) \tag{18}$$

$$w_t - p_{c,t} = c_t + \phi\, n_t \tag{19}$$

where we use lowercase letters to denote the logarithms of the original variables, and where $\pi_{c,t} \equiv p_{c,t} - p_{c,t-1}$ represents CPI inflation.

Firms

Each firm produces a differentiated good indexed by $i \in [0, 1]$ with a production function

$$Q_t(i) = A_t\, M_t(i)^{\alpha_m}\, N_t(i)^{\alpha_n},$$

where $\alpha_m + \alpha_n \leq 1$.

Independently of how prices are set, and assuming that firms take the price of both inputs as given, cost minimization implies that firm i's nominal marginal cost $\Psi_t(i)$ is given by:

$$\Psi_t(i) = \frac{W_t}{\alpha_n(Q_t(i)/N_t(i))} = \frac{P_{m,t}}{\alpha_m(Q_t(i)/M_t(i))}. \tag{20}$$

Letting $\mathcal{M}_t^p(i) \equiv P_{q,t}(i)/\Psi_t(i)$ denote firm i's gross markup, we have

$$\mathcal{M}_t^p(i)\, S_t M_t(i) = \alpha_m\, Q_t(i)\, \frac{P_{q,t}(i)}{P_{q,t}}.$$

Let $Q_t \equiv (\int_0^1 Q_t(i)^{1-1/\varepsilon}\, di)^{\varepsilon/(\varepsilon-1)}$ denote aggregate gross output. It follows that

$$M_t = \frac{\alpha_m\, Q_t}{\mathcal{M}_t^p\, S_t} \tag{21}$$

where we have used the fact that $Q_t(i) = (P_{q,t}(i)/P_{q,t})^{-\varepsilon}\, Q_t$ (the demand schedule facing firm i), and defined $\mathcal{M}_t^p$ as the average gross markup, weighted by firms' input shares.

Taking logs and ignoring constants

$$m_t = -\mu_t^p - s_t + q_t,$$

where $\mu_t^p \equiv \log \mathcal{M}_t^p$. The latter expression can be plugged back into the (log-linearized) aggregate production function to yield the reduced form gross output equation

$$q_t = \frac{1}{1-\alpha_m}\,(a_t + \alpha_n n_t - \alpha_m s_t - \alpha_m \mu_t^p). \tag{22}$$

Consumption and Gross Output

Note that in an equilibrium with balanced trade (and hence $B_t = 0$) the following relation must hold:

$$\begin{aligned} P_{c,t}C_t &= P_{q,t}Q_t - P_{m,t}M_t \\ &= \left(1 - \frac{\alpha_m}{\mathcal{M}_t^p}\right) P_{q,t}Q_t, \end{aligned}$$

where we have used (21) to derive the second equality. Taking logs and using the relations between the different price indexes, we obtain

$$c_t = q_t - \chi\, s_t + \eta\, \mu_t^p, \tag{23}$$

where $\eta \equiv \alpha_m/(\mathcal{M}^p - \alpha_m)$ and $\mathcal{M}^p$ denotes the steady-state markup.

Combining (22) and (23), and invoking the fact that $(\alpha_m/(\mathcal{M}^p - \alpha_m) - \alpha_m/(1-\alpha_m))\, \mu_t^p \simeq 0$ for plausibly low values of α_m and the net markup measures $\mathcal{M}^p - 1$ and μ_t^p, we can write

(24) $$c_t = \frac{1}{1-\alpha_m} a_t + \frac{\alpha_n}{1-\alpha_m} n_t - \left(\frac{\alpha_m}{1-\alpha_m} + \chi \right) s_t.$$

Gross Output, Value Added, and the GDP Deflator

The GDP deflator $P_{y,t}$ is implicitly defined by

$$P_{q,t} \equiv (P_{y,t})^{1-\alpha_m} (P_{m,t})^{\alpha_m}.$$

Taking logs and using the definition of the terms of trade s_t

$$p_{y,t} = p_{q,t} - \frac{\alpha_m}{1-\alpha_m} s_t.$$

Value added (or GDP), Y_t, is then defined by

$$P_{y,t} Y_t \equiv P_{q,t} Q_t - P_{m,t} M_t$$
$$P_{y,t} Y_t = \left(1 - \frac{\alpha_m}{\mathcal{M}_t^p} \right) P_{q,t} Q_t,$$

which can be log-linearized to yield

$$y_t = q_t + \frac{\alpha_m}{1-\alpha_m} s_t + \eta\, \mu_t^p$$
$$= \frac{1}{1-\alpha_m} (a_t + \alpha_n n_t),$$

where the last equality uses the previous invoked approximation.

Note that combining these expressions for consumption and value added we can obtain the following relation between the two

$$c_t = y_t - \left(\frac{\alpha_m}{1-\alpha_m} + \chi \right) s_t.$$

Price Setting

Here we assume that firms set prices in a staggered fashion, as in Calvo (1983). Each period only a fraction 1 – θ of firms, selected randomly, reset prices. The remaining firms, with measure θ, keep their prices unchanged. The optimal price setting rule for a firm resetting prices in period t is given by

(25) $$E_t \left\{ \sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} Q_{t+k|t} (P_t^* - \mathcal{M}^p \Psi_{t+k|t}) \right\} = 0,$$

where P_t^* denotes the price newly set at time t, $Q_{t+k|t}$ and $\psi_{t+k|t}$ are, respectively, the level of output and marginal cost in period $t + k$ for a firm that last set its price in period t, and $\mathcal{M}^p \equiv \varepsilon/(\varepsilon - 1)$ is the desired gross markup.

Note that the latter also corresponds to the gross markup in the zero inflation perfect foresight steady state.

The domestic price level evolves according to the difference equation

$$P_{q,t} = [\theta\,(P_{q,t-1})^{1-\varepsilon} + (1-\theta)\,(P_t^*)^{1-\varepsilon}]^{1/(1-\varepsilon)}. \tag{26}$$

Combining the log-linearized version of (25) and (26) around a zero inflation steady state yields the following equation for domestic inflation, $\pi_{q,t} \equiv p_{q,t} - p_{q,t-1}$:

$$\pi_{q,t} = \beta\, E_t\{\pi_{q,t+1}\} - \lambda_p\, \hat{\mu}_t^p, \tag{27}$$

where $\hat{\mu}_t^p \equiv \mu_t^p - \mu^p$ denotes the (log) deviation of the average markup from its desired level, and $\lambda_p \equiv ((1-\theta)(1-\beta\theta))/\theta\,(1-\alpha_k)/(1-\alpha_k + \alpha_k\varepsilon)$.

Appendix B
Computation of the Oil Share

We think of the U.S. economy as having two sectors, an oil-producing sector and a nonoil producing sector. We define the oil producing sector as the sum of the "oil and gas extraction" sector (North American Industry Classification NAIC code 211) and the "petroleum and coal" sector (NAIC code 324). ("Petroleum refineries," a subsector of "petroleum and coal" is available only for benchmark years, the last available one being 1997. It represents 85 percent of the gross output of the "petroleum and coal" sector.) We define the nonoil producing sector as the rest of the economy.

To compute relevant numbers for 2005, we use data from the Input-Output (I-O) tables from the Bureau of Economic Analysis (BEA) site.

In 2005, "oil and gas extraction" output was \$227b, imports were \$223b, for a total of \$450b. Of this total, \$5b was for domestic final uses, \$440b was for intermediates, of which \$259 went to "petroleum and coal," and \$181b went to the non-oil sector. Petroleum and coal output was \$402b, imports were \$65b, for a total of \$467b. Of this total, \$167 was for domestic final uses, \$279b for intermediates to the non-oil producing sector.

In 2005, total U.S. value added was \$12,455b. Value added by "oil and gas" was \$12b, value added by "petroleum and coal" was \$12b, so value added in the non-oil producing sector was \$12,431b.

These numbers imply a value for α_m of (181 + 279)/(12,431 + 181 + 279) = 3.6 percent, and an estimate for χ of (5 + 167)/(12,431 + 181 + 279) = 1.3 percent.

The shares obviously depend very much on the price of oil. The same computation for the benchmark year of 1997 (which allows us to use "petroleum refining" rather than "petroleum and coal" together) gives 1.7 percent and 1.2 percent, respectively.

For the years 1973 and 1977. sectors are classified according to industry number codes. We construct the oil-producing sector as the of "crude petroleum and natural gas" (1977 industry number 8) and "petroleum refining" (1977 industry number 31). The same steps as before yield $\alpha_m = 2.3$ percent and $\chi = 1.5$ percent in 1973, and $\alpha_m = 3.6$ percent and $\chi = 1.8$ percent in 1977.

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Using a battery of compelling statistical methods, this chapter shows that the statistical effect of oil price shocks on output and inflation is more muted after 1984 than it was in the post-war period up to that point. As it happens, a small response of the economy to oil price increases is more consistent with standard macroeconomic models. There is thus a sense in which developments in the economy may lead this issue to lose its allure. In my opinion, however, it is precisely because we observed puzzling responses to what were arguably exogenous disturbances, that this topic is a great laboratory for understanding central features of the economy as a whole. Thus, I very much welcome this chapter's effort to disentangle the causes of this change in response.

The chapter offers three basic stories for the decline in the response to the price of oil. These are: (a) that "real wage rigidity" was more important in the past than it is today; (b) that "monetary policy credibility" was weaker in the past than it is today, and (c) that the share of energy in the economy was larger in the past than it is today. The message of this chapter is thus optimistic in that it suggests a transformation in U.S. institutions has inoculated the economy against the responses that we saw in the past.

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