Oil Prices and U.S. Aggregate Economic Activity: A Question of Neutrality

Stephen P. A. Brown and Mine K. Yücel

Research suggests rising oil prices reduced output and increased inflation in the 1970s and early 1980s and falling oil prices boosted output and lowered inflation in the mid- to late 1980s.

Stephen P. A. Brown is a senior economist and assistant vice president and Mine K. Yücel is a senior economist and research officer in the Research Department at the Federal Reserve Bank of Dallas.

Considerable research finds that oil price shocks have affected U.S. output and inflation (Hamilton 1983, 1988, 1996; Tatom 1988; Mork 1989, 1994; Kahn and Hampton 1990; Huntington 1998). Research also supports the view that these shocks have been an important source of economic fluctuation in the United States over the past three decades (Miller, Supel, and Turner 1980; Finn 1991; Kim and Loungani 1992). This research suggests rising oil prices reduced output and increased inflation in the 1970s and early 1980s and falling oil prices boosted output and lowered inflation in the mid- to late 1980s. Nevertheless, other studies argue it was not the oil price shocks themselves but monetary policy's response to them that caused the fluctuations in aggregate economic activity (Bohi 1989; Bernanke, Gertler, and Watson 1997).

Bernanke, Gertler, and Watson (BGW) show that the U.S. economy responds differently to an oil price shock when the federal funds rate is held constant than it does when the rate is unconstrained. In the unconstrained case, a positive oil price shock leads to a rise in the federal funds rate and a decline in real gross domestic product. With the federal funds rate held constant, BGW find a positive oil price shock leads to an increase in real GDP. Defining neutral monetary policy as one in which the federal funds rate is constant, BGW argue that monetary policy has not been neutral in response to oil price shocks. They contend the difference in real GDP's behavior shows it is monetary policy's response to oil price shocks that causes aggregate economic activity to fluctuate.

A constant federal funds rate is not necessarily the only definition of monetary neutrality in the face of a supply shock. Friedman (1959) suggests a constant monetary aggregate; Gordon (1998) suggests that neutrality occurs when the monetary authority adjusts policy to hold nominal GDP constant.[1]

For this article, we construct a vector autoregressive (VAR) model of the U.S. economy similar to the BGW model to examine whether the definition of monetary neutrality affects the conclusion that monetary policy's response to oil price shocks accounts for the fluctuations in aggregate economic activity. We find that with the BGW definition of neutral monetary policy—a constant federal funds rate—oil price shocks have prompted a tightening of monetary policy. However, under a different definition of neutrality—constant nominal GDP—it could be argued that the Federal Reserve has taken a neutral course.

MODEL, INTERPRETATION, AND ESTIMATION

Our model is a variant of BGW's VAR model. Both consist of seven variables and equations representing real GDP, the GDP deflator, a commodity price index, the price of oil, the federal funds rate, and short- and long-term interest rates. Both versions of the model can be used to represent money demand, as well as the relationships between oil prices, aggregate economic activity, financial variables, and inflation.

For oil prices, the BGW model uses the "net oil price" proposed by Hamilton (1996), constructed by calculating the difference between the current price and the maximum price seen in the past twelve months (in logs). Hamilton's net oil price is equal to the difference or zero, whichever is greater. In addition, the federal funds rate does not enter the BGW model directly but, rather, works through the term structure of interest rates. The short- and long-term market rates are decomposed into two parts—an expectations of future funds rate component and a term premium component.

Our version of the model has two oil price variables: the Hamilton net oil price and the price of oil. Following Balke, Brown, and Yücel (1999), we include an additional oil price variable to allow for the differential effects of rising and falling oil prices. The net oil price captures only rising oil prices. Unlike BGW, we do not impose a structure on the model and include the federal funds rate directly in the VAR.

Simple theory can help predict how an oil price shock will affect the variables in either model. Higher energy prices resulting from an oil price shock cause a temporary shift in the production function, leading to lower output. The reduction in output, ceteris paribus, results in an excess demand for goods and an increase in the interest rate. The fall in output and increase in the interest rate, in turn, reduce the demand for real cash balances, and given a nominal quantity of money, the price level rises. Therefore, we would expect an oil price shock to lower GDP and increase both interest rates and the price level.[2]

According to Gordon (1998), the Federal Reserve maintains neutrality in the face of a supply shock by acting to hold nominal spending constant. Hence, under this circumstance a decline in GDP, an increase in interest rates, and an increase in the price level can be consistent with a neutral monetary policy—as long as nominal GDP remains constant. In contrast, BGW define a neutral monetary policy as one in which the Federal Reserve holds the federal funds rate constant in the face of a supply shock regardless of the consequences for the price level and nominal GDP. Because a supply shock might boost short-term interest rates, however, holding the federal funds rate constant could be interpreted as accommodative if it results in gains in nominal GDP.

Data

To examine the neutrality issues, we use data similar to BGW's. We use monthly data for January 1965 through December 1997.[3] The real oil price variable is the producers price index of crude oil, with the Hamilton net oil price calculated from the same series. GDP is in constant 1987 dollars. We use the Chow–Lin procedure to obtain a monthly GDP series from the quarterly data, with personal consumption expenditures, industrial production, and total nonagricultural employment as reference series. We also use the Chow–Lin procedure to obtain a monthly GDP deflator series from the quarterly data, with the producer price indexes for capital equipment, finished goods, intermediate materials, and crude materials as the reference series. The commodity price index is the spot market index for all commodities from the Commodity Research Bureau. The short-term interest rate is the three-month Treasury bill. The long-term interest rate is the ten-year Treasury bond. All three interest rate variables are from Citibase.

Following BGW, we use log levels of real GDP, the price deflator, and the commodity price. The federal funds rate and the long-term interest rate are kept in levels. We use log first differences of the real oil price to make it comparable to the Hamilton oil price variable. Because it can be generated by an identity from the oil price series, the net oil price is included as a regressor in each equation, along with the real oil price, but is not a left-hand variable itself.

Variance Decomposition and Impulse Responses

We use both a variance decomposition and impulse responses to assess the relationship between oil price shocks and aggregate economic activity. A variance decomposition apportions the variance of forecast errors in a given variable to its own shocks and those of the other variables in the VAR. It allows us to assess the relative importance of oil price shocks to the volatility of the other variables.

Impulse response functions allow us to examine the dynamic effects of oil price shocks on U.S. economic activity and inflation. The impulse response function traces over time the

Table 1
Variance Decomposition

	RGDP	Deflator	Pcom	Oil	FF	Short rate	Long rate
RGDP	29.7	1.2	6.5	1.4	43.9	15.3	2.0
Deflator	8.4	21.6	64.2	.2	3.8	.8	.9
Pcom	5.8	3.4	76.9	.3	9.5	2.8	1.1
Oil	3.8	2.2	10.3	75.4	3.9	2.7	1.7
FF	22.7	5.2	38.7	1.1	20.7	10.8	.7
Short rate	20.8	5.7	40.8	.7	15.6	15.8	.8
Long rate	13.7	10.7	51.7	.6	6.4	8.0	8.8

NOTE: The variable on the left is being decomposed by the right-hand-side variables shown at the top.

effects on a variable of an exogenous shock to another variable. The persistence of a shock tells us how fast the system adjusts back to equilibrium. The faster a shock dampens, the faster the adjustment. We analyze the effects of a one-time oil price shock and trace its effect on each of the variables.

We use a Choleski decomposition to construct the variance decompositions and impulse responses. This technique decomposes the residual (μ_i) from each equation in the VAR system into a linear combination of the residuals from the other equations (μ_j) and an orthogonal element (ν_i). The structure is as follows:[4]

$$(1)\quad \mu_{gdp} = \nu_{gdp}$$

$$(2)\quad \mu_{defl} = c_{21}\mu_{gdp} + \nu_{defl}$$

$$(3)\quad \mu_{pcom} = c_{31}\mu_{gdp} + c_{32}\mu_{defl} + \nu_{pcom}$$

$$(4)\quad \mu_{poil} = c_{41}\mu_{gdp} + c_{42}\mu_{defl} + c_{43}\mu_{pcom} + \nu_{poil}$$

$$(5)\quad \mu_{ff} = c_{51}\mu_{gdp} + c_{52}\mu_{defl} + c_{53}\mu_{pcom} + c_{54}\mu_{poil} + \nu_{ff}$$

$$(6)\quad \mu_{rs} = c_{61}\mu_{gdp} + c_{62}\mu_{defl} + c_{63}\mu_{pcom} + c_{64}\mu_{poil} + c_{65}\mu_{ff} + \nu_{rs}$$

$$(7)\quad \mu_{rl} = c_{71}\mu_{gdp} + c_{72}\mu_{defl} + c_{73}\mu_{pcom} + c_{74}\mu_{poil} + c_{75}\mu_{ff} + c_{76}\mu_{rs} + \nu_{rl}\,,$$

where μ_{gdp} is the residual from the real GDP equation, μ_{defl} is the residual from the GDP deflator equation, μ_{pcom} is the residual from the commodity price equation, μ_{poil} is the residual from the oil price equation, μ_{ff} is the residual from the federal funds rate equation, μ_{rs} is the residual from the short-term interest rate equation, and μ_{rl} is the residual from the long-term interest rate equation.

The decomposition structure implies that unexpected changes in real GDP (μ_{gdp}) arise from any of the specified variables only with a lag. Unexpected changes in the deflator (μ_{defl}) can arise contemporaneously from innovations in real GDP but can arise from other variables only with a lag. Similarly, as we move down the equations, unexpected changes in one of the left-hand-side variables can arise contemporaneously from innovations in variables on the left-hand side of the equations preceding it, but can arise from the variables on the left-hand side of the equations succeeding it only with a lag.[5]

In addition to the standard impulse responses, we also calculate impulse responses under a counterfactual case in which the federal funds rate is held constant, which is akin to the Sims–Zha case in BGW.[6] In the Sims–Zha case, the federal funds rate response is shut down by setting the rate at its baseline level—that is, its value in the absence of an oil price shock.

OIL PRICE SHOCKS AND AGGREGATE ECONOMIC BEHAVIOR

Using the model and procedures described above, we examine the sources of variation in each variable and the estimated responses of aggregate economic activity to an oil price shock with the federal funds rate free to respond and with the rate constant. We find that innovations in the oil price itself—except possibly through a manifestation in commodity prices—have little effect on monetary policy during the estimation period.[7] We also find that holding the federal funds rate constant prevents a decline in real GDP, but at the cost of higher inflation.

Variance Decomposition

The variance decomposition suggests that oil price shocks are not a major source of volatility for most of the variables in the model. As Table 1 shows, for many of the variables the largest source of shock other than the variable itself is the commodity price; changes in oil prices are a minimal source of disturbance to these variables.[8] The commodity price is the source of 65 percent of the volatility in the price deflator, about 40 percent of the volatility in the federal funds rate and short-term interest rates, and 50 percent of the volatility in long-term interest rates.

For real GDP, the largest source of shocks is changes in the federal funds rate, which contributes nearly 44 percent of the volatility. The GDP variable itself accounts for about 30 percent of its own volatility, and the commodity price accounts for 6.5 percent of the volatility. Oil prices contribute only 1.4 percent of GDP volatility.

Although the federal funds rate is the largest source of volatility for real GDP, the rate's movements do not arise from changes in oil prices. The oil price contributes only about 1 percent of the volatility in the federal funds rate. Commodity prices are the largest source of volatility for the rate, while GDP accounts for almost 23 percent of the volatility. The funds rate itself is the third-largest source of its own volatility, contributing nearly 21 percent. Table 1 shows that the variance decomposition for all three interest rates is very similar, particularly for the federal funds and short-term rates.

These findings suggest it is not the oil price itself but perhaps its manifestation in commodity prices that affects the volatility of economic activity. The commodity price is the largest source of fluctuation for all variables except GDP and oil prices. The main sources of GDP volatility are GDP itself and changes in the federal funds rate. A change in commodity prices is the source of nearly half the volatility for all interest rates in the model. The fed funds rate seems to be responding to changes in general commodity prices, not necessarily just the oil price, because changes in oil prices are the smallest source of volatility for the fed funds rate.

Impulse Responses

Figure 1 shows the impulse responses to an oil price shock in the base case (solid line). As is shown, a positive oil price shock leads to a decline in real GDP, a rise in the price level, and increases in short- and long-term interest rates.[9]

GDP and Inflation Response. We find that a one-standard-deviation shock to the real oil price leads to a transitory decline in real GDP. The maximum decline in real GDP is about 0.005 percent and is realized in the thirteenth month.

Our findings are similar to those of Hamilton (1983), Tatom (1988), Mork (1989, 1994), and Huntington (1998), who find decreases in real gross domestic product (or gross national product) follow an oil price shock. If the maximum decline in real GDP is normalized by the maximum increase in the price of oil, we estimate the resulting oil price elasticity of GDP is –0.008.[10] Our estimate shows a smaller effect than the –0.02 to –0.076 range reported in a 1987 Energy Modeling Forum study (Hickman, Huntington, and Sweeney 1987), perhaps because the model contains commodity prices. Brown and Yücel (1995) also suggest that the elasticity of real GDP to changes in oil prices may have declined with the energy intensity of the economy since the 1980s and that inclusion of data for more recent periods could result in a smaller elasticity estimate.

A shock to oil prices leads to a response in the price level similar in magnitude to the response in real GDP. The one-standard-deviation increase in oil prices leads to a 0.006 percent increase in the price level that is 90 percent complete in the first year. The maximum response is reached in eighteen months. Estimated at the peak of the response, the elasticity of the price level with respect to the real price of oil is 0.011 percent.

The impulse responses of real GDP and the deflator show that the responses for both GDP and the deflator are similar in magnitude. This similarity can be seen in the impulse response of nominal GDP, which is calculated from real GDP and the price level. After the initial period, the impulse is relatively constant throughout the time horizon and the magnitude is very small.[11] Such a finding is roughly consistent with Gordon's definition of neutral monetary policy. It also suggests the response of real GDP and the price level are consistent with a supply-side response to an oil price shock in which the shift in aggregate supply lowers output and raises prices.

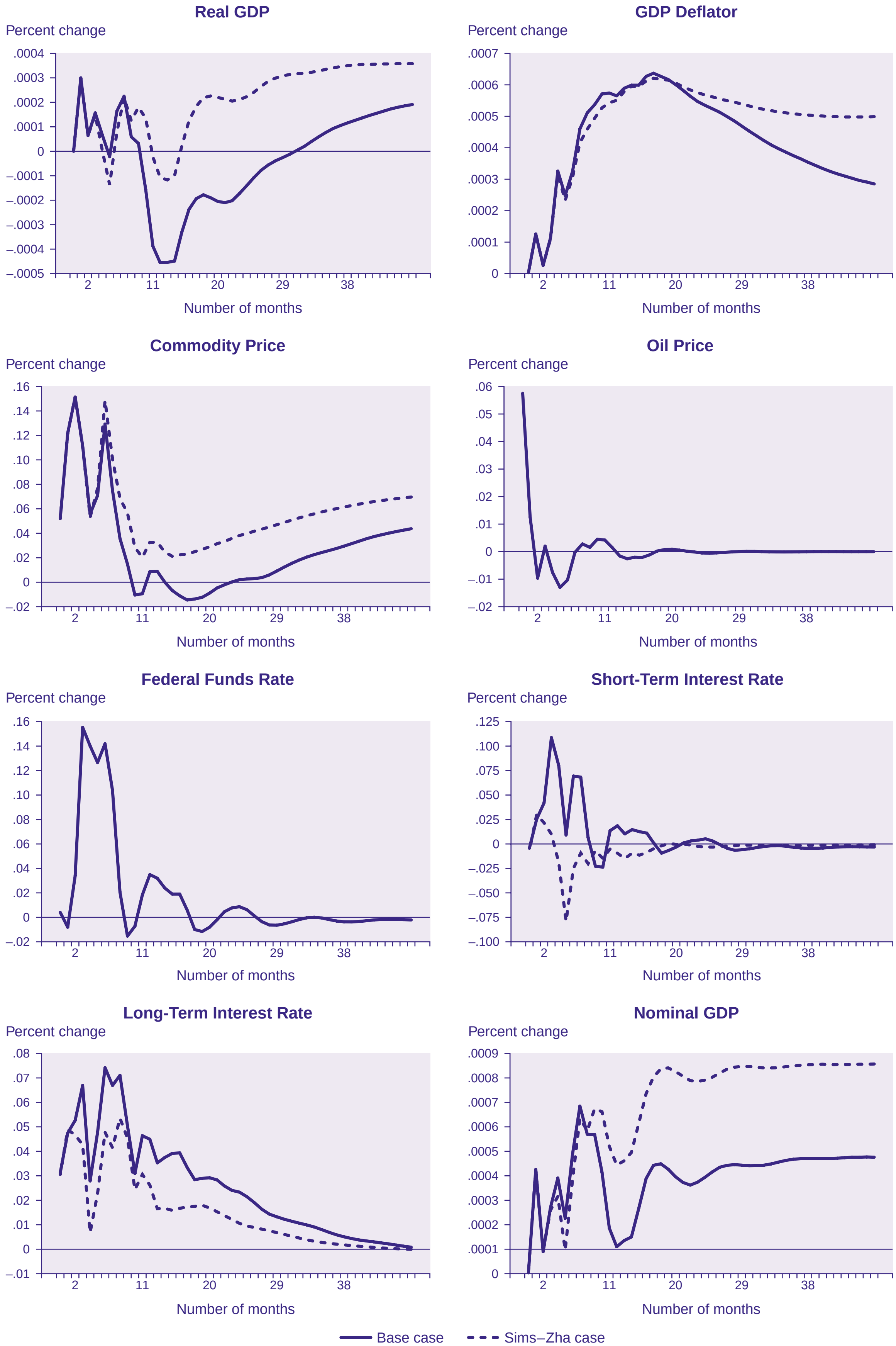
Interest Rates and Monetary Responses. On the financial side, the oil price shock leads to increases in all the variables. An increase in oil prices leads to a rise in the federal funds rate, a smaller rise in the short-term rate, and an even smaller rise in the long-term rate. The spread between long- and short-term interest rates narrows because the long rate rises less than the short rate.

The federal funds rate rises 0.16 percent above its preshock value by the fourth month and then declines until the end of the time horizon. The oil price shock leads the short-term interest rate to increase 0.1 percent, also by the fourth month. The maximum increase in the long rate is 0.07 percent, which occurs at seven months.

BGW interpret a rising federal funds rate as tightening by the Federal Reserve, but other interpretations are possible. If interest rates rise in response to an oil price shock, a higher federal funds rate may be needed to hold nominal GDP constant.

Constant Federal Funds Rate Case. BGW interpret a constant federal funds rate as a neutral monetary response. However, if an oil price shock pushes nominal interest rates upward, holding the federal funds rate constant could mean an easing of monetary policy. To

Figure 1
Response to One-Standard-Deviation Oil Price Shock



examine this issue, we consider the impulse responses of aggregate economic activity to oil price shocks under a counterfactual case in which the federal funds rate is held constant. This approach follows the Sims–Zha experiment in the BGW study.

The dotted line in Figure 1 shows the Sims–Zha case in which the federal funds rate is held constant. As is shown, the GDP responses under the Sims–Zha and base cases are identical for the first three months and very similar for the next several months. At the ninth month, real GDP is higher under Sims–Zha than in the base case and continues to increase throughout the time horizon.

Similarly, the commodity price responses in the Sims–Zha and base cases are nearly identical for the first seven months. Commodity prices in the Sims–Zha case then rise above the base case response and remain higher until the end of the time horizon.

The Sims–Zha case also leads to a higher price level, but it takes some time for the price level to rise above the base case values. As with real GDP and commodity prices, the price level responds very similarly in the first seven months under both cases. The price level for the Sims–Zha case remains lower than the base case level until the twenty-third month, after which it surpasses the base level. Hence, the effect of holding the federal funds rate constant shows up quickly in real activity and commodity prices but is slower to appear in the general price level.

The responses of nominal GDP in the Sims–Zha and base cases are similar for the first nine months. After that, nominal GDP increases and remains at least twice its base-case value until the end of the estimated time horizon. Using Gordon's classifications of monetary policy, the gains in nominal GDP that arise under the Sims–Zha case suggest that holding the federal funds rate constant in the face of an oil price shock represents an accommodative monetary policy.[12] Monetary policymakers can offset the real losses arising from an oil price shock, but only at the cost of higher inflation.

SUMMARY AND CONCLUSION

We use impulse responses from a VAR model economy to assess how oil price shocks move through major channels of the U.S. economy to affect aggregate economic activity and the price level. The model represents the interactions between seven variables: real GDP, commodity prices, the GDP deflator, oil prices, the federal funds rate, and short- and long-term interest rates.

The impulse responses to an oil price shock show that the model responds to a temporary oil price shock with a decline in real GDP, increases in the federal funds rate and other interest rates, and an increase in the price level. The decline in real GDP and the rise in the deflator are similar in magnitude, and, consequently, nominal GDP remains relatively constant. Under Gordon's definition of monetary neutrality—holding nominal GDP constant—a rise in the federal funds rate can represent a neutral monetary policy response to an oil price shock.

When the federal funds rate is held constant under the Sims–Zha counterfactual case, we obtain impulse responses that could be seen as contrary to BGW's assertion that a constant federal funds rate represents a neutral monetary policy. When the rate is held constant in the face of an oil price shock, nominal GDP is higher, as are real GDP, commodity prices, and the price level—all of which are consistent with accommodative monetary policy. In addition, we find the response to oil price shocks appears more quickly in real GDP and commodity prices than it does in the overall price level.

The magnitude of the responses may provide a glimpse of how monetary policy responded to past oil price shocks. In particular, a constant nominal GDP suggests that the Federal Reserve maintained a generally neutral monetary policy. As Koenig (1995) remarks, "That a large fraction of the business cycle can be attributed to supply shocks may mean not that monetary policy is ineffective, but that the Federal Reserve has been doing its job."

NOTES

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1 The different definitions of neutrality need not be mutually exclusive. Koenig (1995) shows that when utility is logarithmic in consumption, the optimal policy would be for the monetary authority to target a geometric weighted average of output and the price level. Such a policy encompasses rules proposed by Hall (1984) and Taylor (1985). In the realistic special case where the market-clearing level of employment is independent of productivity, it is optimal for the monetary authority to target nominal spending.

[2] See Barro (1984) and Gordon (1998).

[3] Some have argued that Federal Reserve policy has changed over this estimation period. See Balke and Emery (1994). We follow BGW and allow for no structural changes in policy. Estimates using post-1982 data yield substantially similar results.

[4] Our ordering follows BGW. We also experimented with an ordering where oil prices were placed first in the model. The results were almost identical.

[5] Because we couldn't calculate variance decompositions with both oil price variables in the model, we calculated two sets of variance decompositions, one with the Hamilton net oil price and one with first differences of the log of oil prices. The two sets were almost identical. Table 1 presents the results with the Hamilton net oil price in the model.

[6] To estimate the impulse responses to a change in oil prices, we need to simultaneously generate impulses in both the oil price and the Hamilton net oil price. To accomplish this task, we use an identity equation that creates impulses in the Hamilton net oil price from impulses in oil prices.

[7] Oil prices are included in the commodity price index.

[8] This result led us to run a model without commodity prices to see if oil prices became a larger source of shock. We do not report any results here because the model was very unstable.

[9] Use of an identity equation to generate impulses in the Hamilton oil price from impulses in oil prices prevents the estimation of confidence bands.

[10] The reported value is calculated on a constant-elasticity basis.

[11] In a test of sensitivity, we ran an unrestricted version of the BGW model and calculated significance bands around the impulses in the base case. The results were substantially similar to those shown here, and the impulse response of nominal GDP to an oil price shock was insignificant in the base case.

[12] We found substantially similar results with an unrestricted version of the BGW model.

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