Energy Prices and Aggregate Economic Activity: An Interpretative Study

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1. Introduction

A considerable body of economic research suggests that oil price fluctuations have figured prominently in national economic activity since World War II. In fact, rising oil prices preceded eight of the nine post-WWII recessions. But an acceleration of U.S. economic activity did not seem to follow the oil price declines that occurred from the early 1980s to the late 1990s. In addition, rising oil prices seemed to have less of an effect on economic activity over the past fifteen years than they did in the 35 years following World War II.

Beyond establishing a relationship between oil price movements and aggregate economic activity, research on the economic response to oil price shocks has gone in several directions. A number of studies have investigated why rising oil prices appear to retard aggregate economic activity by more than falling oil prices stimulate it. Other studies have investigated the channels through which oil price shocks are transmitted to economic activity, including the role of monetary policy. And several have examined the possibility of a weakening relationship between oil price fluctuations and aggregate economic activity.

In this paper, we survey the theory and evidence linking fluctuations in energy prices to aggregate economic activity. We then briefly examine the implications of this research for both monetary policy and energy policy in response to oil price shocks. Research seems to provide relatively reliable guidance for monetary policy. Because the precise channels through which oil

price shocks affect economic activity are only partially known, however, research offers less guidance about how energy policy should cope with oil price shocks.

2. Basic Theory and Evidence

The oil price shock of 1973 and the subsequent recession gave rise to a plethora of studies analyzing the effects of oil price increases on the economy. The 1973 recession was (at the time) the longest of the post-World-War-II recessions, and it gave new gravity to the oil-macroeconomy relationship. The early studies included Pierce and Enzler (1974), Rasche and Tatom (1977), Mork and Hall (1980), and Darby (1982), all of which documented and explained the inverse relationship between oil price increases and aggregate economic activity.

Later empirical studies—such as, Gisser and Goodwin (1986) and the Energy Modeling Forum-7 study documented in Hickman et al. (1987)—confirmed the inverse relationship between oil prices and aggregate economic activity for the United States. Darby (1982), Burbidge and Harrison (1984), and Bruno and Sachs (1982, 1985) documented similar oil-price-economy relationships for countries other than the United States. Hamilton (1983) made a definitive contribution by extending the analysis to show that all but one of the post-World-War-II recessions were preceded by rising oil prices, and that other business cycle variables could not account for the recessions.[1]

In an extensive survey of the empirical literature, Jones and Leiby (1996) find that the estimated oil price elasticity of GNP in the early studies ranged from -0.02 to -0.08, with the estimates consistently clustered around -0.05. Tobin (1980) thought the estimated effects seemed too high to be consistent with a classic supply shock, but Jones and Leiby (1996) argue that

values around -0.05 are in the ballpark for output elasticities that are roughly equal to factor shares. After the 1973 oil-price shock, oil's share in GNP was around 4-6 percent.

Several different channels have been proposed to account for the inverse relationship between oil price movements and aggregate U.S. economic activity. The most basic is the classic supply-side effect in which rising oil prices are indicative of the reduced availability of a basic input to production. Other explanations include income transfers from the oil-importing nations to the oil-exporting nations, a real balance effect and monetary policy. Of these explanations, the classic supply-side effect best explains why rising oil prices slows GDP growth *and* stimulates inflation.

2.1 A Classic Supply-Side Shock

Rising oil prices can be indicative of a classic supply-side shock that reduces potential output, as in Rasche and Tatom (1977 and 1981), Barro (1984) and Brown and Yücel (1999). Rising oil prices signal the increased scarcity of energy which is a basic input to production. Consequently, the growth of output and productivity are slowed. The decline in productivity growth lessens real wage growth and increases the unemployment rate at which inflation accelerates. If consumers expect the rise in oil prices to be temporary, or if they expect the near-term effects on output to be greater than the long-term effects, they will attempt to smooth out their consumption by saving less or borrowing more which boosts the equilibrium real interest rate. With slowing output growth and an increase in the real interest rate, the demand for real cash balances falls, and for a given rate of growth in the monetary aggregate, the rate of inflation increases. Therefore, rising oil prices reduce GDP growth and boost real interest rates and the

measured rate of inflation.[2]

If wages are nominally sticky downward, the reduction in GDP growth will lead to increased unemployment and a further reduction in GDP growth—unless unexpected inflation increases as much as GDP growth falls. The initial reduction in GDP growth is accompanied by a reduction in labor productivity. Unless real wages fall by as much as the reduction in labor productivity, firms will lay off workers, which will generate increased unemployment and further GDP losses. If wages are nominally sticky downward, the only mechanism through which the necessary wage reduction can occur is through unexpected inflation that is at least as great as the reduction in GDP growth.[3]

2.2 Income Transfers and Aggregate Demand

The shift in purchasing power from oil-importing nations to oil-exporting nations that results from rising oil prices is another avenue through which oil price shocks could affect economic activity, as emphasized by Fried and Schulze (1975) and Dohner (1981). The shift in purchasing power reduces consumer demand in the oil-importing nations and increases consumer demand in the oil-exporting nations, but the latter increase is less than the reduction in consumer demand in the oil-importing nations. On net, world consumer demand for goods produced in the oil-importing nations is reduced, and the world supply of savings is increased. The increased supply of savings puts downward pressure on real interest rates which can partially offset to more than offset the upward pressure on real rates that comes from consumers in the oil-importing nations attempting to smooth their consumption. The downward pressure on world interest rates should stimulate investment that offsets the reduction in consumption and leaves aggregate

demand unchanged in the oil-importing countries.

If prices are sticky downward, however, the reduction in consumption spending for goods produced in oil-importing countries will further reduce GDP growth. The reduction in consumption spending necessitates a lower price level to yield a new equilibrium. If the price level cannot fall, consumption spending will fall by more than investment increases.[4] Consequently, aggregate demand will fall, further slowing economic growth worldwide, but Horwich and Weimer (1984) conclude the net effect is smaller than previously suggested. Monetary and/or fiscal policy can be used to stimulate demand sufficiently in the oil-importing countries that the price reduction is unnecessary to restore equilibrium.

2.3 The Real Balance Effect

As discussed in Mork (1994), the real balance effect was the first explanation of how an oil price shock affects aggregate economic activity. According to Pierce and Enzler (1974) an increase in oil prices would lead to increased money demand. The failure of the monetary authority to meet growing money demand with increased supply would boost interest rates and retard economic growth.

2.4 The Possible Role of Monetary Policy

Although the role of monetary policy was prominent in early explanations of how oil price shocks affect real economic activity, it was gradually supplanted by real business cycle theory.[5] Nonetheless, an apparent breakdown in the relationship between oil and the economy during the 1980s and 1990s led researchers to question the pure supply shock models and to probe

additional channels through which oil could affect the economy. Induced change in monetary policy was one such channel.

To some extent, monetary policy can shape how an oil price shock is experienced. If the monetary authorities act to hold the growth of nominal GDP constant, the inflation rate will accelerate at the same rate at which real GDP growth slows. To the extent there is monetary illusion or other market imperfections, an accommodative (restrictive) monetary policy will partially offset (intensify) the losses in real GDP while it increases (reduces) inflationary pressure. In the absence of monetary illusion or other market imperfections, however, monetary policy will feed directly to changes in inflation without any real effects.

If the oil price shock boosts the real interest rate (as described above), the velocity of money will increase, and the monetary authorities will have to reduce the growth rate of the monetary aggregate through further increases in the interest rate to hold the growth rate of nominal GDP constant. If the monetary authorities hold the growth rate of the monetary aggregate constant while its velocity increases, the growth in nominal GDP will accelerate, and inflation will rise by more than GDP growth slows. If the monetary authority acts to hold the real interest rate constant, growth of the monetary aggregate will accelerate, and the rate of inflation will be increased. If the oil price shock does not affect the real interest rate, however, a constant interest rate and unchanged rates of growth in nominal GDP and the monetary aggregate could all be achieved through the same monetary policy.[6]

Bohi (1989, 1991) and Bernanke, Gertler and Watson (1997) argue that contractionary monetary policy accounts for much of the decline in aggregate economic activity following an oil price increase. Bohi analyzes disaggregated industry data for four countries after each energy

shock in the 1970s and finds no relationship between industry activity and energy intensity and no consistent impact of the oil price shocks. He concludes that the obvious explanation of the negative impact of higher prices on output is tight monetary policy. He observes that monetary policy was tightened in each country considered (except Japan) after the oil price shocks. However, he also notes that the oil price shocks occurred at a time when most countries were battling against inflation and were probably pursuing tight monetary policies anyway.

Bernanke, Gertler and Watson (hereafter BGW) show that the U.S. economy responds differently to an oil price shock when the federal funds rate is constrained to be constant than in the case in which monetary policy is unconstrained. In the unconstrained case, a positive oil price shock leads to an increase in the federal funds rate and a decline in real GDP. 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. The difference in the response of real GDP between the two cases shows that it is monetary policy's response to oil price shocks which accounts for the fluctuations in aggregate economic activity.

In a more recent effort, Hamilton and Herrera (2000) revisit the BGW analysis and conclude that the potential for monetary policy to avert contractionary consequences is not as great as suggested in the BGW analysis. By using longer lag lengths than BGW, Hamilton and Herrera show that oil price shocks have a substantially larger direct effect on the real economy. Moreover, with longer lag lengths, even when the federal funds rate is kept constant (BGW's measure of neutral monetary policy), an oil price shock still yields a sizable reduction in output, implying that monetary policy has little effect in easing the real consequences of an oil price

shock.

Several other studies also suggest monetary policy has a less than central role in transmitting oil price shocks. Ferderer (1996) provides evidence that counter-inflationary monetary policy was partly responsible for the real effects of oil price shocks in 1970 to 1990. He includes the federal funds rate and nonborrowed reserves in his model to assess the effect of monetary policy. He shows that monetary policy became more restrictive following oil price changes during the estimation period, but that oil price shocks had a stronger and more significant impact on real activity than monetary policy. Similarly, Davis and Haltiwanger (1998) show that the effect of oil price shocks on employment growth has been twice that of monetary policy shocks.

Taking a somewhat different approach, Brown and Yücel (1999) argue that U.S. monetary policy has been, in fact, neutral in response to past oil price shocks. Using impulse responses based on a VAR model, they find that an oil price shock leads to a decline in real GDP, increases in the federal funds rate and other interest rates, and an increase in the price level. The responses provide a glimpse of how monetary policy responded to past oil price shocks. The decline in real GDP and the rise in the deflator are similar in magnitude. Consequently, nominal GDP remains constant, which satisfies Gordon's definition of monetary neutrality.[7]

Furthermore, Brown and Yücel dispute the claim that a constant federal funds rate necessarily represents a neutral monetary policy response to an oil price shock. When the federal funds rate is held constant in a counterfactual experiment following an oil price shock (as in BGW), Brown and Yücel obtain impulse responses showing that real GDP, the price level and nominal GDP are all higher—a finding that is consistent with Gordon's definition of

accommodative monetary policy.

Nonetheless, oil price shocks increase the potential for errors in monetary policy. In particular, when rising oil prices reduce GDP growth, a counter-inflationary monetary policy could contribute to the slowing of the growth of nominal GDP. If wages are nominally sticky downward, real wages would fail to fall with reduced productivity. Consequently, unemployment would rise, aggregate consumption would fall, and GDP growth would be slowed beyond that which would arise directly from the supply shock. Similar results are obtained if the monetary authority keeps interest rates too high as savings increases, and investment fails to increase enough to offset the decrease in consumption spending.

2.5 Sorting Through the Basic Theories

Of the explanations offered for the inverse relationship between oil price shocks and GDP growth, a classic supply-side shock best explains the facts. It can also explain the positive relationship between oil price shocks and measured increases in inflation. Taken alone, neither the real balance effect nor monetary policy can yield both slowing GDP growth *and* increased inflationary pressure. Income transfers can explain both phenomena only to the extent that monetary policy partially offsets the reduction in aggregate demand.

3. Asymmetry and a Disappearing Relationship

During the 1980s and 1990s it became increasingly apparent that U.S. economic activity responded asymmetrically to oil price shocks. That is, rising oil prices seemed to retard aggregate U.S. economic activity by more than falling oil prices stimulated it. All but one of the post-

World-War-II recessions have followed a sharp rise in oil prices. Yet, an acceleration of U.S. economic activity did not follow the oil price declines that occurred over the past two decades.

The seeming breakdown in the relationship between oil and the economy led researchers to explore different oil-price specifications in an attempt to reestablish the oil-output relationship. When Mork (1989) did not find a significant relationship between oil and GDP, he separated out oil price changes into negative and positive oil price changes, and reestablished a significant relationship between oil prices and GDP.

In follow up studies, Mory (1993) followed Mork and separated the oil price into negative and positive oil price changes and found that the positive oil price shocks Granger-caused the macroeconomic variables, but that negative shocks did not. He also checked for Granger causality at the 2-digit SIC level and found similar asymmetry. Mork, Olsen and Mysen (1994) found asymmetry for seven industrialized countries. Lee, Ni and Ratti (1995) also found asymmetry between the effects of positive and negative oil price shocks, which they attributed in part to price uncertainty. Ferderer (1996) found that increases in oil prices explained more than twice the variation of industrial production growth than did decreases.

Others argued that the persistence of oil price movements combined with asymmetry were necessary to explain the relationship between oil price movements and economic activity. Hamilton (1996 and 1999) proposed his now renowned "net oil price," and found a statistically significant and stable negative relationship with output.[8] Davis and Haltiwanger (1998) constructed another oil price series that combines asymmetry and persistence.[9]

Classic supply-side effects cannot explain asymmetry. Accordingly, a number of studies emphasize other channels through which oil prices may affect economic activity. Monetary

policy, adjustment costs, and asymmetry in petroleum product prices have been offered as possible explanations for the asymmetry.

3.1 Monetary Policy and Asymmetry

Monetary policy is a possible explanation for the asymmetric response of the economy to oil price shocks. If wages are nominally sticky downward but not upward, monetary policy can have asymmetric effects. When oil prices rise, wages that are sticky downward will aggravate GDP losses if the monetary authority fails to hold nominal GDP constant through unexpected inflation. When oil prices fall, however, real wages must rise to clear the markets. Because nominal wages can adjust upward freely, a monetary policy that fails to hold nominal GDP constant through unexpected disinflation need not be stimulative.

Tatom (1988, 1993) and BGW provide some evidence that monetary policy is a contributing factor in asymmetry. Tatom finds that the apparent asymmetric response of U.S. economic activity to oil price shocks disappears when the stance of monetary policy or changes in the misery index (which combines unemployment and inflation rates) are taken into account. BGW's finding that monetary policy is a channel through which oil prices affect economic activity combined with their use of Hamilton's net oil price, which is an asymmetric measure of oil prices, is consistent with a monetary explanation for asymmetry.

In contrast, Ferderer (1996) shows that monetary policy cannot account for the asymmetry in his model. Balke, Brown and Yücel (1999) also show that the Federal Reserve's response to oil price shocks is not the cause of asymmetry. They find that the asymmetry does not go away—and is in fact enhanced—when either the fed-funds rate is held constant or the fed-

funds rate and expectations of the fed-funds rate are held constant. Hence, monetary policy does not appear to be the sole cause of asymmetry on the real side.

3.2 Adjustment Costs

Adjustment costs could lead to an asymmetric response to changing oil prices, as first argued by Hamilton (1988). Rising oil prices retard economic activity directly, and falling oil prices stimulate economic activity directly, but the costs of adjusting to changing oil prices also retard economic activity. Rising oil prices would present two negative effects for economic activity. Falling oil prices would present both negative and positive effects, which would tend to be offsetting. Adjustment costs could arise either from sectoral imbalances, coordination problems between firms, or because the energy-to-output ratio is embedded in the capital stock.

Lilien (1982) and Hamilton (1988) examine how changes in oil prices create sectoral imbalances by changing the equilibrium relationship between the sectors. For example, rising (falling) oil prices would require a contraction (expansion) of energy-intensive sectors and an expansion (contraction) of the energy-efficient sectors. These realignments in production require adjustments that cannot be achieved in the short run, as in Kydland and Prescott (1982). The consequence is rising unemployment and the underutilization of resources whenever oil prices rise or fall.

Huntington (2000) examines how coordination problems associated with changing oil prices might affect economic activity. Each firm understands how changing oil prices affect its own output and pricing decisions, but it lacks the information to know how other firms will respond to changes in oil prices. As a consequence, firms have difficulty adjusting to each others'

actions and economic activity is disrupted whenever oil prices rise or fall. According to Huntington, the coordination problem should be considered an externality.

Atkeson and Kehoe (1999) examine how putty-clay technology (that is, technology in which the energy-to-output, capital-to-output, and labor-to-output ratios can be varied over the long run but cannot be changed in the short run because they are embedded in the capital stock) affects the economic response to changing oil prices. In order for firms to alter their energy-to-output ratios in response to changing energy prices, they must change the capital stock—selecting capital that yields a lower (higher) energy-to-output ratio and higher (lower) capital-to-output and labor-to-output ratios when energy is more (less) expensive. The consequence would be slow adjustment and a disruption to economic organization whenever energy prices change with a greater impact in the near term than the long term.

As explained by Ferderer (1996), uncertainty about future oil prices can also adversely affect economic activity by reducing investment demand. Bernanke (1983) demonstrates that firms will find it increasingly desirable to postpone irreversible investment decisions when they are more uncertain about future oil prices. If the energy-to-output ratio is embedded in capital, the firm must irreversibly choose the energy-intensity of its production process when purchasing its capital. As uncertainty about future oil prices increases, the value of postponing the investment decision increases, and the net incentive to invest decreases. Uncertainty about future oil prices increases with either rising or falling oil prices.

3.3 The Examination of Adjustment Costs

Although asymmetry is now fairly well accepted, relatively few studies have attempted to

determine empirically through what channels (other than monetary policy) oil price shocks might yield an asymmetric response in aggregate economic activity. Work by Loungani (1986); Davis (1987); Lee et al. (1996); Davis, Loungani and Mahidhara (1997); and Davis and Haltiwanger (1998) support but do not directly test Hamilton's adjustment-cost explanation.

Loungani (1986) found that oil price shocks led to a labor reallocation that increased the unemployment rate. Davis, Loungani and Mahidhara (1997) find that negative shocks have a greater effect on state-level unemployment than positive shocks of the same magnitude. Lee, Ni and Ratti also consider sectoral shifts to be consistent with their findings of insignificant response of the economy to oil price declines. When oil prices decline, the sectoral resource reallocation has negative employment and output effects that offset positive supply-side effects.

Davis and Haltiwanger (1998) assess whether oil price shocks affect economic activity through aggregate channels (such as, potential output, income transfers or sticky wage effects) or through allocative channels (such as, altering the match between the desired and the actual distributions of labor and capital). They posit that if oil price shocks are transmitted only through aggregate channels, then employment should respond in a roughly symmetric manner to oil price ups and downs. They look at sectoral job creation and destruction at the plant level from 1972 to 1988. They find that employment growth shows a sharply asymmetric response to oil price ups and downs, working through both the aggregate and allocative channels.

Davis and Haltiwanger show that employment effects are large and negative in response to an oil price increase because both channels work to reinforce each other, while with an oil price decline, the aggregate and allocative channels work in opposite directions canceling out the employment effects. They find that the employment response to an oil price increase rises in

magnitude with capital intensity, energy intensity and product durability. They also find that job destruction shows much greater short-run sensitivity to oil shocks than job creation.

Balke, Brown and Yücel (1999) find significant asymmetric output and interest rate responses to oil price shocks, with the transmission through the market interest rate. They find strong asymmetry in the output response and, in particular, a strikingly similar negative response of output to both positive and negative oil price changes in the short run, which is similar to Mork (1994) and Davis and Haltiwanger (1998). Such findings are consistent with the explanation that oil price shocks necessitate costly adjustment (either inter-sectoral or intra-sectoral as emphasized by Davis and Haltiwanger), or sticky downward wages and/or prices (as emphasized by Mork). Balke, Brown and Yücel also show that oil prices affect both the federal funds rate and the market interest rate asymmetrically.

One explanation for the movements in interest rates is that the asymmetric response of short-term market rates is just a reflection of the asymmetric response of the fed-funds rate through the term structure. Alternatively, interest rates may simply be moving in anticipation of the real effects of oil price changes. Additionally, interest rates may reflect increased financial stress brought about by oil price shock. For example, in the "financial accelerator" model of Bernanke, Gertler and Gilchrist (1996), an adverse shock increases the likelihood of bankruptcy and default on loans, raising the costs of external finance, making it more difficult for firms to obtain loans from financial intermediaries. This results in a "flight to quality" with credit worthy firms being able to go to the commercial paper market while other firms would see the cost of external financing rise.

3.4 Petroleum Product Prices

Petroleum product prices may also contribute to an asymmetric relationship between crude oil prices and economic activity. Public scrutiny of gasoline markets has led to the view that petroleum product prices respond asymmetrically to crude oil prices. Research provides econometric support for public claims that gasoline prices rise more quickly when crude oil prices are rising than they fall when crude prices are falling. Bacon (1991) finds asymmetry for the U.K. gasoline market. Karrenbock (1991); Borenstein, Cameron, and Gilbert (1997); and Balke, Brown, and Yücel (1998) all find some evidence for an asymmetric response in U.S. gasoline markets.

Huntington (1998) translated the findings of asymmetry in petroleum product prices into a possible explanation for the asymmetric relationship between crude oil prices and aggregate economic activity. He finds that the economy responds symmetrically to changes in petroleum product prices, but that petroleum product prices themselves respond asymmetrically to crude oil prices. The result is an asymmetric relationship between crude oil prices and the aggregate economic activity. Huntington also finds that inflation responds symmetrically to crude oil prices. No follow-up studies have examined Huntington's findings.

4. A Further Changing Relationship

Although the relationship between oil prices and economic activity seemed fairly robust and reasonably well understood by the mid-1990s, the relationship may have weakened in the latter part of the 1990s. Persistent upward movements in oil prices in the late 1990s and early 2000s had less measured effect on economic activity.[10]

Rising oil prices led increases in the unemployment rate from the early 1970s through the early 1990s. Unemployment also declined with oil prices from 1982 through 1990 and in the late 1990s. Loungani and Yücel (2000) found the relationship weakened in the late 1990s, however. Updating a previous study by Carruth, Hooker and Oswald (1998) to include data through 2000, Loungani and Yücel find that, although the relationship between oil prices and unemployment holds in the updated sample, the model does not explain the low unemployment rates experienced in the late 1990s very well.

The data also show a weaker relationship between rising oil prices and core inflation.[11] Hooker (1999) reevaluated the oil price-inflation relationship in a Phillips-curve framework. He found that since about 1980, oil price changes seem to affect inflation mostly through their share in the price index, with little or no pass-through into core measures. By contrast, oil shocks contributed substantially to core inflation prior to 1980. Hooker attributes this result partially to the fact that monetary policy in the Volcker-Greenspan era was significantly less accommodative of oil price shocks and so no longer triggered expectations of higher inflation.

Nevertheless, rising oil prices seem to lead to higher interest rates, which is an expected consequence of supply side shocks that have greater near-term effects than long-term effects. Brown and Yücel (1999) suggest that some of the increases in the U.S. federal funds rate that occurred in 1999 and 2000 may have been part of a general increase in interest rates that results from higher oil prices. To the extent the Federal Reserve did not allow the federal funds rate to rise with these increases in market interest rates, inflation would be greater and more evident in the core.

A number of factors may contribute to a weakening relationship between oil prices and

economic activity. The energy-consumption-to-GDP ratio has declined.[12] On this basis alone, Brown and Yücel (1995) estimate that the supply-side effects on the U.S. economy might have been about one-third less sensitive to oil price fluctuations in 2000 than when oil prices were at their height in the early 1980s, and about one-half as sensitive than in the early 1970s. In addition, Loungani and Yücel (2000) and Brown (2000) show that higher energy prices are partly due to the strength of the current expansion, which they tentatively conclude makes the rise in energy prices less disruptive. In addition, the expansion (which started in 1991) has been marked by strong productivity gains that may have obscured the relationship between oil prices and aggregate economic activity. Another possibility is that prior experience with energy-price shocks may have improved the conduct of monetary policy or reduced the costs of adjusting to rising oil prices.

5. Some Policy Implications

A neutral monetary policy will not aggravate the economic effects of an oil price shock, nor will it offset them. The available research suggests that neutral policy is achieved when the monetary authorities hold the growth rate of nominal GDP constant in response to an oil price shock.[13] As it reduces real GDP, a classic supply-side shock reduces labor productivity. Unless real wages fall by as much as the reduction in labor productivity, firms will lay off workers which will generate increased unemployment and aggravate GDP losses. If wages are nominally sticky downward, the only mechanism through which the necessary wage reduction can occur is through unexpected inflation that is at least as great as the reduction in GDP growth.

Beyond taking a neutral stance, monetary authorities can shape how an oil price shock is

experienced. If the monetary authority acts to prevent inflation (and wages are sticky downward), unemployment and the slowdown in real GDP growth will be greater. If the monetary authority acts to offset the losses in real GDP through accommodative policy, inflation will accelerate, and the offsetting gains in GDP growth will be temporary.

With the possible exception of monetary policy, the available research seems to provide only rough guidance to policymaking. In particular, policymakers must know through which channels oil price shocks affect economic activity before they can develop further policies that enhance economic well being. If oil price shocks affect economic activity primarily through direct supply-side effects and allocative effects against which the private sector can take appropriate steps to insulate themselves from the consequences, little policy action beyond sustaining a neutral monetary policy would seem to be necessary. If, on the other hand, the monetary authority routinely errs when confronted with oil price shocks or the economy suffers coordination externalities, policymakers can improve economic welfare by adopting policies that reduce the economy's vulnerability to oil price shocks.

To the extent that policy intervention is appropriate, a variety of means are available to reduce U.S. vulnerability to oil price shocks. These means include reducing exposure to volatile world oil prices through reduced oil imports and the development and use of a strategic petroleum reserve.[14] Given that oil price volatility seems harmful to economic activity, consideration might be given to using the strategic petroleum reserve to lean against the winds of world oil prices—purchasing oil when prices are low and selling it when prices are high.

Similarly, higher taxes on petroleum products or taxes that varied inversely with world oil prices would reduce the oil price volatility that is transmitted domestically. Because the

consumers would see smaller price movements, such actions would make oil demand more inelastic from OPEC's perspective. To the extent that many oil-importing countries adopted such taxation schemes, the volatility of world oil prices would be increased.

In the end, policymaking would be better informed if we developed a better understanding of why the economy seems to have grown less sensitive to oil price shocks. If monetary policy has improved or coordination problems have been reduced, less policy intervention to reduce vulnerability would seem to be needed. A diminution of the basic supply-side effect or strong gains in productivity that overwhelm the oil-economy relationship are unlikely to have similar implications.

6. Conclusions

Both economic theory and the empirical evidence link rising oil prices to real GDP losses. The sensitivity of the U.S. economy to oil price shocks seems to have decreased over the past two decades however. Economic theory suggests a number of channels that could contribute to an inverse relationship between oil prices and economic activity. The most basic is the classic supply-side effect in which rising oil prices are indicative of the reduced availability of a basic input to production. Other channels include shifting demand, monetary policy and adjustment costs. Of these channels, a classic supply-side effect best explains both slowing output growth and rising inflation.

Considerable research finds that oil price shocks work through supply-side effects and adjustment costs. Both contribute to GDP losses. Counter-inflationary monetary policy can aggravate the losses, and some empirical research suggests that it has. Other studies suggest that

monetary policy has been neutral or has erred toward accommodating inflationary pressures.

Over the past decade, an increasing volume of research finds that rising oil prices seem to retard aggregate U.S. economic activity by more than falling oil prices stimulate it. Numerous explanations—ranging from monetary policy and downward sticky nominal wages, to a variety of allocative effects—have been offered for the asymmetry. These allocative effects include coordination problems, the costs of adjusting capital when the energy-to-output ratio is embedded in capital and uncertainty.

Most of the empirical research has been confined to documenting the asymmetry. A few studies, have attempted to investigate the channels through which asymmetry is generated. Davis and Haltiwanger (1998) find evidence that allocative effects contribute to the asymmetry. No study has attempted to determine which of several possible allocative effects are at work.

Balke, Brown and Yücel (1999) find that it is unlikely that monetary policy or downward sticky nominal wages have contributed to asymmetry. Under neutral to accommodative monetary policy, asymmetry cannot arise from either source. They do find that asymmetry is anticipated by the financial markets, however.

The available research provides a reasonably clear blueprint for achieving neutral monetary policy in response to an oil-price shock. Research further suggests that to the extent that energy policy intervention is appropriate to reduce vulnerability, policy should take the form of leaning against the winds of world oil price movements to reduce volatility.

Research provides less guidance about the exact channels through which oil price shocks affect economic activity. Consequently, it remains unclear whether the private sector is capable of providing the optimal level of insurance against price shocks. To us, this suggests that

considerably more research must be conducted before economics can provide sound guidance as to how much policymakers should act to reduce vulnerability to oil price shocks.

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Notes

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1. In contrast, Kim and Lougani (1992) show that energy shocks can only account for a modest amount of GNP fluctuations in their model.

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

3. The necessary change in inflation can be accomplished through a monetary policy that holds the growth of nominal GDP constant. See Koenig (1995).

4. A similar result can be obtained if the monetary authority holds interest rates too high in the face of increased savings, and sufficient investment does not materialize to offset the decrease in consumption spending.

5. See Mork (1994).

6. An unchanged growth rate of nominal GDP, an unchanged growth rate of the monetary aggregate, and a constant federal funds rate have been variously suggested as definitions of neutral monetary policy.

7. Gordon (1998) suggests that monetary neutrality occurs when the monetary authority adjusts policy to hold nominal GDP constant.

8. The net-oil-price variable compares the price of oil each quarter with the maximum value observed during the preceding year. If the values for the current quarter exceed the previous year's maximum, the percentage change over the previous year's maximum is the oil-price value. If the price of oil in quarter *t* is lower than it had been at some point during the previous year, the series is defined to be zero for date *t*.

9. They constructed an oil shock index which is the log of the ratio of the current real oil price divided by a weighted average of prices in the prior 20 quarters with weights that sum to one and decline linearly to zero. Both the oil shock index and its absolute change are included in their VARs.

10. Hooker (1996) found that oil prices Granger caused a variety of macroeconomic variables before 1973 but not after 1973. In response, Hamilton (1996) devised his "net oil price" variable to reflect persistent oil price increases. Using this variable, Hamilton showed the relationship between oil prices and GDP growth was robust from 1948 to 1994.

11. This measure of inflation is thought to provide a better signal of underlying inflationary pressure because it is less susceptible to the fluctuations associated with food and energy prices.

12. This development is not new. The largest declines in energy consumption per dollar of GDP came during the 1970s through early 1980s when oil prices were rising rapidly. The declines slowed after oil prices collapsed in 1986.

13. See Koenig (1995).

14. Brown (1982), Griffin and Steele (1986) and Leiby and Bowman (2001) examine a variety of options for reducing U.S. vulnerability to world oil supply disruptions.