OIL PRICE SHOCKS AND THE MACROECONOMY: WHAT HAS BEEN LEARNED SINCE 1996

Donald W. Jones,† Paul N. Leiby,†† and Inja K. Paik ‡

†RCF Economic & Financial Consulting, Inc.
333 N. Michigan Ave., Ste 804
Chicago, IL 60601
U.S.A.

†† Environmental Sciences Division
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6205
U.S.A.

‡ Office of Policy and International Affairs
U.S. Department of Energy
1000 Independence Avenue, PI-25
Washington, D.C. 20585
U.S.A.

Revised Draft
June 25, 2003
(Forthcoming in *The Energy Journal*)

ABSTRACT

This paper reports on developments in theoretical and empirical understanding of the macroeconomic consequences of oil price shocks since 1996, when the U.S. Department of Energy sponsored a workshop summarizing the state of understanding of the subject. Four major insights stand out. First, theoretical and empirical analyses point to intra- and intersectoral reallocations in response to shocks, generating asymmetric impacts for oil price increases and decreases. Second, the division of responsibility for post-oil-price shock recessions between monetary policy and oil price shocks, has leaned heavily toward oil price shocks. Third, parametric statistical techniques have identified a stable, nonlinear, relationship between oil price shocks and GDP from the late 1940s through the third quarter of 2001. Fourth, the magnitude of effect of an oil price shock on GDP, derived from impulse response functions of oil price shocks in the GDP equation of a VAR, is between -0.05 and -0.06 as an elasticity, spread over two years.

1. Introduction[1]

The macroeconomics of oil price shocks has had a rich intellectual history since the mid-1970s. The early theoretical investigations focused on the traditional, aggregate channels of supply shocks and demand adjustments (Pierce and Enzler 1974, Bruno and Sachs 1982), while the early empirical studies generally regressed GDP on oil prices and several other variables (Rasche and Tatom 1977a, 1977b). Darby (1982) noted that the 1973 oil price shock was not a "clean experiment," as the world was just emerging from the international monetary arrangements established by the Bretton Woods agreement, and the United States in particular from a period of generalized price controls. Ambiguities of the sort Darby noted have continued to make oil price shocks intriguing events for macroeconomists.

In 1983, James Hamilton published an influential article demonstrating that an oil price increase had preceded (Granger-preceded, to be more precise) all but one recession (that in 1960) in the United States since the end of World War II. This finding had the effect of diffusing the spotlight on the 1973 and 1979-80 oil price shocks and expanding researchers' attention to the entire post-war period. Gisser and Goodwin (1986) reinforced Hamilton's findings for the United States, and Burbidge and Harrison (1984) found mixed but overall reinforcing evidence from the United Kingdom and Japan as well as the United States.

Around the same time in the late 1980s, Douglas Bohi (1989) and Knut Anton Mork (1989), in independent research, began re-scrutinizing the relationship between oil prices and GDP, Bohi with a focus on microeconomic mechanisms and Mork keying on the weaker oil price-GDP relationship Hamilton's article reported toward the end of the 1970s. To test for asymmetric effects of oil price increases and decreases, Mork separated the oil price variable into upward and downward movements. The rationale (Gilbert and Mork (1986) and Mork (1989)) was that while price movements up and down have opposite and symmetric effects on the production possibility frontier, any oil price change, regardless of direction, causes some costly resource reallocation. Consequently those two effects worked against, and could largely offset, each other when oil prices fell while they operated in the same direction when oil prices increased. This asymmetric oil price improved the statistical fit of the oil price-GDP relationship through the middle of the 1980s and provided both a vehicle for further empirical study and a relatively unfilled box for micro-foundation theory to fill.

Empirical and theoretical research continued apace in the early 1990s, but was unable to put to rest the potential conflation of oil price shocks and monetary policy and the continued statistical variability of the oil price-GDP relationship. The U.S. Department of Energy targeted research at several of these issues that had arisen regarding the economic potency of oil price shocks, and had the results presented at the "Workshop on International Energy Security: Economic Vulnerability to Oil Price Shocks" in October 1996. Research presented there examined the stability of the oil price-GDP relationship, the division of responsibility for recessions between oil price shocks and other potential causes, and the microeconomic routes by which oil price shocks have their effect. While that research advanced the state of knowledge on each subject, questions still remained in each area.

First, by 1996 the issue of *how* oil price shocks affect the macroeconomy has moved into a relatively prominent position in business cycle research. The asymmetric effect of oil price increases and decreases on the aggregate economy was generally accepted and provided both subjects for research in business cycle mechanisms and opportunities for testing theories about those mechanisms. The need to explain the asymmetry in terms of specific channels or mechanisms has opened a new area of research in oil macroeconomics, with both theoretical and empirical contributions. The asymmetry in the impact of oil price shocks on GDP implies that the routes of effect go beyond the simple mechanisms that were originally envisioned, such as contractions and expansions in the availability of a resource shifting productive capacity or inflationary effects shifting aggregate demand.

Second, sophisticated empirical analysis has begun to be directed at the issue of whether the post-oil-shock recessions were attributable to the oil price shocks themselves or to monetary policy responding to those shocks. Since the late 1970s, a number of prominent macroeconomists have been skeptical that even large price shocks to a resource that accounts for only 3 percent of GDP could cause losses in GDP as large as those experienced in the United States and other industrialized countries in the ensuing recessions (e.g., Tobin 1980). Researchers have resorted to simulations of various types to study how oil price shocks and monetary policy might interact in the lead-up to a recession.

Third, in response to the apparent instability of the oil price-GDP relationship, a series of specifications of oil price changes was investigated. The price change specifications distinguished not only increases from decreases (Mork 1989), but also the relative magnitudes of increases (Hamilton 1996a), and the surprise content of shocks at different

[1] We thank Douglas Bohi, Stephen Brown, Steven Davis, James Hamilton, Mark Hooker, Knut Anton Mork, Hilary Smith, and Mine Yücel for conversations, discussions, and advice over a period of several years. They are blameless for what follows.

dates attributable to recent oil price volatility (Li, Ni, and Ratti 1995). These specifications improved the statistical fit of regressions of GDP changes on oil price changes and other macroeconomic variables, but did not entirely settle the question of whether a stable, long-term relationship between oil prices and prominent macroeconomic indicators existed.

Fourth, research on the magnitude of effect of oil price shocks on GDP has taken a back seat to the study of the mechanism, attribution, and stability issues described above. Nonetheless, the concept of "how much effect" continues to attract the interest of economists charged with making policy recommendations. The best estimate would be empirically based, derived from the impulse response functions of oil price shocks in the GDP equation of a vector autoregression (VAR).

While research up to 1996 advanced the state of knowledge on each of the above subjects, questions still remained in each area. This paper recounts the subsequent progress of understanding on these topics.[2] This paper also cover a small body of literature on the influence of oil prices and the impacts of oil price shocks on the stock market, and a new body of non-U.S. studies that has emerged recently.

2. Mechanisms of effect

The search for the routes by which oil price shocks work their way through the economy has had some important recent additions (although some studies have been available in preliminary versions for five years or longer). Two of these are primarily theoretical analyses (Rotemberg and Woodford 1996, Finn 2000), relying on aggregate models of the economy and connected with data by simulations. The others are empirical, two of which use highly disaggregated data on manufacturing plants (Davis and Haltiwanger 2001) and individual workers (Keane and Prasad 1996). These two disaggregated empirical studies shed light on the sectoral shocks transmission mechanism, formulated theoretically by Lilien (1982) and Hamilton (1988) and explored empirically by Loungani (1986). The other empirical studies examine supply-side and demand-side routes of impact (Lee and Ni 2002), interest rate routes (Balke, Brown and Yücel 2002), and interactions in the markets for refined petroleum products (Huntington 1998).

2.1 Theoretical Models of mechanisms

In purely theoretical studies, Rotemberg and Woodford (1996; R&W) and Finn (2000) develop simulation models of an aggregate economy intended to find mechanisms that will allow oil price shocks to have the magnitude of effect on output that is found empirically. R&W estimate that, empirically, a 10% innovation in the price of oil reduces output by 2.5%, 5 or 6 quarters later; but that their 1-sector model, with perfect competition, can yield only a ½% output reduction for that price increase. They note that, also empirically, real wages also fall by more than their model predicts, and infer that using a sticky-wage labor supply specification would not be the right mechanism by which to get their model to reduce output by the appropriate order of magnitude. Consequently they revise the perfect competition assumption.

In R&W's model, collusive capacity throughout the entire economy permits producers to raise mark-ups beyond what perfect competition would permit. An oil price shock lets them further increase mark-ups, depressing output. The magnitude and temporal pattern of output somewhat parallels the empirically observed path of output response to an oil price shock in an impulse response function, but not particularly closely in the details. However, relying on collusion for the entire five-fold difference in output response to an oil price shock between the purely competitive, aggregate model and the empirical estimate is not satisfying. We can conclude that variable mark-up responses might be important in some sectors, as one source of contribution among several to the magnitude of GDP responses to oil price shocks, but this remains to be tested by empirical investigation.

Finn's (2000) alternative specification of a similar aggregate model relies not on noncompetitive conditions, but attends to variations in the utilization rates for productive capital, which are a function of energy use. An oil price shock causes sharp, simultaneous decreases in energy use and capital utilization. The decline in energy use works through the representative firm's production function directly, reducing output and labor's marginal product. The fall in labor's marginal product reduces the wage and labor supplied. A permanent oil price rise propagates lower energy use, capital utilization and labor supply into the future. Working through the production function, these reductions depress capital's future marginal product, causing both present and future reductions in investment and capital stock. The oil price increase's effects on output and wages are "potentially significant" and long-lived, even if energy's output share is low. Simulated responses of value added and real wages from Finn's model track the responses of those two

[2] Other reviews of this subject have addressed the early years of this research, going back to the mid-1970s (Mork 1994, Brown and Yücel 2002), so we have dealt minimally with the pre-1996 research in this examination of current understandings.

variables in U.S. data (1947-80) from R&W. The mechanism she uses to obtain output responses that are in line quantitatively with empirical estimates is reasonable and could contribute to the sectoral differences in input reallocations that are the core of the sectoral shifts transmission mechanisms.

In summary, the search for mechanisms by which oil price shocks alter macroeconomic output reveals that one must look beyond highly aggregated, competitive models with full factor employment. The combined impression conveyed by the two highly disaggregated empirical studies discussed above is one of extensive reallocation of labor following an oil price shock. Much of this costly reallocation occurs at the 4-digit SIC level and consequently remains invisible in more aggregated, 3-digit data such as those used by Bohi in his critical 1989 study. Mechanisms involving the reallocation of capital, or revision of investment plans, are not addressed in these empirical studies of the labor market, but are implicit. Finn's capital utilization-energy connection offers a clear route for those adjustments across sectors, and is worthy of further testing. At the same time, these results on mechanisms of effect imply that "estimating" oil price-GDP elasticities from one-sector simulation models, even large ones such as the FRB or OECD models, which exclude the allocative channels of response, will necessarily understate those elasticities.

2.2 The labor market

Turning to the empirical studies, Davis and Haltiwanger (2001; D&H) is a revision of their study for the 1996 DOE Conference. D&H draw on an empirical base of quarterly, plant-level Census data from 1972:2 to 1988:4 on employment, capital per employee, energy use, age and size of plant, and product durability, at the four-digit SIC level. They used vector autoregressions to examine the response of job creation and destruction (hirings and terminations) to separately defined, positive and negative oil price shocks–i.e., oil price increases and decreases.

D&H's examination of job creation and destruction distinguishes between aggregate (potential output, income transfer, and wage stickiness) and allocative (closeness of match between desired and actual factor input levels across firms, sectors, and regions) transmission mechanisms. Their test for distinguishing the operation of these channels relies on response patterns of job creation and destruction to oil price changes. Aggregate channels would increase job destruction and reduce creation in response to an oil price increase and, symmetrically, decrease job destruction and increase creation in response to an oil price decrease. In contrast, allocative channels would increase both job creation and destruction, asymmetrically in response to both price increases and decreases. Thus if oil price shocks operate predominantly through aggregate channels, employment would respond roughly symmetrically to positive and negative oil price shocks.

D&H find that both oil-price and monetary shocks cause larger responses in job destruction than job creation in nearly every industrial sector. The magnitude of effect of oil price shocks is about twice that of monetary shocks, and the response of employment to oil price shocks is sharply asymmetric, the response to positive shocks being ten times larger than that to negative shocks. The reallocative effect of oil price shocks is substantial: the 1973:3-1973:4 episode caused job reallocation equal to 11 percent of total manufacturing employment over the following 15 quarters. However, the sectoral-shifts hypothesis that positive and negative oil price shocks would cause the same extent of reallocative response is not borne out in the results.

Keane and Prasad (1996; K&P) used the individual data of the National Longitudinal Survey of Young Men, obtaining a sample size of 4,439 individuals and 23,927 person-year observations based on interviews from 1966 to 1981. Their oil price variable is the real price of refined petroleum products averaged over the 12 months prior to the interview date. Oil price increases depressed real wages for all workers but raised the relative wage of skilled workers. Real wages fell 3% to 4% in the long run following an increase in the real price of refined petroleum products of 1-standard deviation around trend (19%). The short-run effect of an oil price increase on aggregate employment was negative, but the long-run effect was positive, possibly because of complementarities and substitutabilities among major categories of factors. Oil price increases also induced changes in employment shares and relative wages across 3-digit industries. However, oil price changes did not appear to cause labor to flow consistently into sectors with relative wage increases. While K&P find this counterintuitive, reverse causation could be operating: large flows of labor going to particular sectors could depress their wages. Why would not wages equalize across sectors? Skill differentials, for one thing. Oil price changes could destroy part of people's less tangible skills, leaving them to find employment in industries requiring minimal skills, such as retail trade and services.

There also is evidence that oil price changes affect people with different experience levels and "tenure" lengths—number of years in the current job—differently. Employment probabilities for skilled workers rise following oil price increases, suggesting that skilled labor may be a good substitute for energy in the production functions of most industries. Workers with longer experience in the labor force tend to experience greater reductions in real wages following oil price increases; this may be an age effect rather than a human-capital effect. K&P suggest that the rising wage premium for skills in the U.S. economy during the 1970s may in part be related to the sustained increase in the real price of oil over that period. There is much in the details of K&P's findings that is consistent with the sectoral shifts view of Lilien (1982) and Hamilton (1988): considerable reallocation of labor across industries, with differential consequences for skill levels and experience.[3]

While the VAR has been increasingly popular in the time-series analysis of oil price shocks, Carruth, Hooker and Oswald (1998;CHO) use an error correction model (ECM) of equilibrium unemployment in which oil prices play an important role. An ECM is amenable to more precise model specification than is a VAR. Using an efficiency wage model as its basis, CHO introduce a production function with three inputs–labor, capital, and an energy input they call "oil." An increase in the oil price erodes profit margins; and to restore equilibrium some variable must change. Firms are able to change the wage rate only by reducing employment, so as to take advantage of the no-shirking condition that links wages and unemployment in the efficiency wage model. The result is that when oil prices rise, unemployment increases.[4] CHO use a symmetric oil price variable in a regression of the annual change in the level of the unemployment rate on lagged dependent variables, error correction terms, and annual changes in the real oil price and real interest rate. The oil price variable is positive and highly significant, while the interest rate variable just misses significance at conventional levels. They interpret their relative success in out-of-sample forecasting as not supporting the sectoral reallocation mechanism for generating unemployment from oil price shocks. Furthermore, the ability of the symmetric oil price variable to predict the unemployment rate contrasts with the necessity of an asymmetric oil price specification to yield a stable relationship between oil prices and the unemployment rate in the VAR models, as in Hooker (1996c, 1999).

The authors of these labor market studies do not endorse the sectoral-shifts hypothesis as having passed their tests, but only one of the three–D&H–use an asymmetric measure of the oil price variable. D&H themselves set up a strong form of the hypothesis as well–that responses to positive and negative oil price shocks would be the same magnitude. There are several reasons for believing that K&P's evidence on the hypothesis was ambiguous. CHO's success with the symmetric oil price variable in their more closely specified, non-VAR model leaves open the question how an asymmetric specification would have performed. In conclusion, while there is strong evidence of important labor market reallocations and frictional unemployment at the micro level in response to oil price shocks, some revised form of the sectoral-shifts model may apply.

[3] K&P interpret their findings that oil price shocks induce labor reallocation and short-run unemployment as consistent with the sector shifts models, but they interpret the failure of labor to flow toward sectors where the relative productivity of labor rises as inconsistent with those equilibrium sectoral models. We noted above the possibility of endogeneity between the labor flows and the observed, intersectoral wage rate differentials as a possible explanation for labor not moving to higher productivity allocations, as predicted in the Lilien/Hamilton sectoral shocks model. That would depend, of course, on the volume of flows at the margin. Several other phenomena could interrupt the observation and even complicate the prediction the model should be making. First, observationally, people losing their jobs typically take lower-paying jobs and may require several years to reach their former wage level. Second, particularly among more senior employees, current income may exceed productivity as part of a long-term implicit contract that rewards loyalty (or longevity); this would exacerbate the first point. Third, part of an employee's productivity may be attributable to firm-specific human capital which is lost on separation, contributing to the observation noted in the first point.

[4] The same process would follow an interest rate increase.

2.3 Aggregate and allocative channels

Lee and Ni (2002; L&N) combine macroeconomic and industry-specific equations in their identified VAR approach and complement the statistical investigation with analysis of statements made in trade journals during the 1973-74 and 1979-80 oil price shock episodes.[5] The macro and industry blocks are estimated separately for each of 14 3-digit manufacturing industries. Both qualitative statistical analyses indicate that more energy-intensive industries tended to experience the oil price shocks as supply shocks (aggregate impacts) and less energy-intensive industries as demand shocks (allocative impacts). L&N present the impulse response functions (IRF) of the 14 industries as figures and from visual inspection contend that they are too similar to indicate imbalances across sectors that could give rise to extensive reallocations of resources along the lines of the models of Lilien (1982) and Hamilton (1988). Our own visual inspection of those figures, allowing for the 1-standard deviation confidence intervals, differs from L&N's: substantial differences occur in timing, magnitude, and even occasionally direction among the industries' impulse response functions of output to an oil price shock. Recalling Davis and Haltiwanger's finding that much of the labor reallocation following an oil price shock occurred *within* 3-digit industries, L&N do note that their 3-digit data cannot illuminate such intra-industry movements. They also note that their study, looking at manufacturing alone, does not pick up reallocations between manufacturing and service industries, if such occur.

2.4 Interest rate channels

Several studies have touched on interest rates, and even have suggested interest rates as a channel for oil price shocks to influence GNP (e.g., Ferderer 1996; Hooker 1996c, 1999), but Balke, Brown and Yücel (2002; BBY) has been the principal study to analyze that potential mechanism in detail.[6] Their goal is to find sources of the asymmetry in the oil price-GDP relationship. They interpret the possibility of monetary policy responding to oil price increases but not decreases as a source of the widely accepted asymmetry, although this explanation of asymmetry could eliminate oil price shocks as significant contributors to the post-shock recessions.

IRFs showed a strongly asymmetric response of the short-term interest rate to positive and negative oil price shocks, and a modestly asymmetric response of the long-term rate. The GDP response showed the now-characteristic asymmetry. Neither oil price variable was significant, individually or separately, in the GDP, price level, or commodity price equations, but the Hamilton Net Oil Price Increase (NOPI) measure was significant in the federal funds rate and short-term interest rate equations and was marginally significant in the long-term interest rate equation. Both interest rates and the federal funds rate are significant in the GDP equation. They conclude from these findings that an oil price shock works primarily through interest rates.

For a more precise mechanism by which oil prices affect interest rates, BBY refer to the financial accelerator model of Bernanke and Gertler (1989) and Bernanke, Gertler, and Gilchrist (1996; BGG), which yields a "flight to quality" in financial markets following a shock from some source, an effect that can be disproportionate to the size of the initial shock.[7] The financial accelerator model does not appear to contain reasons for asymmetry within its structure,

---

[5]They use monthly data from 1959:1 to 1997:9, lag lengths of 12 months, and Hamilton's 1-year net oil price increase (NOPI) measure of oil price shocks which assigns a zero value to the oil price change unless the price change reaches a level exceeding levels in the past year. Mork's (1989) previous asymmetric specification simply used different variables for positive and negative oil price changes; the NOPI ignores the negative changes as well as positive changes that can be considered ordinary, business-as-usual responses to supply and demand variations. L&B employ a 6-equation, recursive macro block and a 2-equation industry block composed of a demand equation and a supply equation identified by restrictions on pairs of coefficient values.

[6]BBY (2002) is written partly in response to Bernanke, Gertler, and Watson's (1997; BGW) conclusions on the relative weights of monetary policy and oil price shocks. We defer discussion of their examination of monetary policy to section 4 (they do not find support for BGW's conclusion) and focus here on their interest-rate channel. BBY follow BGW and estimate an eight-equation VAR with monthly data from January 1965 through December 1997, using seven lags as selected by the Akaike Information Criterion. Their model is essentially the BGW model with a modification of the oil price variable. One of the equations is an identity relating the logarithmic difference in the oil price to Hamilton's NOPI measure, and the impulse response functions are calculated from changes in the former, filtered through the NOPI. Both oil price variables are used in each equation.

[7]BGG (1996, 1) refer specifically to the oil price shocks of the 1970s as an example of such disproportionate shock-response phenomena: "supposedly the causes of serious recessions but which had relatively small effects on the average firm's production cost and the typical household's budget." The financial accelerator model is an agency model

although the investments it models would be subject to the asymmetries of irreversible investment theory. With this model in mind, BBY examine the effect of oil price shocks on the interest rate spread between 4- to 6-month commercial paper and 6-month Treasury bill rates, substituting a quality spread for the term spread. The NOPI measure is significant in the spread equation, and the impulse response function demonstrates considerable asymmetry in the oil price-quality spread relationship. A positive oil price shock increases the quality spread by more than three times the size of the response to a negative shock.

2.5 Petroleum product market mechanisms

The energy economics literature has noted the asymmetric responses of petroleum product prices to crude oil price changes for well over a decade, as observed by Balke, Brown, and Yücel (1998) in a review of previous studies. Product prices rise more quickly in response to crude price increases than they decline in response to crude price reductions. Using weekly data on crude prices and a variety of spot and wholesale gasoline prices, BBY (1998) find considerable support for asymmetry in the time pattern of downstream price changes to changes in upstream prices, although they find that different specifications of asymmetry yield different results.

Applied to the crude-product relationship, asymmetry has a different meaning than it does in the oil price-GDP relationship. In the crude-product relationship, the asymmetry is in the speed of the response, while in the oil price-GDP relationship, it is in the magnitude of the response. Competition will ensure that the magnitudes of the response of product prices to crude price changes are eventually equal. Otherwise profits in refining and distribution would grow without bound.

Huntington (1998) takes this asymmetric relationship between crude and product prices to the macroeconomic level. Using annual data from 1949-1993, he finds that both other energy prices (coal, natural gas, electricity) and GDP respond symmetrically to changes in petroleum *product* prices, while petroleum product prices respond asymmetrically to changes in crude prices. The asymmetric pattern appears for the effect of the crude oil price on GDP growth, but disappears with a dummy for 1986.[8]

Minding the difference in interpretation of asymmetry in the crude-product price relationship and the crude price-GDP relationship, it is not clear how to interpret Huntington's findings. Brown and Yücel (2002, 202) summarize their reaction as, "No follow-up studies have examined Huntington's findings." Considering the adjustment times in the petroleum product prices found by BBY (1998) and Borenstein, Cameron, and Gilbert (1997), it is surprising that Huntington was able to find the asymmetry between crude and product prices as well as he did with the annual data. It seems difficult to rest the entire case of the magnitude-asymmetry in the GDP response to oil price shocks to differences in adjustment speeds in the petroleum refining and distribution industries.

3. Attribution: Monetary policy versus oil price shocks

Early in the post-1973 era, observers noted that monetary policy had changed about the same time as the oil shock occurred, and raised the question of how much of the post-shock business cycle was attributable to each. Until recently, the most substantial controls for monetary policy in empirical investigations were the use of monetary or interest rate variables in regressions of GDP or unemployment on oil prices. These specifications were unable to account satisfactorily for the possibility that the changes in monetary policy were endogenous responses to the oil price shocks. Several studies have addressed directly the issue of monetary policy versus oil price shocks since the 1996 DOE Conference. Hooker (1999, 2000) has looked into the possibility that systematic changes in monetary policy since the late 1970s may have been responsible for the change in the oil price-GDP relationship that occurred sometime around 1980. Bernanke, Gertler and Watson (1997; BGW) studied the role of monetary policy as the central issue rather than

---

of commercial lending, in which a shock to cash flow reduces firms' net worth and lenders raise the premium on their external financing. The reduced net worth prompts more external finance and raises the premium on it, forcing borrowing firms to reduce purchases and production. This differs from the consumption-smoothing route to an interest-rate increase following an oil price shock, which Brown and Yücel (2000) discuss as a channel.

[8]His test for asymmetry uses a symmetric log-difference oil price variable in conjunction with a variable for a negative oil price change. If the two coefficients offset each other, he considers a relationship symmetric, and asymmetric if they do not. He also finds that the consumer price level responds asymmetrically to energy price changes, but this asymmetry disappears when he dummies for 1986, the year of the oil market crash. Huntington presented an initial version of this paper at the 1996 DOE Conference.

a factor contributing to discontinuity in the oil price-GDP relationship, eliciting an extended reply and further examination by Hamilton and Herrera (2001; H&H). In a study on attribution, but not specifically with money as the implicit null hypothesis, Raymond and Rich (1997) addresses how oil prices affect the business cycle, and whether shocks precipitate or exacerbate low growth.

3.1 Counterfactual simulations of oil price shocks with alternative monetary policies

The most widely cited publication on the role of monetary policy in the oil-price GDP relationship since the 1996 DOE Conference is BGW's (1997) VAR simulation. Using Hamilton's NOPI specification of the oil price shock, which filters out price decreases altogether as well as price increases that merely offset recent declines, they executed a counterfactual analysis of the consequences of the Federal Reserve maintaining the federal funds rate at a constant level rather than raising it. From the resulting IRFs they concluded that most, if not all, of the reduction in GDP during the recessions following the 1973, 1979-80, and 1990 episodes was attributable to monetary policy rather than the oil price shocks. BGW noted their simulations' potential violation of the Lucas Critique involved in holding constant the federal funds rate, but the data used in the VARs were from behavior in the face of the actual federal funds rate.[9]

Appearing in the *Brookings Papers on Economic Activity*, the published paper was followed with a summary of the discussion at the paper's presentation. The report of the discussion is tantalizing, if elusive, even possibly misleading, in its summaries. Christopher Sims, the original developer of the vector autoregression, one of the designated discussants, criticized BGW's violation of the Lucas Critique, but concluded his statement with the dual opinion that, " . . . despite the skeptical tone of my comments I find this paper useful evidence on the effects of systematic changes in monetary policy that, on the whole, does weigh in favor of those effects being substantial. It is quite unlikely that monetary policy could come close to eliminating the output effects of oil . . . shocks, despite the authors' apparent evidence to the contrary. This strong conclusion rests on their use of an unsustainable policy as the counterfactual alternative" (p. 148). The other discussant, Benjamin Friedman, was pulled in different directions by what appeared to him as the implausibility of Hamilton's original finding about the relationship between oil prices and GDP over U.S. business cycles and his assessment that BGW's findings imply rejection of the term structure hypothesis of interest rates.

H&H (2001) re-examine BGW's data and methods and reach diametrically opposite conclusions about the relative contributions of monetary policy and oil price shocks to the observed recessions. They focus on two major shortcomings of BGW's work: (1) the implausibility of the Fed's being able to accomplish the monetary policy needed to eliminate the output losses from oil shocks (i.e., a 900-basis point reduction in the federal funds rate) and (2) BGW's premature truncation of the effects of oil prices on output and employment, by limiting their analysis to lags of no more than 7 months. H&H's reasoning for (1) is, if the recessions were caused by monetary policy, alternative monetary policies could have largely averted those recessions, implicitly the argument of BGW (and Bohi 1989). H&H calculate the changes to monetary policy required to maintain the funds rate at its pre-oil-shock levels in the face of changes in the other variables in the VAR. From one perspective, they find that money supply increases would have had to be large enough to decrease the federal funds rate by 900 basis points over the course of the disruption. From another, the Fed would have had to keep the funds rate below levels that past private business behavior would have predicted, for 36 months in a row, to generate the output, price level, and interest rate paths simulated with the alternative monetary policy. Rational expectations makes it unlikely that private markets would underestimate the next-period funds rate for 36 months in a row. H&H find neither alternative policy convincing, in the sense that the patterns of historical behavior do not indicate that the Fed could have achieved such a policy had it desired to do so.

Regarding critique (2), H&H use several statistical tests to examine the appropriate lag length. Whereas BGW used the Akaike Information Criterion (AIC) to select a lag length of 7 months, virtually all empirical studies have found the largest impacts of oil prices on output in the 3rd and 4th quarters, and continued effects in even later quarters. A log likelihood test, which may be more appropriate than the AIC when outside information exists, rejects the 7-month lag conclusively (a one-in-a-billion chance that the 7-month lag is correct), as do several alternative tests that raise the hurdle against a longer lag length. Finally, after confirming that a longer lag is appropriate, H&H calculate the impulse

[9]Lucas (1976) observed that when equation parameters are estimated for macroeconomic models, they rely on data that embodies private responses to the observed and anticipated government policy rules in place at that time. Thus, given the importance of private behavioral responses and expectations, the parameters could well change when the policy rule changes. The implication is that while such models may be useful for forecasting, they are seriously flawed and potentially misleading for the purpose of evaluating alternative policy rules.

response functions using BGW's simulated monetary policy with the 12-month lag. H&H find that the alternative monetary policy can do little to mitigate the real impacts of the oil price shock when allowing for the full impact period.

Possibly the most important contribution that Hamilton and Herrera make to the oil-macroeconomy discussion with this analysis is to remind participants of the practical limitations on monetary policy. The early discussion of monetary policy's role in the recessions following the oil price shocks of the '70s either contended or implied that an alternative path of monetary policy following those shocks largely could have averted the recessions that followed, without consideration of how hard the Fed might have had to lean into the wind to do so. Monetary policy, like any other policy, uses a resource, and consequently has limits on the degree to which it can be used. Hamilton and Herrera present the case that the monetary policy response necessary to override the impact of an oil price shock probably was impossible to implement.

Balke, Brown, and Yücel (2002) also have restudied the BGW conclusions on monetary policy versus oil price shocks. They put an oil price identity relating the NOPI to the log change in oil price into the BGW model. This modification of the BGW model allows for calculation of nonlinear IRFs. Conducting the same simulation experiment that BGW did, of keeping the federal funds rate constant, with much the same model, they obtained a substantial response of GDP to an oil price shock, and asymmetric responses of GDP and short-term interest rates to positive and negative shocks even with the constant monetary policy.[10] To try to accommodate the Lucas critique, they conduct another simulation with an additional equation with which they attempt to capture private expectations of the future federal funds rate. The responses of GDP and short-term interest rates remain substantial and asymmetric across positive and negative oil price shocks. Their conclusion from this exercise is that asymmetry does not operate only through monetary policy, if at all. This finding led to their investigation of the interest rate channel.

3.2 Limits to the simulation of counterfactual monetary policies

As a methodological point, counterfactual policy simulations with VARs are structurally guaranteed to violate the Lucas critique. The entire set of equations is estimated from market data generated under the policy regime estimated for the Fed's reaction function equation. The typical monetary policy simulation perturbs the oil price variable by a particular amount–one or two standard deviations; holds the federal funds rate at a particular level instead of letting it follow the path it would according to the coefficients estimated for the funds rate equation; and calculates the impulse response functions of all the other variables in the VAR. The coefficients in all of the equations were estimated under the condition that the market participants whose behavior generated the data conducted their business under the expectation that the Fed's policy reactions, as estimated in the funds rate equation, would govern the path of the federal funds rate. As long as an experimenter uses the originally estimated coefficient values on the other equations, no amount of tinkering with the federal funds rate equation will avoid falling afoul of the Lucas critique.[11]

One could be doctrinaire on this point, but it is preferable to rely on the substantial recent research that addresses the magnitude and practical importance of the flaw identified by the Lucas Critique. Leeper and Zha (1999) have developed a procedure for determining whether the violation of the Lucas critique is serious enough in a particular case to bring the results into question or is close enough to what rational agents would have done to yield useful insights. The heart of their model is a distinction between true policy behavior and the policy relationship observed by private agents who not privy to all the information available to the policy makers at time t. Policy is not perfectly predictable to private agents, so they place positive probabilities on more than one set of outcomes, which leaves room for econometric analysis of policies while respecting the Lucas critique. The expected difference between the true policy process and the agents' model of policy is zero. "Modest" policy interventions are modeled as small, short-lived deviations of the modeled from the true policy process. To qualify as "modest," these variations must lie within the range that has occurred historically. As long as deviations are within that range, private agents would be unlikely to believe that policy behavior had changed. Hamilton and Herrera use this concept of a modest policy, and the suggestions made by Leeper and Zha for implementing the concept econometrically, to assess whether the simulation of Bernanke, Gertler and Watson represents a "modest" policy, one that is close enough to what private agents would expect that they would not change their other optimizing algorithms. The BGW simulation, which would have required

[10] BBY decline to characterize holding the federal funds rate constant as simulating a neutral monetary policy. Rather, in Brown and Yücel (1999), they suggest the alternative definition of monetary neutrality as raising the federal funds rate so as to keep nominal GDP constant in the face of an oil price shock. Keeping that rate constant could be an accommodative policy.

[11] Most of the authors who use a procedure such as this to examine the effect of monetary policy cite Sims and Zha (1998) as the fathers of the idea. It is worth noting that Sims and Zha themselves conceded, "That is, we are ignoring the Lucas critique" (1998, 34). They did proceed, however, to justify the interesting character of the exercise.

the Fed to lean into the wind to the magnitude of 900 basis points and would have required that private agents overestimate the funds rate for 36 months in a row, does not qualify as a "modest" policy deviation which likely would have left agents' other optimization algorithms unchanged.

3.3 Other efforts to account for the role of monetary policy

Hooker's (1999) examination of the stability of the oil price-GDP relationship over the period 1954-1995 considered bivariate and multivariate VAR specifications. Including an interest rate variable in the post-1979 subsample eliminated the significance of the oil price variables, and Hooker inferred that oil prices were operating indirectly on GDP through monetary policy in this later period. Thus, while oil prices directly affected GDP in the pre-1980 period, after 1980, they appear to have operated through their influence on monetary policy, and possibly other indirect channels. The statistical significance of oil shock variables in the presence of interest rate variables is restored when a 3-year NOPI specification of the oil price shock is used.

In an alternative focus on the influence of oil prices on the macroeconomy, Hooker (2000) studies the influence of oil prices on core inflation. Paralleling the structural break he found in the oil price-GDP relationship around 1980, he identified a break in the U.S. Phillips curve relationship, augmented with oil prices, around the same time, with oil price changes making a substantial contribution to core inflation before that date but little or none thereafter. He explored the suitability of three explanations for this break: declining energy share, deregulation of energy-producing and -consuming industries, and changes in monetary policy. None of the three hypotheses could account for the decrease in pass-through after 1980; in fact, he found that monetary policy as represented by the federal funds rate displayed smaller, rather than larger, responses to oil price changes after 1979, despite its greater sensitivity to inflation. Hooker noted that BGW also reported this falling sensitivity of the federal funds rate to oil price shocks over time.

Barsky and Kilian (2002; B&K offer an alternative approach to Romer and Romer (1989, 1994) and BGW to demonstrate that the recessions of 1974-75 and 1980-82 were caused by monetary contractions rather than oil price shocks. Key to their effort is the claim that the oil price increases of 1973-74 and 1979-80 had little or nothing to do with supply shocks but rather were endogenous responses to demand. The OPEC price hike in their view could have simply been the breaking of the long-term contract oil pricing system in the face of excess demand, with the price simply rising four-fold to the competitive equilibrium level. This is the issue of the degree of endogeneity of oil prices to supply shocks, addressed most lately by Hamilton (2003); it need not be a zero-or-one issue, and Hamilton shows that dummy variables for dates of supply shocks work as well as the NOPI variables and better than a number of other oil price specifications, partially vindicating the suspicion of endogeneity in oil prices. Neither of the commissioned commentators, Olivier Blanchard nor Alan Blinder, found B&K's endogeneity of the oil price in the two episodes convincing. However, B&K's related observation (p. 150) that Bernanke and Mihov's (1998) index of the stance of monetary policy shows a sharp contraction beginning in early 1973, weakens arguments that the recessions following oil price shocks have been produced by monetary policy responding endogenously to those shocks.

Raymond and Rich (1997: R&R) use Hamilton's (1989; 1994, Ch. 22) regime-switching model to study the role of oil price shocks in accounting for cyclical downturns in the U.S. economy from 1951:Q1 to 1995:Q3. The regime-switching model supposes that a time series is composed of two generating processes and relies on a Markov model to determine endogenously when observations are drawn from one state or the other. A univariate model (VAR of GDP only) clearly identified the 1973-74 and 1979-80 recessions as periods of high probability of being in state 1 (the low-mean, or recession, period), but a bivariate model (GDP and NOPI) gave much lower probabilities for those two recessions being in state 1, although the other recessions over the time period were identified quite similarly in both models. Nevertheless, the sum of the four lagged coefficients of the energy price on the mean of the low growth rate was -0.12 and quite significant. NOPI had no significant influence on the estimate of the transition probability, however. Thus oil price shocks do not appear to precipitate a switch from high growth to low, but rather depress the growth rate when the economy is in a low-growth phase. Their study offers statistical codification to the position that other events frequently have been at work to slow economic growth prior to an oil price shock.

As long as some economists bring to the table a set of priors that oil price shocks cannot have influenced U.S. business cycles in any significant way prior to the 1973 OPEC episode, and possibly neither then nor thereafter, there are limited grounds to believe that the monetary policy versus oil price shocks issue has been laid to rest permanently by the H&H (2001) findings. Nonetheless, the methodological difficulties with the BGW study and the sensitivity of those findings to lag length, must cause their claims to be approached with considerable caution. Hooker's (2000) independent finding that the federal funds rate became less sensitive to oil price changes at precisely the time when the systematic monetary policy hypothesis would require it to have become more sensitive adds strength to the H&H

conclusions. And, as several authors have pointed out, faced with an oil price shock, the Fed has an unattractive menu of choices between inflation and a dip in GDP. The record could be read as saying that the Fed has tried both in the past quarter century.

4. Changes in the oil price-GDP relationship over time

Several analysts have noted that the post-World War II relationship between oil prices and a number of economic indicators changed sometime in the 1980s. R&W (1996, p. 552) state the probable underlying cause in an illuminating fashion when they note that sometime after 1980 OPEC lost its ability to keep the nominal price of oil relatively stable. Thereafter, variations in the demand for oil were reflected quickly in nominal price changes, and several statistical properties of oil prices changed as a result. The meaning of this change in the oil price-GDP relationship is quite important, as it can be interpreted in two alternative ways. The first interpretation is that oil prices once affected GDP but do so no longer; or even that they never did, only the earlier sample period of the data was not lengthy enough to expose the threadbare character of the hypothesis. The second, alternative interpretation is that the relationship was never particularly simple, but that pricing conditions in the world oil market from just after World War II through the late 1970s let simple, linear versions of the relationship approximate the observed behavior. When more flexible behavior appeared in the world oil market, price signals that would have meant one thing in the previous period changed their meanings to market observers. The challenge to analysts under this interpretation has been to discover a sufficiently general relationship between oil price shocks and GDP to fit periods with strikingly different economic conditions in the relevant markets. This has involved experimentation with specifications that some economists (e.g., BGW) have characterized as data mining, as well as the development of new statistical tools for specifying and testing nonlinear models.

Hooker's contribution to the study of the oil price-GDP relationship has been to identify the changes in the statistical relationship of Granger causality of GDP by oil prices, and to search for a statistically stable specification. The interaction of his work with Hamilton's in particular has helped refine the statistical definition of an oil price shock, which in turn has played a critical role in establishing a stable statistical relationship between oil price shocks and GDP. More broadly, the attention to the role of oil price shock specification in the stability of the oil price-GDP relationship has interacted with the microeconomic models of transmission channels to improve the understanding of how oil prices might influence macroeconomic aggregates such as GDP and unemployment. D&H's study of sectoral transmission channels for oil price shocks relies on the theoretical soundness of the asymmetric specification of the oil price shock, as well as the NOPI specification to characterize surprise.

Hamilton (1983) reported the first indication that the statistical relationship between oil prices and GDP was weakening over time. His specification was the log change of the nominal oil price, which allowed symmetric, negative and positive effects. Mork (1989), following theoretical work with Gilbert (Gilbert and Mork 1986) that established an aggregate basis for both positive and negative GDP responses to oil price shocks, offered the first asymmetric specification of an oil price shock using separate variables for price increases and decreases. This specification rehabilitated the oil price-GDP relationship through the mid-1980s, or at least strengthened it. Lee, Ni, and Ratti (1995; LNR) experimented with an alternative scaling of the oil price change that divided the change in each period by an index of the recent volatility of the oil price, a specification that Hamilton (2001) subsequently showed to be capable of yielding a stable oil price-GDP relationship over the entire post-war period. LNR's specification was the first to move toward a measure of the surprise content of the oil price change, a concept that would grow in centrality in this research. This specification gives a large surprise content to a relatively small oil price change if it occurs after a period of stable oil prices, so there is not a one-to-one correspondence between size of oil price change and magnitude of the shock.

Hooker's first work (1996a, 1996b) entered the discussion at this point, with his demonstration that neither the symmetric oil price specification nor Mork's asymmetric specification preserved a stable oil price-GDP relationship beyond the early 1980s. Hamilton (1996a) responded with the NOPI specification of the oil price variable, defined as the difference between the percent increase in a current period and the highest percent increase in the previous four quarters, if positive, and zero otherwise. This specification eliminates price increases that simply correct recent decreases in a free market, thus capturing the surprise element in the oil price change and aligning the measure of the oil price change with the shock concept, which the macroeconomic theory used. Hooker's study for the 1996 DOE Conference (1996c) found that both the LNR and NOPI specifications restored for the entire post-war period the Granger causality of GDP from oil prices that Hamilton found for the symmetric specification, and which Hooker himself found to exist, in the pre-1980 period.

Hooker (1999) studied the performance of the NOPI and LNR specifications. Although both specifications

Granger-caused GDP from 1950 through 1998, he subjected them to three further tests: the sensitivity of the Granger-causality result to a single, particularly influential data point early in the sample; Granger-causality in the post-1980 period only; and out-of-sample forecasting of unemployment in the 1990s using realized values of the two oil price shock specifications. He found that removal of 1957:1 substantially weakened the performance of both specifications. As Hooker notes, that price change was only about 10 percent, but it appeared after a period of very stable prices and hence a low conditional variance as measured by the LNR specification, and it was followed by a recession beginning in August 1957 and an 11 percent fall in GDP in 1958:1. Although removal of this data point substantially changes the statistics calculated, it seems that both the LNR and NOPI specifications capture the surprise content of this oil price change, which was followed clearly by substantial recessionary movements.

In his second and third new tests, Hooker (1999) found that neither the LNR nor the NOPI specification Granger-cause GDP in the 1980-1998 sample and that neither specification improved out-of-sample forecasts of unemployment. However, he does find that both specifications Granger-cause GDP in annual data in regressions on oil prices alone. He interprets this finding as indicating that quarterly changes in GDP are quite noisy and that oil price shocks have their effects on longer-term trends in output over the entire period 1979:1-1998:4.

The most recent contribution to the issue of stability of the oil price-GDP relationship is Hamilton's (2001b) application of a parametric statistical technique for specifying and testing hypotheses about flexible, nonlinear regression specifications (Hamilton 2001a).[12] Hamilton studies the parametric, flexible nonlinear regression and the Mork, LNR, and NOPI specifications, which are linear relationships involving nonlinear variables. He uses rolling F-tests such as Hooker performed to test for stability over the entire sample period 1947:2-1999:4; tests for differential performance over the post-1980 period; and eliminates outliers to test for potential sensitivity to specific data points. To summarize a detailed study, Hamilton found that both the LNR and the NOPI (extended from one- to three-year comparisons) yielded stable relationships with GDP over the entire sample period, but the Mork and 1-year NOPI specifications did not. Further, he pursued an instrumental variables approach to the oil price shock by identifying dates at which particularly large changes occurred in oil supplies coming from a core group of OPEC countries. The results of this regression are quite similar to those using the 3-year NOPI specification. This dummy approach to supply disruptions avoids potential problems with endogeneity in the oil price series.[13]

5. The magnitude of the oil price-GDP relationship

The quantitative strength of the effect of oil price shocks on GDP has been summarized for some time as the oil price-GDP elasticity, the percent change in GDP divided by the percent change in an oil price measure. In linear regressions that are not VARs, the regression coefficient on oil price is the partial derivative of the dependent variable (GDP) with respect to the oil price measure and easily can be transformed to the implied elasticity. In log-log regressions, this coefficient is directly interpretable as the oil price-GDP elasticity. Many recent studies have relied on VARs. For VARs, an exact measure of the partial derivative of the dependent variable (e.g. GDP) with respect to a shock to one of the independent variables at a particular time period is given by the sum of coefficients of the impulse response function. This is a dynamic function, comprised of the partial derivatives of GDP at a given time with respect to the oil price shock at each of a number of periods in the past, possibly beginning with the contemporaneous period.[14] This lets us observe the response of GDP unfold over several years to an oil price shock in a single period. The sum of the impulse response coefficients for a shock at a specific time yields the equivalent of a cumulative oil price-GDP elasticity for a single-period shock.

[12] For the 1996 DOE Conference, Hamilton applied kernel regression techniques using both change and net-change oil price variables to find a functional form that would vary with magnitudes of the data (e.g., such that the functional form would not restrict the oil price-GDP elasticity to be a constant value over an entire time period, during which vastly different oil-price-change behavior may have occurred). That effort involved a combination of linear (oil price change) and nonlinear (NOPI) variables but did not permit statistical inference regarding the satisfactoriness of the functional form, or even straightforward presentation of the results. To remedy these problems, Hamilton developed a technique for determining whether a relationship is nonlinear, what the nonlinearity looks like, and whether it is adequately described by a particular parametric model.

[13] Hamilton (2003) cites Hoover and Perez' (1994a,b) use of dummy variables for oil shock dates in their debate with Romer and Romer (1994) on the ability to distinguish econometrically between monetary policy shocks and oil price shocks.

[14] While a VAR is specified with a given number of lags of the independent variables, typically 12 months or 4 quarters, but sometimes longer, the impulse response function can be calculated for a larger number of periods. Commonly impulse response functions are calculated for as long as 4 years.

5.1 Empirical estimates

Considering the difference between the level of the oil price and the newer measures of oil price shocks that have been developed over the past several years, there are differences in interpretation of the calculated elasticities. The oil price shock elasticities are different from simple price elasticities such as are calculated for bread and beer. Nonetheless it is useful to compare magnitudes of the elasticities calculated with these alternative techniques. Over the last 15 years, for its policy analyses, the U.S. Department of Energy has used oil price-GDP elasticities varying from -0.025 to -0.055. The latter value matches Mory's (1993) estimate from the log-linear regression of GDP on oil price and money supply, and is very close to the sum of lagged oil price coefficients estimated by Mork et al. (1994) with a VAR, of -0.054.

We can compare these magnitudes with several recent estimates for different measures of the oil price shock. First, we use the impulse response function presented in Hamilton and Herrera (2001, Figure 9). The sum of the impulse response coefficients over 42 months is -0.05488. The BGW simulation with the VAR, assuming the federal funds rate could be kept at 4%, would reduce this by about half, to -0.02733. If we consider the effects only out to 18 months, the sum of coefficients is -0.02898 without the accommodative monetary policy and -0.02335 with it. The effects of the monetary policy don't really kick in till after 18 months. Both of these estimations use the 1-year NOPI measure of an oil price shock. Using VARs presented in Hamilton (2003), estimated over 1947-1998, the sum of the impulse response coefficients over 8 quarters is -0.1162 using the 3-year NOPI shock measure and -0.0535 using the LNR shock measure.[15] Recall that the 3-year NOPI approach only records a shock when the price surpasses the highest observed level in the past 12 quarters, and the shock size is only the percentage by which the 3-year high is exceeded. Unsurprisingly, the 3-year NOPI estimate implies a greater GDP response once that hurdle is exceeded than is implied by some other shock measures that have a lesser, or no, hurdle.[16]

5.2 Calculations from macroeconomic models

Examining alternative sources of oil price-GDP elasticities recently, the Council of Economic Advisors has used calculations from the macroeconomic simulation models of the FRB, the IMF, and the OECD. The oil price-GDP elasticities calculated from simulations with some of these models, between -0.01 and -0.002 (depending on monetary response), are completely at odds with the empirical record of how the U.S. economy has responded to an oil price shock, and cannot be taken seriously. The IMF's MULTIMOD, OECD's INTERLINK, and the FRB's FRB/Global all use single-sector production functions (Levin et al. 1997b, 815). A large proportion of the overall impact of an oil price shock derives from intersectoral resource reallocation costs, as the studies reviewed above and in our previous analysis of the literature (Jones et al. 1998) have found, and these one-sector models structurally cannot obtain these effects. Kim and Loungani (1992) demonstrated this in their investigation of oil price shocks in a one-sector model. R&W (1996) and Finn (2000) reinforce this point. INTERLINK uses a one-sector production model for each country: a constant-returns-to-scale Cobb-Douglas production function using only labor and capital as inputs. MULTIMOD also uses only primary factors, no intermediates. Dalsgaard et al. (2001), reporting on the OECD model, specifically say that an oil price shock works its way through the model exactly the way any other non-oil commodity would. Levin et al. (1997a, 1997b) describe FRB/Global similarly. Hunt et al. (2001) discuss asymmetry, but the IMF model reflects it only in the wage-setting equation, in which workers resist erosion of real wages during upward oil price increases but do not resist a real-wage increase caused by falling oil prices. This limited concept of asymmetry highlights the structural reasons why these simulations derive small oil price/GDP elasticities.

The macroeconomic literature has identified three primary routes to the asymmetry between oil price changes and GDP responses: the sectoral shifts hypothesis (costly rearrangement of factors across sectors that are affected differently by the oil price change); the demand composition route; and the investment pause effect (along the lines of the irreversible investment model, in which households and firms defer major purchases in the face of uncertainty). Illustrating the sectoral shifts mechanism, D&H (2001) and Davis et al. (1996) confirm that oil price shocks can lead to many costs as workers lose jobs in one sector or region and are only slowly rehired in others, costs masked by net changes in aggregate employment. Hunt et al. (2001, Section III) alludes to these effects and says that MULTIMOD's

---

[15] We are indebted to James Hamilton for supplying these latter two sets of impulse response coefficients by e-mail, December 19, 2001.

[16] The 3-year NOPI estimate is also insensitive to the recent level of volatility in oil prices, providing oil prices have been below their 3-year high, and so could overstate the expected response after a period of greater variability in prices that does not exceed the 3-year high, such as late 2001-early 2002. In contrast, the LNR estimate uses the current volatility level to scale an oil price shock that would occur now, and accordingly is more in line with what could be expected at the moment.

exclusion of them could bias downward the modeled responsiveness of GDP to oil price innovations, but does not pursue the matter.[17]

The demand composition transmission mechanism operates eventually through employment but begins as a disturbance to sector-specific demand. Demands for durable goods are particularly hard hit during recessions because consumers tend to smooth the reduction in their consumption of non-durables. Probably the most prominent consumer durable is the automobile, and the U.S. automobile manufacturing industry was seriously affected by the oil price shocks of the 1970s. When oil prices increased in the 1970s, U.S. plants producing small cars operated at capacity and plants producing large cars were idled. Eventually more plants that produced small cars were built, but in the short run, total output and employment in this sector declined (Bresnahan and Ramey 1992, pp. 24-27; 1993; B&R). Working with highly disaggregated data, B&R found that plant-level responses exhibited fundamental differences from aggregate responses—greater discontinuity and different distributions of adjustment methods. These plant-level findings suggest that even modest levels of aggregation, such as the 3-digit SIC industry level, would not reveal the details of the adjustments in response to an oil price shock.

Pauses in investment that propagate reductions in orders throughout the economy depend on investors' expectations. The expectations formulations discussed in Hunt et al. (2001) refer to expectations only of inflation. Demand expectations formulations for capital markets are not mentioned, and these are critical in the macroeconomic response to an oil price shock. If capital market expectations are limited to only expected inflation, they would be unable to transmit the shocks they are believed to have transmitted in previous oil price shocks.

In summary, both MULTIMOD and INTERLINK structurally preclude the routes of impact from oil price changes to GDP and unemployment that have been most important empirically. Consequently, it is not surprising that the IMF and OECD reports find very small elasticities.

6. Effects of oil price shocks on the stock market

Most of the microeconomic research on the mechanisms by which oil price shocks operate has focused on either product or labor markets. Research on reallocative effects of oil price shocks in capital markets has lagged behind. The closest macroeconomic research on oil prices has come to focusing on capital markets has been several studies of stock market indexes (Kaul and Seyhun 1990, Jones and Kaul 1996, Sadorsky 1999) and a single study of individual firms' stock prices (Sakellaris 1997). Ideally, stock values reflect the market's best estimate of the future profitability of firms, so the effect of oil price shocks on the stock market is a meaningful and useful measure of their economic impact. Since asset prices are the present discounted value of the future net earnings of firms, both the current and the expected future impacts of an oil price shock should be absorbed fairly quickly into stock prices and returns, without having to wait for those impacts to actually occur.

Kaul and Seyhun (1990; K&S)) examined the influence of the volatility of oil prices on rates of return to assets listed on the NYSE over 1949-1984, annually. Their regression coefficients on inflation variables were insignificant, the oil price coefficient was negative and significant (in the 1966-84 subperiod), and that on industrial production was positive and significant. Jones and Kaul (1996) constructed a standard cash-flow/dividend valuation model to examine stock market efficiency (whether stock price changes reflect current and future real cash flows), focusing their test on the extent to which stock prices also change in response to oil price changes. When industrial production is included as cash-flow variable, the results are as expected by the theory of rational valuation: stock prices change to reflect the exact change in expected future cash flows and future returns of the underlying assets, the coefficients on cash flows are positive and significant, and those on oil prices jointly zero for the U.S. and Canada.[18] Excluding the cash flow variable from the valuation regression yields negative and significant oil price coefficients, and oil prices Granger-precede indexes of stock returns and output. These results show that stock prices rationally reflect oil shocks through their effects on cash flows, and highlight the importance of the industrial production and cash-flow route for oil price effects on the stock market.

Sadorsky (1999) estimates VARs of industrial production, real oil prices, short-term interest rates, and an index of real stock returns (RS) on the S&P 500 over 1947:1-1996:4, monthly. He uses positive and negative oil price changes

---

[17] This was confirmed in personal communication with Benjamin Hunt in Fall 2001. The above interpretation of the FRB/Global Model also was substantially confirmed in personal communication with Andrew Levin in 1999.

[18] For Britain and Japan, the oil price coefficients remain negative and significant, and J&K are unable to explain those cases. The implication is that the U.S. and Canadian stock markets have efficiently incorporated the implications of oil price shocks into their asset prices, but that the U.K. and Japanese stock markets overreacted, for reasons J&K are unable to determine.

separately, and measures of oil price volatility as well as changes in oil prices. In impulse response functions an oil price shock has a negative, statistically significant, immediate impact lasting for months. Oil price shocks have a larger impact on RS variance decompositions after 1986 than before, probably because of the 1986 oil price drop and the 1990 Gulf crisis. RS responds asymmetrically to oil price shocks. Oil price volatility, measured asymmetrically, has a larger impact on RS after 1986. His finding that the volatility of oil prices—probably a risk factor—affects the stock market index, parallels the finding of K&S. The preceding three studies of stock prices do not add greatly to the understanding of oil price-macroeconomic relationships that analysis of GDP has contributed, because the stock market is viewed primarily as discounting cash flows but without attempting to assess the formation of expectations regarding those cash flows

Sakellaris (1997) studied stock prices and excess returns (stock prices minus "fundamental" values–essentially discounted cash flows) of individual firms in four 3-digit SIC industries over 1959-1985. Firms with larger proportions of their capital stocks purchased during periods of low energy prices suffered greater losses in firm value during the energy price shocks of the 1970s. Average annual excess returns to firms over the OPEC oil shocks ranged from -80 percent to +100 percent, with the group average around -13 percent. Perhaps because firms had some time to begin adjusting their capital stocks to the new energy-price regime, and more flexible technologies after 1974, the effect of the 1979-80 shock was smaller than the 1973-74 shock. This response to oil price shocks–some firms' asset values appreciate while others are virtually destroyed, with a negative effect on balance–parallels Davis and Haltiwanger's labor market finding that, although the overall effect was net destruction, some job creation still occurred in response to oil price shocks. Nonetheless, Sakellaris' findings stop short of demonstrating reallocation costs in the capital market, along the lines of the models of Lilien (1982) and Hamilton (1988). We are unaware of studies of allocative disturbances in the capital market that examine the potential for oil price shocks to serve as the shock.

Research on the effect of oil price shocks on asset markets is yet to merge fully with the oil price shock-business cycle literature. The results of this research to date primarily offer confirmation of the oil price-GDP studies from a present-discounted-value perspective. It is not surprising that a short period of low earnings is reflected in a dip in asset values. It is somewhat more interesting to observe that stock markets appear to be forecasting the dips well before their effects on cash flows begin to materialize. Future research may look for more precise information on private forecasts and transmission mechanisms in stock prices and offer further integration of asset and other markets in analyses of the macroeconomic impacts of oil price shocks.

7. Non-U.S. studies

Analysis of macroeconomic impacts of oil price shocks outside the U.S. has lagged behind U.S.-focused studies until recently. The first study of a non-U.S. setting since Mork, Olsen and Mysen (1994) is Papapetrou's (2001) study of Greece, followed by Cuñado and Pérez de Gracia's (2003; C&PG) study of 14 European countries and de Miguel, Manzano, and Martín-Moreno's (2003; MMM) study of Spain. The first two use the VAR approach, and the third is a simulation study of a real business cycle (RBC) model. The 24-month sum of Papapetrou's IRFs of an oil price change on Greek industrial production is -0.027 and on employment is -0.008.[19] She uses VARs of real oil price, a treasury bill rate, real stock returns and industrial production and employment. Oil prices account for roughly 20 percent of the forecast error of industrial production and 11-19 percent of employment, 2 to 3 times that accounted for by interest rates.

C&PG's VARs use industrial production, oil prices, and inflation rates. After unit-root and cointegration tests, they concentrate on Granger causality tests with different oil price shock specifications. The symmetric specifications reject the null of no influence on industrial production in only 7 countries, at either 5 or 10 percent. The positive change and NOPI specifications reject the null in 11 cases each, generally at higher significance levels, but the variance-conditioned specification fails to reject the null in a single case. Only Spain and Italy fail to reject the null under any specification. The effects on industrial production are larger when oil prices are denominated in national currencies than in U.S. dollars, presumably the result of exchange rate effects. A diagram of IRFs of industrial production responses to a 1-s shock in NOPI for six countries–Germany, France, Luxembourg, U.K., Netherlands, and Denmark–show

[19] Papapetrou studies the period 1989:1-1999:6, thus excluding the first two shocks of the '70s and the 1986 oil market crash. C&PG cover 1960-1999, quarterly, covering those events, while MMM calibrate their model over 1970-1998. Papapetrou uses the consumer price index for fuels as her symmetric oil price variable, while C&PG use all the major measures of oil price changes: the symmetric change, the positive element of Mork's simple asymmetric measure, Hamilton's NOPI, and Li, Ni, and Ratti's variance-conditioned measure. MMM's model uses symmetric oil price changes.

considerable variation in magnitude, significance, and occasionally direction, of response but broad similarities in timing. The negative effect peaks about 6 quarters after the shock, and recovery is reached by about 10-12 quarters.

MMM simulate a dynamic general equilibrium model of a small, open economy (Spain) in which oil price changes operate through the production function, much as in Finn's (2000) model, with the same routes of effect. The exogeneity of the interest rate and the absence of an exchange rate leave little scope for monetary policy, which is not modeled. MMM cite the exogeneity of the interest rate to the Spanish economy as an important difference from its endogeneity in the U.S. economy. This point has some force in light of the importance of the behavior of interest rates in the BGW and H&H analyses of the consequences of endogeneity of monetary policy for the interpretation of the U.S. experience. With oil price changes as the only source of exogenous shock, MMM's model tracks Spanish GDP fairly closely from 1970 till the mid-1980s, replicating the 1974-74 and 1979-80 shocks; but from around 1985 through 1998, considerably less so. The model appeals to none of the uncertainty-investment mechanisms developed applied in recent years to U.S. data, but the Spanish positive GDP response to the 1986 oil price collapse is an intriguing contrast to the U.S. experience and that of other large countries. Oil price shocks account for 60 percent of the business cycle fluctuation, in contrast to 16 percent Kim and Loungani (1992) found for the U.S. in their closed-economy RBC model which allowed the interest rate to move.

Neither of the non-U.S. empirical studies deals with the potential endogeneity of monetary policy, which has attracted so much recent attention in studies of the U.S. relationship, and the simulation study excluded monetary policy, which under flexible exchange rates would have been equivalent to an exchange rate policy. The variety of national monetary experiences might make the European countries a useful test bed for examination of oil price-monetary policy relationships, particularly in the larger countries. However, a simple, cross-section/time-series analysis could be complicated by the possibility of countries using different monetary policy rules. Levin and Loungani (1997) reported considerable differences in GDP response to oil price shocks, depending on the choices of rules followed by countries. Their results were more complicated than a country's GDP response to an oil price shock being affected by its own monetary policy rule; it would be also affected nontrivially by the rules followed by trading partners.

Nor were the microeconomic routes of effect explored, but for over a dozen countries, the data requirements would be considerable. Subject to the potential conflation of monetary policy and oil price shock, these two studies provide strong preliminary evidence of the effects of oil price shocks on a large number on European economies.

8. Conclusions: the current state of knowledge about oil price-GDP relationships

First, the most thorough research to date has found that post-shock recessionary movements of GDP are largely attributable to the oil price shocks, and are not events that alternative monetary policy largely could have avoided. Second, two nonlinear and asymmetric specifications of oil price shocks have been found that yield stable oil price-GDP relationships over the entire post-World War II period. These specifications transform the oil price to isolate oil shocks as only those price movements that are novel and potentially surprising: either movements above levels observed in recent price history, or fluctuations that are large compared to recent price volatility. Third, detailed empirical research has shown that considerable reallocation of labor occurs after oil price shocks, amounting to as much as 11 percent of the labor force in manufacturing, and similar reallocations outside manufacturing. Much of this movement is within industry classifications that are sufficiently closely related that they would be missed in studies even at the 3-digit level. These allocative channels by which price affects output turn out to be surprisingly large and influential compared to the more traditionally anticipated, aggregate output channels. They help explain the asymmetric response of GDP to oil price movements up and down, and have their roots in the costly processes by which sector-specific and even plant-specific factors must be reallocated; in the disturbances to sectoral demand patterns, particularly for durable goods; and in the pauses in investments that may occur in the face of uncertainty and surprising price information. Fourth, the best current, empirical estimates (as opposed to simulation constructions) of the oil price-GDP elasticity are around -0.055. This is the cumulative effect on GDP over a 2-year period of a shock in one period only, regardless whether the price increase is sustained. Finally, findings from studies of the effects of oil prices on the stock market parallel the findings from more direct examination of current activity in the form of GDP.

Notwithstanding these conclusions, considerable effort has been required to obtain a functional form that yields a stable relationship between oil prices and GDP over the post-war period. In the Lee-Ni-Ratti conditional variance formulation, GDP impacts at any particular time are dependent on the recent variance of oil prices. Extending the sample period has repeatedly required modifying functional form, and it is possible that another five years' of data will require another modification. The definition of an oil price shock has required modification as well, with Hamilton extending his original NOPI from a one-year peak to a three-year peak. Clearly, from the perspective of macroeconomic consequences, not all price movements are alike. The work of Li, Ni and Ratti has led attention toward measures of the surprise content of the oil price change, where surprise and uncertainty may depend not only on whether the price excursion is noteworthy compared to recent price volatility, but perhaps also on the context of the news and other information surrounding the price event. Conversation with another oil-macroeconomy student is complicated by uncertainty about whether current or recent oil price movements represent something that could precipitate a downturn five or six months later. And although considerable reallocations of resources have been found to follow oil price shocks, not all the predictions of the sectoral shocks hypothesis have found support in the detailed empirical results.

While the mathematical models of business cycles of the last few decades have sharpened the questions economists ask about the causes of fluctuations, to the extent that they have encouraged empirical research to focus on the limited number of variables in structural models, they may have been a mixed blessing. Careful analysis of many economic phenomena has a track record of replacing putative single causes with multiple causes, from the Great Depression to causes of earnings disparities. We imagine that continued research on mechanisms by which oil price shocks contribute to recessions will produce a similar result. No single causal link will be found, or perhaps even emerge as the dominant channel. Questions remain on the details of the sectoral shocks hypothesis, and continued research on that topic may identify somewhat different transmission mechanisms than are currently hypothesized. Continued research on interest-rate channels may lead further into both financial and real capital market mechanisms. Further study of stock markets may identify broader asset revaluation effects than have been sought heretofore.[20] Development of policies to deal with oil price shocks, other than broad monetary and fiscal policies and holding strategic crude oil stocks, if any satisfactory ones are to be found, awaits firmer and more detailed understanding of the mechanisms by which those shocks work their impacts.

References

Balke, N.S., S.P.A. Brown, and M.K. Yücel. (1998) "Crude Oil and Gasoline Prices: An Asymmetric Relationship?"*Federal Reserve Bank of Dallas Economic Review*, First Quarter: 2-11.

Balke, N.S., S.P.A. Brown, and M.K. Yücel. (2002) "Oil Price Shocks and the U.S. Economy: Where Does the Asymmetry Originate?" *Energy Journal* 23(3): 27-52.

Barsky, R. B., and L. Kilian. (2002) "Do We Really Know that Oil Caused the Great Stagflation? A Monetary Approach," *NBER Macroeconomics Annual, 2001* 16/1: 137-183.

Bernanke, B. S., and M. Gertler. (1989) "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* 79: 14-31.

Bernanke, B. S., M. Gertler, and S. Gilchrist. (1996) "The Financial Accelerator and the Flight to Quality," *Review of Economics and Statistics* 78: 1-15.

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

Bernanke, B. S., and I. Mihov. (1998) "Measuring Monetary Policy," *Quarterly Journal of Economics* 113: 869-902.

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

Bohi, D. R. (1991) "On the Macroeconomic Effects of Energy Price Shocks," *Resources and Energy* 13: 145-162.

Borenstein, S., A.C. Cameron, and R. Gilbert. (1997) "Do Gasoline Prices Respond Asymmetrically to Crude Oi Prices?" *Quarterly Journal of Economics* 112: 305-339.

Bresnahan, T. F., and V. A. Ramey. (1992) "Output Fluctuations at the Plant Level." NBER Working Paper 4105. Cambridge, Mass.: NBER, June.

Brown, S.P.A., and M.K. Yücel. (2002) "Energy Prices and Aggregate Economic Activity: An Interpretive Survey," *Quarterly Review of Economics and Finance* 42: 193-208.

Brown, S.P.A., and M.K. Yücel. (1999) "Oil Prices and the Economy," *Southwest Economy* Issue 4: 1-6.

Brown, S.P.A., and M.K. Yücel. (1999) "Oil Prices and Aggregate Economic Activity: A Question of Neutrality,"

[20]Kahn (1986) studied the revaluation of used automobiles over the decade 1973-81 in response to the increased gasoline prices of the decade, in proportion to their fuel efficiency, finding substantial asset revaluation effects on gas guzzlers. These years included a period when the initial 1973 price shock was widely thought to herald a new age of energy prices, thus mixing together long-run responses to perceived obsolescence and asset revaluations induced by price movements believed to be temporary, if severe. Examination of asset prices subsequent to post-1973 shocks might yield a cleaner view of sectoral reallocation impacts in the capital market.

Federal Reserve Bank of Dallas Economic and Financial Review Second Quarter: 16-23.
Bruno, M., and J. Sachs. (1982) "Input Price Shocks and the Slowdown in Economic Growth: The Case of U.K. Manufacturing," *Review of Economic Studies* 49: 679-705.
Burbidge, J., and A. Harrison. (1984) "Testing for the Effects of Oil-Price Rises Using Vector Autoregression," *International Economic Review* 25: 459-484.
Carruth, A.A., M.A. Hooker, and A.J. Oswald. (1998) "Unemployment Equilibria and Input Prices: Theory and Evidence from the United States," *Review of Economics and Statistics* 80: 621-628.
Cuñado, J., and F. Pérez de Gracia. (2003) "Do Oil Price Shocks Matter? Evidence for Some European Countries," *Energy Economics* 25: 137-154.
Dalsgaard, T., C. Andre, and P. Richardson. (2001) "Standard Shocks in the OECD INTERLINK Model," OECD Economics Department Working Papers No. 306, ECO/WKP(2001)32, September 6.
Darby, M. R. (1982) "The Price of Oil and World Inflation and Recession," *American Economic Review* 72: 738-751.
Davis, S. J., and J. Haltiwanger. (2001) "Sectoral Job Creation and Destruction Response to Oil Price Changes," *Journal of Monetary Economics* 48: 465-512.
Davis, S. J., P. Loungani, and R. Mahidhara. (1997) "Regional Labor Fluctuations: Oil Shocks, Military Spending and Other Driving Forces. Revision of paper presented at the DOE Conference, "International Energy Security: Economic Vulnerability to Oil Price Shocks, Washington, D.C., October 1996.
Ferderer, J. P. (1996) "Oil Price Volatility and the Macroeconomy: A Solution to the Asymmetry Puzzle," *Journal of Macroeconomics* 18: 1-26.
Finn, M. G. (2000) "Perfect Competition and the Effects of Energy Price Increases on Economic Activity," *Journal of Money, Credit and Banking* 32: 400-416.
Gilbert, R. J., and K. A. Mork. (1986) "Efficient Pricing During Oil Supply Disruptions," *Energy Journal* 7(2): 51-68.
Gisser, M., and T. H. Goodwin. (1986) "Crude Oil and the Macroeconomy: Tests of Some Popular Notions," *Journal of Money, Credit, and Banking* 18: 95-103.
Hamilton, J. D. (1983) "Oil and the Macroeconomy since World War II," *Journal of Political Economy* 91: 228-248.
Hamilton, J. D. (1988) "A Neoclassical Model of Unemployment and the Business Cycle," *Journal of Political Economy* 96: 593-617.
Hamilton, J. D. (1989) "A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle," *Econometrica* 57: 357-384.
Hamilton, J. D. (1994) *Time Series Analysis*. Princeton: Princeton University Press.
Hamilton, J. D. (1996a) "This is What Happened to the Oil Price-Macroeconomy Relationship," *Journal of Monetary Economics* 38: 215-220.
Hamilton, J. D. (1996b) "Analysis of the Transmission of Oil Price Shocks through the Macroeconomy." Paper presented at the DOE Conference, "International Energy Security: Economic Vulnerability to Oil Price Shocks, Washington, D.C., October.
Hamilton, J. D. (2001) "A Parametric Approach to Flexible Nonlinear Inference," *Econometrica* 69: 537-573.
Hamilton, J. D. (2003) "What Is an Oil Shock?" *Journal of Econometrics* 113: 363-398.
Hamilton, J. D., and A. M. Herrera. (2001) "Oil Shocks and Aggregate Macroeconomic Behavior: The Role of Monetary Policy." Mimeo, Dept of Economics, University of California, San Diego, July (forthcoming *Journal of Money, Credit and Banking*, 2003).
Hooker, M. A. (1996a) "What Happened to the Oil Price-Macroeconomy Relationship?" *Journal of Monetary Economics* 38: 195-213.
Hooker, M. A. (1996b) "This is What Happened to the Oil Price-Macroeconomy Relationship: Reply," *Journal of Monetary Economics* 38: 221-222.
Hooker, M. A. (1996c) "Exploring the Robustness of the Oil Price-Macroeconomy Relationship: Empirical Specifications and the Role of Monetary Policy." Paper presented at the DOE Conference, "International Energy Security: Economic Vulnerability to Oil Price Shocks, Washington, D.C., October 1996.
Hooker, M. A. (1999) "Oil and the Macroeconomy Revisited." Mimeo, Federal Reserve Board, Washington, D.C., August.
Hooker, M. A. (2000) "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime." Mimeo, Federal Reserve Board, Washington, D.C., August.
Hoover, K. D., and S. J. Perez. (1994a) "Post Hoc Ergo Propter: An Evaluation of 'Does Monetary Policy Matter?' in the Spirit of James Tobin," *Journal of Monetary Economics* 34: 47-73.

Hoover, K. D., and S. J. Perez. (1994b) "Money May Matter, But How Could You Know," *Journal of Monetary Economics* 34: 89-99.

Hunt, B., P. Isard, and D. Laxton. (2001) "The Macroeconomic Effects of Higher Oil Prices," International Monetary Fund, IMF Working Paper, WP/01/14, January.

Jones, C. M., and G. Kaul. (1996) "Oil and the Stock Market," *Journal of Finance* 51: 463-491.

Jones, D.W., ed. (2002) *The Macroeconomics of Oil Price Shocks*. ORNL/TM-2002/243. Oak Ridge, Tenn.: Oak Ridge National Laboratory, forthcoming.

Jones, D. W., D. J. Bjornstad, and P. N. Leiby. (1998) "The Findings of the DOE Workshop on Economic Vulnerability to Oil Price Shocks: Summary and Integration with Previous Knowledge." Oak Ridge National Laboratory, September.

Jones, D.W., and P.N. Leiby. (1996) "The Macroeconomic Impacts of Oil Price Shocks: A Review of Literature and Issues." Oak Ridge National Laboratory, September.

Kahn, J.A. (1986) "Gasoline Prices and the Used Automobile Market: A Rational Expectations Asset Price Approach," *Quarterly Journal of Economics* 102: 323-339.

Kaul, G. and H. N. Seyhun. (1990) "Relative Price Variability, Real Shocks, and the Stock Market," *Journal of Finance* 45: 479-496.

Keane, M. P., and E. S. Prasad. (1996) "The Employment and Wage Effects of Oil Price Changes: A Sectoral Analysis," *Review of Economics and Statistics* 78: 389-399.

Kim, I.-M., and P. Loungani. (1992) "The Role of Energy in Real Business Cycles," *Journal of Monetary Economics* 29: 173-189.

Lee, K., and S. Ni. (2002) "On the Dynamic Effects of Oil Price Shocks: A Study Using Industry Level Data," *Journal of Monetary Economics* 49: 823-852.

Lee, K. S. Ni, and R. A. Ratti. (1995) "Oil Shocks and the Macroeconomy: The Role of Price Variability," *Energy Journal* 16(4): 39-56.

Leeper, E.M., and T. Zha. (1999) "Modest Policy Interventions." Federal Reserve Bank of Atlanta Working Paper 99-22, December.

Levin, A.T., and P. N. Loungani. (1996) "Oil, Money, and Economic Activity in the G-7 Countries: Implications of the FRB/MCM." Paper presented at the DOE Conference, "International Energy Security: Economic Vulnerability to Oil Price Shocks, Washington, D.C., October 1996.

Levin, A. T., J. H. Rogers, and R. W. Tryon. (1997a) "A Guide to FRB/Global," Board of Governors of the Federal Reserve System, *International Finance Discussion Papers*, Number 588, August.

Levin, A., J. Rogers, and R. Tryon. (1997b) "Evaluating International Economic Policy with the Federal Reserve's Global Model," *Federal Reserve Bulletin*, October, 797-817.

Lilien, D. (1982) "Sectoral Shifts and Cyclical Unemployment," *Journal of Political Economy* 90: 777-793.

Loungani, P. (1986) "Oil Price Shocks and the Dispersion Hypothesis," *Review of Economics and Statistics* 68: 536-539.

Lucas, R. E., Jr. (1976) "Econometric Policy Evaluation: A Critique," in K. Brunner and A. Meltzer , eds., *The Phillips Curve and Labor Markets*, Carnegie-Rochester Conference Series on Public Policy 1: 19-46.

Miguel, C. de, B. Manzano, and J. M. Martín-Moreno. (2003) "Oil Price Shocks and Aggregate Fluctuations," *Energy Journal* 24(2): 47-61.

Mork, K. A. (1989) "Oil and the Macroeconomy when Prices Go Up and Down: An Extension of Hamilton's Results," *Journal of Political Economy* 97: 740-744.

Mork, K. A. Ø. Olsen, and H. T. Mysen. (1994) "Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries," *Energy Journal* 15(4): 19-35.

Mory, J. F. (1993) "Oil Prices and Economic Activity: Is the Relationship Symmetric?" *Energy Journal* 14(4): 151-161.

Papapetrou, E. (2001) "Oil Price Shocks, Stock Market, Economic Activity and Employment in Greece," *Energy Economics* 23: 511-532.

Pierce, J. L., and J. J. Enzler. (1974) "The Effects of External Inflationary Shocks," *Brookings Papers on Economic Activity 1*: 13-61.

Rasche, R. H., and J. A. Tatom. (1977a) "The Effects of the New Energy Regime on Economic Capacity, Production, and Prices," *Federal Reserve Bank of St. Louis Review* 59(4): 2-12.

Rasche, R. H., and J. A. Tatom. (1977b) "Energy Resources and Potential GNP," *Federal Reserve Bank of St. Louis*

Review 59(6): 10-24.

Romer, C. D., and D. H. Romer. (1989) "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz, *NBER Macroeconomics Annual* 4: 121-170.

Romer, C. D., and D. H. Romer. (1994) "Monetary Policy Matters," *Journal of Monetary Economics* 34: 75-88.

Rotemberg, J. J., and M. Woodford. (1996) "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," *Journal of Money, Credit and Banking* 28: 549-577.

Sadorsky, P. (1999) "Oil Price Shocks and Stock Market Activity," *Energy Economics* 21: 449-469.

Sakellaris, P. (1997) "Irreversible Capital and the Stock Market Response to Shocks in Profitability," *International Economic Review* 38: 351-379.

Sims, C.A., and T.A. Zha. (1998) "Does Monetary Policy Generate Recessions." Federal Reserve Bank of Atlanta Working Paper 98-12, July.

Tobin, J. (1980) "Stabilization Policy Ten Years After," *Brookings Papers on Economic Activity 1*: 19-71.

Toledo, W., and M. H. Marquis. (1993) "Capital Allocative Disturbances and Economic Fluctuations," *Review of Economic Studies* 75: 233-240.