THE FINDINGS OF THE DOE WORKSHOP ON ECONOMIC VULNERABILITY TO OIL PRICE SHOCKS: SUMMARY AND INTEGRATION WITH PREVIOUS KNOWLEDGE

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1. Introduction

Since the Arab oil embargo in the fall of 1973, the U.S. economy has been subject to four periods of oil price shocks and increasing variation in quarterly oil prices. Following the rapid price run-ups of 1973-74 and 1979-80, the economy dropped into recession. In contrast, following the precipitous oil price drop in 1986-7 the level of economic activity remained stable rather than expanding. Again, following 1990-91 oil price increases, the economy entered recession. These observations, taken at face value, leave the policy maker without clear guidance. Despite the desirability of considering actions to smooth out the harmful effects of business cycles, the unavailability of a clear-cut and consistent relationship between oil and the economy prompted some observers to question the desirability of any policy actions. Should policies be directed at eliminating the price swings during supply shocks or in more broadly decoupling the relationship between energy and the macroeconomy? Would monetary policy be effective, or are microeconomic policies needed, or both?

The picture is confounded by the suggestion that oil price run-ups have been correlated with other determinants of economic contractions that may have had greater responsibility for the post-oil-shock recessions than did oil prices. Other hypotheses suggest a changing relationship between oil price shocks and economic activity that has defied clear definition thus far but that may, in fact, have largely broken the oil price-macroeconomy link without government intervention. But perhaps most disturbing is the possibility that the economic instability following the oil price shocks of the 1970s and '80s could be attributed to errors in domestic economic policy, notably monetary policy, that responded to, but were distinct from, oil prices increases. This last possibility might be interpreted by some as meaning that energy never really was a problem and that the billions of dollars spent on energy research and otherwise affected by energy policies were misspent. However, if the inappropriate monetary policy interpretation of the 1970s recessions were to be accepted incorrectly, equally inappropriate changes in energy policies might be encouraged. Clearly, considerable stakes are involved in understanding the relationship between oil prices and the macroeconomy.

Since 1973, a great deal of research has been undertaken to sort out the oil-economy nexus. This paper reports on the most recent set of enquiries that, under the sponsorship of the Department of Energy, were designed specifically to examine the types of policy-relevant issues related above. Prior to this undertaking, two schools of thought on the oil-economy link predominated within policy circles. The first, associated with macro-econometricians such as James Hamilton and Knut Anton Mork, suggested a theoretically open-ended but empirically clear relationship between oil prices and the major indicators of aggregate economic performance, principally GNP growth and the unemployment rate. This relationship could be traced back to the period immediately following the second world war, not simply following the oil price shocks of the 1970s and '80s. The second school of thought, associated with Douglas Bohi, questioned the validity of the relationship identified in the aggregate data. It further suggested that without more concrete evidence linking oil prices and economic activity, other variables, monetary policy in particular, could explain the oil-economy relationships observed following the major oil price shocks, without recourse to a longer-term relationship between oil prices and the macroeconomy. Of course, this discussion greatly simplifies the positions of the principal advocates and neglects a broad and rich body of scholarly enquiry, which we detail below.

Taking this disagreement in the oil-macroeconomic literature as the point of departure, the current authors, economists at the Oak Ridge National Laboratory (ORNL), were charged by the Department of Energy (DOE) with the task of summarizing the state-of-the-science knowledge on the subject and commissioning a limited number of new research projects to study the foundations of the Hamilton-Mork-Bohi debate. The objective was to reach out to new data bases and analytical techniques that might resolve the conflict or move it onto more fruitful questions. ORNL formed a steering committee from the research community to ensure that all scientific views were represented in defining the research projects. Not surprisingly, this approach bore fruit, yet did not fully answer all questions. Better data, more advanced techniques, and targeted inquiry revealed that the Bohi challenge to identify linkages was researchable. In contrast, the effects of monetary policy, while not dominating the oil-macro relationship, were present but more complex than had been recognized initially. In fact, the oil-macro relationships themselves remained complex, with evidence of evolutionary change over the period between the late 1960s and the mid-1980s. While specific questions remain regarding the mechanisms by which oil price shocks contribute to recessions, the deniability of an oil price shock-economic activity relationship was put to rest: the relationship *is* observable.

We tell this story in greater detail in the body of this report. The analytical approaches to the macroeconomics of oil price shocks have been tied tightly to the emergence of the phenomenon of the oil price shock since 1973 as a publicly noticeable event. This interdependence makes it difficult to separate the topics, or analytical questions, from their context in the current events of the past quarter century. The oil price shock-macroeconomic repercussion nexus did not reveal itself all at once. Instead, it emerged haltingly, first giving an impression of a simple linkage, subsequently of a more complex one, and finally of a multifaceted set of relationships. Consequently, the economic analysis of this shock-repercussion phenomenon has changed emphases and directions as subsequent oil price shocks have revealed different aspects of themselves as a general phenomenon. An overview of any topic needs to show how the various questions about that topic relate to one another to yield a coherent picture, and in the case of the oil price shock-macroeconomic activity relationship, these questions emerged parallel to the evolution of the oil price shock itself, which has been a classic "moving target." The motivation for some of the lines of inquiry into the macro effects of oil price shocks would not be particularly apparent without a chronological ordering that highlighted the relationship between the oil price shocks and the research topics and between various research topics. Accordingly, we divide the record of economic research on oil price shocks and the business cycle into two broad periods—before this new research and following it— and both of these broad periods into more specific topical components.

Section 2 tells the story of the evolving understanding of the macroeconomics of oil price shocks through the DOE/ORNL commissioning of the latest research; Section 3 reports the results of that research; and Section 4 considers we know as a result of this new information. We open Section 2 with a graphical review of the history of oil price changes and GNP changes since World

War II. We follow that with a brief overview of theory about the oil price-GNP nexus. The two succeeding parts of Section 2 discuss the beliefs and understanding that developed in two periods, from the mid-1970s through the late ‘80s, and from the late 80s through 1995/96; in the latter period, the research agenda broadened in an effort to address questions that began to emerge late in the first period. The following two subsections review the state of international comparisons and the state of knowledge as of 1995. Section 3 reports first on the information coming from the new sectoral- and state-level research, next on the new assessment of aggregate relationships, and finally on the new investigation of the role of monetary policy in the post-oil price shock recessions.

2. The Progress of Knowledge about Oil Price Shocks and the Macroeconomy

The state of knowledge at the time of this study can be understood best by examining the empirical evidence and the scrutiny to which it had been subjected. Section 2.1 sets the empirical stage by tracing the history of domestic crude oil price-economic activity changes. The body of theory that explains them is previewed in outline in Section 2.2 . Following this, the development of understanding of the oil-energy relationship is reviewed in Section 2.3, through what we term the Mork revision of the relationship and the Bohi challenge to depart from this line of enquiry, around 1989. Section 2.4 then describes the different strands of research, some of it preceding Mork’s (1989) important paper, that led to the state of knowledge in 1995 when this work began.

2.1 The History of Oil-Price and GNP Changes

To understand the development of the literature relating oil prices and macroeconomic activity, it is useful to review the circumstance that called forth the concern over energy price shocks and economics activity. Figure one relates oil price -- and -- --- by --- starting in -- Oil price increases ... Gross domestic product changes apparently responded by...[to be completed with data to be secured]

2.2   Why Oil Price Shocks Could Retard GNP Growth: A Brief Tour of Explanations

Economic theory offers several explanations of how energy price increases could trigger a recession.   Energy is, for practical purposes, ubiquitously used and difficult to substitute for in the short run. A standard macroeconomic analysis suggests that consumers, faced with a price run-up, would attempt to maintain energy purchases in the short run by reducing purchases of other goods and services. The oil price increase would tend to be inflationary, and that increase in the general price level would reduce the real money balances held by the public (the stock of money, adjusted for changes in its value caused by price-level changes). To restore their real balances, the public (both individuals and firms) would reduce their spending on goods (including investment goods) and services below what would be required to keep their oil consumption constant. Unless the recipients of the dollar transfers associated with the oil price increase (largely domestic and foreign oil producers) were to increase their consumption of U.S. goods quickly, the decrease in aggregate demand would trigger a recession. There has been debate over the relationship between the oil price increases and subsequent loss to aggregate demand as it is depicted above, but the causality according to that explanation is straightforward. Equally clear is the policy prescription. The Federal Reserve, through monetary policy actions, could increase the rate of growth of the money supply to accommodate the public's repletion of real balances. Whether or not monetary authorities would choose such a course would depend on their evaluation of the impact of the price shock on subsequent levels of economic activity and on their concern with inflationary pressures.

Price shocks also affect the supply side of the economy by influencing the costs of producing the same volume of GDP as was produced prior to the shock and by changing efficient configurations of other factors of production (e.g., labor, capital, and other materials) relative to oil. Given a fixed capital stock and limited ability to substitute away from the scarcer (higher priced) factor, the production effects of a pure cost increase are closely related to the share of energy in the economy—the GNP share of energy multiplied by the percent price change gives a first-order approximation to the contraction in production capacity. In the short run, this change marks the maximum impact on the economy. Given substitutability, the new price regime also implies that the economy is using inefficient combinations of other, non-oil inputs, a situation which can be corrected through capital investments and, in the labor market, employment adjustments. However, any subsequent combination of inputs would be able to produce less than the efficient combination that existed prior to the price change. Thus, the economic capacity (as opposed to physical capacity) of the economy will have decreased, because for any efficient set of resources, valued at market prices, a smaller physical quantity of GNP can be produced. As equilibrium is reestablished a somewhat different composition of GNP would be produced, reflecting new relative prices for GNP components.

To the extent that demand and supply relationships are dissimilar for different consumers and producers, the predictability of the macroeconomic response, as it was described above, becomes much more complex in terms of both magnitude and timing. Some sectors may emerge as winners and others as losers. For every agent who adjusts by purchasing new technology to accommodate new energy price regimes, e.g., more efficient electric motors, another agent (such as producers of conventional motors) sees the demand for its product fall. Likewise, the foreign trade mechanism comes into play. To the extent that some nations produce goods that rise relatively in popularity (like fuel efficient cars) or fall (like fuel inefficient cars), impacts may be geographically unequal. Hence, uncovering "linkages" between oil prices and economic activity is considerably more complicated than establishing aggregate relationships.

So too is it important to integrate investment behavior into the linkage. If an agent, having observed a price shock, forms an expectation that the shock is of short duration he or she will behave differently than if the expectation is for a new price plateau. If the expectation is for increased price instability, the response may be different than that for generally stable prices. Finally, these expectations may change over time. Investment behavior is a complicated matter involving expectations of both the small and large details of the future, and oil prices appear to affect those expectations.

It has gradually become apparent that the effect of an oil price shock on the long-term productive capacity of the economy is much smaller than the temporary losses due to frictions involved in reallocating resources and delaying activities until uncertainties sort themselves out. This has encouraged a business-cycle view of the relationship, which has supplanted to a large extent the earlier perspective that focused on macroeconomic adjustment to a permanent loss of resources.

All of this, however, is discussed with hindsight. In 1975, when the economy emerged from recession, researchers were examining a broad range of topics that related energy to GNP, but none were directly related to the role of energy in initiating or exacerbating business cycle swings. Early attention concentrated on the role of energy (and other) price controls in leading to “gas lines,” on forecasting future energy demands and their relationships to energy prices, on the potential for substituting domestically produced energy products for imported oil, and on the potential role of R&D in effecting a “technological fix” for the energy crisis. Early research on the relationship between energy prices and the macroeconomy was concerned largely with the impact of persistent prices changes on economic capacity—i.e., how much the economy could produce at full employment. Since energy accounted for only some 3% of GNP in 1973, many macroeconomists, including Nobel Laureate James Tobin, were unconvinced that an oil price shock could have the scope to produce recessions like those of 1974-75 and 1979-80.

2.3 Early Investigations into the Oil Price-Business Cycle Relationship

As noted above, one defining aspect of the literature concerning the energy-economy relationship is the fact that it developed while the world economy was subjected to the oil price shocks of the 1970s, 1980s and the 1990s. Just as it was unclear to the world at the time of the first shock in 1973-74 whether a new energy price era had just arrived or prices would go back down nearly as quickly as they rose, it was not clear to economists how to conceptualize the event for purposes of analysis: Was it a demand shock or a supply shock? Was the reduction in potential GNP a more fruitful subject for analysis or was unemployment? Should concepts appropriate to the analysis of temporary events or permanent changes be used? In addition, following the first price shock the market institutions through which energy commodities were traded and the regional basis from which oil was produced changed substantially. The 1986 collapse of prices in the world oil market revealed that the oil-GNP relationship was more complicated than had been realized when studying the first two shocks and led to renewed examination of the beliefs developed since 1974.

In this section, we examine the development of the understanding of energy-economy relationships, modifications to this understanding due to data gathered following subsequent oil price developments and economic responses, and the challenge by Douglas Bohi to turn to new questions and data. We close the section by examining the avenues taken by researchers prior to the new research undertaken for this study.

2.3.1 Following the 1973-4 Price Spike

Michael Darby (1982) provided the first detailed econometric examination of the macroeconomic effects of the 1973-74 oil price shock. In examining the economies of eight OECD countries using quarterly data spanning 1957-1976 Darby could not reject the oil price explanation of the recession, but neither could he rule out a combination of monetary tightening, recent departure from the Bretton Woods international monetary standard, and elimination of price controls as possible major forces behind that event. Despite having established a clear statistical relationship between oil price changes and economic changes, Darby was reluctant to draw the conclusion from his results that oil was a major, independent causal influence in the 1974-75 recession.[1]

James Hamilton's 1983 study, which included both earlier data and later data covering the 1979-80 price shock, reached much stronger conclusions. Using the vector autoregression (VAR) technique to examine the relationship between oil prices and GNP and unemployment, Hamilton divided his data base into a series of partitions of the 1948-1980 period and, observing that oil price shocks not only had preceded every U.S. recession since World War II, concluded that oil price shocks in business cycles could be viewed as systematically "causing" the recessions.[2] Hamilton's basic model attempted to forecast quarterly changes in the logarithm of real GNP, using four lags in the dependent variable and four lags in quarterly changes in nominal crude oil prices. Dropping the volatile post-war year 1948, the sign of each lagged value for energy prices was negative and significant at approximately the .05 level. These relationships remained strong when Hamilton controlled for indicators of monetary policy. Further, his work indicated that no other "third" variables appeared to cause oil price fluctuations.

Several other studies focusing on the macroeconomic impacts of oil price shocks on the United States economy appeared to corroborate Hamilton's findings, with the result that the role of oil in the business cycle began to be considered more seriously again by many macroeconomists. McMillin and Parker (1994) pushed back Hamilton's findings on the role of oil price shocks to the period between World War I and World War II, as far back as 1924:2. During the period 1929:9-1938:6, the oil price shocks had a stronger effect on industrial production than did the monetary base, the M2 multiplier, and the yield differential (between corporate Baa and long-term U.S. government bonds) together.

Burbidge and Harrison (1984) employed similar VARs on the oil price-business cycle relationship for four countries— the United States, Germany, Britain, Canada, and Japan— with data from 1973 through 1982 with weaker results. Qualitatively, they found the contribution of oil price shocks to the behavior of industrial production and the CPI to have had few similarities across these five countries, which they did not find surprising considering differences in monetary policy, domestic pricing policy for oil, etc. They also argued that the mid-70s recession was underway before the October 1973 price shock. Nonetheless, they found that the oil price changes did account for much of the difference between their base projection (without oil price changes) of industrial production and the actual series in all the countries, except Germany, up to late 1975 or early 1976. They also found that only Japan showed any appreciable impact of oil price changes on industrial production or the CPI during 1979-80. They concluded that it is "less easy than some might think . . . to lay all

[1]Causality is defined in this literature strictly as a temporal phenomenon, with specific definition in the form of "Granger-causality" which is explained in footnote 11.

[2]A vector autoregression (VAR) model is a multi-equation system in which each variable is regressed on a constant and some number k of its own lags as well as on k lags of each of the other variables in the VAR. Each regression in the system contains the same explanatory variables. The regressions can be estimated by ordinary least squares (OLS) techniques.

the blame on external influences, namely OPEC, for the poor economic performance of much of the non-OPEC world over the past 10 years."

2.3.2 The Price Drop of 1986-87

Until 1996, virtually all of the post-World War II oil price “shock” experience was with price run-ups. In 1986-87, oil prices dropped precipitously, but the economy, rather than surging as a symmetrical interpretation of Hamilton’s findings would imply, maintained a steady course. About this time, Gilbert and Mork (1986) developed a conceptual one-sector macroeconomic model with a downwardly rigid wage, in which oil price shocks could have asymmetric effects—i.e., positive shocks cause recession but negative shocks do not cause a boom. In applying this model in an attempt to account for the non-responsiveness of the business cycle to the 1986 oil price fall, Mork (1989) extended Hamilton’s (1983) analysis to 1988:2 using VARs of GNP on the oil price, a monetary policy indicator and several other control variables. The results with this extended sample period seemed somewhat weaker than those of Hamilton’s earlier work. For the full sample period of 1949:1—1988:2, the oil price variable did not perform well, but division of the sample at 1986:1 failed to produce a model that would fit both periods. Subsequently, Mork separated the oil price variable into distinct variables for price increases and decreases. This model passed his cross-period stability test which the model with only oil price changes failed.[3] This implied that the oil-macroeconomy relationship only operated for price increases, a result which seemed plausible to many macroeconomists, even without a clear explanation for it, but not so to some microeconomists.

2.3.3 The Bohi Challenge

Around the same time as Mork’s research, Bohi (1989, 1991) published the results of a sectorally disaggregated study in which he was unable to find any relationship between oil prices and employment in energy-intensive 3-digit ISIC industries in the United States, Germany, the U.K., and Japan. From an examination of monetary policy during the period of the 1970s oil supply shocks, combined with an inability to detect any industry-level employment changes that could reflect contractionary consequences of oil price shocks and the failure of the 1986 price collapse to spark a boom, he concluded that inappropriately tight monetary policy was primarily responsible for the recessions of the 1970s.

Bohi disputed the implication of the postwar time series research that the impacts of much

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[3]Tatom (1988) inferred symmetric effects of oil price increases and decreases from his statistical analysis of some Anderson-Jordan equations and some aggregate production functions containing oil prices. (An Anderson-Jordan model regresses nominal GNP growth on lagged measures of monetary and fiscal policy, and in this case on oil prices as well.) Extending the sample period of previous work to include the period 1981-85, which experienced the beginning of oil price reductions from their high in 1979-80, he obtained numerically stable estimates of oil price elasticities. [An elasticity measures the percent change in a variable caused by a 1% change in another variable. Thus, the elasticity of GNP with respect to oil price is the percent change in GNP caused by a 1% increase in the oil price. This particular elasticity goes by several, interchangeable names in the literature: the GNP elasticity (“oil price” being understood), the oil-price elasticity (GNP generally being understood), and the oil-GNP elasticity.] Hamilton (1988) found unconvincing Tatom’s implicit reliance on long-run shifts, as contrasted to short-run business cycle fluctuations, in the latter’s interpretation of his statistical results and noted the low statistical power involved in inferring seven new parameters from five additional data points.

smaller changes in oil prices during normal periods could be extrapolated to infer impacts from large oil price changes. Consequently he reasoned that data prior to the 1973-4 price run-up were irrelevant to the study of the relationship of oil prices to macroeconomic aggregates. He was likewise critical of aggregated relationships that linked oil and output statistically, but abstracted from linkages that would explain the mechanisms by which oil price changes were transmitted throughout the economy. Bohi also examined the hypothesis of a simple relationship between oil import shares and aggregate impacts of oil price shocks, noting that Japan, which imports virtually all of its oil appeared to prosper during the recent price run-ups while Great Britain, which produced virtually all of its oil, suffered markedly. Bohi challenged researchers to identify industry-level (microeconomic) mechanisms by which oil prices precipitated recessions, or at least contributed substantially to them.

Mork's findings together with Bohi's challenge left many issues unresolved. Had the relationship between oil prices and the business cycle changed sometime in the later 1970s or early 1980s? Had the estimation procedures been especially sensitive to the two major price explosions of the 1970s and simply mis-identified the relationship because of insufficient variance in the earlier data? Was the critical information content of oil prices being missed by the standard data series? Was it really the case, as Bohi contended, that pre-1973 data on the oil price-business cycle relationship were irrelevant, and that there were in fact only three observations of an oil price shock—1973-74, 1979-80, and 1986-87 (now four, with 1990-91)?

2.4 A Broadening Research Agenda

Several major lines of research developed to pursue answers to these questions. One thrust followed Mork's (1989) notion of asymmetry in the oil price-business cycle relationship: was it real or an artifact of data and estimation techniques? Another examined the information content of oil price movements: did oil price changes convey different messages to economic agents during different parts of the post-war period? A third line of inquiry focused on the possibility of a varying or changed relationship between oil prices and the business cycle, particularly after 1986, when the behavior of oil prices appears to have changed: when did the relationship change and what can be said about the nature of the change? Still another group of studies addressed the possibility that monetary policy had turned a minor jolt to the economy into major recessions, and that the influence of oil price shocks had been greatly overestimated. A final topic involved different macroeconomic responses to oil price shocks in different countries. For example, some industrial countries' economies were affected less strongly by the 1979-80 oil price shock than were other countries', which leaves the question, "Why?" Bohi (1989, 1991) relied on this differential response to suggest that differences in monetary policy were responsible for the differential aggregate performances following the price shocks of the 1970s.

2.4.1 Asymmetric Response of Macroeconomic Indicators to Oil Price Shocks: The Aggregate Evidence

The asymmetry question has influenced much of the post-1989 research, to the extent that it has become nearly standard to specify positive and negative oil price changes as separate variables. Nearly all of the empirical analyses after Mork's (1989) study, which separated oil price movements into separate variables, have found asymmetric aggregate GNP responses to oil price changes. However, prior to Mork's study, Tatom (1988) examined the asymmetry issue for the period 1955:I— 1986:III using interactive dummy variables for the period after 1981 on the oil price variable, which was not separated into positive and negative movements. He was unable to find evidence of asymmetry in the oil price-GNP relationship over this period, but Hamilton (1988) questioned the power of statistical tests to reject the null hypothesis of no interactive effect of the dummy variable with the oil prices given the relatively small increase in the number of observations.

The studies which have found significant asymmetries in the relationship have used different sample periods, different control variables, different periodization of the data, different estimation methods, and even different countries. Using separate variables for oil price increases and decreases, Dotsey and Reid (1992) corroborated Mork's finding of an asymmetric response over the period 1954:I— 1991:III in the United States. Mory (1993) estimated the oil price-GNP relationship for the United States from 1951 to 1990, using annual data and separate price increases and decreases and controlling for government purchases and M2 money supply. He estimated the oil price-GNP elasticity for price increases, over 1952-90, at -0.067, highly significant statistically. Mork, Olsen and Mysen (1994) applied a VAR model similar to Mork (1989) to the experience of seven OECD countries (the United States, Canada, Japan, Germany, France, the United Kingdom, and Norway) over the period 1967:3-1992:4. The responses to oil price increases were negative and significant for most of the countries, but were positive for Norway, probably because of the substantial share of oil production in that country's economy. The responses to price decreases were mostly positive but not significant, except in the U.S. and Canada, where those responses were statistically significant. McMillin and Parker (1994), in their study of oil prices in the interwar business cycles did not separate oil price movements into positive and negative changes but did note that downward oil price shocks were particularly prominent during the period. While they did not examine the consequences of the downward shocks, they inferred mitigating effects on other depressing shocks. Altogether, the prevalence of negative price shocks during this period did not destroy the causal relationship in the data between oil prices and industrial production, such as appears to have happened sometime in the 1980s, as we discuss below.

Researchers have pointed to several possible mechanisms that might contribute to this asymmetry: the sectoral shocks hypothesis (sometimes called the employment dispersion hypothesis) of David Lilien (1982), the closely related matter of composition of demand, and uncertainty effects on investment (Pindyck and Rotemberg 1984). Empirical work on most of these hypotheses has emerged only recently however.

The sectoral shocks hypothesis appeals to the costs that firms incur whenever their input or output prices change. After a general price shock, some firms will want to hire new employees, and others to lay some off, but the transition is not smooth for the workers affected. Those newly hired probably will not be those just laid off, so thinking in terms of net employment change misses the important concept of "gross employment creation and destruction" (the sum of layoffs and new hires—a term coined subsequently by Davis et al. 1996, in their independent contributions), which can impose costs far beyond what would be expected by the volume of net employment change. The more dispersed across sectors are shocks to the economy, the higher will be the unemployment rate according to this hypothesis, because more reallocation of resources with industry-specific skills or specifications is required. The reasoning was that a wider dispersion of unemployment across industries entailed more labor reallocation between sectors, which requires more time to match skills to job requirements, hence leading to a higher aggregate unemployment rate. Conversely, a lower aggregate unemployment rate would tend to be more concentrated in certain industries rather than being composed of simply lower unemployment rates across all industries. Prakash Loungani (1986) tested the dispersion hypothesis using quarterly U.S. data over the period 1947-1982. He found that when the relative price of oil is held fixed, the inter-industry dispersion of unemployment has little residual explanatory power for fluctuations in the aggregate unemployment rate. He suggested that this result might imply that oil price shocks may have been the principal such reallocative shock affecting the U.S. economy during this period, and that the oil price shocks of the 1950s as well as those of the 1970s may have required an unusual amount of interindustry reallocation of labor. Nevertheless, he left that as an open research question. Davis (1987, p. 329) added additional evidence in support of this view by reporting research which showed that "oil price shocks explain much of the time-series variation in the pace of labor reallocation (as proxied by a Lilien-type dispersion measure) and do so in a way predicted by the sectoral shifts hypothesis."

Kim and Loungani (1992) added some further, indirect evidence that something about the more disaggregated structure of the economy was important to the mechanism(s) by which oil price shocks affect the business cycle. They developed a one-sector[4] business cycle simulation model with perfectly flexible wages and commodity prices and examined energy price shocks as the sole source of exogenous shocks to the supply side of the economy. Comparing simulation results with annual data for the period 1955:3-1987:4 (and 1949-87), energy-price shocks accounted for only 16% to 35% of the variation in output, depending on the type of substitutability between productive inputs with which they modeled production. Energy price shocks alone also did not replicate key features of business cycle data such as the tendency of consumption to be smoother than output. Because these results depend on the total aggregation of output into a single, undifferentiated sector, they suggest that oil price shocks are likely to have some of their most potent effects on the business cycle via routes that rely on interindustry differences.

The hypothesized 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, plants in the U.S. that produced small cars operated at capacity and plants that produced 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). Working with highly disaggregated data, Bresnahan and Ramey found that the plant-level responses exhibited fundamental differences from the

[4]A one-sector economic model characterizes all output with a single sector— i.e., it does not disaggregate output at all into different types of goods. This type of model— or this type of aggregation of output— has a long tradition in economic analysis, particularly in macroeconomics and growth theory.

aggregated responses--both greater discontinuity and different distributions of adjustment methods. These plant-level findings suggest that the 3-digit SIC industry level detail employed by Bohi would not be sufficiently disaggregated to reveal microeconomic adjustment mechanisms in response to oil price shocks.

Demand composition also may be able to account for a good deal of the international differences in responses to oil price shocks. The exports of Japanese cars during the 1970s reveal the potential for auto demand increases to have offset direct negative impacts in Japan of oil price increases (Murrell, Hellman, and Heavenrich 1993, p. 21; Motor Vehicle Manufacturers Association 1981, p. 69; 1992, p. 46). In 1970, Japan supplied 12.5% of world vehicle exports; by 1975, that share had climbed to 24.8%, and by 1980 it peaked at 39.4%. Following the 1979-80 oil price shock, Japan exported an additional 1.4 million vehicles (over 500 thousand to the United States alone), equivalent to roughly 3.75% of its GNP; the foreign exchange inflow would have similarities to an injection of high-powered money (the most potent type of monetary expansion). This demand shock may have been able to largely offset the 1979-80 oil supply shock in Japan. Investment multiplier effects also can be set off by impacts on narrowly defined industries, sending demand and employment shocks much more widely through the economy.

The investment-uncertainty hypotheses have their underpinning in what has become known as "irreversible investment" theory. Recent research on investment under uncertainty indicates that uncertainty has a different effect, and probably a larger one, on investment decisions than what would be implied by a simple cost-benefit assessment of a one-time investment opportunity (Pindyck 1991). Investors recognize that the passage of time can clarify present uncertainties, and the mathematics of the decision produces an asymmetry between investors' assessments of possible good and bad resolutions of those uncertainties: investors weight a possible bad outcome more heavily than an equally sized, possible good outcome. (This asymmetry is known as "the bad news principle": Bernanke 1983, pp. 90-93.) Consequently, the deferral of investment is a rational option which can have the appearance in aggregate data of a very high rate of return being required for investments involving specific uncertainties or in periods of high, generalized uncertainty. To the extent that oil price shocks raise uncertainty to businesses, they will tend to delay investments. The investment multiplier transmits the initial postponements in investment to substantially larger reductions in employment and output as reductions in orders ripple through the economy.

As a group, these theories began to provide a conceptual basis for the apparent asymmetry of the oil-macroeconomy relationship. Research on asymmetry of macroeconomic responses to oil price shocks evolved into separate strands of research on particular transmission mechanisms. Each posed specific transmission mechanisms that might be observable at the level of the industry or firm.

2.4.2 Expectations and Price Run-ups: What do Oil Price Shocks Mean to Economic Agents?

The question logically arises why should uncertainty in energy prices be treated any differently than uncertainty in other input prices or in other aspects of business? Is not uncertainty merely another cost of doing business? One answer to this is that some uncertainty can be characterized as essentially "anticipated" and differs from that uncertainty occurring as a "surprise." To investigate this issue, Lee, Ni, and Ratti (1995) constructed a transformation of the oil price variable based on its statistical error structure to account for the surprise content of its movements and used separate variables for positive and negative changes. This transformation was able to generate a stable relationship between oil prices and GNP from 1949:3 to 1992:3, suggesting that anticipated oil price fluctuations cause no particular problems but that truly unexpected *increases* do contribute to business cycle shocks. Although they did not explore mechanisms further, they suggested that these results point to sectoral reallocation and investment uncertainty as important routes of oil prices' influence on the macroeconomy.

Ferderer (1996) investigated the role of uncertainty surrounding oil price fluctuations further, by developing a variable describing the volatility of oil prices during a month, with separate variables for the change in oil prices. He examined the asymmetry issue with separate variables for positive and negative oil price changes, along the lines of Mork (1989). Rather than a crude oil price such as the refiner acquisition cost used by Mork (1989), Ferderer used a weighted average of oil product prices, which appears to possess different variance properties from the crude price series. Over the period 1970:01— 1990:12, Ferderer found that positive oil price changes induced substantially more volatility into those prices than did negative price changes, but that both of the directional oil price changes and the volatility of oil prices embody important information that is independent of that contained in indicators of monetary policy. Inclusion of the oil price volatility measure eliminated the significance of the oil price level (or change) variable in the VAR for industrial production growth, in contrast to Lee, Ni, and Ratti's finding that controlling for volatility in the construction of the (crude) oil price variable improved the significance of the oil price-GNP relationship. Ferderer's result, by itself, would tend to imply that most of the effect of oil price increases comes from their uncertainty or volatility rather than from the sharp change in level. This is different from saying that the mechanism by which oil price shocks affect the macroeconomy is increased uncertainty about a variety of phenomena other than oil prices.

Ferderer also concluded that monetary tightening was not the sole cause of the 1970s recessions. In examining the asymmetry of business cycle response to oil price increases and decreases, he found significantly different coefficient values for increases and decreases (the former over twice as large as the latter). Those coefficient values converged a good deal when oil price volatility was included in the equation, but increased when a monetary policy indicator was added as well, suggesting that uncertainty was a significant avenue contributing to asymmetry. Ferderer found that oil price increases and decreases had symmetric effects on the indicators of monetary policy, suggesting that asymmetry does not operate via that route.

2.4.3 Changes in the Fundamental Relationship

There is a variety of reasons to believe that the energy-economic relationship may change over time. Prior to 1973, domestic oil price controls were in effect, with oil price levels relatively low but stable. Following 1973, prices were stable at a higher level, but decontrol was finding favor. With the passage of time oil prices were essentially decontrolled and spot markets replaced longer term contracts internationally. Forward and futures markets for both crudes and several products emerged in the 1980s. These changes, coupled with other factors, led to greater variance in oil prices. Given these significant changes, it is not unreasonable to expect that the causal factors linking oil and the economy would likewise change.

One means to examine changes in these causal factors is to search statistically for a logical break point, at which alternative model structures provide superior forecasts. Hamilton (1983) had found a structural break[5] in the relationship between oil prices and GNP at 1972:IV/1973:I, as had Gisser and Goodwin (1986). When Mork (1989) extended Hamilton's (1983) analysis of the effects of oil prices on U.S. GNP beyond 1980 to 1988:2, he obtained weaker results: his coefficients on lagged oil prices were close to zero and only marginally significant. A test for stability of the oil price-GNP relationship before and after 1986:1/2, after there was a substantial downward trend in oil prices, indicated a stable relationship. This finding prompted him to explore the asymmetric specification of oil price changes reported above, which restored the finding of a stable relationship over the full time period 1949:1-1988:2.

Hooker (1996a) devoted explicit attention to this weakening of the oil price-GNP relationship in later periods, studying that issue at some length. He found not only a structural break at the end of 1973, but that oil prices actually lost their causal role in determining movements in GNP after 1973. The use of separate variables for oil price increases and decreases failed to restore the relationship, as it had for Mork (1989). Hooker's explorations with Ferderer's oil price volatility concept found a weak relationship between oil price growth rates and volatility in the 1948-73 period, suggesting that the latter variable is not a simple surrogate for the former. In general, Hooker found that the evidence supporting various asymmetry hypotheses was not robust to sample period and specification. In simple terms, the fundamental relationship first identified by Hamilton appeared to be eroding.[6]

2.4.4 Monetary Policy Issues

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[5] A "structural break" is a discontinuity in the relationship estimated among variables. In the context of regression equations used to estimate such a relationship, a structural break can be said to have occurred during some time period if different sets of coefficient values best fit the relationship over different parts of the time period. For a somewhat more concrete example, suppose that in estimating the relationship between oil prices and GNP between 1955 and 1990, we obtain a statistically significant regression coefficient (significant at the 0.05 probability level) on the oil price variable (ignore lags for the example) of -0.054. However, if we divide the full period into two sub-samples, say from 1955-72 and 1973-90, we find a significant coefficient of -0.062 (say, at 0.01 probability level) on the oil price variable in the earlier sup-period and a significant coefficient of -0.021 (again at 0.01 probability level) for the latter period. Clearly the statistically significant relationship for the full period mis-states the actual relationships governing each sub-period, which also have stronger significance levels. We would say that there is a structural break "around 1972-73." Something changed in the relationship between oil prices and GNP around this time. An alternative interpretation of the different, significant relationships which can be estimated by breaking the full sample period in two at 1972-73 is that the relationship was changing prior to 1972, and may have continued changing after 1973 before reaching its final, new status, but only by that year are there enough observations on the new relationship to obtain a statistically significant estimate of it. The potential for complication in both the economic interpretation and the statistical estimation can be imagined readily, for example, when in fact can the "structural break" be said to have occurred? Can it be identified to a particular year or only to a span of time? These issues are addressed in the new research, and the new evidence is presented below.

[6] McMillin and Parker's (1994) finding of a significant, causal relation for the interwar period, during which real oil price decreases were common, has not been brought into the research on asymmetry and changing structural relations. Further exploration of oil-macro relationships in that period could yield insights into the transmission mechanisms producing asymmetry and offer a sample period with a different variance structure with which to explore changing structural relationships.

Darby (1982) first raised the possibility that the apparent effects of the 1970s oil price shocks on employment and GNP in the United States were spurious artifacts of simultaneous events in monetary and fiscal policy—specifically, the dissolution of the fixed international monetary standard, with corresponding contractions in monetary growth, and removal of price controls. The specification of his regression model, however, allowed oil prices only a role in changing the "natural rate" of unemployment, not a transient but substantial role in precipitating a business cycle fluctuation. He obtained a very small regression coefficient on his oil price variable, which he compared with oil's small share in GNP, and inferred an important causal role for monetary policy.

Bohi (1989) followed this line of reasoning regarding the roughly simultaneous appearance of the oil price shocks and U.S. monetary contractions, but he also followed the progress of monetary policy in Japan, Germany, and the U.K. as well during these episodes. While U.S. monetary growth contracted in both 1974 and 1980 (it actually was contracting in 1973, going into the oil price shock), followed by severe U.S. recessions, Japan's monetary behavior paralleled that of the U.S. following the 1973-74 oil price shock but not after the 1979-80 one. Correspondingly, Japan experienced a severe recession in 1974-75 but not in 1980-81. Contrasting particularly the U.S. and Japanese experiences, Bohi suggested that the regression analyses spuriously were assigning the effects of monetary policy in particular, but tight fiscal policy as well, to oil prices in the first two oil price shocks. For all four countries, Bohi endeavored to place the oil price shocks within the full macroeconomic context of the times and found that there were enough alternative candidates at whose doors the 1974-75 and 1980-81 recessions could be placed that the causal role of the oil price shocks themselves could be doubted. Bohi also introduced the suggestion that monetary policy, U.S. policy in particular, may have responded to the inflationary pressures anticipated to be set off by the oil price shocks.

In his 1983 article, Hamilton tested and rejected the hypothesis that oil prices Granger-caused movements in monetary variables over 1949-1972. The oil price variables in his VARs had statistically significant effects on GNP and unemployment when controlling for the effects of the M1 money supply as an indicator of monetary policy. All of the more recent studies of oil price-business cycle relationships have included control variables for monetary policy—most commonly the M1 or M2 money supply or the federal funds rate—and have found a clear, prominent, and independent role for oil prices in addition to monetary policy. Several of the recent studies have addressed somewhat incidentally the issue of monetary policy versus oil price shocks as the principal influences of the 1970s recessions. In addition to those already mentioned, Dotsey and Reid (1992) simulated the 1973 oil price shock and the following recession and, controlling for monetary shocks, attributed a 4.23% loss in GNP to oil prices. Ferderer (1996) noted that the correlation between positive oil price shocks and oil price volatility could give the impression that oil price movements possessed no information that predicted movements in industrial production and that monetary policy was the sole contributor to the business cycles of the '70s, but that this was only an artifact of the correlation between the two oil market variables. In fact Ferderer found that while oil prices *did* affect the monetary policy indicators, they had a separate effect on industrial production in addition. However, the extent of the exogeneity or endogeneity of monetary variables was unclear, and it is consequently not clear that the empirical evidence cited above satisfactorily answers the question of the relative roles of monetary policy and oil price shocks in generating the recent recessions.

The possible endogeneity of monetary policy in general, and to oil price shocks in particular, is an important issue in the study of macroeconomics. It is accepted that monetary authorities respond to conditions in the economy, either via rules or by discretionary actions. If monetary authorities have incorporated oil price changes into the rules that determine their monetary targets, and their pursuit of those targets has influenced the business cycle, to which cause should the economic shock be attributed—oil or money? There are, in fact, three separate issues here. First, has the Federal Reserve incorporated oil price changes or some measure of oil price *shocks* into its monetary policy rules? (Of course, if it had, it wouldn't tell! More on this below.) Second, if it has, how would we know from studying the empirical evidence? Third, if the answer to the first question is "yes" and the second problem can be addressed satisfactorily, is the question of oil or money only a philosophical matter? By 1995, there was little systematic evidence on any of these three questions as they relate to oil prices, but the theoretical structure of at least the first two had become reasonably well understood.

On the question of how the Fed responds to economic events, in recent years, the analysis of monetary policy has largely accepted that monetary authorities (the Federal Reserve in the United States) appear to have rules that they follow to help them decide when to alter monetary policy in one direction or the other and by how much.[7] However, if they either announced those rules or made them so transparent that the public (including academic economists) could learn them on its own, their policy decisions would lose much of their effectiveness because private agents could anticipate them and make their adjustments beforehand. Such a rule which governs official money supply decisions has been called the reaction function, but studying the rule is a complicated empirical problem for several reasons.

Expressed in supply-demand terms, do oil prices affect the money supply decisions of the Federal Reserve? To determine the answer to this question, analysts are finding that teasing out of the data just what the money supply decisions of the Fed really were is a problem in its own right. While monetary policy may or may not be at least partly endogenous to oil price shocks, the actual money supply is endogenous to ordinary economic fluctuations, so a simple measure of the money supply or changes in it need not be a satisfactory indicator of changes in monetary policy. First, the public, as well as the Federal Reserve, is able to influence money supply by some of their decisions, so changes in money supply alone are not exact measures of changes in monetary policy governed by the Fed's reaction function. Additionally, if the demand for money is changing at the same time as the money supply is being changed by policy and private actions (i.e., if oil price movements affect the demand for money), additional analytical effort is required to identify the exogenous change in money supply—the policy component of the change in the intersection of demand and supply curves for money— i.e., the reaction function.[8] This is one of the important issues that Hooker (1996c) explored in his work sponsored by DOE, which was the first analysis to incorporate the latest methods for identifying exogenous components of monetary policy into the analysis of oil price shocks. Discussion of the third issue in the monetary policy versus oil question we defer to section

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[7]The existence of rules need not exclude the occasional use of discretionary action.

[8]A useful and accessible treatment of the issue of empirically identifying monetary policy is Zha 1997.

3.3, where we discuss Hooker's examination of monetary policy.

2.5 International Differences in Responses to Oil Price Shocks

Empirical evidence on different macroeconomic responses to oil price shocks was first presented by Burbidge and Harrison in 1984, as discussed above, but Bohi (1989) was the first researcher to identify the different national responses as a challenge for theory. He pointed to differences in Japanese responses to the 1973-74 and 1979-80 oil price shocks, differences between the Japanese and U.S. responses in the 1979-80 episode, and the similarity between the British and U.S. responses to both shocks despite the fact that Britain became a net oil exporter during the interim. Mork, Olsen, and Mysen estimated VARs of the aggregate GNP-oil price relationship for a number of OECD countries but did not explore explanations for differences among countries except for the case of Norway, which had positive GNP responses to oil price shocks, probably because of the share of oil exports in its economy. Cursory examination of the responses of various industrial countries indicates interesting patterns of similarities and differences. Some countries with similar industrial structures have responded differently, while other countries with strikingly different physical and economic characteristics have responded quite similarly. There seems to be a rich vein of potential information in these patterns of national characteristics and responses to oil price shocks that promises to enrich the understanding of the oil price-GNP relationship.

2.6 The State of Knowledge in 1995

By the summer of 1995, research on the macroeconomic impacts of oil price shocks had developed considerable sophistication.[9] However, despite the weight of the evidence on several topics, enough empirical puzzles remained to cast doubt about whether the role of oil in business cycles was understood with sufficient precision to guide new policy initiatives.

First, while some weight of opinion existed among macroeconomists that oil price shocks had indeed played an important, causal role in the recessions of the 1970s-'80s, the causes of asymmetry remained hazy and to some extent speculative. Clearly the empirical relationships between oil prices and GNP and other macroeconomic indicators were proving elusive enough to explain to be worrisome. The precise form of the relationship, if one existed, between oil prices and GNP remained an open question. This strengthened the criticism that it was improper to extrapolate from a large set of small price changes to a small set of large price changes.

Second, no studies had squarely met Bohi's claim that the microeconomic mechanisms underlying the aggregate data remained to be demonstrated. Except for the auto industry, where little disagreement existed, the research on oil-related business cycle transmission mechanisms remained at an aggregate level despite their ultimate reliance on microeconomic phenomena such as plant managers deciding to lay off some employees or purchase a different brand of product that used

[9] Many of the papers with subsequent publication dates were in active circulation prior to their publication and actually were affecting directions of research prior to their formal publication.

less energy. In microeconomic terms such as these, how could an oil price shock account for the magnitudes of the recessions witnessed in the 1970s and early '80s, if oil's share in GNP was only 2 to 3%, and all energy's share was no larger than 6%, especially when 3-digit industry data revealed no major changes in employment or output in oil-intensive industries after the great oil price shocks?

Finally, the issue of monetary policy versus oil price shocks as causes of those recessions had not been put to rest. If oil price shocks affected monetary policy, as some research was beginning to indicate, and the monetary policy caused the magnitudes of the recessions, should not the blame be put on bad, or at least deliberate, monetary policy rather than on oil price shocks? But to what extent did monetary policy react to the oil price shocks, and to what extent was it independent? If the post-oil price shock business cycle downswings are caused by the presence of oil prices in the Federal Reserve's money supply (or reaction) function, it may be disingenuous to declare that "money is the problem and not oil."

3. The New Evidence

To focus attention on these questions the Oak Ridge National Laboratory, on behalf of the Department of Energy, funded four new studies. Two studies focused on identifying microeconomic mechanisms by which oil price shocks contribute to business cycles. The other two examined the changing nature of the fundamental oil-economy relationship and the validity of extrapolation from small price changes to large price shocks. All four studies were structured to provide special attention to monetary policy. In addition the Federal Reserve Board contributed new information regarding the effect of monetary policy at the workshop at which the results of the DOE/ORNL-sponsored research was presented.

We discuss these studies in three sections. We first treat the two microeconomic papers in Section 3.1 We examine the fundamental relationship papers in section 3.2 and the monetary papers in Section 3.3

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3.1 Evidence of Linkages at the Sectoral Level

The Bohi (1989) study that first raised the question whether the oil price shocks of the 1970s really caused the subsequent recessions examined employment at the 3-digit industry level. The two studies conducted for the 1996 effort also focused on transmission mechanisms via the labor market, and opened to consideration the possibility that other microeconomic mechanisms also contribute to the oil price-business cycle relationship. The data used in the first of these studies (Davis and Haltiwanger) was highly disaggregated: the Longitudinal Research Datafile from the Census Bureau furnishes quarterly data on job creation and destruction from 1972 through 1988, at the level of the individual manufacturing plant. Many other characteristics of the plants are available as well, including number of employees, capital intensity, energy intensity (measured as energy costs divided by value of shipments), age of plant, and product durability. The authors conducted their analyses at the 4-digit level of industry disaggregation.

The second study (Davis, Loungani, and Mahidhara) used more aggregate employment and unemployment data but greater regional detail. This study used two measures of state-level data on unemployment rates and total employment, combined with information on industry mix (capturing fixed capital in the state) and the industrial composition of demand shocks facing each state. The panel data set contained information on the 50 states plus the District of Columbia, annually from 1954-92. For the first time data on the spatial components of business cycle behavior were used to help identify oil- induced transmission mechanisms affecting labor markets.

3.1.1 Analysis of the Oil-Economy Relationship at the Four-Digit SIC Level

A distinguishing feature of the Davis and Haltiwanger's study is its use of the concept of job creation and job destruction as separate variables rather than aggregating employment change through a single, net employment change, variable. Both the creation of new jobs (through new hires) and the destruction of existing jobs (through layoffs) involve considerable expense for all parties concerned, and the total volume of these gross employment actions substantially exceeds the net employment change. In an given example below, over four years of a business cycle, a relatively modest loss of 60,000 jobs masked a total labor reallocation of 410,000 jobs. The quarterly job reallocation rate averages 10.7% of manufacturing employment over the cycle. This more detailed accounting of reallocations in the labor market helps reveal asymmetries in macroeconomic responses to business cycle shocks by allowing separate responses to the underlying components of aggregate employment.

Additionally, aggregate business cycle shocks, including oil price shocks, operate through two distinct groups of "channels" -- aggregate and allocative channels -- which can have qualitatively different impacts, depending on the type and direction of the shock and the affected variable in question. Aggregate channels affect all sectors similarly; these are the potential output, income transfer, and sticky wage effects traditionally identified by macroeconomic theory and variable mark-ups (percent difference between cost and price in imperfectly competitive industries).

Allocative channels alter the closeness of the correspondence between desired and actual ratios of productive inputs (labor, capital, and materials). "Closeness" includes physical distance, the complement and distribution of skills embodied in workers, the productive attributes of plant and equipment, and the ways capital and labor are organized to produce goods and services.

Shocks devalue or destroy intangible inputs such as informational and organizational capital as well (Davis, Haltiwanger, and Schuh 1996, 106-112). An oil price shock will simultaneously reduce job creation and increase destruction via aggregate channels, while through the allocative channels it increases both creation and destruction. This qualitative difference in relationship is a primary means of empirically identifying the strength of the transmission channels in the linkage between an oil price shock and aggregate economic performance.

Equipped with these data and economic concepts, Davis and Haltiwanger explored the labor-market transmission channels for oil price shocks with the VAR approach. Their specification included seven variables: an oil price shock index, its absolute change, total manufacturing job creation and destruction (separate variables), an index of monetary policy, and sectoral job creation and destruction. They constructed the oil price shock index as the logarithm of the real price of oil divided by the weighted sum of prices over the past twenty quarters, with the weights summing to 1 and declining linearly to zero. They estimated VARs for plants in some 450 4-digit manufacturing industries, in addition to those for aggregate manufacturing employment.

From these data Davis and Haltiwanger estimated that a positive oil price shock 1 standard deviation in magnitude led to the destruction of 290,000 production worker jobs and the creation of 30,000 over the first two years after the shock. After four years, net employment response is a net loss of 60,000 jobs but a gross reallocation of 414,000 jobs, which exceeds 3% of total manufacturing employment. The oil price shocks of the 1970s were well in excess of one standard deviation: the shock of 1973-74 was 1.7 times the standard deviation, and that of 1979-81 was about 2 standard deviations.

The pattern of job creation and destruction fits the profile of an allocative disturbance: job destruction rises and job creation declines. The short-run net response is negative, peaking at five quarters. The longer term employment response is roughly zero but masks substantial, longer term job reallocations: i.e., eventually employment returns to previous levels, but that fact alone neglects all the costs of people moving between jobs in the meantime. At the 4-digit industry level, these employment responses to positive oil price shocks increase with the capital intensity of the plant, the durability of the product made at the plant, the fraction of the industry's employment at young plants, and energy intensity. Of the job reallocation over the four years following a positive, 1-standard deviation oil price shock, only 15% is in and out of manufacturing, and 45% is within the same 4-digit industries. 78% is within energy intensity classes, and only 5% is between them. As an indicator of the magnitude of the relative contribution of oil price shocks to business cycle fluctuations, those shocks account for 20 to 25% of the variance in 8-step ahead forecast errors for manufacturing, which is twice the share for which monetary shocks account.[10]

This work also identifies an impact asymmetry. A negative oil price shock of the same magnitude has about one-tenth of the employment consequences of the positive shock. After four quarters, the negative shock has a modest depressing effect on job creation and a modest elevating effect on destruction; by five quarters, those two trends have reversed to exactly offset each other, and yield a modest net increase by eight quarters.

The magnitude of employment responses to monetary shocks is estimated at one-third to one-half that to oil price shocks. Monetary shocks are thus shown to be significant, but not singular, contributors to the aggregate fluctuations. The predominant channels for the effects of monetary

[10] This technical terminology is difficult to avoid, but its translation to more intuitive terms is possible. For each period in the sample period, the VAR procedure yields forecasts of the dependent variable (employment measures in this case) that are based on previous values of itself and other variables. These forecasts are the best estimates of the value the employment variable will take at, say, eight periods in the future that can be derived from the information embodied in the lagged values. Comparing the predicted (forecast) values with the actual values, we can obtain the variance of the forecasts, which can be decomposed into weighted variances of the other variables, including oil price and monetary shocks in this case. Thus, 25% of the unpredictability of employment behavior can be attributed to the unpredictable component of oil prices eight quarters previously.

shocks are aggregate. Job creation and destruction respond in opposing fashions to a monetary shock in two-thirds of all 4-digit sectors, whereas creation and destruction respond in parallel to an oil price shock in two-thirds of the same sectors. The results show that 32% of the employment reallocation in response to monetary shocks is in and out of manufacturing, 37% is within 4-digit industries, 60% is within energy intensity classes, and 11% between energy intensity classes.

3.1.2 Analysis of the Oil-Economy Relationship at the State Level

Davis, Loungani, and Mahidhara (DL&M) also focus on the labor market but are able to contribute additional insights into transmission mechanisms in two major directions: migration and the industrial structure of derived demand. Using their 51-"state," 35-year panel data set, DL&M abstract from the common components of national business cycles and focus instead on the determinants of the strictly regional (state) components of business cycles. To distinguish between effects on the level and composition of employment in a state, they study two definitions of both unemployment and employment, which have different industry coverage. Their oil price shock variable is constructed so as to separate the effects of oil prices on the average national growth rate of a 2-digit industry and the consequent contribution of a state's industry composition to the impact of an oil price shock on it.[11] They control for the state effects of defense and NASA contracts and direct military expenditures as additional, exogenous determinants of business cycle fluctuations. To control for the differential effects on states of other, national shocks, such as monetary policy changes, they construct a measure designated MIX, which is an interaction of the residuals from the national regressions used to construct the oil price variable (see footnote 2) and state industry employment shares. To capture the effect of the industrial structure of demand in a state, DL&M interact national differences between industry and aggregate stock returns with the state industry employment shares.

In regressions of the civilian unemployment rate on oil price shocks, defense contracts, military spending, the MIX variable, and the derived demand variable, contemporaneous and one-year lagged oil price shocks have as large an effect as all "other" shocks together, as captured in the MIX variable, have.[12] A one-standard deviation oil price shock will have a peak unemployment response of very nearly one percentage point (not 1%!). The other variables have markedly smaller impacts. In further examination, oil price shocks appear to have been the largest driving force behind regional unemployment fluctuations, both in the average level of dispersion among states and the variation of that dispersion over time. They are also the most important driver of fluctuations within states, having been especially important in Michigan, Indiana and Ohio.

DL&M used a VAR on state panel data from 1958-92 to explore the relationships between

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[11]The national component is derived by regressing the national growth rate of each 2-digit industry on defense contracts and contemporaneous and lagged oil price shocks. Then, the sum of the two estimated, industry-specific, oil price coefficients times their respective oil price realizations in year t is multiplied by that industry's employment share in a state in year t. This product is summed over all ten two-digit industries for each state in each time period.

[12]The regression accounts for 92% of the variance in the civilian unemployment rate.

employment, unemployment and labor force participation as each of those variables adjusts to oil price shocks. Because the two data series on employment are measured and behave differently, they studied separate VARs with each definition. The BLS (Bureau of Labor Statistics) measure is based on a large survey of non-agricultural businesses and reflects the number of paid positions, so people holding two jobs could be counted twice. It excludes self-employment, agriculture, private household employment, and military personnel.

The CPS (Current Population Statistics) measure is broader, covering all civilian employment with a monthly household survey. Remembering that the differencing procedures on these state panel data yield regional cycle variations rather than total variations, which include variations which affect the entire nation, the peak effect of an oil price shock on the BLS employment measure is a decrease of 0.86% after two years; nine years later, employment still remains nearly one-half percent below its initial level. The CPS measure experiences a slightly smaller and later impact, peaking at a 0.78% reduction at four and five years, but in the tenth year after the shock it is still 0.67% below its initial level. The peak effect on the unemployment rate is an increase of a little over 0.2 percentage points (not 0.2 percent) one year after the shock. It returns to its initial level after six years. The labor force participation rate is depressed by about one percentage point in the first year (statistically significant), and remains at that level for the entire, following decade. DL&M infer a substantial migration response from these interactions from the fact that both the labor force participation and unemployment responses are much smaller than the employment response. Both the impact effects and the longer term responses imply strong migration responses. The CPS employment measure, which covers employment losses not covered by the BLS measure, shows considerably larger longer term migration responses than does the BLS measure.

3.1.3 Summary of Sectoral Studies

These two studies of the labor market responses to oil price shocks in the United States reveal very clearly that the shocks of the 1970s and ‘80s had measurable, significant, and in some cases lasting effects, via rearrangement of labor demands. Much of the labor force reallocation induced by the oil price shocks would be difficult to detect at 3-digit industry disaggregations. These estimated consequences of the oil price shocks are separated from the effects of monetary policy, and in the latter study from all other sources of business cycle fluctuations as well. Both studies still find a stronger effect for oil price shocks than for monetary policy. The frictions involved in the reallocation of specialized factors of production appear to account for the asymmetric GNP responses to positive and negative oil price shocks as well as the magnitude of the GNP response to positive shocks. Nonetheless, research to date has not identified exactly what those reallocation frictions are. These sectoral shocks tend to move demands for labor away from the labor supply’s current geographical location pattern, and the costs of migration to bring those supplies and demands back together geographically appear to pose a significant economic impact, as identified in the research of DL&M. Other impacts may involve capital reallocations and the loss and re-acquisition of intangible capital by both workers and firms.

3.2 The aggregate relationship between oil prices and the macroeconomy

We examine changes to the fundamental relationship between oil and economy activity in two step. First, we examine the work by Mark Hooker that concentrates on the stability of the relationship by examining the forecasting properties of alternative model specifications and break points using diagnostic statistics. Next we examine the work by Hamilton that extends his earlier analyses using an approach called kernel regression to examine potential non-linearities in response functions. We would also note that Hooker and Hamilton corresponded over the period this work took place allowing each to test innovations by the other.

3.2.1 The Stability of the Fundamental Relationship

Hooker (1996a, b) took up this examination of the stability of the oil price-GNP relationship. He began by reproducing Hamilton's (1983) result that oil prices significantly Granger-caused both unemployment rates and GDP in the period 1948-1973:3. However, no specification of the oil price variable was able to yield significant Granger causality between oil prices and either GDP or unemployment in either the later sample period (1973:4-1994:2) or in the full period, 1948-94.[13] In response to Hamilton's (1996a) comment, Hooker (1996b) found that Hamilton's net-oil-price-increase variable (zero if the price increase was not larger than any price increase in the previous four quarters, positive if so) was able to significantly Granger-cause both the unemployment and the GDP growth rate over the full sample period of 1948-1994, but not over the "OPEC" sample period of 1973:4-1994.

Three major explanations, and several variants, have been offered for this change in the statistical relationship between oil prices and the major business cycle indicators. The first explanation is that oil prices no longer affect aggregate output. A variant of this explanation is that they never did. Hooker (1996a) was unable to find support for the hypothesis that output or any other macroeconomic indicator Granger-caused oil prices in either the early or late sample periods. Most macroeconomists have not accepted either the "no longer" or the "never did" explanations, which puts the research focus back on accounting for the statistical changes.

Specification error— getting the definition of variables, inclusion of variables, equation structure, or some combination of the above wrong— is the second general explanation. Mork (1989) began to address possible specification error with his separate variables for oil price increases and decreases, and that modification did indeed improve the performance of the model. Nonetheless, several scholars have raised further potential specification problems. Ferderer (1996) produced some evidence that the volatility of oil price movements had separate explanatory power in addition to the level, or changes in the level, of oil prices. Li, Ni, and Ratti (1995) found the distinction between positive and negative oil price changes useful and appropriate but also found that even those variables performed more satisfactorily when they were weighted by an indicator of the "surprise" content of the change. Hamilton (1996a, b) took another approach to the surprise content issue addressed by

[13]Granger causation is a concept from time series statistical analysis. Variable X is said to Granger-cause variable Y if previous observations of X can predict (are correlated significantly with) subsequent observations of Y, controlling for lagged values of Y. If X does not Granger-cause Y, a regression of future values of Y on current values of X and present and lagged values of Y will yield zero coefficients on X. Inferring genuine causality from statistically significant Granger causation without further information is dangerous.

LN&R with his net oil price increase variable, described above. Each of these transformations of the oil price variable addresses a specific, theoretical transmission mechanism which the most basic specification was unable to capture, primarily costly factor reallocation and delays in investment.

The third explanation that has been offered by several scholars (e.g., Darby 1982; Bohi 1989, 1991) is that monetary policy may have roughly paralleled oil price shocks, leaving a high degree of collinearity between monetary policy indicators and oil prices. There are two distinct variants of this potential explanation. First, sometime in the 1970s, possibly even during the first oil price shock of 1973-74, monetary policy began responding systematically to oil prices. Bohi's expression of this variant of the monetary policy explanation was quite strong: that, indeed, monetary policy had been largely responsible for the recessions of 1974-75 and 1980-82 and that the preceding oil price shocks had had little to do with the downturns. He had been unable to find correspondingly large movements in employment or output in energy-intensive 3-digit industries but the Federal Reserve had pursued a tight monetary policy following those price shocks.

These findings were on the table, so to speak, when Hooker (1996c) began his research. He used the apparent change in the variance properties of the crude oil price series as an opportunity to elicit improvements in specification of models to estimate the relationships between oil prices and GNP (GDP) and the unemployment rate. He worked with each of the major specifications of oil prices: the original, symmetric oil price change variable, in both nominal log differences and real levels; the separate oil price increase and decrease variables; the oil price volatility measure[14]; and the two versions of the oil price surprise variable, LN&R's transformation of positive oil price changes with a measure of its autoregressive forecast error and Hamilton's net-oil-price-increase variable, which assigns a value of zero to positive price changes which fail to reach the "surprise" threshold.

Hooker used two methods to explore the performance of these alternative oil price specifications. The first, a specification stability test, broke the full sample period into two subsamples at different times within the middle 70% of the full period (1955:1-1990:2) and compared the stability of the oil price coefficients across subsamples, holding all other coefficients constant. The other method, robustness over different sample periods, altered the sample period in two different ways, first by expanding the sample forward from a fixed starting date, and alternatively by rolling forward a sample period of fixed length. Each specification, for both GDP and unemployment, experienced a structural break sometime between 1955 and 1990. The symmetric specifications showed possible break points over almost the entire range between 1958 and 1990. For Mork's specification of increases only, the relationship with unemployment clearly experienced a break point which could have occurred at any point between 1958 and 1987, but stability of the relationship with output could be rejected at the less stringent probability level (5%) but not at the more stringent level (1%). For this specification, a break point was more likely in the pre-1973 period. The statistical test rejected stability for the separate oil volatility measure in the unemployment equation, with a break point somewhere between 1958 and 1980, but could not reject stability for the GDP equation at the

[14]Ferderer (1996) constructed his volatility measure as monthly variances of weighted, daily product prices. For his volatility measure, Hooker used the variance of monthly crude prices during a quarter. Hooker's specification has the disadvantage of using only three observations to estimate the variance but the advantage of being available for the entire period 1948-95.

more stringent significance level. A break point for the output equation was indicated sometime between 1975 and 1980. The relationships using the other oil price measure that incorporated volatility, corresponding to the LN&R measure, experienced break points sometime in 1973-74. The net-oil-price-increase variable produced a stable relationship at the more stringent significance level for rejection (1% but not 5%) for the unemployment equation, and at even looser significance levels for rejection (rejection at 10% but not at 5%). These tests indicate that the traditionally suspected dates for changes in the oil price-macroeconomic relationship— around 1973-74, 1980 or 1986-87— were not the only periods when the change could have occurred. Hooker also pointed out that the greater instability in the unemployment relationship offers greater statistical power to identify the correct specification of oil prices, although most research has focused on the oil price-GDP relationship.

Hooker's second approach to evaluating the oil price specifications estimated Granger causality of the different measures over different sample periods, of both varying and constant length. The variable and constant sample length tests yielded conflicting results. The variable-length tests suggest that the oil price-macroeconomic relationship broke down in the post-1986 period, when oil prices began to fall and their volatility began to rise: both of the surprise variables— the price change scaled by forecast error and the net-oil-price-increase— extended the stability of both equations (GDP and unemployment) through the end of the sample period. However, the rolling sample period tests which fixed the sample length showed virtually the opposite results: most of the oil price specifications, for both equations, lost their Granger causality in sample periods ending as early as the 1970s. The LN&R surprise variable Granger-caused both output and unemployment in samples through 1979, but then lost its predictive power abruptly thereafter. Altogether, these tests suggested to Hooker that the revised specifications of the oil price variable, by themselves, do not resolve the question of what caused the oil price-macroeconomy relationship to change. This conclusion says that we must look beyond the oil price itself. Hooker's regression models incorporated versions of several of the more prominent, microeconomicallly based theories about asymmetric macroeconomic responses to oil price shocks, but this additional structure did not repair the weakening of the oil-macro relationship in later sample periods. This result was particularly important since, if it were to hold up in further research, it would say that the economic explanations to date for the change in the aggregate relationship find no support in the data. This was a particular object of Hooker's further research, reported below.

3.2.2 Relating Oil Price Changes by Size to Economic Activity Changes

For much of the past decade, the research community has specified functional forms[15] for

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[15] "Functional form" is the exact structure of a regression equation. To demonstrate, a general functional form that a researcher could implement in a regression analysis is GNP = f(lagged GNP, oil prices, monetary policy indicator), which says that "GNP is a function of lagged GNP, oil prices, and some indicator of monetary policy." Fine, but how do we implement this general idea? It does not tell us *how* oil prices are related to GNP— just that they are related. One possibility for getting more specific would be a linear relationship, allowing for a constant term so that GNP can grow even if oil prices and monetary policy do not change, using the first differences of logarithms of all variables, only positive first differences for the refiner's acquisition of oil as a measure of oil prices, and M1 as the measure of monetary policy:

$$\log GNP(t) - \log GNP(t-1) = a + b[\log P(t) - \log P(t-1)]^{+} + c[\log M(t) - \log M(t-1)] + e,$$

regression equations that represented alternative transmission mechanisms, but those specifications have imposed a single, "average" coefficient for an entire time period. None of these specifications has squarely addressed Bohi's contention in 1989 that there had been by that date, effectively, only three observations of an oil price shock. Regardless of one's analytical techniques, a sample of three observations of any phenomenon seriously hampers inference, but Bohi's contention can be modified slightly to hypothesize that the large shocks have much greater relative impact than do the smaller, more routine fluctuations in oil prices and are correspondingly more important in determining the value of an estimated regression coefficient showing the effect of oil prices on GNP or unemployment.

To address this modification of Bohi's speculation regarding the importance of the relative size of an oil price movement, Hamilton (1996b) used a kernel regression technique to estimate a variable, size-dependent relationship between oil price changes and GNP changes. The kernel technique does not require a priori specification of a functional form but rather, by calculating the derivative of the conditional expectation function of the dependent variable, allows a size-dependent relationship to be elicited from the sample of observations. For example, rather than imposing a single, "average" elasticity of the dependent variable with respect to an independent variable, the elasticity can be estimated as a function of the value of the independent variable.[16] The kernel technique uses information from similar-sized observations, regardless of their separation in time (in a time-series sample) or space (in a cross-sectional sample) on the independent variable to estimate a conditional regression coefficient, an elasticity when both dependent and independent variables are in logarithms. In the case of the problem of oil prices in the business cycle, the emergence of the asymmetry hypothesis has led researchers to believe that the size of the elasticity of GDP with respect to oil prices may vary with both the direction and size of the oil price change.

The nonparametric kernel estimation method is ideally suited to estimating this kind of highly nonlinear relationship between variables, but being a nonparametric technique the usual measures of statistical significance cannot be used in hypothesis testing. Consequently, while Hamilton used the kernel technique to explore the possibility of a nonlinear relationship between oil price shocks and GNP growth, to compare the performance of alternative oil price specifications statistically, he returned to VARs estimated by ordinary least squares (OLS) regression, which yield straightforward information on the statistical significance of the regression coefficients that describe the relationship between oil prices and aggregate economic performance indicators.

In his kernel regressions, Hamilton estimated the oil price-GNP function over the period 1947-1992 using four lags of GNP (rates of change), four lags of oil price rates of change, and third- and fourth-period lags of a net oil price change variable, defined as the difference between the percent

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where e is the error term. Another functional form could use separate positive and negative log differences of the oil price measure. Yet another functional form might use the positive log difference of the oil price, and the square of the positive log difference. Picking the "correct" functional form involves developing a model of how oil prices are thought to affect GNP and examining a number of statistical properties of the regression equation using that particular form.

[16] Goel and Morey (1993) offer a useful discussion of kernel regression applied to demand elasticity estimation in economics. For a more technical review, see Hamilton (1994: 165-167).

increase in a current period and the highest percent increase in the previous four quarters. The rationale for the net increase variable is that economic agents will take little notice of oil price increases that do no more than correct for recent price decreases— i.e., are considered just normal market fluctuations. Separating these especially informative price increases from "normal" increases leaves a fairly large range of price increases to which the economy has no aggregate employment response but correspondingly increases the estimated coefficient on those price increases to which there is an employment response. A diagrammatic presentation of the results showed that even a sizeable oil price increase would have little or no effect on the GNP growth rate unless its magnitude exceeded those of other recent changes— i.e., unless the change was greater than required for price corrections in "normal" market conditions. Under certain conditions, a 30% increase in the real oil price might have no effect on GNP growth at all, while under other circumstances, a 10% increase could drop the GNP growth rate by a full percentage point (e.g., from 3% per year to 2%). Oil price increases following oil price decreases of comparable magnitude had no influence on the growth of GDP. Pursuing this line of reasoning, however, increases followed by increases of comparable magnitude also had little or no influence on GDP growth. Hamilton interpreted these results as consistent with Li, Ni, and Ratti's (1996) implication of the surprise component of oil price increases: in a more volatile price regime, neither period's change is as meaningful as it would have been in a regime of greater permanence of price changes.

Returning to VARs estimated with OLS, Hamilton compared the statistical performance of three specifications of the oil price variable: the symmetric percent change such as he used in his 1983 study, Mork's increase-only variable, and his own variant on the increase-only variable based on the "net increase" variable he used in the kernel regressions, but defined to be zero unless the percent increase is larger than any percent increase in the previous four quarters (i.e., it does not take negative values). The relative sizes of the responses under the three specifications of the oil price variable are striking: for the sum of coefficients over four quarterly lags, the symmetric specification yields a value of -0.168, the increase-only variable yields -0.297, and the net-increase variable a value of -0.400. This represents, roughly and intuitively speaking, eliminating the effects of averaging the magnitudes of GDP response as we move from the smaller to the larger sums of coefficients. Including the four lags of the federal funds rate as an indicator of monetary policy reduces the summed net-oil-price-increase coefficients to -0.28.

Hamilton and Hooker discussed their results as they emerged during this research so that each could take advantage of the findings of the other. Thus, while Hooker conducted his specification searches with Hamilton's net-increase specification of the oil price variables as well as with others available in the published literature, Hamilton was able to try passing his variable, with the kernel regression technique, through Hooker's series of specification tests. First, to consider the possible influence of oil prices on monetary policy, Hamilton regressed the federal funds rate on four lags of itself and four lags of his net-oil-price-increase variable. He found that if the oil price were to rise by 10%, the federal funds rate in the following period would rise by 48 basis points (the only statistically significant coefficient of the four lags). The net-increase variable offered a superior explanation of changes in the federal funds rate than did the simpler increase-only variable, which Hamilton interpreted as indicating that the Federal Reserve's reaction function is not concerned with oil price increases that only correct a recent decline. Decreases in oil prices had no influence on the federal funds rate.

Hamilton studied several stability tests along the lines of those that Hooker explored for each of these three oil price specifications, using kernel regressions. The percent of variance explained with the net-increase variable was one-third greater than that obtained with the symmetric change variable, and slightly, but significantly, greater than yielded by the increase-only variable. The net-increase variable survived the break-point test at 1971:4, yielding a significant (at the 10% level), stable relationship over the entire period 1949:1-1994:2. Since the period after 1973 was the part of the sample period which appeared difficult for other price specifications to explain, Hamilton estimated the equation over the later period only— 1973:4-1994:2; the sum of the coefficients was highly significantly different from zero.

3.2.3 Summary of the Aggregate Studies

These findings— both Hooker's and Hamilton's— are significant for the understanding of whether, and how, oil price shocks affect the aggregate economy. Supported by the micro-level analyses of Davis and Haltiwanger and Davis, Loungani and Mahidhara, they show quite clearly that the U.S. experience of the past twenty-five years is consistent with large and lasting impacts of positive oil price shocks. The absence of a boom following the 1986 price collapse, or even emerging slowly after those prices began sliding after 1981, is not evidence of no relationship. These shocks seem to have substantial demand channels, although not ones that are easily counteracted by monetary policy. The total macroeconomic impacts are larger— substantially larger, in fact— than would appear from reductions only in potential GDP: these impacts must include sizeable unemployment consequences as well. Nevertheless, the issue of monetary policy's role in the recessions of the 1970s and early '80s is not fully addressed by these results, and we turn to further new analyses of that issue.

3.3 Oil Price Shocks and Monetary Policy

The previous section described how the influence of monetary policy became an issue of particular interest in the study of the macroeconomic consequences of oil price shocks. Hooker's research on aggregate specifications of the oil price-macroeconomy relationship set the stage for his own research into the specification of monetary policy in these equations. All of those studies had controlled for the effects of monetary policy as a matter of course, but Hooker sharpened the focus on the potential for confounding the effects of oil price shocks and monetary policy on business cycles.

Monetary policy has been represented in the statistical examinations of oil-economy relationships by several types of variables. Changes in monetary aggregates— M1 and M2 definitions of the stock of money and nonborrowed reserves— have been used commonly as indicators of alterations in Federal Reserve policy, although their exogeneity has been a perennial issue among macroeconomists. Alternatively, some scholars have used an interest rate as a less direct indicator of monetary policy— the federal funds rate and the Treasury bill rate— and, more generally, of credit shocks— the quality spread between the 6-month commercial paper rate and the 6-month Treasury bill rate and the term spread between the 10-year constant maturity government bond and the federal funds rate. Previous studies have found that the impact on GDP and unemployment attributed to oil price shocks is significantly larger when estimated without a monetary policy variable than with, but such a finding is typical for the case of an improperly excluded variable.

Although oil prices have been unaffected by monetary policy, several researchers have found evidence of monetary variables following oil price movements. Hamilton (1983) noticed that oil prices could Granger predict changes in the growth rate of money supply M1 with an 8-lag test but not with a 4-lag test, over the full sample period, 1949-1980. Ferderer (1996) found that both his oil price level and volatility variables Granger-caused changes in the federal funds rate and the level of unborrowed reserves, and that his oil price volatility measure failed to achieve statistical significance when the federal funds rate was included in the equation for industrial production growth.

In the final part of his research, Hooker addressed the phenomenon that part of the movements in monetary variables, and in monetary policy itself, is endogenous, not simply to oil prices but to changes in demands for money and credit from any sources. The monetary and credit measures used to date in studies of the oil-economy relationship have not accounted for the facts that (1) the Federal Reserve accommodates some of the changes in money and credit demand,[17] leaving only a portion of the movements in those variables truly exogenous, monetary policy shocks, and (2) the interest rates also move in response to changes in private demand. Hooker used separate variables for the endogenous and exogenous components of monetary policy, with a method developed by Strongin (1995),[18] to address whether the oil price shocks of the 1970s had simply induced inappropriate monetary policy which led to the recessions of that decade or actually had been an independent factor themselves in those events.

Hooker's VARs which included the exogenous component of monetary policy instead of the Treasury bill rate as the indicator of monetary policy yielded much less evidence of change in the oil-macro relationship among the various oil price specifications. When instability did appear, it occurred much later in the sample period than was the case with the T-bill. The GDP equations with the standard oil price specifications were stable until 1980, at which time a break could have occurred anytime until 1987. The unemployment equations still demonstrated instability as early as 1987. The price increase variable in the output equation maintained the same relationship throughout the entire sample period, although the unemployment equation still shows evidence of change in 1974 or anytime thereafter. The output and unemployment equations using the oil price volatility equation

[17]The monetary authority has a reaction function, which describes the relationship between its monetary tightening and loosening and some combination of major macroeconomic indicators such as GDP growth, unemployment, and inflation. To preserve the effectiveness of its actions the monetary authority keeps secret the exact functional form and parameter values, but both have been the subject of empirical study and examination with simulation techniques.

[18]In Strongin's procedure, the monetary policy shock— the exogenous component of monetary policy— is identified as the orthogonalized error in the nonborrowed reserves equation of a structural VAR using total reserves, the federal funds rate, and the ratio of nonborrowed to total reserves. Simple use of the monetary base as an indicator of monetary policy cancels out the policy innovation component of reserve changes, leaving the accommodated portion of the reserve demand shock. The only remaining indication of exogenous policy would come from any effect of the policy innovation on currency demand.

behaved much as they did with the price increase variable, while the price surprise variable standardized by its forecast error (the LN&R variable) experienced the opposite pattern— a stable unemployment equation and a break in the GDP equation between 1974 and 1980. The net-oil-price-increase variable obtains strong and consistent predictive power for both GDP and unemployment equations for the entire period, appearing to dominate the other oil price transformations in capturing the transmission mechanisms consistent with the aggregate relationship between oil prices and the business cycle.

Andrew Levin and Prakash Loungani presented simulation analyses conducted at the Board of Governors of the Federal Reserve System of the effects of three alternative monetary policy rules on the oil price-GDP relationship. Using the Board's Multi-Country Simulation Model, Levin (1996) compared the consequences of three monetary policy rules, each of which prescribes a short-term interest rate target on the basis of (a) the deviation of current output from potential and the deviation of either (b) the current price level from a specified path or (c) the current inflation rate from a target rate. The first of these was a nominal GDP target; the second the so-called "Taylor's rule," which uses both the inflation gap and the income gap; and the Henderson-McKibbin rule, which alters the parameter values used in Taylor's rule.

Based on simulations of relationships that are not especially well understood, the numerical results of these simulations are of less interest for the subject of oil price-economy relationships than are the differences in results among the rules and their applications by different industrial countries. There were two major groups of "moving parts" in these simulations: the monetary policy rule chosen by the United States and the coordination of monetary policies among countries. For any type of coordination, or lack thereof, of monetary policy among countries, the choice of monetary policy rule chosen by the United States (or any other country) affects the impact of a 25% oil price shock on GDP growth. For any given policy choice by the United States, the monetary rule chosen by other industrial countries (arbitrarily chosen to be the same for each of the other countries, for the sake of keeping the cases to be compared to a manageable number), also affects the impact that the simulated oil price shock has on the U.S. economy. These results pointed in two important directions: the importance of the actual monetary policy rule to the consequences of an oil price shock and the scope for different countries' monetary authorities to strategically protect their own national interests. Empirical results on these two topics remain to be developed.

If monetary authorities have incorporated oil price shocks into their monetary reaction functions, and an oil price shock leads to tightening of money supply growth, which in turn, throws the economy into recession—or at least retards its growth rate—can oil prices be let off the hook so to speak? The new, microeconomic-level research found that oil price shocks have large effects on microeconomic decisions, independently of monetary policy, but the indicators of monetary policy used in those studies did not separate movements in those indicators into endogenous and exogenous components. If those findings were replicated with the more sophisticated measures of monetary policy, it would seem clear that oil price shocks had effects independent of monetary policy, but what could be said about the part of the oil price shocks that has its effect through endogenous monetary policy? Should it be credited to money or to oil? What if the microeconomic studies with measures of endogenous and exogenous monetary policy revealed that *all* of the real effects of oil prices were passed to the economy via endogenous monetary policy? In these cases, it would be clear that without the oil price shock, the economy would not have entered recession and the ultimate causality of the oil price shock would be established. However, if there were no significant endogenous component of monetary policy after an oil price shock *and* exogenous monetary policy were found to have a significant effect on GNP growth, the causality of monetary policy and the inconsequentiality of the oil price shock would seem to have been demonstrated. To date, these tests have not been performed.

4. The Contributions of the New Studies

Prior to this workshop, five doubts had been raised regarding whether historical oil price shocks really *had* substantially contributed to the economic recessions which followed them. The current research shed considerable light on these issues, in each case reinforcing the view that oil price shocks are important influences on macroeconomic activity. The workshop was very successful in resolving a number of key issues and paradoxes relating to the macroeconomic consequences of oil price shocks. It did not accomplish, however, a complete unification of microeconomic mechanisms and macroeconomic consequences which offer a clear restatement of the fundamental oil-economy relationship. Some mechanisms were shown to operate without a doubt, others were not directly addressed, and questions still remain about the interaction of oil prices and monetary policy. Overall, however, this research demonstrated beyond any doubt that oil price shocks are important business cycle events even though key features of how they attain that importance remain to be understood better. We review the important understandings that were produced.

4.1 Microeconomic consequences of shock identified

First, it had been argued that in order to believe that oil shocks have macroeconomic consequences, we must be able to say something specific about the mechanisms by which those losses occur. If oil price shocks lead to aggregate GNP losses, then surely there must be some microeconomic evidence of dislocations in particular industries. Bohi was unable to identify such disaggregated effects, raising the question that perhaps other forces were at work causing the recessions. The research on job creation and destruction presented at the workshop showed that indeed we can observe quite significant sectoral dislocations and micro-phenomena in response to oil price shocks. These effects are observable both in individual industries at the 4 digit SIC level (Davis and Haltiwanger) and in state-by-state aggregate employment data (Davis, Mahidhara, and Loungani). The disaggregated results also strongly supported a view of oil price shocks as allocative disturbances, initially causing job losses in some industries and regions, followed later by job creation elsewhere.

4.2 Asymmetry of Oil Price Shock Effects are Consistent with Theory and Micro-mechanisms

The reliability of the relationship between oil price shocks and GNP had been questioned on the basis that while oil price increases were usually followed by recessions, the oil price decrease of 1986 was not followed by a boom. When the post-1986 experience is included in empirical estimates for simple models relating percentage oil price changes linearly to GNP growth, the estimated price shock effects are smaller and less reliable statistically than in earlier sample periods. If the observed effect of oil prices is asymmetric with respect to the direction of price movements, the argument went, then perhaps we do not understand the phenomenon well enough to be assured that it exists. The research confirmed that GNP effects are indeed asymmetric with respect to price increases and decreases, but emphasized that this asymmetry is a natural consequence of the way price shocks affect the economy, *not* a paradox. Oil price shocks have both aggregate and allocative consequences. A sudden price increase has two reinforcing, adverse effects: the cost of a key input rises, so aggregate production possibilities must contract; and also the sudden price movement causes an allocative disturbance and losses since productive factors specific to certain sites and industries are temporarily underemployed. In contrast, a price decrease has two offsetting effects, one good, the other bad. A price decrease is good from the view of an aggregate economic production function, but a price disturbance, in any direction, causes allocative losses.

Hence we should expect, rather than be surprised by, the asymmetric effect of oil price shocks. This asymmetry was clearly observed in all the studies, at different levels of economic disaggregation. Hamilton provided a convincing confirmation of Mork's nonlinear specification, and demonstrated how using a nonlinear model of oil price effects increases both the magnitude and significance of estimated losses due to oil price increases.

4.3 Role of Macroeconomic Policy in Explaining Post-shock Recessions is Limited

The question had been raised whether previous post-shock recessions are actually attributable to misguided macroeconomic policy, rather than oil price movements. The studies emphasized that while macroeconomic (monetary and fiscal) policies matter, they are not enough to explain all of the observed dislocations. Oil prices still have substantial explanatory power. The case was made that monetary policy is at least partly endogenous to oil price shocks, but also raised the possibility that monetary policy behaved *as if* monetary authorities had targeted oil price increases as a factor in setting monetary targets. The state-level research indicated that oil price shocks accounted for as much of the observed recessions as all other shocks together, including monetary policy.

4.4 International Differences in Responses to Oil Price Shocks

It had been observed that not all industrialized economies responded the same way to oil price shocks. In particular, Japan suffered a recession after the 1973 shock, but did not after the 1979-80 price rise. Do these international discrepancies cast doubt on the general validity of the oil price-macroeconomic relationship? While this research did not directly reassess the international experience, the mechanisms and theory presented indicate that there is no reason to believe that all economies would react identically. The effect of an oil price allocative disturbance depends on a country's industrial structure and its labor and capital market institutions. Furthermore, explanations were offered for the 1979-80 Japanese experience. It can be argued, for example, that the oil price increase did indeed have a negative effect on their economy, but that Japan's growth was fueled by rapidly expanding exports, including an expansion of automobile exports to the U.S.

4.5 A Single Explanation Applies Across the History of Oil Price Experiences

Finally, it has been posited by some that structural changes have occurred in the U.S. economy and the oil market which have reduced the importance of oil shocks, or eliminated their significance altogether. If true, this would mean that oil price-GNP models which work well up to the mid-1980s would no longer apply, and we should see evidence of structural instability in the econometric estimates as recent history is added. The work by Hooker shed considerable light on this issue but also added fuel to the controversy. Hooker showed that when the oil price movements are transformed to account for the nonlinearity of their effect on GNP, and when the analysis is properly conditioned on macroeconomic policy, a stable relationship between oil price shocks and GNP is both structurally stable and quite significant all the way through recent history. However, he doubted that this relationship is in itself likely to remain stable, noting that no specification that omitted monetary considerations predicted recent history well. From this he concluded that observations prior to 1973 may have less relevance in predicting current behavior than they once did. He also found however, that when he controlled for the exogenous component of monetary policy, his most sophisticated representation of oil price shocks—Hamilton's net oil price indicator—proved a stable and robust indicator of economic activity. From this Hooker concluded that much aggregated behavior is now incorporated in monetary and policy variables whereas purely economic responses are lodged in sectoral responses. Such behavior can only be observed with micro data and can only be explained by a return to micro-theoretical descriptions of firm behavior.

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