THE MACROECONOMIC IMPACTS OF OIL PRICE SHOCKS: A REVIEW OF LITERATURE AND ISSUES

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January 5, 1996

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Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-840R21400

1. INTRODUCTION

Over the past twenty years, dozens of scholars have explored the relationships between oil price shocks and the macroeconomic performance of national economies. Different methods of analysis have yielded different results, sometimes sharply different, sometimes modestly. This paper offers a review of that empirical research and a discussion of its different findings. Knut Mork (1994) recently has offered an excellent review of oil and the business cycle. We have benefited from his review and generally concur with his views, but we offer different emphases. First, we stress somewhat more than Mork does the implications of methodological differences in estimating macroeconomic impacts of oil price shocks. We expand on his discussion of the production function approach and contrast that approach with business cycle approaches. Second, in our discussion of simulation models, we focus on the extent to which those models yield empirical information rather than just information on the artificial output of a model. In fact, the empirical implications of simulations vary. The research one decides is relevant evidence of macroeconomic impacts of oil price shocks is important to what one's assessment of what the "evidence" indicates. Third, we explicitly discuss the interrelations between events in the oil market and the development of methodology for studying oil price shocks. The treatment of those shocks as permanent or recurring seems to lead to some important methodological differences--possibly the most important of which is reliance on an essentially microeconomic, production function approach or application of techniques developed in business cycle research. Fourth, we develop somewhat more than Mork does the relationships between the topics of asymmetric macroeconomic response and transmission mechanisms. This link is critical in assessing attribution of macroeconomic movements to various causes. We also consider how international comparisons of macroeconomic responses can illuminate attribution questions.

We begin with a discussion of the events of the 1970s and early '80s which both yielded the subject matter and affected its analysis. The following section reviews the development of several themes in the macroeconomic research on oil price shocks. Next, we focus directly on the methods of estimating the magnitude of impact of oil price shocks on the macroeconomy and the empirical results obtained with different methods. The subsequent section relates the empirical issue of asymmetry of macroeconomic response to the theoretical and empirical search for mechanisms for propagating oil price shocks throughout the economy, i.e., their roles in business cycle transmission mechanisms. Section 6 reviews the evidence from different industrialized countries, and section 7 discusses the attribution issue, i.e., to what extent were oil price shocks or something else responsible for the recessions following the oil price shocks of the 1970s and '80s. A concluding section attempts to identify trends and outliers in empirical findings.

2. HISTORICAL BACKGROUND

The analysis of the effects of oil price shocks on GNP has been complicated by other important events and changing economic conditions during the period in which the oil shocks occurred. It has been over twenty-two years since the Arab OPEC oil embargo associated with the Yom Kippur War. The ensuing quarter-century included two additional oil supply shocks, in 1979-80 and 1990-91, a major oil price collapse in 1986, three worldwide recessions, bouts with inflation across the world, and sluggish economic growth in several major industrial countries. Just prior to this period, the world monetary system replaced the post-World War II system of pegged exchange rates with a floating-rate system, and during the period the world capital market became increasingly integrated.[1] The simultaneous occurrence of inflation and recession in the mid-1970s surprised macroeconomic policy makers who were conditioned to see those conditions as alternative regimes.

The oil supply shocks of 1973-74 and 1979-80 were boldly visible events followed by considerable turmoil in various markets. Both shocks were followed by worldwide recessions, and the earlier shock by a several-year period of inflation as well. The coincident timing of the oil supply shocks and the periods of macroeconomic disturbance was too close for possible causal links to be ignored, and considerable attention was devoted to studying the macroeconomics of these events. Nevertheless, these periods, particularly the earlier one, included other events whose effects became entangled with those of the oil price shocks. Several industrial countries, including the United States, were just dismantling price controls, which may have affected both real economic events and the accuracy of the data recording them. Monetary and fiscal policies in several countries were parts of pre-existing campaigns against inflation, so on that score as well, the oil price shocks were not ripples in a completely calm pool. While some empirical estimates of the effect of the 1973-74 shock indicated an effect on GNP as high as 7%, other researchers had difficulty reconciling such a magnitude of effect with the small relative share of oil, or even all energy, in GNP (1.5% for oil and 3.5% for all energy). Of course, as Cochrane (1994, p. 349) points out, this "small input" problem applies to money as well as oil: the cost of holding reserves plus cash is the interest cost, which amounts to about 1/10% of GDP.

Then in 1986, disagreements among OPEC members precipitated a collapse in the price of oil which, notably, did not produce a economic boom. This asymmetry in macroeconomic response to oil price spikes and collapses elicited different responses among researchers regarding the underlying causality of the oil price shocks and the previous recessions.

The Iraqi invasion of Kuwait in August 1990 effectively removed some 9% of world oil production from the market and caused considerable uncertainty in the oil market. Saudi Arabia and several other OPEC producers increased production so as to nearly fully offset the losses of Iraqi and Kuwaiti supplies. Before the political situation stabilized and the effectiveness of the alternative supply increase proved itself, the oil price rose from around $21/barrel to around $40/barrel. Within 6 months the price had fallen back to pre-disruption levels. The institutions in the oil market were considerably more mature than in the early 1970s, and official strategic petroleum reserves existed, although their use was minimal. Once again, the price shock was followed by a recession in 1991 and 1992.

[1] Kenen (1994, p. 505) notes that the changes in the international monetary system and the oil price shocks of the early 1970s are not unrelated: "If a single event can take credit for the decision to accept floating exchange rates, it must be the sharp increases in the price of oil that followed the outbreak of war between Egypt and Israel in October 1973."

3. DEVELOPMENT OF THE EMPIRICAL LITERATURE ON THE MACROECONOMIC IMPACTS OF OIL SHOCKS

The empirical literature on the macroeconomic impacts of oil supply shocks evolved as the new state of the oil market revealed itself gradually after 1973.[2] One of the initial beliefs following the 1973-74 price shock was that the new, higher price of oil might be a permanent feature of a changed natural resource regime. Accordingly, one recurrent theme was the aggregate economy's response to a sudden, permanent price shock. How would an economy adjust to the new circumstances? This assumption underlies Rasche and Tatom's (1977, 1981) application of the potential GNP concept to the oil price shock problem and continues as late as the work of Bruno and Sachs (1982, 1985) on adjustment to supply shocks. Even Eastwood's (1992) investigation of the implicit substructure of some oil-macro simulation models assumes a single, permanent price shock.

Another theme in the empirical macroeconomic studies of the oil price shocks has been what could be called the attribution issue: to what extent was recession caused by the oil price shocks, government policies, or other events? Rasche and Tatom's estimate of a 7% long-run reduction in real GNP due to the 1973-74 oil price increase appeared suspiciously high to a number of macroeconomists who focused on the share of oil in GNP (e.g., Tobin, 1980, pp. 31-34). Darby (1982) estimated the impact of the 1973-74 oil price shock on real income in eight OECD countries. He was unsatisfied with the ability of the available data to distinguish among three factors that may have contributed to the recession: the oil price shocks; a largely independent course of monetary policy fighting inflation in the wake of the 1973 collapse of the Bretton Woods system; and a partly statistical-partly real effect of the imposition and subsequent elimination of price controls over the period 1971-75. Darby looked forward to the availability of internationally comparable data which would permit similar investigation of the 1979-80 oil price shock, but this line of research has not been pursued consistently since the early 1980s.

James Hamilton's (1983) study of the role of oil price shocks in United States business cycles has had considerable influence on research on the macroeconomics of oil price shocks. As Mork's (1994) review paper outlines, economists worked for nearly a decade on methods of incorporating oil price shocks into macroeconomic models before a synergy developed between real business cycle (RBC) models and oil price shocks. An oil price shock proved to be a believable mechanism which yielded the unanticipated, temporary supply shocks needed by the RBC models. The subsequent decline of the real oil price, despite the two shocks of the 1970s, appeared to put a new light on the origins--and the probable future--of oil price shocks. To the extent that the oil market had undergone a permanent change in the fall of 1973, that change seemed to be more one of moderately effective cartel power centered in a politically unstable part of the world than one of a permanent shift into escalating scarcity of minerals. Subsequent research on OPEC supply behavior (Griffin 1985; Jones 1991; Dahl and Yücel 1991; Wirl 1990) and on the predictive capability of the Hotelling exhaustible resource model in the oil market (Watkins 1992) has reinforced this unfolding interpretation of the events of oil market events of the 1970s and 1980s. Hamilton (1983) shifted the macroeconomic analysis of oil shocks from demand-side phenomena to the supply side, a movement which Rasche and Tatom's supply oriented analyses had not entirely accomplished, and relied on the statistical concept of Granger causality to test for directions of effect in a business cycle setting of recurrent shocks.

Hamilton's placement of oil price shocks in the framework of the RBC models raised several issues at the same time it appears to have displaced subsequent research directly focused on the contribution of macroeconomic policy on post-oil shock recessions. First, the historical record includes two negative price shocks: the 1960 oil price drop and the collapse of world oil prices in 1986. In neither case did nations' economies experience a boom after the negative price shock. This raised the issue of possible asymmetry in the

[2]For a more complete review of the initial macroeconomic work following the 1973-74 shock, see Mork (1994).

macroeconomic response to oil price shocks. Was asymmetric response to be expected theoretically, or did the asymmetric response simply reveal that the impacts of the positive oil price shocks of the 1970s were substantially overstated, having been confused with other events? Second, closer association with the business cycle literature brought to oil-macroeconomic research a well-developed (although still evolving) body of thought on business cycle transmission mechanisms. These routes of effect of oil prices on the economy at large are what other oil researchers working more within microeconomic traditions have called "microeconomic transmission mechanisms." These two issues dovetail, with the latter providing theoretical explanations for the empirical findings of the former.

Subsequent literature on the macroeconomics of oil shocks has addressed the issues of magnitude of effect, causality, and asymmetry for a number of OECD countries. The most recent estimate of the elasticity of GNP with respect to oil price is -0.055 (Mory 1993). The *most* recent estimates available have allowed for the possibility of asymmetric macroeconomic responses to oil price increases and decreases. The most recent GNP elasticity estimates for *increases* are -0.107 (Mory 1993) and -0.054 (Mork et al. 1994, Table 2; cf. Mork 1989) for the United States over the periods 1951-90 and 1967:1-1992:4.[3] The corresponding elasticities for other OECD countries over the latter period range from -0.024 for Canada to -0.098 for France (with a positive estimate of 0.051 for Norway) (Mork et al. 1994, Table 2). Both studies report statistically significant negative elasticities for oil price increases and nonsignificant positive elasticities for price decreases. Mory reported a significant elasticity of -0.055 for the United States using price increases and decreases together. These studies will be discussed in greater detail below. Using a ratchet model of asymmetric price responses, Smyth (1993) finds support for an alternative concept of asymmetry to that implemented by Mory and Mork et al., a process in which only oil price increases above the previous maximum price reduce aggregate production, price changes below that range having no effect.

4. APPROACHES TO ESTIMATING THE MAGNITUDE OF MACROECONOMIC IMPACT

In this section we offer a brief summary of three general approaches to examining the GNP impact of oil price shocks: the aggregate production function approach; multiple equation macroeconomic model simulation approach; and the real business cycle approach.[4] We also survey the estimated magnitudes of the elasticity of GNP with respect to the price of oil. We attempt to be representative rather than comprehensive, although we strive to report fully the more recent estimates.

4.1 Production function estimates

The aggregate production function approaches adopt an essentially microanalytic viewpoint and specify gross output as a function of energy and other factors. GNP is equal to gross output net of energy costs. The relationships between productive factors and GNP are estimated, with particular attention to the effects of oil price shocks on GNP.

4.1.1 Estimating procedures and estimated magnitudes

[3]Mory's estimates use annual data with oil prices lagged one year behind GNP. Mork et al. use quarterly data, with contemporaneous oil prices and 5 quarterly lags; the sums of their quarterly coefficients for their multivariate regressions are reported above.

[4]Not all studies fit neatly into one of these three categories, but this general grouping of approaches is still of some use.

Rasche and Tatom (1977b, 1981) estimated an aggregate Cobb-Douglas production function for the United States and five other OECD nations for the period 1949-78. Using the first-order condition for the energy input, they substituted the price of energy for its quantity, but used quantities for labor and capital. Their dependent variable was real GNP. Their long-run estimate of the energy price-GNP elasticity for the United States was -0.070. Their highest estimate was for Japan, at -0.171, and their lowest was for Germany, -0.019. Estimates for the U.K., Canada, and France were -0.035, -0.044, and -0.041. Darby (1982) suggested that these estimates might have been biased by a combination of the tendency for labor and capital inputs to overestimate real output in a recession and the possible mixing of the contracyclical effects of included oil prices and omitted real money balances. The thrust of his suggestion is that energy prices are picking up the effect of restrictive monetary shocks, although he was unable to prove that suspicion to his own satisfaction with international data extending through 1976:4. He also suggested that Rasche and Tatom's results may be artifacts of price decontrol in the early 1970s, but again he was unable to demonstrate that conclusively. As Darby said, "Perhaps we should not be surprised that with effectively one degree of freedom we cannot arrive at firm estimates of both an oil-price coefficient and its standard error."

Mork (1994, pp. 23-24; cf. Toman 1993, p. 1195) points out that Rasche and Tatom's approach to estimating the effect of an oil-price increase on *potential* GNP runs afoul of GNP accounting procedures. With GNP calculated as a residual after the cost of intermediate inputs such as energy have been deducted from gross output, double deflation to separate base-year prices for inputs and outputs causes Rasche and Tatom's effect on potential GNP to disappear in the accounting process (cf. Bruno and Sachs 1985, pp. 252-255).[5] Since the data are incompatible with the model, the interpretation of statistically significant regression coefficients, of the expected sign and plausible magnitude range, remains unclear. Deflation by a common price index would identify the decline in full-employment real value added.

In a Cobb-Douglas production function estimation for the United States, with labor, private capital, public capital, and a relative energy price, using annual data from 1948-1985, Ram and Ramsey (1989) obtained statistically significant energy price-GNP elasticities of -0.074 and -0.069, depending on the disaggregation of public capital.

Smyth (1993) relied on an aggregate Cobb-Douglas production function format to estimate asymmetric price responses to energy price shocks. Using a model of price ratchet effects in time series developed in Jackson and Smyth (1985), he allows for separate effects of price increases below the historic maximum price, price increases above the historic maximum price, and price decreases. The model yields separate slope coefficients for the three types of price change and separate intercept terms for each cycle of price changes, thus avoiding forcing different slopes through a common intercept. The inputs used are labor and private capital, and the price of energy is used as in Rasche and Tatom's work; annual observations from 1952-1990 are used. He obtains a nonsignificant positive elasticity (0.020) for price decreases, a nonsignificant negative elasticity (-0.018) for price increases below the historic maximum price, and a significant negative elasticity (-0.052) for price increases above the historic maximum. He interprets the first two elasticities as effectively zero and the overall results as implying that energy price changes within the range of previous experience has no effect on aggregate output, but that price increases above that range have a sharp, negative impact.

[5] Real GNP is defined as the total value of domestic production, less imports and the value of intermediate inputs, with each component expressed at the constant prices of the same base year. This method of price deflation, called double deflation, indicates that the prices of output, imports, and intermediate inputs are each deflated relative to their own base-year prices. Thus, GNP is calculated by subtracting the shock-period oil inputs evaluated at their pre-shock price from domestic production evaluated at its base-year price. The effect of rising input prices on GNP disappears in the accounting procedure.

4.1.2 The Potential GNP Effect and Adjustment Costs: Two Different Phenomena

When the initial concern was with permanent price shocks, the adoption of aggregate production function approaches and the focus on potential (long-run or full employment) GNP losses was natural. However, as it became clearer that shocks were transitory, and that their effects were asymmetric with respect to the direction of price changes, research attention shifted to approaches which allow for rigidities, factor unemployment, and other possible adjustment cost mechanisms.

The concept of the potential GNP effect of an oil price shock is that, with a fixed budget constraint (or even one in which costly borrowing is possible), a higher price for oil constricts the production possibilities frontier, or equivalently, the factor price frontier. This sort of effect is quite familiar from real trade theory. With a temporary oil price shock, the potential GNP contraction also is temporary. If no adjustment costs are incurred--i.e., full employment is maintained throughout the period of the shock, the potential GNP effect is the only loss which would occur, and it would be incurred for the duration of the higher price regime.

In general, the literature on macroeconomic costs of oil price shocks based on the production function estimation of potential GNP losses is a microeconomic approach to a macroeconomic issue which relies either on intuition or black box mechanisms to account for the discrepancies involved in the failure to satisfy first-order conditions for profit maximization in the presence of unemployment. While the magnitudes of many of the empirical oil-shock-cost estimates derived from that approach may seem "reasonable," reasonableness is defined from a microeconomic perspective which does not identify what magnitude of *adjustment* costs, as contrasted with production frontier shrinkage effects, may be plausible.[6]

When Rasche and Tatom (1977a,b) wrote on this subject, they anticipated implicitly that the new oil price was permanent and that their estimated GNP elasticity indicated that real output in the United States would be about 4% lower in the long run than it would have been without the oil price shock (7% in Rasche and Tatom 1981).[7] Accordingly, macroeconomic policies implemented without taking into account the permanently lowered production capacity of the U.S. economy would be inappropriately stimulative of inflation.

This reduction in the production frontier abstracts from all adjustment costs of moving from the old, lower-price equilibrium to the new, higher-price equilibrium for a permanent price increase, or the period of adjustment and price discovery associated with a temporary price shock. It is a pure, long-run factor supply mechanism which contains no implication for the path which output and employment will take between two equilibria. The production frontier identifies the least possible cost of a factor price increase in a frictionless environment, and in that sense offers a lower bound to the aggregate cost of an oil price shock, allowing, of course, for substitution effects following relative price changes [for discussion, see Bohi (1989, p. 34), Bruno and Sachs (1985, Chapter 3)]. With pre-shock oil shares in GNP running between 2% and 3%, a doubling of prices raises that share instantaneously to 4-6%, which is the general range of the estimated oil price-GNP elasticities estimated with the production function and alternative approaches. (Output elasticities are equal to

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[6]The reasonableness of the magnitude of estimated macroeconomic effects attributed to energy price shocks by and large has referred to the share of oil in GNP, relying on output elasticities and elasticities of substitution in one form of aggregate production function or another. See, e.g., Bohi (1989, pp. 24-25, 34-39). In contrast, Hamilton (1988) develops a macroeconomic model in which the short-run decline in output is bounded by the output share of goods that use energy in production or consumption rather than by the value of energy's share in total output.

[7] Rasche and Tatom's corresponding estimates for several other countries were similar: Canada, -0.11; Germany, -0.04 to -0.05; U.K., -0.09, marginally significant; France, -0.11; Japan, -0.114).

factor shares for any production function homogeneous of degree one; that rule is a rough guide to judging first-order reasonability of statistical results.) Does this imply that macroeconomic adjustment costs are approximately zero? The short answer is "no." Because the potential GNP model does not specify any adjustment mechanisms or costs, it is not a model of macroeconomic adjustment costs. It is a mis-specified model, which appears to yield the same order of magnitude impact of energy price shocks on aggregate output as other models if one uses post- rather than pre-disruption cost shares.

Macroeconomic adjustment costs appear prominently in the labor market (contractually fixed wages leading to unemployment), other factor markets (lowered utilization of fixed capital stock, altered investment plans), and demand (intermediate and inventory demands among industries, final demands among consumers). The production function, variously estimated, may yield information about short- and long-run substitution possibilities among factors but offers no information on these other mechanisms.[8] Additionally, it is well known that time-series regressions yield estimates of short-run substitution and other responses, rather than long responses. Thus it is also unclear how the potential GNP change derived from time-series estimates of production functions could yield estimates of full-adjustment reductions in aggregate productive capacity.

Bruno and Sachs' (1982) model of supply shocks posits some adjustment process in the labor market [what Lucas (1980, pp. 702, 709) would call free parameters], although the exact mechanisms remain a black box. The resulting adjustment costs amount to nearly an additional 75% over the costs of their continuously full employment case. Bruno and Sachs (1985) add a commodity market to get a general equilibrium model but rely on the same adjustment mechanisms as in their 1982 article. There is a formalization of adjustment costs in the labor market, which represents an advance over macroeconomic reasoning based strictly on the production function, but still no real explanation of them.

4.2 Simulations

A great deal of research effort was expended in the early 1980s in modifying numerical models of the macroeconomy to include energy and simulating them to explore the macroeconomic consequences of oil price shocks. Mork (1994, pp. 24-27) describes the painstaking modifications required, suggesting that the effort yielded much understanding. Most notable was the comparative modeling effort coordinated in 1982 by the Energy Modeling Forum Study Group 7 [EMF-7, documented in Hickman, Huntington & Sweeney (1987)]. This study compared the responses of 14 major macroeconomic models to four energy price shocks, including one (20 percent) oil price reduction.[9] The assumed shocks were permanent one-time price changes. Virtually all of the models showed real GNP declining through the second year of a positive price shock, although the magnitude of loss varied substantially.[10]

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[8]Mork (1985) develops a macroeconomic model of adjustment to commodity price shocks in which technical substitutability and complementarity among factors in the production function is only one component in economy-wide substitutability, which is affected by aggregate supply and aggregate demand.

[9]The fourteen EMF-7 models were (Hickman et al., 1987:14): (1) Large quarterly forecasting models--BEA Quarterly Econometric, Chase Quarterly Macroeconomic, Data Resources Quarterly, LINK, Michigan Annual Econometric, MIT-PENN-SSRC (MPS), Wharton Quarterly; (2) Smaller specialized/diverse models--Claremont Economics Institute, FRB Multi-Country, Hickman-Coen Annual Growth, Hubbard-Fry, MACE (Macro Energy), Mork Energy Macroeconomic, and the St. Louis (FRB) Reduced Form. Only the last four of these models were originally developed to evaluate energy price shocks. The other large and detailed models were designed for macroeconomic forecasting and policy analysis. All of the models used econometrically estimated parameters, typically based on data from 1955 to 1980.

[10]For a 50% oil price increase, the EMF-7 median U.S. GNP loss in year two was 2.9%, with half of the models reporting results within 0.6% of the median.

The macroeconomic simulation approach, while empirically based, relies on the accuracy of the structural representations used. Given this caveat, one important benefit of simulation is that it allows decomposition of the simulated losses into their pathways and components. Accordingly, the EMF-7 Working Group sought to identify the principal mechanisms by which energy shocks are transmitted to the economy. They also considered the effects of policy. For the EMF-7 models, about 70% of the losses were declines in real GNP, and 30% were terms-of-trade or purchasing power losses which do not appear in national income accounting, but can be tracked by some models. An important EMF study conclusion is that, of the GNP losses, the potential (full employment) losses typically comprise only a small fraction, while "the dominant losses appear to be the 'cyclical' losses . . . where actual output is reduced more than potential output" due to labor and other factor unemployment (EMF-7 Working Group 1987, p. 21). The mechanism by which these cyclical losses occur in the EMF models is mostly through temporary aggregate demand reduction.

One of the problems with many macroeconomic simulation efforts, including most of those in the EMF-7 study, was that the model specifications led to symmetric responses to oil price increases and decreases. The EMF-7 modelers were hesitant to endorse this finding (Hickman et al. 1987, p. vi), since their work was based on the pre-1983 experience. The EMF-7 models did not represent adjustment problems, rather focusing on the aggregate relationships of economic activity (Hickman et al. 1987, pp. 5, 47). Given the models' reliance on the aggregate demand effects of the shock, it is not surprising that the simulated shock effects were symmetric with respect to shock direction, and that accomodative macro policies were found to mitigate (but not completely offset) the GNP losses [Hickman et al. 1987, p. 7]. A second, more fundamental problem with the macroeconomic simulation approach is its reliance on the model's structural representation of yet-unresolved mechanisms by which the shock works through the economy. The variation in the GNP elasticities resulting from these studies, which used the same data for their simulations, highlights the importance of just what the relationships might be which transmit oil price shocks to the macroeconomy: different relationships clearly make a good deal of difference. The seriousness with which this subject has been pursued indicates the research community's recognition that accepting seriously incorrect characterizations of those relationships can be costly in terms of policy mistakes.

It is not productive to group all oil-macroeconomic simulation modelling together indiscriminatly as a single class of research which does not yield empirical evidence on oil-macro relationships. Many of the larger, and particularly the earlier, oil-macro simulation efforts, described thoroughly in Hickman et al. (1987), derived the parameter values used in the simulations from eclectic sources, frequently from empirical estimates from sample periods considerably earlier than the price-shock periods simulated. More recently, however, a number of simulation efforts have derived parameter values from econometric estimates over the same period simulated. These original parameter estimates are themselves direct empirical evidence of oil-macro relationships. The simulations themselves suffer from assigning pre-determined relationships among variables little, if any, more than ordinary regression models may suffer from specification errors. We turn to some of more recent, relatively small-scale simulation work.

Bruno and Sachs (1982) estimated a price-theoretic model of aggregate production with energy as an intermediate input and studied the effects of an energy supply shock both analytically and empirically. They posited two alternative types of adjustment in the labor market, continuous full employment and a Phillips curve type adjustment. Empirically, they estimated single-and multiple-equation regressions of the U.K. factor price frontier, manufacturing sector output, and manufacturing sector labor demand for the period 1956-1978 (annual data) and simulated the model with the parameter values estimated from the regressions. The coefficients of the energy price variable were negative and significant in all equations under nearly all specifications. Their energy variable was energy used in manufacturing, with a price index appropriate to that mix of energy supplies. Their estimates suggested that during the period 1973-78, energy prices directly accounted for over half of the 15% fall in output per unit of capital. They conducted three simulations: a 10%, unanticipated rise in the energy price in 1980, with full employment; the same increase in the energy price but with slow real wage adjustment; and a 10% rise in the energy price announced in 1980 but beginning only in 1983, with slow real wage adjustment. In the steady state of the simulation, the three scenarios produced the same result, a depression of the growth rate of real output of 2.6 percentage points. Their simulated values for 1980, 1985 and 1990 yielded an output depression of 2.5 and 2.6 percentage points with continuous full employment and depressions of 4.2, 4.4 and 4.5 percentage points with slow real wage adjustment. The third scenario--the pre-announced price hike--affected only the value of Tobin's q (the real equity value of firms' capital stock) in 1980, but reduced the growth rate of output by 4.7 and 4.8 percentage points in 1985 and 1990.

Darby's (1982) simulation included GNP, price level, nominal money supply, short-term interest rates, exports and balance of payments. As noted above in the discussion of Darby's criticisms of Rasche and Tatom's GNP elasticity estimates, inclusion of an effect of the oil price shock in the aggregate production function made a considerable qualitative difference to the path of GNP for five OECD countries--the U.S., the U.K., Canada, Germany, and the Netherlands--over the period 1973:2-1975:2. For the remaining variables, the direct oil effect made a quantitative difference apparent in Darby's results, but did not change the *direction* of any effects.[11] The question which remained for Darby was whether oil price shocks in fact had a significant role to play in the aggregate production function.

Nasseh and Elyasiani (1984) developed an eight-equation aggregate supply model which they estimated for five countries--the U.S., the U.K., Canada, Germany, and France--then simulated over the period 1973-79. Their estimation used annual data, with 29 observations for the United States (the precise period was not identified), 20 for the U.K., 24 for Canada, 19 each for france and Germany. In the simulations, they calculated the deviation from a base forecast of the path of each variable, with the base forecast a projection of energy price growth equal to the average of its growth rate in the five years prior to 1973. They do not calculate the impact of an energy price shock on output but rather for price level change, wage rate change, the level of the real wage, labor productivity, total employment, the unemployment rate, energy demand, and the capital utilization rate. They computed root mean square error for each variable for each country, from which they calculated Theil's statistics for bias, variance and covariance components. The simulation's replication of those variables' behavior for the time period was quite good for most variables for all countries except France, which performed well only for energy demand and unemployment. They calculated the marginal effect on each variable of a 1% increase in the price of energy for each year from 1973 through 1979. The model indicated substitution of labor for capital, with consequent positive effects on total employment and negative effects on the unemployment rate, but substantial depressing effects on both the capital utilization rate and labor productivity.

Of these simulation efforts, only Darby's includes monetary or fiscal policy variables. This is clearly a limitation, and it is probably a more serious omission in Nasseh and Elyasiani's replication of the 1973-79 period.

4.3 Business cycle estimates

The real business cycle approach attempts to explain booms and recessions in the economy as responses to random external shocks. Real business cycle (RBC) models usually do not rely on wage rigidity, but rather explain employment levels by the shifting short-run equilibrium between labor supply and demand. These labor market equilibrium shifts follow from unanticipated shocks to the aggregate production function, which affect firms' short run demand for capital and labor. About of decade of research effort has gone into refining the

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[11] Darby presented these results only graphically (see his Figures 3 and 4), so we cannot report actual magnitudes with any precision.

representation of oil price shocks in RBC models and statistically testing their importance as a contributor to business cycles. In this category of estimation procedures, various forms of real income equations, other than production functions, have been used to estimate macroeconomic effects of oil price shocks. Frequently, the estimations use reduced-form equations, but general equilibrium macroeconomic models underlie these estimating equations.

Darby (1982) followed Barro's (1978) regression specification procedure, which combines a Lucas (1973) aggregate supply function with an aggregate demand function using nominal money, real government spending, and real exports as arguments. He incorporated the effect of real oil prices in the specification of the natural employment level of real output. The estimating equation regresses real GNP on lagged GNP, a time trend, four lags in innovations in nominal money, four lags in innovations in real government spending on goods and services, four lags in innovations in the ratio of exports to GNP, a one-period lag in the real price of oil, and four lags in changes in the real oil price. Innovations are defined as residuals from optimal ARIMA processes. The equation is estimated separately for the U.S., the U.K., Canada, France, Germany, Italy, Japan, and the Netherlands over the period 1957:1-1976:4. He reported only the coefficients on the oil price variables. The estimated coefficients on the lagged oil price were negative for all eight countries, but were statistically significant only for the U.K., France, Japan, and the Netherlands. The lagged oil price change variables had a similarly mixed performance. The U.S. had significant negative coefficients for three of four lags, the U.K. and Japan only one each, France had three significant positive lagged coefficients, and the Netherlands had one significant positive lagged coefficient and one negative. Cumulative long run oil price elasticities of GNP were significant at 5% for the U.S., the U.K., Japan, and the Netherlands, and at 1% for France, with values of -0.021, -0.057, -0.191, -0.118, and -0.095 for each country respectively. Darby noted that, "Despite some differences in detail, the calculations here tell broadly the same story as that of Rasche and Tatom," but he described in detail his reservations about such an interpretation: the French, Italian, and Japanese data "may be quite unreliable," and the U.S., the U.K., and the Netherlands all removed general price controls during 1973 and 1974; neither Canada nor Germany had price controls during the period, and in neither country did any significant coefficients on oil prices or oil price changes appear.

Darby estimated additional equations for the U.S. over the period 1949:1-1980:4, relating real GNP to the total unemployment rate, the layoff rate, employment in manufacturing, mining and construction, a price control dummy variable, and lagged oil price changes. Again, results for the effects of oil prices were mixed at best, although as Darby indicated, his sequential application of significance tests to various coefficients is not strictly legitimate. Additionally, he noted that if the most stringent view of his examination were taken, it would indicate only that oil-price effects do not operate through the production function; they may still operate through aggregate demand, employment, or other labor market variables.

To account for any induced changes in nominal money supplies, real exports and interest rates, Darby conducted simulations with the Mark IV International Simulation Model for the U.S., the U.K., Canada, Germany, and the Netherlands over the period 1973:2-1974:3, with and without direct real-income effects. The principal lesson from these simulations is that whether there is a direct income effect or not makes a considerable difference to the path of real GNP. Darby's overall conclusion from this research was that, as of 1982, not enough was known about the effects of the 1973-74 and 1979-80 oil price shocks to command wide agreement. He offered no other conclusion.

Hamilton (1983) examined the stability of the regression relationship between nominal oil price changes and the logarithm of real GNP.[12] (He also examined Granger causality between oil price changes and various macroeconomic indicators, which we discuss below.) Hamilton separated 1948:2-1980:3 into two subperiods, 1948-72 and 1973-80. Statistically significant relationships between oil price changes and GNP characterized both periods, but estimation of the full period yielded smaller coefficients than either period estimated separately. For both periods separately, the third and fourth quarter lagged oil price coefficients were significant at 0.01, and the 2nd quarter lag at better than 0.10. For the earlier period (1949:2-1972:4), the oil-price coefficients at the second, third, and fourth lags are -0.082, -0.170, and -0.177; for the latter period (1973:1-1980:3), those coefficient values are -0.038, -0.078, and -0.115.

Burbidge and Harrison (1984) conducted vector autoregressions (VAR) and created moving-average representations of the oil price effect on several macroeconomic variables--industrial production, the short-term interest rate, M1 money supply, average hourly earnings in manufacturing, and the consumer price index--for five countries--the U.S., the U.K., Japan, Canada, and Germany. They computed impulse responses to oil price changes with seven-variable VAR models and decompose the behavior of prices and outputs over the period 1973/10-1982/6 into several elements, one of which is the contributions of oil-price innovations. They presented their results graphically rather than numerically, which makes direct comparison of their findings with those of other studies difficult. Qualitatively, they found contribution of innovations (shocks) in the oil price 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 found that the mid-70s recession was underway before the October 1973 price shock. Nonetheless, they found that the oil price innovations did account for much of the difference between their base projection (without oil price innovations) of industrial production and the actual series in all the countries except Germany, up to late 1975 or early 1976. They find that only Japan showed any appreciable impact of oil price innovations on industrial production or the CPI during 1979-80. They concluded that it is "less easy than some might think . . . to lay all the blame on external influences, namely OPEC, for the poor economic performance of much of the non-OPEC world over the past 10 years."

Gisser and Goodwin (1986) estimated St. Louis-type equations for four macroeconomic indicators, real GNP, the general price level, the unemployment rate, and real investment. They regressed ach of those variables independently on contemporaneous and four lags of the M1 money supply, the high employment federal expenditure measure of fiscal policy, and the nominal price of crude oil. They use quarterly data over the period 1961:1-1982:4. The coefficients of the contemporaneous oil price and those of the third and fourth quarterly lags were highly significant in the GNP equation, negative in sign, cumulatively larger than the corresponding coefficients on fiscal policy and half the cumulative magnitude of the money supply coefficients. The oil price variables also had significant positive coefficients in the price level and unemployment rate equations and significant negative coefficients (contemporaneous and third and fourth lags) in the investment equation. The values of the significant oil price coefficients in the GNP equation were -0.020 (contemporaneous), -0.030 and -0.049 for the third and fourth quarterly lags, and -0.11 for the cumulative impact.

Mork (1989) introduced his statistical examination of asymmetric macroeconomic response to oil price changes with regressions of general oil price changes. To better account for the period of price controls in the early 1970s than Hamilton's (1983) study did, Mork constructed another oil price series using refiner acquisition

[12]Hamilton (1983, p. 238, n. 7) defends his use of the nominal oil price rather than a real measure on two grounds: (1) the nominal oil price is the exogenous variable which belongs in a reduced-form regression because it is the variable under institutional control which forms the shocks; and (2) he does not believe that the expected change in the relative shadow price of oil equals the market price divided by a contemporaneous price index.

cost (RAC) to supplement and, for 1974:2 and subsequent periods to replace, the producer price index for crude oil. For the period 1971:3-1974:1, he multiplied the quarterly rate of change in the RAC by the ratio of the 1970-74 change in the annual log RAC to the corresponding change in the annual log PPI. His regression model included four lags of real GNP growth, the 3-month Treasury bill rate, the unemployment rate, a wage inflation index, an import price deflator, and the oil price index. Three of the four lags on the oil price variable were negative, but only one was significant, with an estimated value of -0.029. However, dividing the sample period into segments before and after the 1986 oil price collapse (beginning the second period at 1986:2), he found that the same model would not fit both periods. This prompted him to examine separate variables for oil price increases and decreases. Otherwise using the same model, the third and fourth quarter lags of the oil price increase variable were negative (both -0.049) and highly significant. The sum of all four coefficients was -0.144. None of the coefficients on the oil price decrease variables was significant, although two were positive in sign, and their sum was only -0.017. This model passed his cross-period stability test, which the model with only oil price changes failed.

In his exploration of asymmetric macroeconomic responses to oil price changes, Mory (1993) estimated a simple regression of GNP on the oil price, with a one-year lag (both variables in first logarithmic differences). Using a sample period of 1951-1990, he obtained a GNP elasticity of -0.0551, highly significant statistically. Although he did not control for other influences in that regression, in his subsequent regressions with separate variables for oil price increases and decreases, he controlled for government purchases and M2 money supply (all again in first logarithmic differences). Over the period 1952-1990, the GNP elasticity of oil price *increases* was -0.0671, again statistically significant. We discuss his examination of asymmetric response further below.

Bohi and Powers (1993) estimated, using OLS, St. Louis-type equations for gross state product (GSP) and employment on a cross section-time series (annual percent changes) of U.S. states for the period 1972-86. Their independent variables were national money supply (M1B), the high employment federal expenditures measure of fiscal policy, and the refiner acquisition cost of crude.[13] For two of the groupings of states--oil producers and other energy producers--they obtained insignificant coefficients on the oil price variable, positive for the former and negative for the latter; for non-oil producers, the coefficient of the oil price was negative and significant, but small, -0.006. The estimated coeficients of the money supply variables ranged from 0.34 for non-oil states to 0.92 for oil producers; the coefficient of the fiscal policy variable was positive and significant (0.62-0.70) for non-oil states and other energy producers but negative and just significant at 5% in the oil producing states. The estimated constant terms were significant for non-oil states and other energy producers, with values of 14.86 and 13.07, implying average annual growth rates for those two groups of states of 14.8% and 13.1%. It is not clear why the estimated coefficients on the money supply should have such a wide range across these particular groupings of states, and neither is it obvious why the fiscal policy variable should have a negative coefficient in the oil producing states. The errors-in-variables problems introduced with the use of identical values of the independent variables for a given period for all three independent variables are likely to have serious effects on the estimated coefficients and render them unusable for testing hypotheses. Additionally, the grouping of states into those expected to be positively and negatively affected by oil price shocks introduces a negative dependence between the estimated coefficients of the oil price and the constant term, which may account for the unbelievably high estimates of the constants. Since this panel data set has no cross-sectional variance among the regressors, and considering the errors-in-variables problems introduced with the national data, it may have been a more effective strategy to reduce the number of hypotheses tested to focus on the behavior of the oil price coefficient. Specifying common coefficients for the money supply and fiscal expenditure variables while allowing

[13]Personal correspondence, D. R. Bohi, December 1995.

region-specific coefficients on the oil price and the constant term would have reduce the number of free parameters about which to speculate.

Romer and Romer (1989, 1994) have presented findings which they claim support the hypothesis that monetary policy explains the bulk of the variation in economic activity from 1947 through 1987. Hoover and Perez (1994a,b) have shown that their methodology does not distinguish between monetary and supply shocks and that oil price shocks can produce the same results the Romers obtain with monetary shocks. Dotsey and Reid (1992) have examined the Romers' hypothesis in more detail with a U.S. quarterly time series over 1954:I-1991:III with VARs of GNP and the unemployment rate, using separate positive and negative changes in oil prices and two interest-rate indicators of monetary policy (the federal funds rate and the spread between the 10-year Treasury bill rate and the funds rate). They find significant evidence of asymmetric responses of both GNP and the unemployment rate to oil price shocks and insignificant responses to monetary shocks. Proceeding further with variance decompositions and impulse response functions, they find that positive oil price changes account for 5-6% of the variance in GNP, while the federal funds rate accounts for about the same and the interest rate spread accounts for about 8%. The cumulative response of GNP to a 1% increase in oil prices peaks at 7 quarters with a value of -0.094%, corresponding to a 4.23% loss in GNP from a 45% increase in oil prices attributable to the 1973 oil embargo. Altogether, Dotsey and Reid find that "both tight monetary policy and oil price increases are statistically associated with declines in economic activity" (Dotsey and Reid, 1992, p. 26).

Mork, Olsen and Mysen (1994) applied essentially the same model as Mork (1989) to the experience of seven OECD countries over the period 1967:3-1992:4. Their model also included the contemporaneous oil price and five quarterly lags for price increases and decreases separately. For the United States, the contemporaneous price increase and the first and second lags were significant, and of negative sign; the sum of the coefficients was -0.054. The contemporaneous price decrease variable and the third and fourth lags of that variable were positive and significant, with a total cumulative value of 0.079. Five of the other six countries--Japan, West Germany, France, Canada, and the United Kingdom--had roughly similar patterns of coefficients, while Norway had positive, statistically significant elasticities for both price increases and decreases. The large share of the petroleum sector in the Norwegian economy they believe accounts for that result. We will discuss this work further in the section on asymmetric response.

Lee, Ni, and Ratti (1995) have taken as their starting point the observation, first noticed by Mork (1989), that extending the sample period into more recent years sometimes eliminates the statistical significance of an oil price variable in a vector autoregression (VAR). With an 8-variable VAR, they reproduced this result by extending the sample period from 1949:1-1988:2 to 1949:1-1992:3. They subsequently replaced the simple oil-price-change variable with a variable representing the oil price change relative to recent volatility in oil prices. They normalized unexpected movements in real oil prices with the conditional variation of oil price changes constructed with a generalized autoregressive conditional heteroskedasticity (GARCH) model. Their measure of an oil price shock which reflects the magnitude and variability of the forecast error is $e_t^* \equiv e_t/h_t^{1/2}$, where $e_t \sim N(0,h_t)$ is the error term in an autoregression of the change in real oil price, z_t, and

$h_t = \gamma_0 + \sum_{i=1}^{q} \gamma_i e_{t-i}^2 + \sum_{j=1}^{p} \gamma_{q+j} h_{t-j}$. A large increase in real oil prices relative to recent volatility will induce resource reallocations. The higher recent volatility, the less information current oil price changes contain about future oil prices, and the more reluctant economic agents will be to make reallocations on the basis of any given oil price change. Using e^* for the oil price change variable (and e^{*+} and e^{*-} for separate positive and negative movements in this normalized, unexpected oil price change), Lee et al. estimated several VARs for real GNP growth over periods extending from 1950:3-1992:3 (and subperiods ending in 1986:1 and 1988:2). (The other regressors were lagged GNP growth, the GNP deflator, the unemployment rate, the 3-month Treasury bill rate, real wage growth, and import price inflation.) The e^* variable, not distinguishing the direction of change, yielded negative, significant coefficients for 1- and 4-quarter lags in the two earlier subperiods, but only in the 4-quarter lag in the full sample period. Using the separate positive and negative oil-price-change variables, they obtained significant negative coefficients for 1-, 3-, and 4-quarter lags for all sample periods on the positive change variable. The coefficients on the negative change variable had a mixture of positive and negative signs, generally not significant, with the exceptions of the 4-quarter lags for the two longer sample periods. The variable e^{*+} accounted for 25.3% of the variance of the forecasted GNP growth at the 1-year horizon in the 10-variable VAR, while the T-bill rate, accounting for the next largest fraction, captured 14.6%. In exploration of the impulse responses of output and employment to e^{*+}, the response of output was negative and significant only at 3, 4, and 8 quarters, with a sum of responses over a 24-month horizon of -0.65. The response of the unemployment rate was somewhat stronger, with a sum of responses of 1.86, and all the responses between quarters 4 and 8 significant, indicating a cumulative loss of employment not offset at alter dates by subsequent GNP growth rates during the second and third years after an oil price shock. They suggest that this pattern may indicate that recovery of output after an oil price shock is mainly accounted for by productivity increases.

Raymond and Rich (1995) have used Hamilton's (1989; 1994, Chapter 22) regime-switching model to study the role of oil price shocks in accounting for cyclical downturns in the U.S. economy over the period 1952:2-1988:2. The regime-switching model supposes that a time series is composed of two generating processes (states) and relies on a Markov chain model to determine endogenously when observations are drawn from one state or the other. Raymond and Rich compared univariate and bivariate forms of the model, with GNP and oil prices in the latter.[14] With a univariate model (VAR of GNP), the regime-switching model clearly identified the 1973-74 and 1979-80 recessions as periods of high probability of being in state 1 (the low-mean, or recession, period), but the bivariate model, which used oil prices in addition to GNP, gave much lower probabilities for those two recessions being in state 1, although the other recessions over the time period were identified quite similarly in both models. Nevertheless, the sum of the four lagged coeffecients on the energy price was -0.12 and quite significant. Their interpretation of these results is that while energy prices play a role in the business cycle, they may not be of first-order importance, but they are extending their work to let the transition probabilities in the Markov chain model be functions of energy prices.[15]

Extension of sample periods beyond 1985 have reduced the statistical significance of oil price variables in the studies using more recent data (Mork 1989; Lee, Ni, and Ratti 1995). Hooker (1995) has explored U.S. data for the period from 1948:I to 1994:II and, corroborating the structural break-point identified by Hamilton

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[14]They used Mork's (1989) adjusted oil price series which accouts for periods of price control in the early 1970s.

[15]Personal communication, R. W. Rich, November 1995.

(1983) at 1973:III/IV, finds a drastically weakened relationship between oil prices and both GDP and unemployment in the period 1973:IV-1994:II, although the oil price-macroeconomic performance relationship was very strong for the earlier period. He finds neither GDP growth nor unemployment Granger-caused by oil prices in either levels or differences in this later period. His efforts to explain this finding by possible endogeneity of oil prices and several versions of asymmetry hypotheses were negative: no macroeconomic variable Granger-causes oil prices in the later period, and three measures of oil prices to account for asymmetric macroeconomic responses (squares of log-differences, within-quarter standard deviations of monthly prices, and separate price increases and decreases) yielded results very similar to those using simple price measures. Nevertheless, decompositions of VAR projections similar to the procedure of Burbidge and Harrison (1984) indicated substantial roles for oil prices in accounting for U.S. unemployment in the recessions following the 1973 and 1989-80 oil price shocks, whereas Burbidge and Harrison found little scope for oil prices in accounting for the post-1979 recession. His VAR decomposition was unable to predict the path of U.S. unemployment for the post-1990 oil shock recession. Hamilton (1995), in a commentary on Hooker's work, accepts Hooker's methodology and findings, but offers some further findings of his own using Hooker's data. First, the structural break at 1973:III/IV appears to be related to factors other to oil prices, possibly the slowdown in growth after that quarter. Second, noting that after 1985, the large increases in oil prices appear to follow large decreases, he constructs a net oil price-change variable: the percentage change in the oil price over its maximum value in the previous four quarters, with the value set to zero if the oil price in quarter t is lower than at some point in the previous four quarters. This variable and the quarterly oil price change perform quite similarly over the period 1948:I-1973:III, but the relationship between GDP growth and the net oil price-change variable remains significant and negative over the entire sample period. In the 1973:IV-1994:II subperiod, that relationship remains significant, but somewhat weaker (t statistics of -3.0 in the earlier subperiod and -2.2 in the later). Hamilton agrees that the evidence seems to indicate that a given oil price shock before 1973 had a larger macroeconomic effect that a shock of similar size after 1973, but he predicts another oil price shock followed by a recession sometime within the coming decade.

The relevance of examining periods prior to the 1973 oil-price shock has been questioned occasionally, but extension of time series back to as early as 1948 has revealed oio price shocks to have been potent macroeconomic influences prior to the period of OPEC dominance in the world oil market. McMillin and Parker (1994) have examined the period between the First and Second World Wars (monthly data for 1923:2-1938:6, estimating from 1924:2 forward) with decompositions of the forecast error variance of VARs. Their regressors were the price of oil relative to the wholesale price index, real government expenditures, the monetary base, industrial production, the wholesale price index, the commercial paper rate, the M2 multiplier, and the yield differential between Baa corporate bonds and long-term U.S. government bonds. Their analysis indicates that oil price shocks were significant influences on industrial production and wholesale prices in this earlier period, comparably to finding for the later periods. They found that oil price shocks accounted for 20-26% of the variance of the forecast error of industrial production with 24- to 48-month lags; the estimates at 6 and 12 months were less than twice their standard errors. Oil price effects on wholesale prices were significant immediately, in contrast, but their effects over the 24- to 48-month lag period were smaller than the equivalent effects on industrial production, accounting for around 14% of the forecast error variances. In historical decompositions of the difference between dynamic forecasts and actual time series of industrial production, oil price shocks reduced root mean squared errors by 13 to 24%, more than the reduction contributed by monetary and fiscal variables. Many of the oil price shocks in this pre-World War II period were negative and helped account for booms in the period.

What seems to be emerging via the business cycle research is that, from the theoretical perspective of general business cycle determinants, oil price shocks should have been precipitators of business cycles long before the post-1973 oil market regime if they are to be candidates for precipitating the post-1973 recessions.

As earlier time series have been examined, this indeed appears to be the case. While that possibility has seemed remote to some scholars, the work by Lee, Ni, and Ratti (1995) seems to demonstrate that, if the genuinely surprising component of oil price innovations is accurately measured, that possibility may not be nearly as remote as once thought. This likelihood is bolstered by the findings of Hooker (1995) and Hamilton (1995), and those of McMillin and Parker (1994) offer direct corroborating evidence for the earliest period yet studied, using only relative oil prices rather than oil prices modified by indicators of the surprise element of the shock. Technically, methods of treating the surprise component of oil price shocks and of handling the upswings and downswings of business cycles are emerging as important in isolating the macroeconomic consequences of oil price shocks.

5. ASYMMETRY AND TRANSMISSION MECHANISMS: THEORY AND MEASUREMENT

Some scholars have suggested that the failure of the 1986 oil price collapse to spark an economic boom is grounds for skepticism that positive oil price shocks have led to or substantially deepened recessions (Bohi and Toman, 1983, p. 1104). The implicit assumption is that the macroeconomic consequences of oil price increases and decreases should be symmetric. The efforts to resolve this issue have led to a search for the mechanisms by which oil price shocks affect the macroeconomy. The 1986 oil price collapse has indeed served as an intriguing counterexample in the literature on the macroeconomic costs of oil price shocks. As Hamilton (1983) noted, the 1960 oil price drop did not spark a particular boom in the United States, and as Mork (1989) discovered, the oil price variable in Hamilton's model did not perform as well when the sample period was extended beyond 1986 as when the sample ended before that year.

The most recent line of research on macroeconomic transmission mechanisms of oil price shocks is being developed in the literature on real business cycle models. These models were first developed in the early 1970s, just prior to the first oil price shock of that decade. It was some time before oil price shocks were suspected to be the sort of recurrent, unanticipated shock which that class of models employs to obtain exogenous supply-side disturbances to macroeconomic equilibrium. David Lilien's (1982) dispersion hypothesis has been a central focus of this research applied to oil price shocks. The dispersion hypothesis posits that a considerable amount of unemployment can be accounted for by sectoral shifts in demand, which require time for reallocation of labor. This mechanism involves exogenous allocative disturbances causing reallocation of specialized labor and capital. The speed of reallocation may be determined by the particular type of disturbance (Davis 1987). Using quarterly data over the period 1947-1982, Loungani (1986) found that when the relative price of oil is held fixed, such 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 re-allocative 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 interindustrial reallocation of labor. Nevertheless, he left that as an open research question. Davis (1987, p. 329) reports that his own research "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." Reinforcing this interpretation of empirical findings on the dispersion hypothesis, Long and Plosser (1987, p. 336) found that the explanatory power of common, aggregate disturbances to industrial output is "significant, but not very large for most industries." Sectorally independent, random productivity shocks can cause co-movement of activity across different sectors (Long and Plosser 1983).

The dispersion hypothesis modifies the conventional macroeconomic model specification that both the magnitude and direction of oil price shocks are important. Under the dispersion hypothesis, the direction of the change is not important: both positive and negative changes increase the amount of labor reallocation required (Loungani, 1986, p. 539). Clearly these reallocation effects are in addition to relative price effects which would tend to contract or expand the production possibilities frontier with price increases or decreases. Furthermore, one of the implications of the dispersion hypothesis is that traditional aggregate demand policies would have limited effect in the face of such allocative disturbances.

Mork, Olsen, and Mysen (1994) begin with the one-sector macroeconomic model of Gilbert and Mork (1986) and, for the case of downwardly rigid wages, develop separate expressions for the elasticity of GNP with respect to oil price increases and decreases. For oil price increases, the one-sector GDP elasticity is $-e[1/(1-s_K) - \sigma]$, and for decreases is $-e\eta$, where e is the value ratio of oil imports to GDP, s_K is the cost share of capital in the production of gross output, σ is the short-run direct elasticity of substitution between oil and labor, and η is the labor supply elasticity. The downward elasticity is smaller in absolute value than the upward elasticity provided $\sigma+\eta < 1/(1-s_K)$, which is the condition for downward wage rigidity to be binding when the oil price increases. Expanding to a two-sector model (one sector using energy, the other producing it), they derive separate GDP elasticities for price increases and decreases composed of weighted sums of corresponding sectoral elasticities. Inspection indicates that, in general, the elasticities for price increases will differ from those for price decreases. The elasticity for a price increase is likely to be negative unless the energy sector accounts for a large portion of the economy, and vice versa for the elasticity for price decreases, although the latter is likely to be smaller than the former in absolute value. If the elasticities of labor supply for the two sectors are small enough and the domestic energy sector is large enough, the aggregate elasticity for price decreases could be positive while the corresponding elasticity for price increases is negative.

We introduced Mork et al.'s (1994) empirical results above in the discussion of the magnitudes of empirically estimated macroeconomic impacts. They estimated regressions of GDP on only contemporaneous and lagged oil prices as well as multivariate regressions which included also the inflation rate (measured by the GDP deflator), short-term interest rates, the unemployment rate, and the growth rate of industrial production for the entire OECD as a proxy for exogenous export demand. The oil price effects were stronger and more frequently statistically significant in the multivariate analyses than in the bivariate. All countries except Norway experienced negative relationships between oil price increases and GDP growth. The significance level was weakened somewhat for Germany in the multivariate case but was strengthened for Canada and France. In the multivariate estimation, the U.S., Canada (both at the 2% level), Japan (at 3%), and Germany (at 10%) demonstrated significant evidence of asymmetry. They note that this relationship holds up well through 1992, thus weathering the latest oil price shock, associated with the 1990 Persian Gulf War.

The studies by Mork (1989), Mory (1993), and Mork et al. (1994) all separated positive and negative oil price shocks into distinct variables, but appear to have relied upon a single regression intercept. The studies by Smyth (1993) and Jackson and Smyth (1986) suggest that some unknown biases may be introduced by such a procedure, particularly in longer time series which contain several price cycles. This appears to be an area in which further investigation may be appropriate.

In previous studies, Tatom (1988, 1993) informally considered the hypothesis that the effects are symmetric and was unable to reject that hypothesis for U.S. data. He pointed to Mork's (1989) omission of any effect for the 1986 U.S. Tax Reform Act, which he believed accounted for the failure of the U.S. economy to expand following the oil price collapse of the same year. Although Mork et al.'s (1994) cross-country examination of asymmetry does not account for the U.S. tax reform in 1986, it seems to supersede Tatom's intuition.

A further business-cycle study on the subject of asymmetry and transmission mechanisms is the recent real business cycle model simulated by Kim and Loungani (1992). Their purpose is to distinguish the controversial role of stochastic shocks to technology in such a model from other real shocks. They specify an energy price shock as such an alternative and study what proportion of the variance in the volatility of output over the business cycle can be accounted for by the two types of shock. They develop a one-sector model with perfectly flexible wages and commodity prices. That model, using energy price shocks alone as the sole source of exogenous supply shocks accounts for only 16% of the variation in output with a CES production function and 35% with a Cobb-Douglas production function. The use of energy price shocks alone also does not replicate such features of business cycle data (they consider the period 1955:3-1987:4, or 1949-87 annually) as the tendency of consumption to be smoother than output. On balance Kim and Loungani conclude that their results "do offer some support to the views of macroeconomists who downplay the impact of energy shocks on the economy (p. 186)," citing Tobin (1980) who thought that the oil share of GNP was too small to be consistent with the magnitudes of estimated impacts reported, and Darby (1982), whom they associate with the view that monetary policy was responsible for the 1973-74 recession. However, Kim and Loungani note that their particular model abstracts from many of the routes by which contemporary macroeconomists have thought energy price shocks may affect the macroeconomy, specifically naming rigid wages and non-energy prices, the effect of uncertainty on irreversible investment projects (Pindyck and Rotemberg 1984, Dixit and Pindyck 1994), and the reallocative effects of the dispersion hypothesis (pp. 186-187). Their results tend to reinforce suspicions which have emerged in the past decade regarding the importance of the allocative effects of oil price shocks in the labor market.

Federer (1996) has explored the role of oil price volatility in contributing to macroeconomic disturbances with the monthly standard deviation of daily oil prices with monthly U.S. data over 1970:1-1990:12. With the now standard complement of VARs, variance decompositions, and impulse response functions, he finds that oil price volatility accounts for a significant proportion of the fluctuations in the growth of industrial production; both oil price changes and the oil price volatility measure have stronger and statistically more significant effects on industrial production than to either of two monetary policy variables (growth in nonborrowed reserves and the federal funds rate). He finds that oil price changes do have effects on nonborrowed reserves and the federal funds rate, but real oil price changes have additional effects on industrial production than their effect via monetary variables. He interprets his findings as supporting the hypothesis that oil price shocks operate through both sectoral shock channels (along the lines of the models of Lilien 1982 and Hamilton 1988; cf. Loungani 1986) and via uncertainty effects on irreversible investments.

Karras (1993) estimated a structural VAR of real GNP, the real federal deficit, the GDP deflator, the M2 money supply, the U.S. dollar-SDR exchange rate, and the price of oil over the period 1973:I-1989:IV. From the reduced-form residuals obtained in the first stage of estimation, he used an instrumental variables procedure to obtain structural shocks to each of those data series. Six of fourteen estimated coefficients of the restriction equations in the second stage had standard errors at least twice their point estimate; the estimate of the oil price does not exceed its standard error in any structural equation. In a variance decomposition, non-oil shocks to aggregate supply account for the bulk of the forecast error of GNP, declining from 77% at one month to 48% at 20 months, with tight standard errors. Oil price innovations account for small percentages of the forecast error in GNP at 1 and 4 months, with large standard errors, but for 18% at 8 and 20 months, with point estimates half again the size of standard errors. Monetary shocks account for larger proportions of forecast error variances than do oil-price innovations at 1 and 4 months, tapering off somewhat at 8 and 20 months, but all variance estimates have tight standard errors. Karras's approach to identifying shocks relies on the error structure of the data series, and oil price shocks so defined account for a small amount of variation in GNP; more direct methods of inferring the volatility of oil prices attribute a more prominent role to oil price shocks.

Taking the asymmetry of the economic response to the 1986 oil price collapse as one of its departure points, Bohi's (1989) monograph and his (1991) article distilling that longer work involve efforts to identify microeconomic mechanisms by which energy price shocks might propagate their effects throughout the economy. That work is in a microeconomic tradition, as contrasted with the macroeconomic-business cycle tradition of the work discussed above. Bohi begins his search for mechanisms by accepting the premise that more energy-intensive industries will be more seriously affected by an energy price shock. From the partial-equilibrium, price-theoretic perspective this is reasonable, but it is a well-established fact of the empirical business cycle literature that industries producing durable goods are harder hit during recessions than are industries which produce currently consumed products, both intermediate and final goods (Mork 1994, p. 34). This is an effect from the demand side, rather than directly in the labor market, although much of the industry adjustment will occur in the labor market, as well as in inventory behavior. Automobiles are the quintessential durable good of today's industrial societies, but the energy price shocks affected different automobile manufacturing companies differently. That complicated a simple division of expected impacts along industry lines, even at the 4-digit SIC classification level.

Noting Lilien's (1982) research on allocative shocks, Bohi (1989, p. 67) directed much of his attention to the behavior of industry-specific wages and unemployment, but did not cite Loungani's investigation of the role of oil price shocks as such allocative shocks. His statistical investigation is restricted to estimation of zero-order correlations between energy intensity and real wages, energy intensity and employment, energy intensity and labor productivity, and between real wages and employment, apparently at the 3-digit ISIC level of industry (1989, p. 56; cf. p. 15 for discussion of the industry data used in the correlations). The 3-digit ISIC industry classification distinguishes between pig iron and iron and steel ingots, but not between high- and low-fuel economy vehicles [for the U.S. SIC see Office of Management and Budget 1987; for the analogous, but not identical, Standard International Trade Classification (SITC), see United Nations 1975, 1986]. Bohi considers only the demand-side of the labor market--e.g., intertemporal substitutions between labor and leisure on the supply side, which can be quite high, remain unaddressed. The high, positive, statistically significant correlations between real wages and employment surely mix demand and supply effects in the labor market (1989, Table 5-3, p. 56): a pure, demand effect would show a negative correlation between the real wage and employment.

Bohi addresses the composition of demand as a possible route of effect of energy price shocks, but again maintains his pure price-theoretic focus rather than incorporating business-cycle considerations. As in his analysis of the labor market, he estimates zero-order correlation coefficients between energy intensity and changes in industry output price indexes, between intermediate input cost shares and changes in output price indexes, and between energy intensity and changes in inventories (the latter two for Germany, Japan and the U.K. as well as the U.S.) (1989, pp 68-69).

In both analyses, of the labor market and of demand composition, no formal models are constructed to guide expectations regarding statistical results or to facilitate interpretation of the results obtained. Bohi's interpretation of his results is that ". . . the conclusion to be drawn from these observations runs counter to the hypothesis that energy explains the two recessions of the 1970s" (1989, p. 71). In the absence of formal modeling of business cycle transmission mechanisms, the simplicity of statistical methods employed, and imprecision of implied hypothesis (few researchers would claim that monetary and fiscal policies have played no role in recent business cycles; rather it is a matter of the contributions of various causal factors), the information content of Bohi's results is unclear.

Composition of demand as a transmission has been investigated by Bresnahan and Ramey (1992, pp. 24-27), who have found that when oil prices increase, plants that produce small cars operate at capacity and plants that produce large cars are idle. Eventually more plants that produce small cars are built, but in the short run, output and employment decline. Possibly further-reaching is their finding that the plant-level responses exhibit fundamental differences from the aggregated responses--both greater discontinuity, suggesting non-convex adjustment costs, and different distributions of choice of adjustment methods. These plant-level findings suggest that the 3-digit SIC industry level may not be sufficiently disaggregated to reveal microeconomic adjustment mechanisms in response to oil price shocks.

At the aggregate level, this demand composition mechanism can be quite sizeable. The exports of Japanese cars during the 1970s reveal the scope for demand to have offset direct impacts 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. This demand shock may well have been able to largely offset the oil supply shock.

Addressing the issue of asymmetry has led to a more general search for transmission mechanisms by which oil price shocks may be propagated into economy-wide recessions. The most empirically compelling shock which initiates the dispersion hypothesis' employment mechanism is oil price shocks. There is evidence at both the plant and aggregate levels that oil price shocks may operate through demand composition effects. Nonetheless, in the search for particular types of shocks which, via various transmission mechanisms, initiate business cycles in general, oil price shocks have not been shown to be principal causes of business cycles. However, in these explorations for the *causes* of business cycles, specification of transmission mechanisms from any candidate causal type of shock can greatly influence the assessment of a category of shock, so the assessment of transmission mechanisms remains quite important. It may be somewhat more disturbing to think that, because of the regularity of the multivariate facts of business cycles, it might be necessary to think in terms of exclusive shocks--i.e., if monetary shocks are the precipitators of business cycles, then technology shocks, oil shocks, or others, cannot be (cf. Cochrane 1994, p. 296).

6. EXPERIENCE IN DIFFERENT COUNTRIES

We have touched on evidence from different industrial countries in earlier sections. Here we recapitulate that information and discuss its implications. There is considerable evidence, derived from different methodologies, that energy price shocks have affected many of the OECD countries. However, those effects vary in magnitude, lag structure, and statistical significance. Do those differences call into question the existence of a link or links between energy price shocks and macroeconomic performance? Do they suggest that the recessions following the energy price increases of the past two decades were in fact caused by some third variables which have not yet been clearly identified or satisfactorily measured?

The OECD countries for which empirical estimates of energy effects on the macroeconomy are available--the United States, the United Kingdom, Canada, France, Germany, the Netherlands, Italy, and Japan--differ in ways which could be expected to influence their vulnerability to oil price shocks. Most relevant to the subject at hand, they differ in their industrial structures, their compositions of overall energy supply, their societies' and governments priorities and macroeconomic and microeconomic policies, and their labor market structures and institutions. Also, not all the data from these countries are exactly comparable, as Mork et al. (1994, pp. 25-26) note in some detail. Darby (1982, p. 741) has questioned the quality of the relevant data from France, Italy, and Japan, while Mork et al. (1994, p. 27) have raised similar questions about German GDP data as a result of their statistical performance. Accordingly one would not expect to find exactly the same response pattern to any shock across these countries.

As noted above, if the dispersion hypothesis proves robust as a mechanism for transmitting oil price shocks to the rest of the economy, aggregate demand policies may be relatively ineffectual in compensating for allocative shocks [e.g., the case in Canada documented by Helliwell et al. (1982)]. If such is the case, it would weaken the case for subtracting the effects of an apparently successful macro policy in one country from the aggregate impact in another country which did not use the same policy.

On balance, does the international evidence support or undermine the notion that energy price shocks have been important, contributing causes to the recessions of the 1970s and 1991-2? There has been no formal effort to develop a methodology which would facilitate rigorous answers to this question. Less formal reasoning may be a satisfactory substitute however. Different patterns of response in countries varying in many relevant dimensions[16] does not seem like a fundamental empirical inconsistency with the hypothesis that the observed responses to oil price shocks reflect underlying behavioral regularities *involving* those shocks.

7. THE ATTRIBUTION ISSUE: ALTERNATIVE EXPLANATIONS OF POST-OIL SHOCK RECESSIONS

It is useful to distinguish between business cycle transmission mechanisms and the sources (or causes or precipitating shocks) of business cycles. Hamilton's (1983) study propelled oil price shocks into candidacy for the, or one of a few, causes of business cycles. That study did not attempt to identify mechanisms by which the effects of oil price shocks might be propagated throughout the economy. The two subjects are closely linked, however, because it is necessary to identify how any candidate type of shock--monetary, technology, supply, consumption, etc.--actually operates before it can be determined whether it is theoretically satisfactory and empirically observable. In the theoretical literature on the sources of precipitating shocks which initiate business cycles, it is possible to create models of the same shock which operate in different manners. According to the transmission mechanisms and institutional specifications in a model, the dynamic behavior of output and employment in response to a given shock may replicate the empirical regularities of business cycles better or worse. Kim and Loungani's (1992) modeling of energy as a type of supply shock in a real business cycle model demonstrates this: while energy price shocks could account for only 16-35% of the variance of output over the business cycle, that shock, with the institutional specification of perfectly flexible wages, does not yield a pattern of consumption smoother over time than output, a basis fact of business cycles. Kim and Loungani did not draw the conclusion that energy price shocks therefore were not a source of business cycles.

In business cycle research, a principal, current quest is to identify the type (some scholars would admit types) of shocks which precipitate business cycles in general (see Cochrane 1994 for a review and independent exploration). In the literature on the oil market, the focus has been, until recently, on the role of oil price shocks in precipitating or exacerbating the recessions of 1974-75, 1980, and 1991-92, and what the alternative causal candidates might be. To date, the principal alternative candidate for those business cycles has been monetary shocks. This review focuses on the latter body of literature, but the existence of the more general analysis of the causes of business cycles and the occasional overlap of these two bodies of literature should be kept in mind. Several analysts have suggested, with differing degrees of conviction, that the magnitudes, and particularly the timings, of the recessions of the 1970s were not attributable primarily to the oil price shocks of that decade. We review those suggestions as well as other evidence bearing on them.

[16]By "relevant" dimensions, we mean factors which reasonably can be expected to affect the reaction of an economy to an oil price shock. For instance, the fact that the French speak French and the Americans speak English is not relevant to the problem, but the fact that France obtains over 20% of its energy supply from nuclear power while the United States derives around 5% from nuclear may be relevant.

7.1 Do oil price shocks mask monetary policy or other third variables?

Darby (1982) suggested two possible alternatives to the 1973-74 oil price shock for the recession of 1974-75: (1) the progress of monetary policy during the stresses on the pegged currency system in the late 1960s and early 1970s and policy responses to its collapse in 1973; and (2) the real and statistical effects of price controls in several countries in the early 1970s and of their removal in the mid-70s. The two effects need not be considered mutually exclusive. Earlier, James Tobin (1980, pp. 31-32) had expressed reservations about attributing recessions of the magnitude of those in 1974-75 and 1979-80 to oil because of the relatively small ratio of oil purchases to GNP. Darby was unable to make an attribution of the 1974-75 recession to either oil price shocks, monetary policy, or price control and decontrol solidly enough to feel comfortable with an answer. He concluded that there seemed to be grounds for firmly held, diverse opinions on the matter, and that at the time of his research there was effectively only one degree of freedom in the data available on that question. We have been unable to find work which directly extends Darby's line of research with the subsequently available data. Apparently interest in that direction of research declined because the preferred methods of answering the attribution question changed shortly thereafter with the publication of Hamilton's (1983) work. Hamilton empirically investigated the direction of causality between oil price shocks on the one hand and aggregate output and employment series and monetary and fiscal policy indicators on the other. Hamilton did not address the price control issue but did appear to satisfy the research community regarding the direction of causality between oil price shocks and the significance of the marginal contribution of oil shocks holding constant policy indicators. Later, Mork (1989) did adjust his oil price series for the effects of price controls during the period 1972-74.

Helliwell (1988, p. 26), in a review article on the ability of available macroeconomic analytical techniques to explain the worldwide stagflation of the 1970s, relies on the asymmetric impacts of oil price shocks to suggest third-variable hypotheses, principally changes in domestic and foreign demand conditions. He concluded that the failure of the reductions of energy and other raw material prices since 1982 to cause sharp rebounds of productivity casts doubt on the idea that "stagflation could be due primarily to the impact of raw materials prices on producer behavior . . ." He notes however, that for most of the European countries, the value of the U.S. dollar rose by more over 1982-85 than the dollar price of oil fell. Also, the only literature on the macroeconomic/business cycle effects of oil price shocks which he cites are the pieces by Bruno and Sachs, which are quite restrictive but nevertheless show an important contribution of oil prices.

Several subsequent papers have found statistically significant, sizeable effects of oil prices on the macroeconomy in the presence of direct controls for monetary and fiscal policy indicators (Burbidge and Harrison 1984; Gisser and Goodwin 1986; Helliwell et al. 1982); Mork (1989) and Mork et al. (1994) used indirect controls in the form of interest rates and inflation rates. Mork et al. (1994) take their examination beyond the 1990 oil price shock. Helliwell et al., in their simulation of the behavior of the Canadian economy over the 1970s, found that while Canadian fiscal policy dampened the macroeconomic effects of the 1973-74 oil price shock to a substantial extent, the Canadian economy began to pay, on balance, for that fiscal policy by 1980, leaving unclear how the effects of such policy should be accounted relative to the costs of the oil price shock in other countries.

Cochrane (1994, p. 347) estimated some simple VARs using the producer price index for petroleum and found that while innovations in oil prices do produced sustained reductions in output, over a 3-year horizon, they account for only 8% of the observed reduction. Elsewhere (p. 329), he calculated that monetary shocks could account for only about 10% of the reduction in output over business cycles if he restricted his calculations to VARs which generated output responses consistent with monetary theory. The variance in output which technology shocks can explain range from nearly 80% to essentially zero, depending on the structure and parameterization of the real business cycle model used, but the identification of technology shocks may be so tenuous as to make the entire concept vacuous (pp. 345-346).

What can be said, on balance, for the question of whether monetary and fiscal policies, rather than the oil price shocks, were responsible for the recessions of the 1970s? The application of sophisticated economic models and econometric techniques to this question have left considerable, perhaps primary, causal scope for the oil price shocks in the cyclical behavior of the 1970s and periods before and after. The studies have been shooting at a moving target over the past fifteen years, as new shocks occur, new data become available, and new models and techniques are developed, but sophisticated empirical research appears, on balance, to be supporting the causality of oil price shocks in recessions in general and the independence of their contribution from that of monetary and fiscal policies to the recessions of the early 1970s through the early 1990s. The issue of the price controls of the early 1970s seems to have been neglected largely since Darby's (1982) paper. Several authors have raised the possibility that the Federal Reserve in the United States may have reacted to oil price shocks with reductions in the growth rate of the money supply (Darby 1982; Bohi 1989, pp. 71-74). Are succeeding recessions then attributable to oil price shocks or monetary policy? Does policy need to focus on the Fed rather than OPEC, as Cochrane (1994, p. 299) suggests, or are the Fed's preferences over inflation and unemployment part of the environment in which oil price shocks occur?

7.2 Monetary Policy as the Null Hypothesis

The most persistent voice to date which remains skeptical of the role of oil price shocks in the business cycles of 1974-75, 1980-82, and 1991-92 is that of Bohi (1989, 1991; Bohi and Toman 1993; Toman 1993, pp. 1197-1198). In our discussion of the components of this issue, we have reviewed the principal elements in Bohi's original (1989) work, so we only recapitulate that work and examine the progression from empirical demonstrations to conclusions in it.

Bohi (1989, pp. 1-3, 83-84) handily summarized his principal reasons for questioning the importance of energy shocks for the economy: First, the observation that the cost of energy seems too small a share of gross national product to account for the large losses in GNP after 1973 and 1979. Second, the abruptness of economic slowdown after the oil price shocks, which "may be taken as a source of doubt rather than support for the view that energy could be held responsible," since the volume and mix of inputs used in production (such as energy) do not change significantly in the short-run. Third, the absence of any apparent positive effect on economic performance after the drop in oil prices in 1986, i.e., the lack of symmetry at the aggregate output level. Fourth, his failure to find disaggregated industry-level evidence that energy prices caused widespread dislocations in economic activity, after looking at possible mechanisms by which price shocks may have exerted their influence. These points encapsulate the empirical observations upon which Bohi's founds his reasoning. We now turn to the basis of his empirical findings.

Bohi's point of departure was the observation that the energy price-GNP elasticities empirically estimated with aggregate data seemed higher than ordinarily would be expected, considering the share of oil in the aggregate production function.[17] Could those aggregate GNP elasticities be misleading? His approach to investigating the question of whether or not the energy price shocks really had caused the recessions of the 1970s was to seek empirical evidence of the chain of causation from energy price shock to producer behavior in labor markets

[17]Noting a miscalculation, Bohi later revised his calculation of the net loss of <u>potential</u> GNP which could be attributed to the 1973-74 energy price shock (1989, pp. 24-25), from 0.72% to 5.21%, which is quite close to the magnitudes of impact estimated with both the aggregate production function and business cycle approaches (Bohi to D. L. Greene, pers. comm., August 4, 1992).

particularly, but also in inventory holding. Looking at data from the United States and several other OECD countries, he was unable to find impressive correlations between energy intensity and employment changes at the 3-digit ISIC industry level, or, on the demand side, between energy intensity and inventory changes. He interpreted these results as suggesting that some broader forces than an energy price shock were behind the two recessions of the 1970s. Turning to monetary and fiscal policy as alternative explanations, Bohi discussed the changes in M2 money stocks and in public borrowing as percent of GNP in the United States, the United Kingdom, Germany, and Japan, based on inspection of several tables. He concluded that tight monetary and fiscal policies during the periods of price shock were responsible for the general weakening of those countries' economies.[18] His assessment seems to be stronger than that of Rasche and Tatom (1981, pp. 49-55), who concluded from casual inspection of growth of M1 money stocks in six countries between 1970 and 1975 that restrictive monetary policies exacerbated the contraction which the 1973-74 oil price shock would have caused in the presence of the best choice of monetary policies, which they believe would have been neutral monetary growth. Bohi's assessment also is less tentative than that of Darby (1992), whose rigorous, statistical examination of the 1973-75 period led him to suspend judgment.

It may be useful to recapitulate Bohi's conclusions, which he offers in several layers, progressing from cautious to admittedly "harsher." He first states that "One possible conclusion . . . is that the energy connection is more subtle than can be revealed with the data analysis contained in this study. Certainly, bivariate correlations between energy intensity and activity variables of different industries may not capture possible complex interactions among these variables" (p. 85). But he interprets the inability of bivariate correlations to detect relationships across a number of industries as a mounting of negative evidence, and he modifies the first, cautious conclusion to, "The least that can be said is that the burden of proof for justifying large government expenditures for energy security programs has not been met" (p. 85). Continuing, "A harsher interpretation of the results of this study . . . should be mentioned. The absence of any measurable macroeconomic costs due to the energy price shocks eliminates this argument as the basis for a tariff on oil imports . . . . [T]he absence of a macroeconomic loss associated with higher energy prices dilutes (if not eliminates) the economic justification for government investment in petroleum reserves." (p. 86).

Reliance on Bohi's findings and conclusions in subsequent research literature has been limited: Bohi and Toman (1993, p. 1106) and Toman (1993, p. 1198) cite those conclusions to call into question the cogency of the previous two decades' research on macroeconomic impacts. Toman (1993, p. 1198) places considerable reliance on Bohi's results, saying "While Bohi's analysis does not represent the last word on the subject, it does shift a considerable burden of proof to those who would favor a strong link between energy price shocks and macroeconomic losses." Mork (1994, p. 28) offered an alternative assessment: ". . . Bohi (1991) went so far as to suggest that no macroeconomic effects would result from oil price shocks provided monetary policy was kept from being contractionary. Bohi's view is extreme, however, and can hardly be said to fit the data . . ."[19]

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[18] In his interpretation of tight monetary policy, Bohi (1989, Table 7-6, p. 76) reports that the real interest rate in the United States fell by 3.85 percentage points from 1973 to 1974 and by 4.97 percentage points from 1978 to 1980, neither event indicative of particularly tight monetary policy. Bohi interprets these movements as indicating the strength of inflationary pressures rather than the tightness of monetary policy (p. 75).

[19] In the only other reference we find, Smythe (1993, p. 109) suggests that his own results with separate regression intercepts for an asymmetric response model "go some of the way, but not all of the way, to support the results of Bohi [1989, 1991] that the effect of energy price increases has been overstated. . . ." Smythe's analysis uses an aggregate production function estimation, the limitations of which in this context have been discussed above.

8. CONCLUSIONS

It is difficult to enumerate the hypotheses which have been tested in oil price shock research because of the diverse forms in which they have appeared. Nonetheless, we can recount the major questions which have been asked, if not always resolved fully to date. These questions include the third-variable issues of whether monetary policy was principally responsible or whether price controls caused real and accounting problems which were confused statistically with the oil price shocks. Other hypotheses included in the research may be better discussed as issues of estimated magnitudes, lag patterns, asymmetry, and statistical significance; transmission mechanisms; and international comparisons. We consider these questions in turn.

The discrimination of price-shock causes from macroeconomic policy causes for the recessions following oil price shocks since the early 1970s has been the object of considerable attention. Relatively early in the literature--the early 1980s--suspicion arose that macroeconomic policies, particularly but not exclusively monetary policies may have played a relatively larger role than had the energy price shocks, but limited data availability as late as 1982 hindered separation of the effects. Beginning in 1983, the real business cycle macroeconomic literature turned to the oil price shocks and found statistical causality running from oil price changes to a number of business cycle indicators: GNP, unemployment rates, interest rates. Controlling for indicators of monetary and fiscal policy, the oil price changes still had sizeable, statistically significant impacts on GNP, in the neighborhood of 4-5%, expressed as an elasticity. If one is inclined to use the microeconomic reference of oil's share in GNP as a guide to what magnitude of macroeconomic impact would be reasonable, such a magnitude is not unreasonable, as Bohi's (1989, pp. 24-25) framework implies.

Was the 1973-74 oil price shock a leading cause of the 1974-75 recession, or was that business cycle partly a statistical artifact of accounting under price controls and partly a real response to price control and subsequent decontrol? Darby (1982) addressed this question after the 1989-80 oil price shock but before data were available to address the issue in a cross-country comparison, and that question does not seem to have been pursued since Darby's paper. We do not know whether it is a question which fell through the cracks or whether its importance was considered to have diminished as subsequent events developed in the world oil market and the world economy--continuing stagflation, the 1986 price crash, the 1990-91 oil price shock. Mork (1989) did subsequently adjust the oil price series to account for U.S. price controls in 1971:3 and 1974:1, but without reference to Darby's questions regarding price controls and the entire recession. Raymond and Rich (1995) found that use of the regime-switching model, controlling for oil prices, substantially reduced the probability that the 1974-75 recession, as well as that of 1980, represented a "recession regime," while not controlling for oil prices yielded high probabilities of those years being draws from that regime. Lee, Ni, and Ratti (1995, figs. 2-3, plotting the growth rate of real oil prices and their standardized oil price shock variable) corroborate that finding to some extent but complicate it with the finding that normalization of the oil price change variable by the volatility of recent oil prices reveals much greater potential for economic shock from the Iranian upheaval of 1953, the Suez Canal incident of 1956-57, and the oil price increase of 1969. According to their normalized variable, the 1973-74 shock was of slightly lower magnitude than that of 1969, similar in magnitude to those of 1979 and 1981, far less than that of 1956-57, and larger than that of 1953. Their normalized oil price shocks match quite closely the NBER business cycles plotted in Raymond and Rich's figures 2 and 3, with which the probabilities of recession regime correspond very closely.

We turn to hypotheses about the magnitudes, lags, and significance of the price shock effects. The three principal methods of estimating macroeconomic impacts of oil price shocks have been: the potential GNP approach using aggregate production functions; business cycle estimation relating GNP changes to changes in indicators of monetary and fiscal policy, oil prices, and other macroeconomic control variables derived from real business cycle models; and econometric simulation models. The two former types of estimation offer the most direct empirical evidence, but of those two the potential GNP approach suffers from GNP accounting problems in which double deflation eliminates the shrinkage of the production possibility frontier caused by an oil price increase, as well as from implicitly incorporating a number of microeconomic profit-maximizing assumptions inconsistent with unemployment over business cycles. Nevertheless, the orders of magnitudes of estimated GNP effects of oil price shocks deriving from the potential GNP and the business cycle methods overlap considerably. It is not clear whether the potential GNP estimates represent simply a robust mis-specification. Estimates from the business cycle methods for the United States are in the range of -1.5% to -2.5% for individual lags, and from -5% to -7% for cumulative effects. For other OECD countries, the lowest cumulative impact estimate is -2.4% for Japan and the highest is -10.8% for West Germany, all over the period 1967:3-1992:4. The contemporaneous impact tends to be statistically significant, negative, but not regularly smaller or larger than the various lagged effects. The fourth-quarter lag tends to be relatively strong, while first-quarter lags tend to be weaker and of lower statistical significance than contemporaneous impacts.

Oil price increases and decreases appear to have asymmetric effects, with the latter commonly having weaker statistical significance and smaller magnitude. Rather than standing out as grounds for suspecting the reliability of the estimated impacts of positive price shocks, recent research on macroeconomic transmission mechanisms predicts that oil price *changes* in general will cause losses from costly factor reallocations. Nonetheless, some statistical problems may remain in the current estimates using separate variables for oil price increases and decreases.

Transmission mechanisms have been of concern in the macroeconomic literature on oil price shocks for ten years or more. Bruno and Sachs (1982, 1985) expressed the tentativeness of their results at least partly because of their black-box treatment of labor market adjustments. Empirical research on the dispersion hypothesis, by which the sectoral dispersion of unemployment changes affects aggregate unemployment, has suggested that oil price shocks may indeed be the principal, allocative shock having such a magnified effect on unemployment (Loungani 1986; Davis 1987). Bohi's (1989, 1991) efforts to identify microeconomic transmission mechanisms were hampered by his tight, microeconomic focus which abstracted from such important business cycle phenomena as the sharp reduction in demand for most durables during recessions, regardless of the energy intensity of their production, as well as from the simplicity of the statistical techniques employed.

The diversity across countries of estimated magnitudes and lag structures of macroeconomic impacts of oil price shocks is to be expected and cannot be considered as prima facie evidence of no general, underlying process or interpreted as inconsistency. The differences in national economies, ranging from factor as basic as the social preferences of their citizenries and the implementations of those preferences through government policies to industrial structure, lead us to expect different coefficients on oil prices among different countries. Some of these differences could not be well captured in time series, and cross sectional data are not available for enough countries to provide sufficient degrees of freedom to execute useful regressions. Purely cross-sectional samples also pose problems in identifying lag structures in cyclical phenomena. Differences in data also complicate international comparisons. For example, researchers occasionally have had to be satisfied with slightly different definitions of interest rates and price-level indices. This does not appear to be a serious problem. Countries have different lag structures in the impact of oil price changes, as well as different cumulative impacts, even when controlling at least indirectly for indicators of macroeconomic policy.

As with many research topics, several problems have hampered empirical investigation of the macroeconomic impacts of oil price changes. First, the problem itself, in its most prominent form, is relatively new, and there are few observations. Second, the problem, as well as the oil community's understanding of it, has changed over the past two decades. First widely believed to be a permanent change in energy regimes, it has come to be seen more as a cyclic, or at least as an acyclically repetitive, phenomenon, with more in common with business cycles than with permanent, Hotelling-type resource scarcity. National policy responses and characteristic national responses of private business to oil market uncertainties have both changed over time and differed among countries. These responses frequently create difficult-to-observe, third variables which may be appealed to as untested, alternative hypotheses. Third, the evolving understanding of the problem appears to have moved the focus of empirical analysis away from more microeconomically-based frameworks and even from standard macroeconomic models to explicit business cycle models. The empirical methods applied also evolved. For instance, the question of whether the 1970s recessions were caused by the oil price shocks or by monetary policy was first addressed in a sophisticated empirical manner by Darby, but that approach was not continued as new data arrived, probably because the question began to be addressed using Granger-causality methods in business cycle regressions. The development of time-series techniques in econometrics sometimes introduces subtle shifts in the questions as well as offering sharper answers.

The most promising prospects for continued advances in understanding the macroeconomic impacts of oil price shocks appear to lie in the direction of business cycle research, and particularly in the analysis of business cycle transmission mechanisms. The labor market has received the lion's share of attention as a channel for transmission mechanisms. Investment in the uncertain climate caused by oil price shocks has received less attention, but the time may be ripe for advances in that area. The microeconomics of energy price changes are better understood than are the macroeconomics, yet the topic of this review is clearly macroeconomic. Pointing that out would be redundant were it not for the confusion which has been created in this field by the occasional mixing of implicit microeconomic assumptions and analysis with macroeconomic results.

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