The Economic Consequences of Higher Crude Oil Prices

Final Report
EMF SR 9

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A summary of the discussion and participants at the previous workshop can be found at http://www.stanford.edu/group/EMF/research/doc/summary%2002-08-05.pdf

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Executive Summary

Although average world crude oil prices have risen more than $30 per barrel since the end of 2001, the U.S. economy has remained strong, growing at about 3.5% annually over this period. This experience may suggest that the U.S. economy has entered a new era where it is invulnerable to higher oil price levels and oil price shocks. This report summarizes and evaluates the previous research and studies on the economy's response to past oil price increases in order to understand whether oil price shocks are no longer a macroeconomic problem.

A key conclusion is that sudden oil price shocks affect the economy far differently than do higher oil price levels achieved over a number of quarters. When oil prices move gradually higher (perhaps somewhat erratically), as they have done over the last several years, they do not directly result in economic recessions, even though the economy may grow modestly slower. Moreover, economic policies may cushion the impact and offset much of the adverse effects.

When oil interruptions or other surprise events jolt oil prices, however, the economy will be more vulnerable to recessions and higher costs and prices throughout the economy. These adverse impacts are likely to exceed oil's direct share (in value terms) in the economy, because macroeconomic frictions augment the initial effects. If these shocks happen at a time when baseline economic conditions prior to the shock display relatively weak economic growth with high inflation rates, they may have considerably larger effects than when the economy is growing relatively rapidly with little or no inflation. When monetary and demand-oriented fiscal policies are restricted by inflationary fears, the economic damages could be significant.

The report attempts to provide some guidance on the relative size of these impacts. When oil prices move upward gradually, the economic impacts are relatively modest. Estimates from large-scale macroeconomic models seem to measure the impacts under these conditions. When oil price shocks scare households and firms and cause temporary idle resources in the near term, the impacts are likely to be substantially larger than estimated by these models and may be closer to those evaluated by less structured, time-series (vector autoregressive) models based upon historical data.

Introduction

Although average world crude oil prices have risen more than $30 per barrel since the end of 2001, the U.S. economy has remained strong, growing at about 3.5% annually over this period. This experience seems dramatically different from previous episodes when rapidly rising oil prices often preceded economic recessions. Has the U.S. economy entered in a new era where it may be invulnerable to higher oil price levels and oil price shocks?

This report summarizes and evaluates the previous research and studies on the economy's response to past oil price increases in order to understand whether oil price shocks are no longer a macroeconomic problem. A key conclusion is that recent oil price developments have been far different from previous oil price shocks induced by sudden oil interruptions. For this reason, it is too premature to assume that future disruptions are not a problem for policymakers.

There have been several other recent surveys of the past research on the economic impacts of oil price shocks (Brown and Yucel, 2002, 2004; Jones, Leiby and Paik, 2004; and Labonte, 2004). Since these other articles have exhaustively reviewed the available literature, our report focuses instead on interpreting these results and applying them to various conditions of interest to policymakers.

After outlining four possible scenarios with higher oil prices, this report will address what constitutes an oil price shock, how would the economy respond to higher oil prices generally, and how would sudden oil price shocks affect the economy. The report also provides preliminary estimates on the approximate quantitative effects on the economy, although the economic consequences of such episodes will depend critically upon the initial economic conditions and monetary policy that prevail at the time when oil prices are increasing. The final section outlines a few key points in thinking about the possibilities of future energy price shocks.

Four Possible Scenarios with Higher Oil Prices

Although the US Energy Information Administration counts 24 episodes in the post World-War-II era as oil supply disruptions (Appendix A), Hamilton (2005) identifies only five significant events as having serious economic consequences. This observation underscores an important point: many oil supply interruptions have relatively mild implications for the economy. When significant events happen, however, the implications can be widespread and very serious.

This report will discuss four different conceptual scenarios involving higher crude oil prices. Only one of these cases merit the type of concern that policymakers had during the 1970s or early 1990s. For the other three cases, the economy will probably weather the impacts reasonably well.

Table 1 develops these four scenarios by considering two different axes: the type of oil price increase and the underlying macroeconomic conditions prior to the oil price change. "Higher oil price" conditions in the upper row on the far left reflect a situation much like today when market conditions are pushing prices along a steady upward path to restore demand and supply imbalances. Since oil prices are inherently volatile, this upward path will not be smooth but it will avoid any major surprise events. These conditions are fundamentally different from those represented in the second row for the "oil price shock" conditions, where sudden supply or demand changes induce rapid price increases that scare people and firms and create such widespread uncertainty that inferior decisions are made about production, consumption and wages and prices. Such price events appear more representative of the 1970s than recent price volatility. Although many energy economists treat these two conditions the same, they should be considered as very distinct events.

Table 1. Oil Price and Prior Economic Conditions

		Low Inflation and Interest Rates Prior to Oil Price Change	**High Inflation and Interest Rates Prior to Oil Price Change**
		Monetary policy can be accommodating	Monetary policy can **not** be accommodating
Higher Oil Price	Oil prices move steadily higher but not rapidly over consecutive months.	*Policy Fix (~0%)*	*Slower Growth (<2%)*
Oil Price Shock	Oil prices move rapidly upward over consecutive months.	*Slower Growth (<2%)*	*Possible Recession (~5%)*

Both of these price events can happen at a time when economic conditions either prevent or allow an effective monetary policy response as an offset to the disruption. During the 1970s, policymakers were faced with high interest rates and inflation both before and during the disruptions. Many professional economists were pessimistic that the central bank could intervene successfully to offset output reductions without accelerating inflation under those conditions.[1] Today, inflation rates appear tamed and interest rates are extremely low. Armed with a policy rule that adjusts monetary policy to expected output growth and inflation rates (the Taylor rule), many economists are more confident about what they can achieve.

This confidence needs to be tempered in several ways, however. First, today's very low nominal interest rates limit the flexibility of monetary authorities to respond to sudden economic downturns, especially if they are caused by a combination of oil price shocks and other factors such as a collapse in the real estate bubble. Second, economic conditions may not always be so favorable for monetary policy. Interest rates could rise in the future as the economy adjusts to a continued long-term imbalance between a growing federal deficit, boosted by uncontrolled federal expenditures and low taxes, and the trade deficit. In addition, inflationary pressures may already be building, partly due to energy price increases both before and after the Katrina storm. And third, how well will the central bank do in following its rules when a really scary oil shock happens? Although these concerns cannot be resolved in this paper, the possibility that such conditions could arise suggests the merit in considering the two separate columns of Table 1.

Labels have been affixed to the four boxes in the table. The box in the southeast corner summarizes the "possible recession" conditions, where oil shocks are rapid, unexpected and very scary to firms in the economy and where macroeconomic conditions prevent the central bank from mounting an effective offset.

Completely opposed to these conditions are those in the northwest box carrying the label "policy fix". Oil prices are moving steadily higher but firms and households understand the trends. They know that some arbitrage to protect themselves from higher prices in the future can help them adjust to the new conditions. Although higher oil prices can sap some of the economy's strength, these effects are considerably smaller, as will be discussed later. As a result, the central bank does not need to make major adjustments in their monetary policy to keep the economy's path from veering. And when they do adjust their rules, economic conditions are favorable to their success.

The other two boxes represent conditions where the economy may grow more slowly than otherwise but will not spin into a recession. How much growth is affected will depend upon whether the economic impacts are large and how ineffective monetary policy has become. Overall, however, policymakers should be most concerned about the conditions represented in the lower right-hand box of Table 1.

The estimates in parenthesis in each box represent the approximate second-year economic impact that might be expected if oil prices should double and remain higher under those conditions. The impacts are expressed as the reduction in the real output (GDP) *level* rather than the reduction in output growth *rates*. Thus, an oil disruption

[1] The early modeling studies by Mork and Hall (1980) and Hickman, Huntington and Sweeney (1987: pp. 60-63) concluded that there were significant restrictions on monetary policy's effectiveness during these years. Recent evaluations (e.g., Hamilton and Herrera, 2004) confirm these results.

occurring in today's economy with little or no inflationary pressures would reduce the real GDP level by about 2% after the second year. When averaged over the two years, the economic growth rate would be about 1% lower. If inflationary pressures should build and interest rates are pushed higher between now and the next oil price shock, the GDP impacts are likely to be more serious and reach levels experienced during the 1970s, with the GDP path being about 5% lower by the second year.

These estimates are offered as being illustrative rather than definitive. Readers should be reminded about the use of "ready reckoners" or simple elasticity conclusions made by Barrels and Pomerantz (2004: p. 27):

> These conclusions indicate that great care should be taken in using 'ready reckoners' for the effects of oil prices on output and inflation. Such estimates should be seen as conditional on the assumptions made by the investigator and on the tools used in the analysis.

They have not been derived from a single model but instead are based upon our judgment about past research on the economic impacts of previous oil shocks. Although Barsky and Kilian (2004) and Kilian (2005) provide some thoughtful critiques of this past literature and correctly note that there remain many unresolved issues about the appropriate channels and the size of the effect, this paper focuses on the empirical evidence, which strongly suggests significant oil price shock effects at both the industry and aggregate levels of the economy. This report describes these results and how they may apply to different conditions.

This report will focus upon changes in the nation's output as measured by the inflation-adjusted gross domestic product (GDP). Most macroeconomic modelers and available research studies focus upon this variable, and policymakers are certainly interested in what happens to it. Oil price increases, however, have another effect that is excluded by conventional GDP measures. A permanent oil price increase will reduce the country's income and purchasing power, requiring the nation to export more goods and services to import each barrel of oil.[2] Even if oil price increases do not influence output (GDP), they will reduce the real domestic income. Much of the recent outrage by Americans over higher oil prices has focused upon the effects on their real income or purchasing power rather than by any immediate effect on output and employment.

What is an Oil Price Shock?

Defining an oil price shock is very difficult; measuring an oil price shock is even more challenging. In this section, different concepts will be discussed in order to understand the distinction between higher price levels and surprise shocks.

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[2] Denison (1982) and Hickman et al (1987, chapter 3) explain how the real income effect differs from real output changes as measured by the National Income and Product Accounts.

Supply Disruptions and Prices

Policymakers often want a simple rule that translates supply interruptions into price shocks. If the world loses a percentage of Middle Eastern oil production, how much will prices rise? Most macroeconomists never address this issue, because their analysis begins by *assuming* a pre-determined oil price increase.

Economic damages from a disruption are linked to the *net* rather than the *gross* disruption in oil supplies. Net disruptions refer to the amount of oil removed from the market, after accounting for additional production from regions with secure excess capacity, oil inventory changes from both commercial and government stocks, expectations about future oil market conditions, and psychological factors related to the nature of the disruption. These oil offsets are usually political decisions made by governments (Saudi Arabia or the Strategic Petroleum Reserve) or complicated decisions that cannot be modeled purely as a function of price (commercial inventory releases or build-ups). Offsets can either increase or decrease the amount of oil removed from the market, they can be erratic in that they occur in some shocks but not in others, and frequently they can have significant effects. As a result, estimates of the net disruption will be highly dependent upon the analyst's judgment about these trends. Empirical estimates of oil price changes during previous oil disruptions may provide an approximate guide to the *average* effect, but appear unable to account for differences in expectations and market fears across different disruption types.

Once the analyst estimates the net disruption associated with a particular event, there remains considerable uncertainty about how the market's producers and consumers will respond as prices change. In general, greater sensitivity to price changes by either group will reduce how much oil prices will rise for any given net oil disruption.

Gasoline accounts for much of the world's current oil consumption. Recent econometric gasoline demand studies, surveyed by Goodwin, Dargay and Hanly (2004) and Graham and Glaister (2004), confirm previous results that gasoline consumption in many different countries declines by –0.2% to –0.3% during the first year after a 1% price increase. Since recent crude oil prices are approximately 40% of gasoline prices,[3] the appropriate price response for crude oil will be about –0.08% to –0.12%. This estimate is also consistent with the demand response (–0.08%) from a recent econometric estimate of total crude oil consumption in 96 different countries (Gately and Huntington, 2002). This crude oil demand estimate includes the response of all petroleum products rather than gasoline alone.

The response of oil production to price changes is much more suspect. Surveys find a range of different estimates that often vary widely. Most econometric studies focus on the United States and frequently find an insignificant or negative response between oil prices and production (Dahl and Duggin, 1996, 1998). Much of the problem

[3] This estimate is based upon 2005 prices for the United States and several European countries, weighted by their percent of total gasoline consumption.

appears to be that reliable data on drilling costs, taxes and the user cost of capital is not available to obtain robust results. Since it seems unlikely that oil production would not increase no matter how high oil prices became, we suggest an estimate (+0.05%) based upon a number of different oil market models that participated in an earlier EMF study (Huntington 1992).

Economists refer to the percentage change in quantity demanded or supplied for each 1 percent change in oil price as price elasticities of demand and supply. Such estimates convey useful information about how producers and consumers behave, without requiring detailed knowledge about how oil quantities are measured or in what currencies oil prices are represented. However, there is an important disadvantage in using fixed price elasticities directly to measure the impacts of a large disruption (e.g., more than 5% of world supplies). Fixed elasticities mean that oil consumption and production change less in physical barrels as the oil price reaches increasingly higher levels. As a result, oil prices must rise substantially in order to restore the market's equilibrium after a large net oil disruption.

In order to apply the same rule for large and small net oil disruptions, a better rule appears to be a constant response in terms of barrels produced or replaced for each $1 change in the crude oil price. For small disruptions, this rule will track the constant elasticity rule pretty closely. For large disruptions, this rule will allow prices to rise with increasingly larger disruptions but not excessively so. The above price elasticities can be converted into a barrel-per-dollar change rule by calibrating the estimate to existing price and total quantity levels. World oil consumption is rapidly approaching about 85 million barrels per day (MMBD) in early 2005 and WTI Cushing crude oil prices were averaging about $58 per barrel in July 2005.[4] Multiplying the price elasticities for demand (-.08) and supply (.05) by (85/58) results in oil consumption and production changing by -0.117 and 0.073 MMBD, respectively, for each $1 per barrel increase in oil price.

When the absolute values of these responses are summed and inverted, the linear physical response indicates that oil prices will rise by $5.26 for each 1 MMBD net oil disruption.[5] Table 2 reports this estimate in boldface italics as our *best guess* in the middle column and row on the left-hand side. Also reported are the price changes associated with lower and upper bounds on the supply and demand elasticities.[6] These additional cases indicate that one cannot rule out any price effects in the $3.50 to $10.50 range (per 1 MMBD of net disruption). For completeness, the table reports these price effects in terms of percent changes from $58 in the right-hand side.

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[4] The world consumed 84.4 MMBD in the first quarter of 2005 (US Energy Information Administration, 2005, Table 2.4). *Wall Street Journal* provides information on WTI Cushing crude oil prices, as reproduced at http://www.eia.doe.gov/emeu/international/prices.html#CrudeSpot.

[5] 1/[.073-(-.117)] = $5.26 per 1 MMBD change.

[6] These bounds have been constructed to reflect the uncertainty associated with any reported econometric estimate as determined by the standard error associated with the coefficient. Since the estimates are best guesses from a range of different studies, these ranges must be viewed as approximate at best.

The linear response rule essentially allows the price elasticity to increase as a net disruption removes oil and raises price. Accordingly, for the same sized net disruption, prices do not rise as much as they do with a constant elasticity (or percent rule). This result is shown in tables reported in Appendix B.

Although there are other approaches for increasing the price elasticity at higher prices, none are easy to explain nor do they significantly improve the estimate. One approach would be to arbitrarily assign higher elasticities at higher prices, although it is difficult to know which elasticities to use and at what prices. Another approach would be to allow the price elasticity to increase as oil's share of the economy increases. Economists sometimes argue on conceptual grounds that the price elasticity should equal the fixed elasticity of substitution between oil and other commodities, divided by one minus oil's value share. As prices rise, oil becomes more important in each consumer's or firm's total budget, because substitution away from oil is limited in the short run. The higher oil value share decreases the denominator, which raises the price elasticity. The linear response rule appears to capture this phenomenon without unnecessarily complicating the explanation.

Table 2. Effect of 1 MMBD Net Oil Disruption on Crude Oil Prices

$/MMBD Rule (Row=Demand Elasticity; Column=Supply Elasticity)

	0.025	0.050	0.075	0.025	0.050	0.075
-0.040	$10.53	$7.60	$5.95	18.2%	13.1%	10.3%
-0.080	$6.52	***$5.26***	$4.42	11.2%	9.1%	7.6%
-0.120	$4.72	$4.03	$3.51	8.1%	6.9%	6.1%

It is possible that consumers and producers cannot turn over their capital equipment as rapidly in the first few months as during the first year, producing even higher prices than estimated above. Consumers and producers, however, may change their behavior in other important ways rather than pay these higher prices. On net, data availability does not allow one to ascertain how producers and consumers will respond over much shorter periods than the first year.

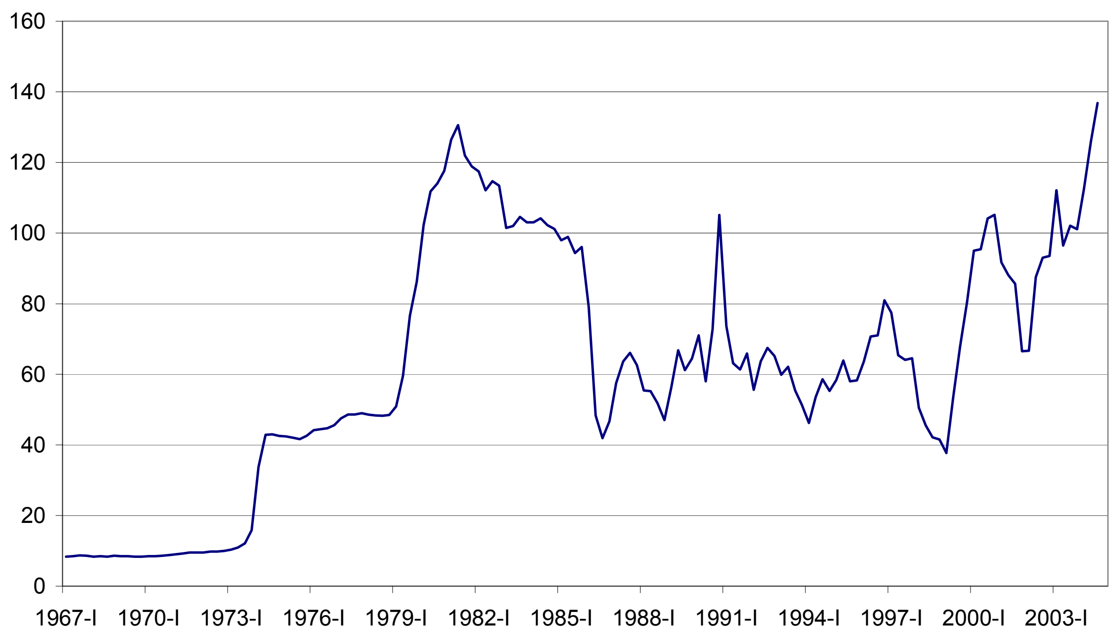
Sudden and Gradual Price Increments

Sudden price shocks involve not only very rapid price increases but also novel price movements that have not been experienced recently. These unprecedented price movements scare people and create widespread uncertainty about deciding the appropriate production techniques, purchasing new equipment or consumer durable goods like automobiles, and negotiating wages and prices. As firms and households adjust to the new conditions, some plant and equipment will remain idle and some workers will be temporarily unemployed. In contrast to a gradual oil price increase, the economy may no longer be operating along its long-run production-possibility frontier.

Although differentiating these two types of price increments is conceptually easy, empirical separation is much more difficult. Some economists do not consider recent oil price increases to be price shocks, even though they were unexpected for the most part. What determines an unexpected scary price shock from gradual price increases that may not create as serious impacts, even though they annoy firms and households endlessly?

An important characteristic of a price shock is that the price change should be large relative to recent price changes. The price shocks during the 1970s were immediately preceded by very stable oil prices that neither increased nor decreased much between months. After oil prices crumbled in 1986, oil price volatility became much more pronounced, as emphasized in Figure 1. With increased price volatility, market participants began to expect price oscillations and also began to diversify some of the risks of unstable prices by participating in oil futures markets. The economy would be more adversely affected by sudden price increases that were larger than recent price oscillations (Lee, Ni, and Ratti, 1995).

Figure 1. Nominal Oil Prices (indexed to 2000 prices)



Hamilton (2003, 2005) has offered several useful approaches for thinking about oil price shocks. First, he measures oil price shocks by a variable for net oil price increases. Hamilton's variable consists of positive[7] price increases when oil prices exceed their level over the last 3 years. Otherwise, the variable is zero. This approach is attractive because oil price movements must be novel (and thus potentially disturbing to

[7] Negative oil price changes are considered below. Hamilton's technique is similar in spirit to approaches in agricultural supply (Wolffram, 1971, and Traill, Colman, and Young, 1978) and energy demand (Gately, 1992, and Gately and Huntington, 2002) where maximum prices and asymmetric responses are important.

producers and consumers) to have an estimated effect. Oil price increases that simply reverse a previous recent decrease have little or no effect. He uses this variable in econometric equations that explain changes in real income and finds that it performs quite well. In essence, he uses empirical estimates derived from historical data to help identify what are the characteristics of an energy price shock.

Second, another way to identify oil price shocks is to use physical supply disruptions to explain oil price changes. Trends in monthly oil production for Iran, Iraq and other key producers from 1973 to the present confirm at least 5 key instances where oil price increases were preceded by significant production declines. Hamilton uses these exogenous events with largely political origins as an instrumental variable to explain price increases. This procedure allows one to determine the explanatory power of just the *components* of price movement that can be described by these supply episodes alone. The instrumental variables are used to differentiate exogenous oil-price shocks caused by supply interruptions from other oil price movements. The results of this approach that represents quantity disruptions in oil supplies directly are comparable to the results based upon the net oil price series above. The implication of this analysis is that the information on supply shock episodes is very similar to the information on price. One cannot clearly say if it is the shock events or the price changes that are leading to the GDP changes.

Oil Price Increases and Decreases

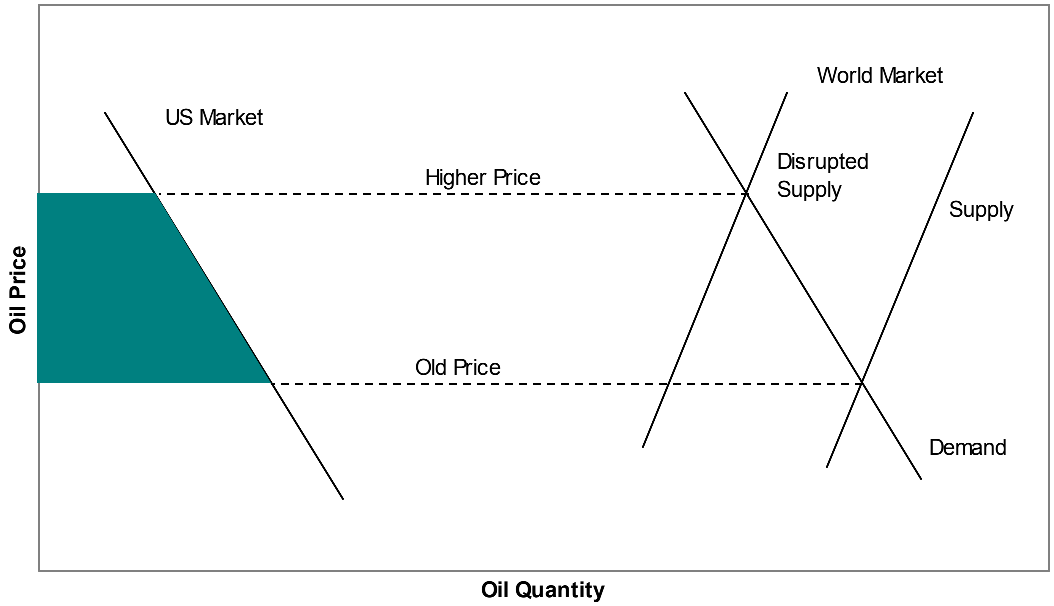
In addition to being novel, the direction of oil prices appears to matter quite a bit. Although positive oil price shocks have reduced economic growth, negative oil price shocks (or sharp price reductions) have not stimulated economic growth very much. Empirically, this evidence applies to both the United States (Loungani, 1986; Mork, 1989; Hamilton, 1996; and Davis and Haltiwanger, 1999) and other industrialized countries (Mork, Mysen and Olsen, 1994; Huntington, 2004; Jimenez-Rodriguez and Sanchez, 2005).

In the energy-economics literature, analysts refer to this conclusion as demonstrating that the economy responds *asymmetrically* to oil price increases and decreases. Another term might be that the response is nonlinear; the negative response between oil price increases and economic growth is considerably greater at prices higher than the current level than it is when they are lower. Many economists often attribute this asymmetric or nonlinear response to macroeconomic frictions, as will be discussed in a later section.

As a result, the economy responds significantly only when both oil prices are increasing and they have exceeded their previous peak over the last three years (from the discussion in the preceding section). Otherwise, the response is considerably less.

Economists have not tested whether oil price decreases that allow the price level to fall below a recent historical trough have fundamentally different impacts than those

Figure 2. External Supply Shock



price declines that lie within the range of recent experience. These tests would be an obvious extension of this approach and probably should be done.

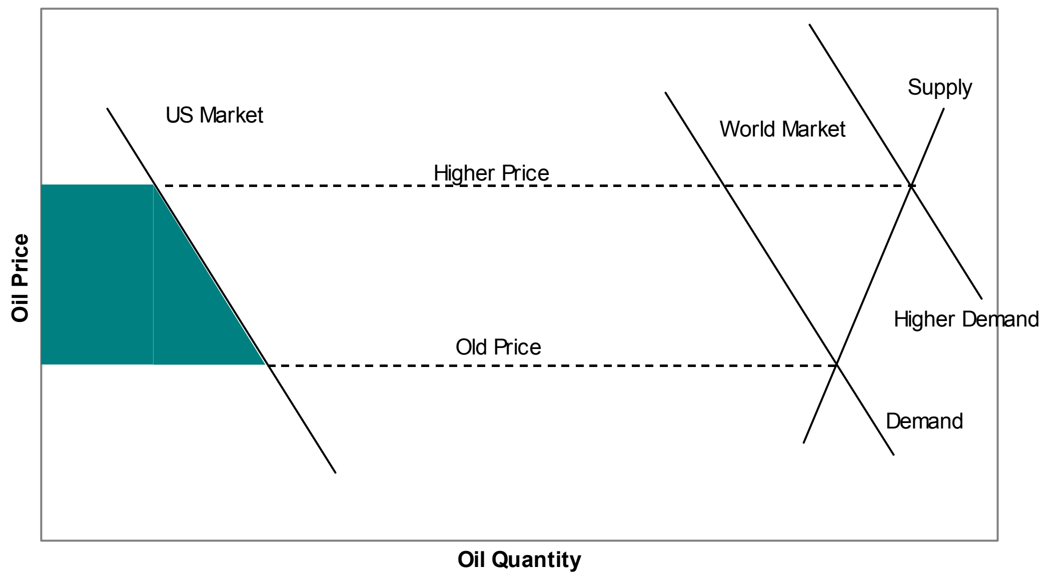
Supply-Driven and Demand-Driven Shocks

Many of the oil price shocks prior to the early 1990s were clearly associated with easily detected interruptions in physical supplies from major countries like Iran, Iraq, Kuwait and Saudi Arabia. These developments contrast sharply with today's oil market, where rapid demand growth by China and India, reinforced by demand expansion in the United States, have been key drivers of recent oil price increments. In essence, oil price shocks have become a demand rather than supply phenomenon.

It is not clear that demand-driven shocks are any less painful than supply-driven shocks. A sudden importation of diesel fuels into China or a possible breakdown of the Chinese power grid could have many of the same impacts on the US economy as a supply interruption. World prices paid by the United States will rise in either case. If the price shocks are sudden, they will probably have similar economic impacts.

What seems more important is whether the shocks are external or internal. When the United States is contributing to a higher price because it is growing faster, it is more likely that the US will be gaining rather than losing. Barsky and Kilian (2004) argue that previous oil disruptions were not completely exogenous political events but that expansive economic policies prior to the disruption eventually contributed to higher oil prices. In essence, unwise economic policies prior to the oil disruption contributed to

Figure 3. External Demand Shock



both higher oil prices and the poor economic outcomes of the 1970s. Thus, internal demand-driven shocks should be analyzed quite differently than either external demand-driven or supply-driven shocks.

Figure 2 captures the essence of the supply-driven market of previous decades. World oil supply and demand determine the oil price in the right-hand side of the chart. Under pre-shock conditions, they determine the old price level, which then governs the US oil import decisions as shown on the left-hand side of the diagram. When oil supplies are disrupted in the world market, the oil price moves to the higher price level. U.S. consumers and firms respond by reducing their consumption.

The US oil import demand curve is related to gross output and value added (labor and capital's share of output) through the production function. Under certain conditions, the area under the U.S. oil demand curve will represent gross output.[8] As the oil price increases, energy will account for more gross output than before, especially because substitution possibilities are severely limited in the short run. That will cause GDP (both value-added production and the prices paid to labor and capital) to fall by the shaded area. The US economy will be unequivocally worse off after the external supply shock.

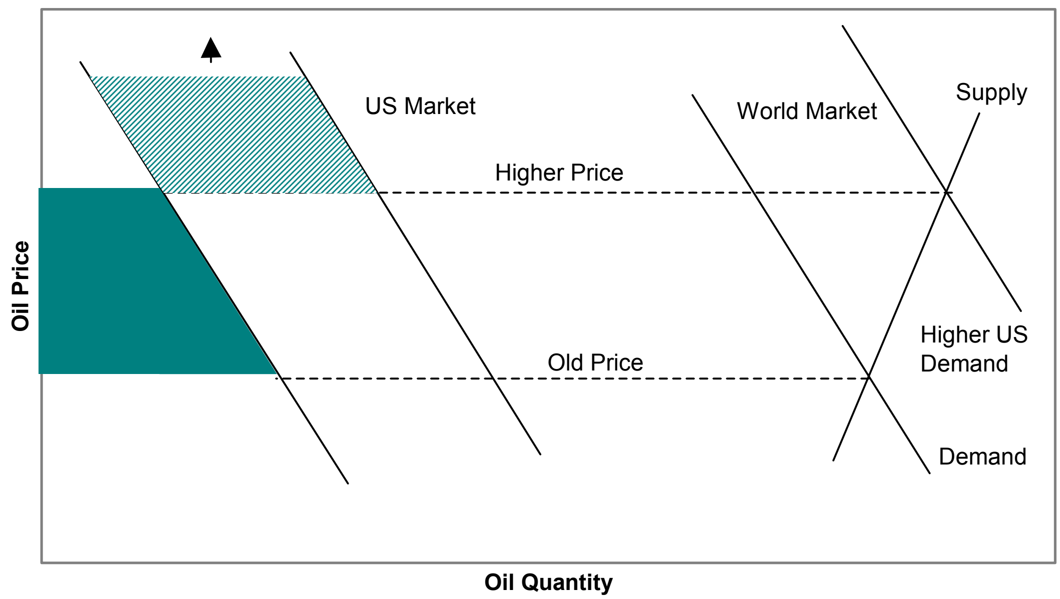
The newer demand-driven conditions are highlighted in Figure 3. Once again, world oil prices on the right side of the figure are being driven higher, although this time the key determining factor is a shift in oil demand by a country other than the United

[8] The story changes somewhat for an economy that produces some of the oil that uses. That possibility does not significantly alter the basic conceptual point explained in the figure.

States. As with a supply-driven shock, however, the US economy experiences a very similar loss in gross output and GDP. Based upon these first round effects, the US economy suffers similarly for both supply-driven and demand-driven shocks *when they are external*.

When the demand shock results from an internal expansion in the US economy, however, the situation changes significantly, as shown in Figure 4. Under these conditions, the key determining variable is an outward shift in world demand caused by higher US output growth. That development shifts not only the world oil demand curve but also the US oil demand curve. Even though the higher price causes the US economy to lose the same shaded GDP area as before, simultaneously the economy is also augmenting its income by the hatched area shown in the diagram. It is no longer true that the US economy is losing income from the oil price shock episode.

Figure 4. Internal Demand Shock



Figures 2-4 deal only with the direct first-round effects of an oil price shock. Excluded from this discussion are the important international trade issues that are another reason for focusing upon external and internal shocks rather than supply-driven and demand-driven ones. External supply-driven shocks should harm all oil-consuming economies, perhaps some more than others. As a result, trade between countries might be lower, thus contributing another mechanism for lost opportunities from a shock. In contrast, external demand-driven shocks mean that some economies are experiencing more rapid growth and this expansion should increase trade between countries.

Nonoil Fuel Shocks

Some shocks may be completely internal. Good examples would include the natural gas price shocks that jolted California in 2000 or that caused prices to escalate throughout North America beginning in the 2002-2003 winter. These episodes affected the US but did not directly reduce growth in other countries, whose trade was probably not affected appreciably either. Nonetheless, these internal shocks did place certain industries like the fertilizer producers at a severe competitive disadvantage relative to foreign firms in this industry. As a result, internal supply shocks have both favorable and unfavorable effects on the US economy, relative to external supply shocks.

If shocks are simply a foreign tax on US wealth, the traditional "OPEC-tax" argument, domestic fuel shocks should not be a problem. It is possible that domestic firms may not immediately respend their profits as quickly as consumers would have, but that argument can be applied to any product in the US economy. It would appear, however, that if domestic energy price shocks are a problem, the source of the problem lies in macroeconomic frictions or some similar explanation rather than as a simple foreign tax dragging down the economy.

Finally, it needs to be underscored that price shocks caused by deregulating an industry are fundamentally different in concept than any of the shocks discussed here. When the US began to remove its control on wellhead natural gas prices in the early 1980s, there was considerable concern that these prices would "fly up" because they had been controlled for so long.[9] Any "fly up" resulting from a price that was held artificially low cannot be analyzed in the same way as an oil price shock. Essentially, although the regulated price may be low, the "shadow price" will be much higher. Firms with curtailed natural gas service will face much higher costs in terms of either substituting more costly fuels or relocating to southwestern regions where gas is available.

What Happened in 2003 and 2004?

Oil price shocks could be a problem for the economy if they are positive increases rather than negative decreases and if they are sudden, unexpected and scary. Can the 2003 and 2004 oil price increases be described in this manner?

Recent oil price developments have some similarities with previous oil price shocks. The financial markets did not expect oil prices to continue rising over the last several years. As a result, hedging decisions to protect users from higher prices may have undervalued how high prices could move.

In other respects, these developments appear to be quite different. During the supply shocks of previous periods, crude oil price increases often exceeded 20 percent over several consecutive months. Although volatile, recent prices have been rising less

[9] In fact, prices did not escalate in either the domestic oil or gas business, when deregulation occurred, because world energy prices were retreating rapidly from unsustainable price levels imposed by the oil-producing cartel. One of the important political lessons from past experiences with deregulation is that timing is everything.

rapidly on a monthly basis. For example, crude oil prices doubled over 3 months of 1990, but they increased by only two thirds over 12 months in 2004. Recent price increases have been less intense, although still erratic, and seem rather different from earlier price escalations. Even as crude oil prices in late 2004 began to increase beyond their peak over the last three years, it remains unclear that these events are what economists mean by "shocks". [10]

Buyers and sellers also trade for oil in the future, either under long-term contracts for future deliveries or through options to buy or sell oil in the future. In current markets, these futures prices decline only modestly from today's high levels. This trend suggests that traders expect that current oil markets will remain tight for a number of months, resulting in more permanent than temporary price increases (Gramlich 2004; Bernanke 2004). When energy users anticipate that price increases are more permanent than temporary, these expectations should result in larger impacts on real GDP.

Economic Consequences of a Higher Oil Price

When oil price changes are gradual and the economy is not operating close to its natural output level, these events may produce reductions in aggregate demand that push the economy below its potential output level. As a result, unemployment and excess capacity increase in the short run before wage and price can adjust to new equilibrium levels, causing these adverse impacts to fade in the long run.

The key exogenous variable in any oil shock analysis based upon a macroeconomic model is the *nominal* price for oil imports. Higher nominal prices increase the aggregate prices for all goods and services and reduce aggregate spending. As the costs of other goods and services rise, the real oil import price begins to decline. This variable, the real oil price level, is therefore partially an output of the macroeconomic simulation. If policy favors augmenting output rather than curbing inflation, the economy will have higher output but lower real oil prices. If policy favors curbing inflation rather than unemployment, the economy will have lower output but higher real oil prices. Since real oil prices are both partly endogenous and subject to policy choices, most macroeconomic simulations do not try to hold *real* oil import prices constant at a given post-shock level.

Nominal rather than real oil prices play a critical role in the aggregate demand responses in most macroeconomic models. In the neo-Keynesian framework, many important macroeconomic frictions prevent rapid changes in nominal prices for final goods (due to the costs of changing "menu" prices) or for key inputs (e.g., wages). Moreover, nominal price stickiness is asymmetric in that firms, unions and other organizations are much more reluctant to accept reductions in their purchasing power through lower prices than increases in income through higher prices. When a nominal oil price shock threatens this purchasing power by creating pressures for lower nominal prices for final products and non-energy inputs, the adjustment process is slowed with

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[10] Recall that Hamilton's net oil price increase series registered any oil price increase as a "shock" as long as the oil price level exceeded its past peak over the last three years. This point underscores that oil price shocks cannot be determined by a strict formula alone but requires careful analyst judgment too.

multiplying effects throughout the economy. These frictions can feed upon each other, as in an economy already experiencing prior inflationary pressures, causing wage-price spirals, as occurred in the 1970s. When these price increases affect wages and other prices in this way, economists often refer to the oil price increase as influencing the "core" inflation rate (probably only temporarily).

U.S. Estimates Based Upon an OPEC Tax

When core inflation effects are absent, oil price increases operate reasonably similar to an "OPEC tax", where the receipts are directed towards foreign oil producers. U.S. oil consumers suffer a reduction in their disposable income and as a result cut their spending on U.S. goods and services. If foreign oil producers do not spend as much or as quickly on domestic goods as do U.S. residents, aggregate demand for U.S. production will shift down. How quickly and how much they spend on U.S. goods and services and assets will be critical in determining the size of the "OPEC tax." The more that they spend back in the US economy, the lower will be the net "OPEC tax". If domestic energy firms also temporarily delay their spending relative to U.S. consumers, this tax may extend beyond the foreign oil producers.

Although this effect will be referred to as an "OPEC tax" in this report, this term does not mean that OPEC is the initiator of the action that causes oil prices to increase. Nor does it mean that all oil import revenues flow to OPEC countries and none will flow to other countries like Russia and Norway. If rising oil demand increases oil prices, foreign oil producers will earn higher receipts from an event that operates like a tax and they will need to spend this income. This tax effect depends upon how foreign and domestic countries spend their income rather than upon the purchasing power of U.S. income. For example, the US suffers a decline in purchasing power when imported oil prices change, but the OPEC tax effect on U.S. output may be absent if foreign oil-producing countries spend their income at the same rate as U.S. consumers do.

Under these conditions, quantitative estimates of the impacts from gradual oil price changes would not be any greater than those reported recently for the Global Insight US model (Gault 2005). They represent an upper bound, because most large-scale macroeconomic models do not differentiate between the economic effects of oil price shocks and gradual oil price increases. By blending the responses to these two very different events together, they may be understating the effects of oil price shocks and overstating the effects of gradual oil price increases.

Macroeconomic simulations report the percent losses in real GDP levels (or increases in price deflators) as a function of each $10 per barrel increase in crude oil prices. As the oil price rises from $30 to $40 to $50 per barrel, the proportional oil price increase declines, but the percentage impact on real GDP remains the same. Thus, the percentage change in real GDP relative to the percentage change in oil price—the output-response equivalent of the price elasticity term for oil consumption and production described previously—declines at higher oil prices. This approach for reporting impacts reflects the structure of these frameworks, which focus on short-run aggregate expenditures when substitution away from oil is very limited. A $10 increase in oil prices raises the economy's expenditures on oil by the same amount at $30 as it does at $40. Measured relative to the same baseline GDP level, these additional oil expenditures represent the same share of total economic output regardless of the initial oil price level.[11] For this reason, the impacts from the macroeconomic simulations in this section are reported for each $10 per barrel increase in price rather than for each 1% increase in the crude oil price.

When oil prices rise from $30 to $40 per barrel, US GDP in the Global Insight simulations reported in Table 3 declines by 0.3, 0.6 and 0.4% *below baseline GDP* after the first, second and fifth years, respectively.[12] In an economy growing at 3 or 4 percent per year, these reductions in the real GDP level will slow down the growth rate but will not cause a recession. Macroeconomic simulations do not generally report the results in terms of economic growth or inflation *rates.* This reporting convention partly reflects the nature of the economic impacts, which operate with a lag on the first few quarters and years but begin to fade over time. In later quarters and years, economic growth may actually increase more than in the baseline because the economy begins its recovery. This higher growth rate in later periods, however, hides the fact that the employment and output may still be lower due to higher oil prices.

Moreover, policymakers may be more interested in the dollar impact on the nation's residents rather than on variations in the growth rate. The bottom of Table 3 reports an estimate of the total output losses based upon the percentage reduction in real GDP in the Global Insight projections multiplied by the GDP level in the first quarter of 2005. This component represents the value of lost output represented by the production of fewer goods and services. Also shown are estimates of the oil wealth losses that are calculated as the change in the world crude oil price times the June 2005 level of total petroleum imports. This component represents the reduction in real wages and returns to capital that result from the higher price paid for oil imports. Although this reduction in purchasing power is not measured by real GDP reported in national statistics, declines in national income due to higher oil prices are very much an economic impact as are the output losses. Wage earners are not only concerned about what wage they are paid, but also whether their wages keep pace with the costs of the goods and services that they buy.[13]

These inferred estimates appear to show that the nation loses as much from the oil wealth effect as it does from reduced output during the first year. Between the first and second years, the combined losses of the two components have increased from $75 billion to $111 billion. Although real GDP is an inferior measure of economic welfare for a variety of well-known reasons, these estimates do indicate why policymakers might be interested in oil disruptions.

[11] This approach may not be appropriate if the model was not as closely tied to an expenditure framework. In contrast, the impacts from statistical studies in the next major sector are usually expressed in terms of the percent change in the oil price.

[12] The reported impacts seem more persistent than what some economists expected from a tax increase.

[13] The approach of computing separate oil wealth losses and adding them to output losses is explained in Hickman, Huntington and Sweeney (1987).

Impacts on inflation rates, unemployment and other important economic variables are also shown in Table 3. Aggregate consumption declines more than investment, mainly because interest rates remain essentially unchanged because the central bank can ease its monetary policy in these estimates. The relatively mild effect on investment is strikingly different from the 1970 experiences, where disruptions created vastly larger impacts.

Since the Global Insight modeling system is reasonably similar to other macroeconomic models used for forecasting and policy analysis, its impacts are also similar to other available estimates (Table 4). Although the output effects in some simulations (e.g., NIESR) are lower than in others, the price deflator effects are larger. The split between inflation and output effects in any simulation will be determined largely by policy assumptions rather than by the oil price increase. One approach for understanding the total effect on the economy is to compute the misery index, which is the sum of the inflationary effect as measured by the price deflator and the (absolute change) in aggregate output. The misery index is reported as a diagnostic tool for understanding the results rather than as a measure of policy interest.

Table 3. Impacts of a Permanent $10 Rise in Oil Prices

Oil prices rise from $30 to $40.
(Percent deviation of levels from baseline)

Year:	1	2	… 5
Real GDP	-0.3	-0.6	-0.4
Real Consumption	-0.4	-0.7	-0.6
GDP Price Index	0.2	0.5	0.9
CPI	0.7	1	1.3
Core CPI	0.1	0.3	0.6
Employment (000)	-125	-451	-270
Unemployment Rate	0.1	0.2	0.1
Short-Term Interest Rate (pct pts)	0	0	-0.1
Current Account ($bln)	-30	-29	-47
Inferred GDP Impacts (Billion $) #			
Real GDP	-36.6	-73.2	-48.8
Oil Wealth Loss	-38.2	-38.2	-38.2
Real Income=Real GDP+Oil Wealth Los	-74.8	-111.4	-87.0

Source: Global Insight U.S. Model simulation as reported by Gault(2005) unless otherwis
Inferred estimates have been computed by author based upon 2005, first quarter
GDP and June 2005 total petroleum imports.

Table 4. Macroeconomic Model Estimates of Economic Impact
(Percent change from baseline for a $10/Bbl oil price increase)

	Year 1	Year 2	Year	Oil Intensity
Global Insight			2003	3758
Output	-0.3	-0.6		
Price Deflator	0.2	0.5		
Unemployment	0.1	0.2		
Interest Rates	0.0	0.0		
Misery	0.5	1.1		
Gramlich			2003	3758
Unemployment	0.3			
Core Inflation	>0.3			
FRB/US			1999	4008
Output	-0.2	-0.4		
Price Deflator	0.5	0.3		
Unemployment	0.1	0.2		
Interest Rates	0.5	0.2		
Misery	0.7	0.7		
NIESR			2003	3758
Output	-0.20	-0.47		
Price Deflator	0.30	0.51		
Misery	0.50	0.98		
NIESR-Taylor Rule			2003	3758
Output	-0.15	-0.24		
Price Deflator	0.36	0.77		
Misery	0.51	1.00		
IMF			2000	3912
Output	-0.8			
Price Deflator	0.6			
Misery	1.40			
EMF Study			1982	5826
Output	-0.79	-1.61		
Price Deflator	0.63	1.12		
Unemployment	0.31	0.67		
Misery	1.42	2.73		

EMF Study - Adjusted			1982	5826
Output	-0.51	-1.04		
Price Deflator	0.40	0.72		
Unemployment	0.20	0.43		
Misery	0.91	1.76		
Average (GI,FRB,NIESR)				
Output	-0.23	-0.49		
Price Deflator	0.33	0.44		
Unemployment	0.10	0.20		
Misery	0.57	0.93		

Table Notes:

Year (third numerical column) provides approximate time when simulations were performed, where 2003 refers to a study done in that year or later.

Oil intensity is measured in BTU per GDP (2000 $).

Misery index change = price deflator change - output change.

Many of the more recent estimates (positioned at the top of the table) show reasonably similar "misery" effects, indicating that while the models may produce a somewhat different distribution between inflationary and output effects, the total size of the impact on the economy appears somewhat similar. The estimates from a much earlier Stanford University Energy Modeling Forum study are higher because the simulated oil shocks happened when: (1) oil use was much more important to the economy (please see last column); and (2) the economy was experiencing much harsher prior inflationary pressures than exist today. The second EMF entry that is marked "adjusted" simply scales down the estimated impacts by the lower oil intensity existing in 2003.

Oil's Relative Importance

When the oil price increase is simply a tax on domestic wealth, oil's relative importance in the economy will be a critical factor determining the size of the economic impacts. Since oil's value share of total output has declined by about 50 percent from its pre-1973 share, the oil price increase needs to be twice as large to have a comparable tax effect on the economy. When the oil price increase is more than a simple OPEC tax and perhaps produces macroeconomic frictions and a wage-price spiral, these other mechanisms may produce effects that offset and obscure the role of oil's relative importance. The next major section on the impacts of oil price shocks discusses this topic in greater depth.

Linear Impacts

The responses to an OPEC tax are symmetric in that the impacts of a price decline mirror those of a price increase. When oil prices decline, income is transferred back to domestic consumers, who spend larger shares of their income more quickly on domestic goods and services than do domestic and foreign producers. If oil import price changes are simply a tax, there is no reason to expect a nonlinear or asymmetric response when oil prices fall relative to when they increase.

Responses are generally linear relative to the dollar-per-barrel price change. As a result, proportional oil price changes will have larger impacts at higher oil price levels because the dollar-per-barrel increase is larger. There may also be "threshold" effects that produce still even larger economic impacts at higher oil prices, but these estimates do not incorporate them. For example, very large price increases could further dampen investment and spending by derailing the confidence that firms and households have for the economy's near-term future and the central bank's ability to manage the country's money supply effectively.

What Other Feedbacks Are Critical?

In addition to the transfer of income overseas to oil-producing countries and their propensity to respend their new wealth on US goods and services and assets, what other feedbacks are important for the estimates from macroeconomic simulations?

The assumed monetary response is critical to the estimated impacts. In most recent Global Insight simulations, the monetary response uses a reaction function that responds to both the output gap and inflation. If inflationary pressures are low prior to the shock, the central bank can allow the money supply to expand, thereby preventing the interest rate from rising and offsetting the GDP loss. Under these conditions, the principal effect is the reallocation of income to foreign oil producers who spend less on U.S. output.

Inflation tends to be less of a problem than in previous simulations of past shocks. Much of the lower inflationary effects of the oil price shock probably reflect initial economic conditions that have already removed inflationary pressures. Recent simulations do not allow wages to increase as much as in the past, because wages respond to value added (production) prices rather than to consumer prices.

Exchange rate responses tend to moderate the US impacts. Not all countries see higher oil prices, if their exchange rates offset the increase in $/barrel. Global Insight projections call for foreign GDP impacts that are reasonably similar to the US GDP impacts. This view is supported by IMF estimates (to be discussed) that show European and US impacts to be very similar to each other, although Japanese impacts may be somewhat less.

Finally, expectations of firms and households about the duration of the oil shock can have important influences on the size of the impacts. Barrel and Pomerantz (2004) found that a temporary shock produced a 30% smaller impact than a permanent shock in their macroeconomic simulations. Properly anticipating that an oil price shock would be permanent caused a rise in the long-term interest rate and a contraction in investment and other interest-sensitive spending.

What Policies Can Be Used to Offset the Impacts?

When the oil price increase is a tax that reduces spending on U.S. goods and services, governments can mitigate the negative impacts through other policies. The tradition of combining tax, spending and monetary policy is well established in macroeconomics and frequently means that a tax will not have negative effects if policymakers are allowed to combine fiscal and monetary measures into an integrated policy package that allows growth while curbing inflation rates and keeping interest rates attractive. For example, an OPEC tax increase could be offset by reducing income taxes, by increasing government expenditures, or by easing monetary policy.

If inflationary pressures are already operating in the economy, these demand-side policies would not be effective in restoring output, because they would increase inflationary pressures or the interest rates. Under these conditions, policymakers confront a particularly severe dilemma about whether they want to restore some of the output loss by risking greater inflation or control inflation rates with higher output and employment losses. Among the few policy options available under these conditions is a release of public oil stockpiles (the Strategic Petroleum Reserve or SPR), which reduces oil prices and restores aggregate economic output.

Foreign Responses to Oil Price Increases

The International Monetary Fund (IMF) used the MULTIMOD model to estimate the global impacts of a $10 per barrel increase above 2003 levels. These impacts differ from the Global Insight estimates in that they include the endogenous effects between the growth rates of different countries. By contrast, the Global Insight estimates assumed that the other industrialized countries would grow at the same rate as the US economy.

Table 5. Impact of a Permanent US$10 per Barrel Increase in Crude Oil Prices After One Year (% of 2003 GDP)

	Real GDP	Inflation
World	-0.5	n.a.
Industrial Countries	-0.6	0.4
United States	-0.8	0.6
Euro area	-0.8	0.6
Japan	-0.4	0.2
Other	-0.4	0.2

Source: IMF (2000) and staff estimates as reported by Oularis (2005).

US economic activity would decline by 0.8 percent after one year, which is substantially larger than the Global Insight estimate, and the US inflation rate would increase by 0.6 percent, as shown in Table 5. Global activity will fall by about 0.5 percent after one year. US and European economic activity impacts are similar, but both are about twice the impact in Japan and other industrialized countries.

The impact on developing countries is hard to estimate because econometric models and data are not readily available for these nations. In addition, there is a lot less certainty about how effective monetary and fiscal policies will be in these countries. For this reason, the IMF developed simple terms-of-trade simulations to determine the additional export earnings needed to finance existing oil purchases. These results, which are reported in Table 6, reflect each country's dependency upon oil imports. Oil-exporting nations gain significant wealth, because oil production is concentrated in a relatively small number of nations. Although oil-importing developing countries lose about 0.7 percent of their aggregate wealth, these impacts are distributed across a number of different economies. As a result, the negative effects from a price increase of $10 per barrel appear manageable for many countries. Nevertheless, the gap exceeds 2 percent of GDP for 24 countries (not shown), mostly the small island and African countries. The negative impact can have particularly serious long-term effects on future growth, if access to capital is limited.

Most of these countries appear to have sufficient foreign reserves to buffer the negative impact on the current account. Moreover, non-fuel commodity prices—an important source of export earnings for some low-income, oil-importing countries—have risen in line with oil prices.

Economic Consequences of Oil Price Shocks

If future events in the Middle East should suddenly disrupt oil supplies and increase oil prices, the economic impacts are likely to be much more serious than those for an OPEC tax. With larger impacts to offset, governments will need to be more aggressive about ameliorating them with a limited set of policy measures. These efforts of accommodation will be made more difficult to the extent that correct public policy decisions must be made under emergency conditions. These conditions will particularly challenge policy makers if inflation and real interest rates rise in the intervening years between now and the next disruption.

Table 6. Expected Current Account Impact of a $10 Increase in Petroleum Prices in 2004

	billions of US$	% of 2003 GDP
Other Emerging Markets and Developing Countries	101.7	1.3
Total Exporters	133.5	4.3
Total Importers	-31.8	-0.7
Africa	21.9	3.9
Nigeria	7.4	12.8
Central and Eastern Europe	-2.2	-0.3
Former Soviet Union	24.7	4.3
Russia	20.3	4.7
Developing Asia	-14.9	-0.5
Indonesia	0.3	0.2
China	-7.6	-0.5
India	-5.6	-1
Middle East	65.3	9.3
Libya	4.5	18.4
Kuwait	5.9	13.3
Qatar	3.4	16.8
Saudi Arabia	29.3	13.3
United Arab Emirates	8.5	10.6
Iran	9.2	6.7
Iraq	3.4	13.6
Western Hemisphere	6.9	0.3
Venezuela	7.9	9.3
Argentina	1.3	1.1
Brazil	-1.2	-0.2
Mexico	6.3	1

Actual dollar increase in the price of crude oil is US$8.35.

Source: OECD International Energy Agency (IEA).

As reported by Oularis (2005).

U.S. Estimates Based Upon Macroeconomic Frictions

The previous impact estimates for higher oil prices were based upon large macroeconometric models that establish multiple relationships through statistical analyses of historical data. The advantage of the large U.S. model detail is that new conditions and policies may be better represented than in simpler analyses. That advantage, however, also has its limitations. First, the value of the more detailed simulation will depend upon whether the right constraints and assumptions are chosen to represent the new conditions. And second, the modeling framework may not incorporate all of the possible frictions in key sectors that serve to magnify the effects of oil shocks throughout the economy.

For this reason, some analysts have directly investigated the economic impact of oil shocks with reduced-form statistical analyses of historical data. These approaches adopt a much simpler approach focused specifically upon the relationship between crude oil prices and some measure of the economic impact, such as aggregate output, inflation or unemployment. The advantage of these studies is that they focus specifically upon the question at hand, the impacts of oil price shocks. The principal concern is that they may fail to control for key macroeconomic variables and relationships that influence how the economy responds to oil price changes.

Reduced-Form Statistical Estimates

Nine of the last 10 U.S. recessions (post World War II) were preceded by an increase in crude oil prices.[14] Statistical tests by a number of researchers on quarterly data reject the hypothesis that this observation was a coincidence.

A number of empirical studies have used reduced-form time-series analyses relating economic growth and oil price changes to test this hypothesis directly. Like the large-scale macroeconomic models, they also use statistical techniques. However, they focus specifically on the relationship between economic growth and oil prices and ignore the many complicated economic relationships incorporated in the larger-scale frameworks. Results from these studies will be referred to as statistical estimates, because the model does not try to explain the various avenues through which oil prices affect economic behavior.[15]

Efforts by Hamilton (2003) have led to an established approach for investigating this issue. The researcher massages the oil price series to make it more representative of an oil price shock rather than simply counting each dollar or percent increase in the oil price reported in the official statistics. Since Mork's study (1989), all estimates separate oil price increases from decreases. Hamilton prefers to represent positive oil price changes with the net oil price increase series discussed in the previous major section on what constitutes an oil price shock, but other researchers have scaled the oil price change relative to its recent variance (Lee, Ni and Ratti, 1995), or have compared it to recent average oil price levels (Davis and Haltiwanger, 2001). The equation explains economic growth rates as a function of the past growth in the economy and past changes in this net

[14] The quarterly data for the United States covers the post-World-War-Two era and hence the oil supply interruptions that began in 1956, 1973, 1978, 1980 and 1990.
[15] Researchers who use these models, however, have offered very specific theories that explain their results, as will be explained below.

crude oil price series. Many studies add the past values of additional variables to the system in order to incorporate their interactions with the oil and GDP variables.

Researchers do not report results from reduced-form statistical studies that can be easily compared to the elasticity estimates for macroeconomic models. Studies often present charts showing "impulse response functions" that summarize the impacts of a one-time change in oil prices.[16] This one-time change in the oil price increase should be viewed more like a permanent than a temporary change in the oil price level. The analyst does not force the oil price back to its original level in some future quarter, as would be the case in a temporary oil price shock. The percentage economic impacts vary with the percentage change in the modified oil price rather than to the dollar price change, in contrast with the macroeconomic models discussed previously.

Most impulse response functions are difficult to read and interpret as simple responses to price changes. One of the few researchers who have reported these results in tabular form is Jimenez-Rodriguez and Sanchez (2005). Table 7 replicates their US results for several different specifications. The asymmetric results allow separate GDP estimates for oil price increases and decreases, while the net oil price estimates evaluate the GDP response when oil prices exceed the maximum over the last 12 quarters. After about the first year (four quarters) following a doubling of the oil price, the real U.S. aggregate output level is almost 5 percent lower in the asymmetric specification. We think that their estimates are comparable to other studies, as reviewed in Appendix D, and therefore have adopted them for our review. If their sixth-quarter GDP elasticity (approximately 0.05) is applied to a 33% price increase, to be comparable to the Global Insight response, real GDP would decline by 1.4 percent. That estimate is much more similar to the second-year EMF study response (1.6 percent) than it is to the more recent Global Insight response (0.6 percent) for the same year in Table 4's comparison of previous macroeconomic simulations.

Combining the two asymmetric estimates (for positive and negative oil price changes) provides a very approximate estimate for the effects of a temporary oil price shock. The Jimenez-Rodriguez and Sanchez (2005) study did not try to evaluate a temporary shock, but the author has inferred one from their results because temporary shocks are considered important. This estimate allowed oil prices to increase by 1% in the beginning (period=0) until the fourth period, when oil prices were reduced by the same amount. The temporary shock and its impact resemble an oil price increase through the fourth quarter, but the lower price in the fourth quarter offsets some but not all of the positive shock by the eighth period. By the eighth quarter, the impact from this temporary shock would be about 70% of the comparable impact for a permanent shock.[17]

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[16] Technically, the analyst adjusts the error term in the oil price equation.
[17] This approach assumes that firms and households expect a permanent shock initially but are later surprised when they learn that it was only a temporary one.

Table 7. GDP Impacts of Oil Price Shocks

Quarter	Asymmetric Increase	Asymmetric Decline	Net Price	Temporary
4	-0.048	-0.014	-0.046	-0.048
6	-0.051	0.002	-0.058	
8	-0.046	0.011	-0.054	-0.032
10	-0.044	0.010	-0.048	
12	-0.042	0.010	-0.043	

Source: Jimenez-Rodriguez and Sanchez (2005) for asymmetric and net price estimates. Temporary estimates are computed by the author as described in the text.

The Jimenez-Rodriguez and Sanchez (2005) study is recently completed and estimates the US response as part of a system that also includes the response of other major OECD countries. They found that the oil price coefficients were stable over time for the different OECD countries. That conclusion means that comparably sized oil price shocks had similar impacts on aggregate output at the end of the century as they did during the 1970s. The impacts did not diminish as oil intensities decreased in each country. This finding of stable coefficients contrasts sharply with the Hooker (2004) finding for the effects on core U.S. inflation, as will be discussed below.

What Explains the Different Impacts?

The impacts from both the reduced-form statistical studies and the previous macroeconomic simulations reported in the EMF study are substantially larger than the Global Insight estimates of –0.3 and –0.6 percent for these two years. What are the reasons that explain why the reduced-form statistical evidence and previous macroeconomic simulations show more pronounced effects? Are these factors permanent changes in the economy or can some energy, economic and policy conditions revert back to the way they were in the 1970s?

The next five subsections briefly discuss five reasons for why many recent estimates are smaller: fewer macroeconomic frictions, the declining relative importance of oil in the economy, the reduced inflationary conditions and lower inflation rates prior to a disruption, diminished oil wealth effects, and more learning about how to cope with shocks.

Macroeconomic Frictions

Direct reduced-form estimation often attribute their larger impacts to a range of macroeconomic frictions that could make the economy's response to an oil price shock fundamentally different than an oil price increase. Large macroeconometric models incorporate a number of important aggregate demand relationships, but their structures do not differentiate between oil price increases and decreases or between surprise events and more gradual price adjustments. Unless the model incorporates expectations about future oil market conditions, higher prices contract the economy proportionately, regardless of whether the oil price increases are novel and unexpected or whether they are gradual. The simpler reduced-form models relating real GDP to oil prices may be better suited for oil price shocks because they explicitly differentiate shocks from expected price changes.

One macroeconomic friction that contributes to large indirect effects on the economy is the distortions in demand between products and sectors. These demand adjustments operate at the sectoral rather than the aggregate level and are not incorporated in large macroeconometric models. As demand shifts away from fuel-inefficient to fuel-efficient automobiles, labor and capital need to be reallocated between plants. It is costly, however, to transfer resources quickly (Hamilton 2003). Capital equipment may become idle and hence retired prematurely. Labor needs to search for new positions, as jobs are lost in some sectors and created in others. Microeconomic evidence on employment trends shows that sudden oil price changes in either direction causes significant job creation and destruction at the industry level (Davis and Haltiwanger, 2001; Haltiwanger, 2005).[18]

The other macroeconomic friction is the distortions in wages and prices after an oil price shock.[19] The new Keynesian approach to macroeconomics emphasizes the wage and price stickiness that characterizes modern industrial economies (Ball, Mankiw and Romer, 1988). If wages and prices are completely flexible rather than being sticky and capital and labor inputs do not change, the direct impacts of an oil price change will be relatively small. When wages and prices are sticky, however, the demand for capital and labor can change significantly in the short run. These indirect effects can be relatively larger than the direct impacts. Typically, these impacts operate through the economy's aggregate cost structure or its aggregate price level. In the near term, higher oil prices are not offset by lower labor costs. Not only are wages bid higher to maintain purchasing power, but labor productivity temporarily falls. Firms pass through these higher costs to their consumers in terms of higher prices for their products.[20] Higher prices in all sectors reduce aggregate spending through the interaction of the goods market and the monetary rule adopted by the central bank.[21]

These frictions reinforce the output decline due to higher oil prices but operate against the favorable effect of lower oil prices. Resources need to be reallocated as much as when oil prices fall as when they rise. Similarly, if organizations are risk averse, they will allow wages and prices to rise when oil prices fall, but will seek to prevent lost purchasing power when oil prices fall. In either case, frictions will cause the responses to oil price shocks to be asymmetrical.

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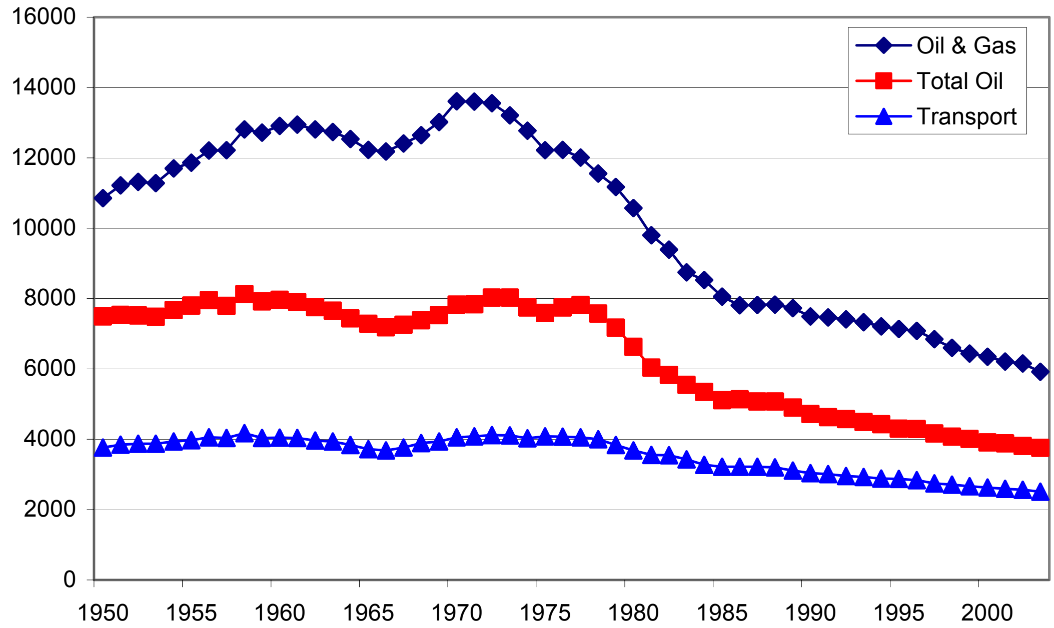
[18] The Davis and Haltiwanger study focuses on employment rather than output and hence its results are not discussed in detail in this report.

[19] Large macroeconometric models probably incorporate wage and price stickiness, although proprietors often do not emphasize these frictions when discussing their recent results. In contrast, these frictions played a critical role in explaining why these systems estimated relatively large impacts from previous oil price shocks (Hickman, Huntington and Sweeney, 1987).

[20] Firms must see a downward-sloping demand curve for their product in the new Keynesian paradigm. Typically, analysts assume that there are many monopolistically competitive firms.

[21] Romer (1998, 2005) provides an updated discussion that refines some troublesome aspects of the IS-LM framework but yet maintains its simplicity.

Figure 5. Oil & Natural Gas Intensity (Btu/$)



Oil Value Share

Oil's share of total economic output has fallen sharply over the last several decades. Figure 5 displays the post-war energy trends for combined oil and natural gas and for petroleum. In 1972, the US used 8026 million BTUs of petroleum for every dollar of GDP. In 2003, the total oil intensity has fallen by 53 percent[22] to 3758 million BTUs (US Energy Information Administration, 2004). Table 1 showed that an adjustment for declining oil intensity would convert the EMF median estimate for second-year output impact from –1.6 percent to –1.0 percent, much closer to the comparable Global Insight estimate of –0.6 percent.[23]

Revising previous macroeconomic simulations downward for declining oil shares may not be warranted, however. The limited empirical evidence on this issue (Mork, Mysen and Olsen, 1994; Huntington 1998, 2004; Hooker, 2002) fails to find significant effects for the oil value share in either U.S. or international studies. Weighting the oil price change variable by the economy's oil share in the previous year does not contribute explanatory power that is not already incorporated by the unweighted oil price change variable. Essentially, too many other factors were operating and appeared to be more important.

The oil value share will be an important condition shaping the impacts if the direct effects are very important and the indirect effects are purely secondary. However,

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[22] The combined oil and natural gas intensity fell by 56%.

[23] The recent Global Insight estimate also reduced the inflation effect and lowered the losses due to international trade with other countries, so a direct comparison cannot be made.

many researchers think just the opposite. If macroeconomic frictions are important, some European nations may experience larger economic losses, even though their economies are less dependent upon oil consumption. Similarly, while the US economy has become less dependent on oil, other changed conditions may be even more important. Moreover, while the US economy has reduced its dependence upon oil within its manufacturing and commercial sectors, most oil consumption today is highly concentrated in the transportation sector, where the oil intensity declines shown in Figure 5 are much more modest. Oil is critical for transporting goods and people by road, ship or airplane, where interfuel substitution is often severely limited and lower than in other sectors of the economy. The impacts on GDP are a function not only of the oil value share prior to the shock but also of the elasticity of substitution between energy and other inputs. Limited substitution when there is an oil price shock means that the economy must increase its oil value share considerably.

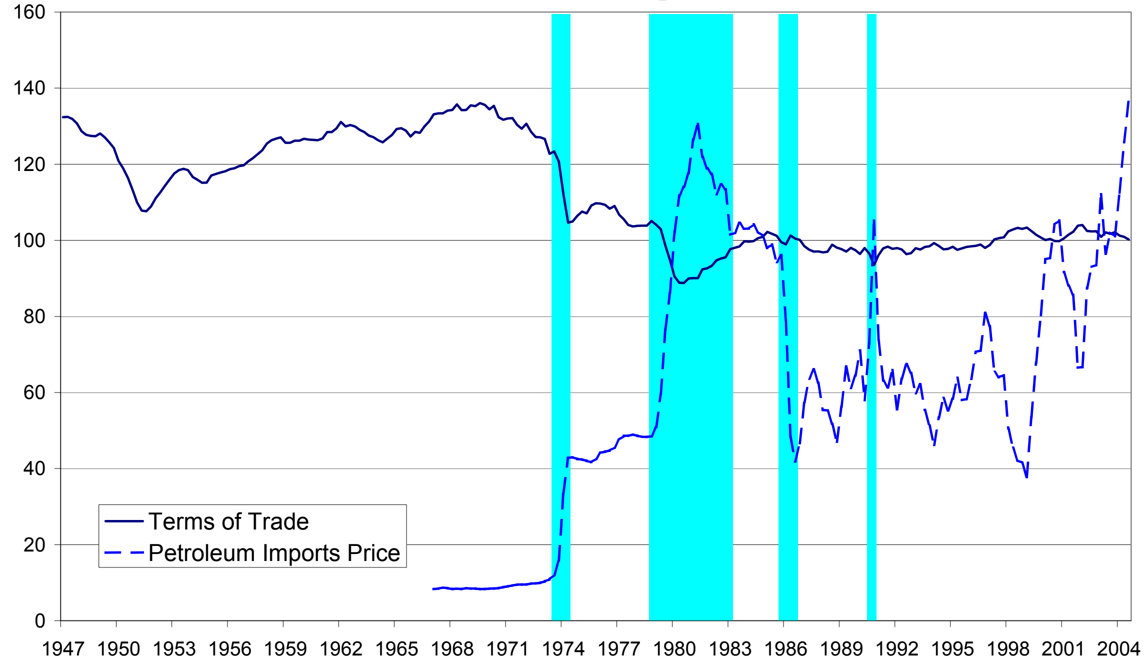
State of the Economy

The larger estimates may also reflect baseline economic conditions, prior to an oil disruption, that are fundamentally different from today's economic environment. During the 1970s, the oil price shocks appeared in an economy that was already experiencing inflationary pressures. When the prices of food, raw materials and energy began shocking the economy, institutions tried to protect their purchasing power by passing along these costs to others buying their input or final product. Core inflation refers to the effects on the price deflator for all items except food and energy. Hooker (2001) convincingly shows that oil price changes moved core inflation rates a lot through 1981, but they had no significant effect after that year. To bolster his argument, he also shows that other possible explanations fail to explain this sudden shift in the relationship between oil prices and core inflation. He rejected as possibilities such developments as declining oil intensities, the deregulation of energy-intensive sectors like trucking and airplane travel, and changes in the central bank's monetary accommodation policy during price shocks. The main lesson learned by monetary authorities was not how to manage their way through an oil price shock, but rather how to prevent inflationary pressures before a price shock appeared.

Mitigating the effects of oil price shocks on core inflation does a lot towards reducing the output losses in a neo-Keynesian macroeconomic framework. Prior to 1981, with rampant inflationary fears, the government was unlikely to risk more inflation by expanding the nominal money supply. As core inflation began responding to an oil price shock, a higher price level for all goods and services increased interest rates by reducing the economy's inflation-adjusted money supply. Contracting investment and other interest-sensitive spending contributed to output reductions throughout the economy.

Hooker's thesis about the unstable coefficients relating oil prices to core inflation should be tested within a framework that also explains aggregate output. Huntington (2004) applies similar logic in analyzing different countries' aggregate output responses to oil price shocks, but he does not directly incorporate core inflation rates. He allows the aggregate output response to oil prices to vary depending upon the gap between actual and potential output. Since potential output measures the natural output level where

Figure 7. Oil Prices and U.S. Terms of Trade (indexed to 2000 prices)



inflation is neither increasing nor decreasing, the gap should indirectly incorporate the inflationary pressures within the economy. Narrower gaps (e.g., less unemployment) mean more cost pass-through (see Gordon 1975) and greater output losses in a study of 14 different countries.

Oil Wealth Losses

The oil price shocks during the 1970s reduced not only aggregate output but also the country's purchasing power. Real national income fell as the costs of buying international goods (including oil) rose more than the income earned through U.S. exports. The higher prices made the country poorer by requiring more exports for importing each barrel of oil, leaving less aggregate output for domestic consumption.

After the 1970s, oil price changes should have had similar effects on the country's purchasing power. Oil import price increases should have reduced real income, while oil import price decreases should have increased real income. These potential income shifts should have had some effects on short-run economic conditions.

Lower oil import prices during the mid-1980s, however, did not create gains in international wealth or terms of trade. For reasons unrelated to the oil price collapse, the depreciating U.S. dollar forced nonoil import prices higher and export prices lower in 1986. These effects offset the favorable effects of lower crude oil prices on the U.S.'s international purchasing power, as measured by its terms of trade (Huntington 1998). Figure 7 emphasizes that the US's international purchasing power for all goods and services did not improve in 1986 like it suffered during the 1970s.[24] In addition, movements in the measured terms of trade have been very small since the mid-1980s.

Adjusting to Shocks

The oil price shocks of the 1970s completely surprised firms and households in many different countries at the same time. As inflation rates accelerated, the value of stocks and bonds tumbled sharply. Firms and households made decisions about production and prices that had important consequences for the strategies of other firms in the economy (Huntington 2003). And yet, there was little opportunity to coordinate strategies in such an uncertain world.

Now, after several different oil price episodes, one might argue that there has been significant learning about how to cope with the uncertainties created by oil price shocks. It is unlikely that firms and households will be surprised in the same way or to the same degree as they were by earlier shocks. In the process, new institutions have appeared, such as the financial markets for establishing oil future prices. Even if they do not eliminate the problem, such learning and institutional development may make future price shocks less damaging.

What Policies Can Be Used to Offset the Impacts?

Many of the same policies for offsetting the effects of higher oil prices can conceptually be used for ameliorating the adverse impacts of oil price shocks. A principal difference, of course, is that governments must implement these polices during an emergency when firms are uncertain about the direction of future prices and few people know how long the surprise shock will last or whether it will be followed by other disruptions. The possibility of introducing unwise policies remains extremely high under these conditions.

More aggressive policies will also need to be implemented during an oil price shock than for a higher oil price level, because the impacts are larger.

A final constraint on appropriate policy measures may be the underlying economic conditions. When interest rates and inflation are problems under baseline conditions (prior to the shock), standard policy responses like easing monetary policy may not be an easy option to implement. This risk of accelerating inflation often deters governments from adopting accommodating policies that try to restore lost aggregate output. One's optimism about policy offsets depends critically upon the future direction

[24] The Bureau of the Census publishes a series called "command-basis gross national product" in Table 1.8.6 on its website. This measure deflates exports of goods and services and income receipts from abroad by the implicit price deflator for imports rather than for exports. The terms of trade effect in Figure 7 is the adjustment (ratio of prices) used to convert the export series, where the value for the year 2000 equals 100. Denison (1981) explains the logic behind this variable. See Appendix C for additional details.

of the US economy and whether the current fiscal and current account deficits are temporary problems that can be resolved before the next oil disruption.

How Large Are the Impacts?

If crude oil prices rise early in a particular year, what will be the impact on the economy at the end of the second year? The impacts discussed in this section refer to how much the real output or price *level* deviate from their baseline value rather than how much the growth or inflation *rate* changes. These estimates are tentative working numbers that hopefully will stimulate others to improve upon them with additional research.

Responses to Higher Oil Prices

If the economy is operating at its potential output level where the inflation rate is not changing, a permanently higher oil price will reduce the economy's potential gross output. Higher prices discourage oil usage, which reduces the productivity of labor and capital. Monetary and demand-oriented fiscal policies will not offset these output reductions because the oil prices are affecting the economy through its long-term supply than through short-term demand channels.

If the economy is operating well below its potential output level, the impact on total spending may be larger, perhaps reaching 2% after the second year for a doubling of oil prices. The top rows of Table 8 summarize these impacts as well as those for the price deflator for all goods and services and the unemployment rates. They are based upon the Global Insight estimates (2005) reported at the February workshop. If one believes that these impacts should be linear with every $10 per barrel increase rather than with each one percent change in crude oil prices, multiply these estimates by .285 (=logarithm (33%)). This adjustment represents the proportional change when the oil price rises from $30 to $40 per barrel.

Responses to Surprise Oil Price Shocks

Oil price shocks will produce considerably larger economic impacts if they occur when inflationary pressures are building and interest rates are relatively high. The above Global Insight estimates would be too low, because monetary policy is unlikely to be as effective and because the model predicts that the economy responds to surprise events like it would to steadily higher prices. This analysis has chosen an elasticity (-0.05) approximately equal to the one estimated by Jimenez-Rodriguez and Sanchez (2005).

Table 8. Summary of Estimated US Oil-GDP Elasticities

	Year 1	Year 2
Higher Oil Price		
Real GDP	-0.011	-0.021
GDP Price Deflator	0.007	0.017
Unemployment Rate	0.004	0.007
Oil Shock		
Real GDP	-0.024	-0.050
GDP Price Deflator	0.019	0.034
Unemployment Rate	0.009	0.020

Macroeconomic frictions cause the economic impacts of an oil price shock to exceed oil's value share of U.S. gross output. The direct effects of an oil price shock are augmented by a combination of sectoral demand shifts and costly reallocation of inputs, wage and price stickiness and informational inefficiencies. If the underlying economic conditions should turn considerably less favorable than they are today, disruptions could create substantial economic losses, much larger than those recently estimated with macroeconomic models.

Modeling and Understanding Oil Price Shocks

Elasticities are useful indicators of how important the problem may be, but they should not imply that we are certain about the size of the impact. Our confidence is higher for the effects of a higher oil price level than it is for an oil price shock. There are several important modeling issues whose resolution might help to better understand these impacts and the various approaches for estimating them.

First, can macroeconometric models do better at differentiating the responses to an oil price shock and a higher oil price level? Some critics want the macroeconometric models to develop much more industry and sectoral detail in order to represent the macroeconomic frictions that seem to be very important. A more cautious view, however, says that these models are already large enough. Moreover, the primary alternative approach, the VAR dynamic systems, contains even less detail but they are supported by a believable story. Until the mid 1990s, the VAR approach did not differentiate between oil price shocks and higher oil prices. Then, researchers began to develop different oil price series that made this distinction explicitly. Proprietors of large-scale models could also make the same adjustments in their key equations. The two modeling approaches share the same common philosophical orientation about estimating historical relationships with econometric equations.

Second, what accounts for the larger VAR estimates relative to those from large-scale models? Is it simply the macroeconomic frictions, and especially sectoral shifts, that are often used to explain these results? Or could it be that they represent fewer other structural relationships whose effects might be to mitigate the economic responses to oil price changes? Generally, the elasticities are larger when monetary and other policies are ignored than when they are included in the estimates. (See Appendix D.) These results suggest that monetary policy has been more restrictive on output when oil prices have been higher and that the oil variable, if entered alone, has incorporated some of the effect of the excluded variables. There could be other such variables that are included in the larger macroeconomic models but excluded from the simpler VAR approaches.

Third, it would be very valuable to understand better how large-scale models represent oil price shocks under a variety of macroeconomic conditions. A particular sensitivity would be to evaluate oil price increases under different assumptions about the ability of monetary policy to provide an effective offset. The recent Global Insight estimates represent a world where baseline economic conditions are very favorable to monetary policy responses. Could these same policies have been successfully applied during the 1970s or even 1990? An advantage of these models is that they should be able to represent how the economy's response to oil price changes and policy shifts changes with different economic conditions. And understanding these differences should help in understanding the economic risks of oil price shocks that could happen sometime in the future when conditions are very different than today.

And fourth, empirical studies on estimating the oil-GDP relationship with quarterly data have focused on some important research issues but they have not informed policymakers and their advisors on some other important issues. How does the economy's response change if oil value shares should decline or pre-shock inflation rates become weaker? How does a one-time blip in oil prices differ from a more persistent change in prices? To what extent can economic policies offset the impacts of oil price increases? To rectify these concerns, it may be valuable for a government agency to incorporate a VAR or some similar modeling approach. Increasing the agency's flexibility to evaluate a number of different shocks and conditions would be a decided advantage.

Conclusions

After many years of research on the economic impacts of oil shocks, there remain many important unresolved issues. There is little agreement on the major explanations for why the oil shocks caused economic recessions. OPEC taxes, sectoral demand shifts, and wage and price stickiness have all been offered as potential causes. Controversy surrounds the issue of whether the 1970 recessions were caused simply by poor economic policies rather than by oil price shocks. Moreover, some economists remain skeptical about the empirical evidence linking oil price shocks to reduced aggregate economic activity.

The critics have raised some useful points, but it seems premature to embrace their conclusion that oil price shocks are not a problem for policymakers. First, oil price shocks have caused economic problems in a range of different countries and this macroeconomic evidence is very consistent with the detailed sector-level analysis on the issue. A key lesson has been to clearly differentiate a higher oil price level from sudden oil energy price shocks. Second, arguments that monetary policy caused the recessions need to be based upon analysis that allows the adverse effects to extend beyond six months after the oil price shock.[25] Adopting the more realistic assessment that the first one or two year impacts are relevant, as found in a range of different studies, casts doubt on the robustness of the critics' conclusions that monetary policy could have easily accommodated the oil price shocks of the 1970s.

A few key conclusions are worth highlighting at this point:

1. Until the Katrina and Rita storms, recent oil price increases have been too gradual and steady to cause an economic recession. By themselves, these developments would not force an economy growing by 3 to 4 percent per year into a recession.
2. As long as the oil price increase reflects adjustments to stronger world oil demand growth rather than supply interruptions, the impacts on the economy will probably be no worse than those associated with an "OPEC tax" and may even less. These impacts will tend to be relatively mild because the value share of oil in total output continues to be relatively small. And like any other tax, the adverse impacts on expenditures for U.S. goods may be offset, perhaps completely, by a combined package of monetary and fiscal measures.
3. Currently, the oil futures markets expect the oil price to recover from the Katrina and Rita storms and return to their pre-storm paths over the next several months. By themselves, these events should not derail the economy, but they do make it more vulnerable to other economic dislocations. Moreover, the recovery of the energy infrastructure in the Gulf of Mexico may happen more slowly than is currently expected.
4. Nonetheless, policymakers will continue to be concerned about oil price shocks as long as oil markets remain tight with little excess capacity. Surprise oil shocks from overseas will probably create much larger economic impacts than will be experienced from the recent U.S. storms. Surprises create macroeconomic frictions that include the adjustment costs of shifting resources from one sector to another as well as wage and price stickiness. These developments will require much larger and more aggressive fiscal and monetary policies, to the extent that they are possible.
5. A "perfect storm" may unfold in the future when oil price shocks happen as the fiscal and trade deficits worsen and interest and inflation rates move higher. These conditions would complicate considerably any government response for offsetting the impacts.

[25] See the discussions between Bernanke, Gertler and Watson (1997, 2004) and Hamilton and Herrera (2004).

Appendix A: Previous Oil Supply Disruptions

Table A.1: Historic Oil Supply Disruptions

Oil Supply Disruption Event			Start Date	Disruption Length	**Gross Shortfall**	
Event #	Description	Cause of Disruption	mm/dd/yy	Months	In MMBD	As % of Demand
1	Iranian Fields Nationalized	Embargo/Economic Dispute	03/01/51	44.7	0.7	7.1
2	Suez War	Mideast War	11/01/56	5.0	2.0	12.7
3	Syrian Transit Fee Dispute	Embargo/Economic Dispute	12/01/66	4.0	0.7	2.3
4	Six Day War	Mideast War	06/01/67	3.1	2.0	6.4
5	Nigerian Civil War	Internal Struggle	07/01/67	16.3	0.5	1.5
6	Libyan Price Controversy	Embargo/Economic Dispute	05/01/70	9.2	1.3	3.3
7	Algerian-French Nat'l Struggle	Internal Struggle	04/01/71	5.1	0.6	1.4
8	Lebanese Political Conflict	Internal Struggle	03/01/73	3.1	0.5	1.0
9	October Arab-Israeli War	Mideast War & Embargo/Economic Dispute	10/01/73	6.1	1.6	3.4
10	Civil War in Lebanon	Internal Struggle	04/01/76	2.0	0.3	0.6
11	Damage at Saudi Oilfield	Accident	05/01/77	1.0	0.7	1.4
12	Iranian Revolution	Internal Struggle/Embargo	11/01/78	6.0	3.7	7.0
13	Outbreak of Iran-Iraq War	Mideast War	10/01/80	4.1	3.0	6.0
14	UK Piper Alpha Offsh. Plat. Explosion.	Accident	07/01/88	17.3	0.3	0.6
15	UK Fulmer Float. Stor. Vess. Acc.	Accident	12/01/88	4.0	0.2	0.4
16	Exxon Valdez Accident	Accident	03/24/89	0.5	1.0	1.9
17	UK Cormorant Offshore Platform	Accident	04/01/89	3.0	0.5	1.0
18	Iraq-Kuwait War	Mideast War & Embargo/Economic Dispute	08/01/90	12.0	4.6	8.9
19	Norwegian Oil Workers Strike	Internal Struggle	05/01/96	1.0	1.0	1.4
20	Local Protests in Nigeria	Internal Struggle	03/01/97	1.0	0.2	0.3
21	Local Protests in Nigeria	Internal Struggle	03/01/98	3.0	0.3	0.4
22	OPEC (ex. Iraq) cuts production in effort to increase prices.	Embargo/Economic Dispute	04/01/99	12.0	3.3	4.4
23	Venezuelan Oil Strike	Internal Struggle	12/02/02	2.5	2.0	2.7
24	Iraq War	Mideast War	03/19/03	1.4	1.9	2.6

Source: Compiled from the U.S. EIA by Paul Leiby. See EIA website, "Global Oil Supply Disruptions Since 1951," http://www.eia.doe.gov/security/distable.html for one version of these data. Categorizations suggested by Paul Leiby.
Notes: The EIA table concedes that "Definitions of >oil supply disruptions= are not entirely consistent from one case to the next." As an example of this variability, the latest version of the table (as of 1/02/2004), inexplicably, excludes the 1990 Iraq-Kuwait war and the Nigerian strikes in the late 1990s. There are some problems with these data, however. The ending dates of some disruptions are difficult to identify. Also, we are not sure whether disruption magnitude is consistently measured as initial (gross) loss or as a loss net of some market response from other suppliers.

Appendix B: Comparison of Different Rules for Estimating the Price Impacts of Oil Disruptions

An oil disruption that is not replaced by supplies from excess capacity, stockpiles or other offsets will tend to raise crude oil prices more when producers and consumers do not respond much to price than when they do. There are two very different approaches for estimating this price effect:

- A linear rule that requires the same increase in price (dollars per barrel) for each one MMBD of net oil disruption;
- A constant-elasticity (or fixed-percentage) rule that requires the same percentage increase in price for each one percent decline in oil supplies due to a net disruption.

Table B.1 compares the price effects estimated with each rule for the same net oil disruption equal to 1% of world supplies. Each row represents a case with a different price elasticity of demand, while each column represents a case with a different price elasticity of supply. The top set of rows displays the price effects determined by the fixed-percentage rule. The percentage changes in price computed by this approach are shown in the shaded cells but are also shown as dollars per barrel for easy reference on the right side. The lower set of rows displays the price effects determined by the linear rule. The changes in price ($ per barrel) computed by this approach are shown in the shaded cells but are also shown as percent changes for easy reference on the left side. Regardless of how oil price results are reported, the fixed-percentage rule reveals larger price impacts than does the linear rule.

Table B.1: Comparison of Constant Elasticity (% Rule) and Linear Rules for Price Effects

	0.025	0.05	0.075	0.025	0.05	0.075
% Rule						
-0.04	16.7%	11.8%	9.1%	$11.41	$8.06	$6.23
-0.08	10.0%	8.0%	6.7%	$6.85	$5.48	$4.57
-0.12	7.2%	6.1%	5.3%	$4.90	$4.16	$3.61
$/MMBD Rule	0.037	0.073	0.110	0.037	0.073	0.110
-0.059	15.4%	11.1%	8.7%	$8.92	$6.44	$5.04
-0.117	9.5%	7.7%	6.5%	$5.52	$4.46	$3.74
-0.176	6.9%	5.9%	5.1%	$4.00	$3.41	$2.97

By assumption, the linear rule always scales the price impacts to the size of the net disruption. A 10% net disruption will produce 10 times the price impact of a 1% net disruption. By contrast, the price impacts based upon the fixed-percentage rule rise faster than the size of the disruption. These findings are summarized in Table B.2. The last two columns are particularly insightful because they show how much greater are the price effects of increasingly larger net oil disruptions. Although the price effects of a 5% net disruption under the fixed-percentage rule is only 6 times the price effects of a 1% net disruption, the price effects of a 20% net disruption is 57 times more.

Table B.2: Comparison of Price Effects by Disruption Size

	Price Increase		Scaled Price Increase	
Size	Fixed Percentage	Linear Rule	Fixed Percentage	Linear Rule
1%	8.0%	$4.46	1	1
5%	48.4%	$22.31	6	5
10%	124.9%	$44.62	16	10
20%	456.5%	$89.23	57	20

The fixed-percentage rule based upon constant elasticities is most useful for small changes from the baseline conditions. When much larger changes are being evaluated, as may be the case in oil disruption analysis, the assumption of constant elasticities appears to be too restrictive. For this reason, the linear rule is preferred to the fixed-percentage rule for large net oil disruptions.

Appendix C: The "OPEC" Tax

Oil import price increases are often called an "OPEC tax" because U.S. wealth is shifted abroad to groups that will not spend as much or as quickly as U.S. residents on domestic goods and services. Alternatively, they may not invest in US assets as much as US residents. The size of this "tax" will be the difference between oil revenues sent overseas to the Persian Gulf minus whatever spending is returned to the US economy by OPEC purchases and investments. There have also been some discussions that domestic oil producers may not respend their higher incomes as quickly, but usually the argument applies to foreign governments who own the oil resources that are imported. The argument surfaced during the 1970s because the Middle Eastern governments appeared unprepared for the sudden inflow of funds resulting from the oil price shocks.

The OPEC tax concept is controversial, partly because it is hard to document empirically. Today, there are reports that these governments are extremely knowledgeable about how to handle their profits and that the money does not remain idle or flow disproportionately to other countries. Moreover, the tax argument seems incomplete because less spending should reduce the aggregate price level, when empirically higher oil prices have increased the aggregate price level. The case for an oil tax mechanism, however, may make more sense when interest rates and prices for all goods and services do not change much with an oil shock, as in the recent Global Insight estimates.

A key assumption is that the economy operates well below its long-run potential path so that its aggregate spending is not limited by shifts in the economy's production. Additionally, the economy's aggregate price level for all goods and services does not change. Under those conditions, the economy's planned spending seeks a balance with its output through the typical Keynesian equation:

$$Y = C + I \tag{1}$$

where Y is output, C is desired aggregate consumption, and I is desired aggregate spending for investment, government purchases and net exports. Consumption should be related to disposable income, Y-T, where T refers to taxes. If consumers do not spend all of their income,

$$C = b\,(Y-T) \tag{2}$$

where b denotes their marginal propensity to consume. Substituting equation (2) into (1) yields the standard Keynesian relationship between income, taxes and autonomous spending (I):

$$Y = -\,[b / (1-b)]\,T + [1 / (1-b)]\,I \tag{3}$$

The coefficients preceding the tax and autonomous spending variables are the tax and fiscal multipliers, respectively. As taxes remove disposable income from households, they spend less. This reduced spending trickles through the economy causing additional reductions in aggregate spending. The tax multiplier equals the fiscal multiplier minus one; it is smaller because not all of the taxed income would have been spent.

This illustrative model greatly simplifies the issue by assuming that the multipliers depend only upon households' willingness to spend their income. The U.S. economy, however, has a number of different built-in automatic stabilizers like Social Security payments and taxes, unemployment compensation, other income support programs, and federal grants-in-aid, all of which tend to cushion the economy as disposable income fluctuates. In addition, some spending will be for imports rather than domestic goods and services. And finally, the aggregate price level may rise and contract the economy. All of these factors cause the measured multiplier effects for the U.S. economy to be substantially smaller than if they were based solely upon the economy's propensity to spend additional income.

Empirical estimates of the fiscal multiplier for the U.S. economy range between 1.5 and 2.5 (Wyckoff, 1981: p. 101). More recently, the average fiscal multiplier for eleven different macroeconomic models was 1.5 after the first year, before fading to essentially zero in the longer run (Adams and Klein, 1991).

Table C.1 provides estimates of the OPEC tax based upon these empirically estimated multiplier estimates. The impact depends upon the oil price change, the relative importance of oil imports in the economy, the rate at which foreign governments recycle oil revenues back into the U.S. economy, and the tax multiplier effect. At the February EMF workshop, Global Insight evaluated the impacts of crude oil prices increasing by 33% from \$30 to \$40 per barrel. Oil imports in 2004 accounted for approximately 1 percent of the U.S. GDP. The first shaded column shows the percentage reduction in real GDP for different multiplier effects, if foreign producers do not spend any of the new wealth that they have earned. Since this case is based upon a rather extreme assumption, the second shaded column reveals the impacts if half of the oil revenues are returned.

Global Insight reports a first-year GDP impact of about –0.3%, which is within the range shown in Table C.1, unless none of the additional OPEC wealth is returned to the U.S. economy *and* the fiscal multiplier is at the higher end of the empirical estimates. When the multiplier equals the average value found by Adams and Klein, the oil tax mechanism appears to account for much of the Global Insight estimate--0.1 to 0.2% of the total 0.3% effect. This result, however, depends upon the monetary authorities being able to accommodate the oil price shock without risking greater inflation. When they don't have that freedom and interest rates rise sharply, other effects will become important and reduce the relative importance of the oil tax mechanism.

Table C.1. Examples of Output Loss Due to OPEC Tax

Oil Price		$30	$40		
Oil Imports/GDP		1.00%	1.33%		
Recycling Rate (%)				0%	50%
Net Tax				0.33%	0.17%
		Multipliers			
MP Consume:		Tax	Fiscal		
	0.33	0.5	1.5	-0.2%	-0.1%
	0.5	1.0	2.0	-0.3%	-0.2%
	0.6	1.5	2.5	-0.5%	-0.3%

Notes:

Tax multiplier = b/(1-b), where b=marginal propensity to consume.

Fiscal multiplier = 1/(1-b), where b=marginal propensity to consume.

MP Consume refers to spending behavior after incorporating built-in automatic stabilizers.

Appendix D: Command-Basis Gross National Product

Sometimes economists want to focus on the purchasing power of domestic income rather than the value of goods and services produced within the economy (as measured by the gross national product). Suppose that the economy suddenly needs to produce two bushels of wheat for export in order to import one barrel of oil, rather than use the one-to-one relationship that held previously. By casting all expenditures in terms of base-year prices, Gross National Product (GNP) as reported in the National Income and Products Account traditionally does not adjust for relative price changes.

Using a rationale clearly described by Denison (1982), the U.S. Bureau of the Census regularly publishes a series called "command-basis gross national product". Under the new conditions, this series would value each bushel of exported wheat at one half its previous value. Essentially, this measure deflates exports of goods and services and income receipts from abroad by the implicit price deflator for imports rather than for exports.

Suppose that the economy reaches an equilibrium where aggregate income (Y) equals aggregate expenditures:

$$Y = A + X - M,$$

where A refers to domestic absorption (e.g., consumption, investment and government purchases) and X and M refer to exports and imports, respectively. Each nominal expenditure can be disaggregated into a price and quantity term. If the price deflators are allowed to change but the real expenditures are held constant, the relationship between the GNP measure of real income and domestic absorption becomes:

$$y\, dp_y - a\, dp_a = x\, dp_x - m\, dp_m$$

where small letters denote real expenditures and dp_i refers to the respective price term. After substituting $a = y - x + m$ for real absorption,

$$y\,(dp_y - dp_a) = x\,(dp_x - dp_a) - m\,(dp_m - dp_a)$$

This equation shows that the purchasing power of domestic income will deteriorate if import prices rise more than those for final domestic goods, but that this purchasing power can be augmented if export prices rise more than those for final domestic goods.

Figure 7 in the text reports the terms-of-trade adjustment, $(dp_y - dp_a)$. As it increases, the nation's purchasing power increases relative to the GNP measure. Holding constant the prices of exports and nonpetroleum imports, higher oil prices will reduce the nation's purchasing power. More generally, however, purchasing power will be a function of the price changes for all three sectors: exports, petroleum imports and nonpetroleum imports.

Appendix E: GDP Elasticities

Elasticities measure the response of one variable as a function of changes in another variable. The standard practice is to use percent rather than absolute changes to minimize the need for detailed knowledge about the variables, currencies and physical characteristics. Although elasticities appear to be easy concepts, deriving meaningful responses from empirical data can be very challenging. The opportunities for misreading empirical observations are considerable.

Economists summarize their knowledge about energy consumption decisions by deriving consumer responses to energy prices and income. The price (income) elasticity of demand measures the percent change in energy consumption for a one percent change in an energy price (income). In a similar fashion, one could conceptually measure the oil- price elasticity of real GDP, which will be referred to as the GDP elasticity.

It is somewhat easier to specify this relationship in terms of the differences between levels rather than the differences in how much these variables are changing over time. Thus, the measure often focuses upon how much the *level* of real GDP or the price deflator changes between two sets of conditions rather than how much the economic growth or inflation *rates* vary between these cases. In this sense, it is exactly comparable to the price and income elasticities of demand used by energy economists.

Estimates can specify the deviation (as a percent) in real GDP levels as a function of either the absolute or percent deviation in oil prices. Either approach seems acceptable as long as the results are interpreted carefully. Economic theory suggests strongly that, in the absence of major "threshold" effects, the direct response of the GDP and price levels to oil price changes should be proportional to oil's value share in total output. This relationship can be expressed as:

$$dY/Y = b\ (PQ/Y)\ (dP/P) = b\ (Q/Y)\ dP$$

where P, Q and Y refer to oil price, oil quantity and real output, respectively, dY and dP are changes in real output and oil prices, respectively, and b is a scaling coefficient. When the impacts are expressed as a linear function of the oil price in US$ per barrel, this equation shows that oil intensity in physical units (Q/Y, or barrels per dollar of output) is the critical factor. When the impacts are expressed as a linear function of the percent difference in oil price, oil's value share (PQ/Y, or oil expenditures per dollar of output) is the important factor. GDP elasticities in this report will be expressed as functions of the percent difference in oil prices (the second concept).

Can meaningful conclusions be derived about the range of this response based upon empirical studies? The problem with any elasticity estimate is that it is often only approximate and measurement problems can cause serious difficulties in certain situations.

To begin evaluating the difficulties, consider the Energy Modeling Forum (EMF) comparison of macroeconomic models, where Hickman, Huntington and Sweeney (1987: p. 24) report that the median decline in real GDP after two years was 2.9 percent for a one-time, permanent 50 percent increase in nominal crude oil prices. This single estimate can easily produce three different elasticities that vary by more than 50% from the lowest value. The elasticity could be calculated relative to base year levels (-.029/.50 = -0.058), to the post-shock levels ((-.029/.971)/(.50/1.50) = -.090), or as an average between the two (-.074, often called an arc elasticity). A close approximation of the arc elasticity is the ratio of the changes in logarithms for the two variables (ln(1-.029)/ ln(1 +0.5) = -.073). This paper will compute elasticities with the logarithmic-change approach, because the responses are based upon sizable oil price changes.

Elasticities assume that other important exogenous variables are controlled when oil prices are changed. The above elasticity from the EMF study assumed that changes in monetary policy, government expenditures and taxation rates are held constant. This attentive focus to applying the same policy assumptions to all model responses makes the different model results in this study more comparable to each other than is often found by comparing different studies in the literature. Table E.1 compares a selected set of empirical quarterly studies on included variables, use of real or nominal oil prices, and quantifying growth variables at annual or quarterly rates.

In the empirical literature, each analyst has his own preferred approach for standardizing on monetary and fiscal policies. These differences make it extremely difficult, even impossible, to develop comparable elasticities, because different variables are being controlled or the same variable is being controlled in different ways.

A useful example of this type of problem is the range of elasticities reported in estimates on annual data by Mory (1993). One of his estimates (-0.055) almost matches the preferred estimate in the Jones, Leiby and Paik (2004) survey. It excludes, however, any variables other than real output and crude oil prices and it also mixes the response to oil price reductions with that to oil price increases. In an effort to improve his equation, Mory made two adjustments that substantially changed his elasticities. First, he disaggregated the response into separate components for price increases and price decreases, which nearly doubled the elasticity to -0.107. Second, he included the money supply and government purchases, which proceeded to lower his elasticity by more than 35 percent to -0.067. It is this latter estimate that should be compared with the other estimates and that is also probably of most interest to the policymaker.

Analysts frequently estimate the oil price-economic growth relationship on quarterly data with vector autoregressive (VAR) models. These frameworks are dynamic specifications in which past changes in both GDP and oil prices (and usually other variables) influence current GDP growth. Thus, the economic growth equation would include at least the following variables:

$$y_t = \alpha_0 + \Sigma\ \alpha_i\ y_{t-1} + \Sigma\ \beta_i\ o_{t-1}$$

where y and o refer to logarithmic changes in real output and oil prices (which can be decomposed into increases and decreases or expressed as a net oil price increase series) at different time periods t. To estimate the response of the total system of equations, the analyst introduces a one-time deviation in the oil price increase variable and reports the results as an "impulse response function". Since it is often difficult to read and interpret the impulse response functions, surveys (Jones, Leiby and Paik, 2004; Labonte, 2004) sometimes estimate the response from the sum of the oil price coefficients in the economic growth equation.

This sum is at best only an approximate estimate of what the actual response would be in the system. Table E.2 compares this sum with simulations conducted by the author based upon the economic growth equation as reported in each study. The last column shows that this response or inferred GDP elasticity is usually about 20 percent higher than the summed price coefficients. The latter estimates are smaller because they ignore the influence of changes in past economic growth on current economic growth. Moreover, since there are often other equations in each study's system, the oil price change will affect other variables, which may augment or reduce the impacts on real GDP.

The estimates reported for the Jimenez-Rodriguez and Sanchez (2005) study refer to the total impact on real GDP accounting for all variables. This estimate is the most useful parameter for policymakers, even though it includes some policy responses during past oil shocks in its estimated parameters. Unfortunately, the study does not also report its detailed oil price coefficients, thereby making it impossible to compare them with those estimated in other studies. One of the important conclusions from Table E.2 is the rather wide range of reported coefficients and elasticities from the group of models. The total price coefficients over four quarters range from -.05 to -.15.[26] Differences in study designs and samples often lead to considerable differences in the estimated GDP response.

This study has selected the Jimenez-Rodriguez and Sanchez (2005) estimate for the total impact on real GDP as the comparable impact for oil price shocks when prior economic conditions prevent policymakers from adopting accommodating monetary policies. Their -.048 estimate appears comparable to the –0.05 estimate from the interesting set of scenarios conducted by Hamilton and Herrera (2004) on monthly data, where their Figure 9 compares the impulse response functions of a 10% oil price shock both with and without accommodating monetary policy. This value also appears close to the estimate of –0.055 offered by Jones, Leiby and Paik (2004) in a review of previous studies.

Few researchers have applied their system to evaluate temporary oil price shocks, a topic with considerable policy interest. Firms and households may either correctly expect that a shock will be temporary or incorrectly anticipate a longer-run phenomenon. If they are surprised by a shock that suddenly becomes a temporary disruption, the shock

[26] Single equations estimated on annual data have similar price coefficients over the first year, ranging from –0.067 for Mory (1993) to –0.110 for Huntington (1998).

during the first quarter would have similar effects to those shown in Table E.2. When the price retreats in the next quarter, economic activity may recover. When these two separate events are simulated and their impacts combined, inferred real GDP responses are obtained, as reported in Table E.3. The impacts are approximately 50% of the more permanent oil price shocks. These estimates assume the same responses to price increases and decreases, because not all studies reported a full set of asymmetric responses. When asymmetric responses prevail, the impacts of a temporary price shock will be greater than estimated in the table because a retreating oil price does not stimulate output as much. When price retreats do not stimulate the economy at all (as in the net oil price series), the impact of a temporary shock will equal that of a permanent shock.

Table E.1. Selected Quarterly Statistical Studies of Oil and GDP

Study	Date	Period	Oil Price	Growth Rate (Variables)	Other Variables
Hamilton	1983	1948:2-1980:3	nominal	quarterly	Unemployment, price deflator, hourly compensation, import
Gisser&Goodwin	1986	1961:1-1982:4	nominal	annual	GDP deflator, real investment, unemployment rate, money stock, high-employment budget
Mork	1989	1949:1-1988:2	real	annual	GDP deflator, import deflator, hourly earnings, unemployment,T-bill rate
Mork	1994	1967:3-1992:4	real	annual	Inflation, interest rate, unemployment, OECD industrial production
Hamilton	2003	1949:2-2001:3	nominal	quarterly	none
Jimenez-Rodriguez	2005	1972:3-2001:4	real	quarterly	Real exchange rate, real wage, inflation, short run interest rate, long run

Table E.2. Inferred Real GDP Response to Permanent 1% Oil Price Shock in Quarterly Studies

Study	Date	Model	Sum-Price	Elasticity After Quarter 0	1	2	3	4	Elasticity(t=4) /Sum-Price
Hamilton	1983	symmetric	-0.115		0.004	-0.002	-0.053	-0.127	1.11
Gisser&Goodwin	1986	symmetric	-0.103	-0.020	-0.021	-0.023	-0.052	-0.100	0.98
Mork	1989	asymmetric	-0.144		-0.031	-0.049	-0.108	-0.168	1.17
Mork	1994	asymmetric & bivariate	-0.061	-0.014	-0.022	-0.042	-0.046	-0.077	1.26
Mork	1994	asymmetric & mutlivariate	-0.050	-0.015	-0.035	-0.063	-0.062	-0.073	1.45
Hamilton	2003	net price-4Q	-0.063		-0.009	-0.022	-0.038	-0.074	1.17
Hamilton	2003	net price-12Q	-0.105		-0.024	-0.050	-0.076	-0.124	1.18
Hamilton	2003	instrumental	-0.157		-0.028	-0.085	-0.112	-0.186	1.18
Jimenez-Rodriguez	2005	asymmetric						-0.048	
Jimenez-Rodriguez	2005	net price-12Q						-0.046	
Summary:									
Largest			-0.157	-0.020	-0.035	-0.085	-0.112	-0.186	
Average			-0.100	-0.016	-0.021	-0.042	-0.068	-0.116	
Smallest			-0.050	-0.014	0.004	-0.002	-0.038	-0.073	

Note: Summary excludes Jimenez-Rodriguez results.

Table E.3. Inferred Real GDP Response to "Temporary" 1% Oil Price Shock in Quarterly Studies

				Elasticity After Quarter					Elasticity(t=4) /Sum-Price
Study	**Date**	**Model**	**Sum-Price**	**0**	**1**	**2**	**3**	**4**	
Hamilton	1983	symmetric	-0.115		0.004	-0.006	-0.051	-0.074	0.65
Gisser&Goodwin	1986	symmetric	-0.1025	-0.020	-0.001	-0.002	-0.029	-0.048	0.47
Mork	1989	asymmetric	-0.144		-0.031	-0.019	-0.058	-0.060	0.42
Mork	1994	asymmetric & bivariate	-0.061	-0.014	-0.008	-0.020	-0.004	-0.031	0.51
Mork	1994	asymmetric & mutlivariate	-0.05	-0.015	-0.020	-0.029	0.001	-0.010	0.21
Hamilton	2003	net price-4Q	-0.063		-0.009	-0.013	-0.016	-0.036	0.56
Hamilton	2003	net price-12Q	-0.105		-0.024	-0.026	-0.026	-0.048	0.46
Hamilton	2003	instrumental	-0.157		-0.028	-0.057	-0.027	-0.074	0.47
Summary:									
Largest			-0.157	-0.020	-0.031	-0.057	-0.058	-0.074	
Average			-0.100	-0.016	-0.014	-0.021	-0.026	-0.048	
Smallest			-0.050	-0.014	0.004	-0.002	0.001	-0.010	

Note: "Temporary" shock allows price to recover after first quarter with a symmetric response.
Impacts will be larger if real GDP responds less to price recovery.

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