Oil Shocks and Real U.S. Income

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Abstract: The analysis explains how previous oil shocks have affected real U.S. income. Real income differs from aggregate economic output (GDP) because it includes the purchasing power losses associated with more expensive imported petroleum. Real income declines immediately during the same quarter as the oil price shock as opposed to the output effects, which are lagged over several quarters. These immediate losses can be significant, reaching as much as 1.7% of the baseline value in the same quarter, for a doubling of crude oil prices. Expanding coverage to include purchasing power losses allows policy analysts to evaluate a range of different policy instruments that can influence oil prices, such as the building and release of the strategic petroleum reserve.

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1. Introduction

Since the 1956 Suez Canal crisis, sudden and unexpected imported crude oil price shocks have caused serious economic dislocations in major oil-importing countries. Many empirical studies have focused upon the decline in physical aggregate output as measured by real gross domestic product (GDP).[1] Output impacts are important for understanding trends in factor productivity, inflation and unemployment. This paper will reference these aggregate output impacts as “real product” effects.

Policymakers may also be concerned about how higher imported oil prices influence real disposable income. Higher oil prices reduce a country’s international purchasing power (PP) by raising the real price of imported oil. As a result, not only may the economy produce less output, but a greater share of this output may also be allocated to exports to buy more expensive oil imports. This paper will reference impacts that incorporate both lost output and these PP losses as “real income” effects, as distinguished from the “real product” effects measured by real GDP.

In many situations, policy economists will want a broader measure of impacts (income) than a narrower measure (output). Real output effects and their associated employment impacts often do not translate directly into meaningful economic welfare effects, because these macroeconomic adjustments may not result from changes in relative prices. In contrast, real income effects based upon purchasing power losses are more closely associated with the welfare effects that result from changes in relative prices. Welfare effects may be important to

[1] See Hamilton (1983) and extensive literature reviews by Brown and Yucel (2002), Brown, Yucel and Thompson (2004) and Jones, Leiby and Paik (2004).

incorporate not only for disruptions but also for a range of oil policies that can affect the oil price, like filling or releasing oil from public stockpiles. Occasionally, these additional PP effects have supplemented estimates of the loss in real GDP (Huntington and Eschbach, 1987), but most studies do not.

This article expands the coverage of economic impacts to include real income rather than real output effects. These two measures are closely aligned and their levels move together for most periods. When the prices of oil or other tradable goods change sharply, however, these two measures of economic activity may grow at very different rates. Analysts who want a broader measure of economic impacts can choose a published data series from the U.S. Bureau of Economic Analysis that measures real income as defined here. The use of this series, however, does raise certain empirical issues that are explored below.

The next section differentiates between the real product and real income series and explains what each variable measures. Section 3 discusses the measurement of oil price shocks and section 4 adopts the standard approach for evaluating the impacts of oil price shocks on real output. After confirming that the oil-economy relationship still holds, the analysis modifies the oil price variable to be more representative of oil price shocks. Section 5 considers a broader measure of the impacts—the effect on the real "command" national income series as measured by the U.S. Bureau of Economic Analysis.[2] Particular attention is given to both the timing and causes of the additional PP effects. Concluding comments in the last section summarize the principal findings.

[2] Published data for the United States are available for command GNP but not command GDP. However, previous studies of the aggregate output responses to oil prices have used GDP rather than GNP. Although GNP and GDP measure different concepts, they are not as different for the United States as they are for other countries. Regression results show very similar impacts of oil prices, whether aggregate output is measured by real GNP or real GDP. To be technically consistent with how the data is constructed, this paper will refer to "real output GDP effects" and "real command GNP effects".

2. Real Product and Real Income

Real GDP measures output in terms of a set of domestic prices that exclude changes in international purchasing power due to changes in the prices of petroleum and non-petroleum imports and exports. Recognizing this problem, the U.S. Bureau of Economic Analysis regularly collects and reports an additional series called "command GNP", which adjusts the national income accounts for changes in the country's terms of trade (Denison 1981). It is helpful to understand the rationale and approach for this adjustment before using this alternative measure.

National income accounting measures inflation-adjusted value-added output volume by constructing gross domestic product at constant prices. At the national level for the total economy, it begins with the fundamental accounting relationship that equates aggregate output to total spending disaggregated by major components,

$$Y \quad = \quad C + I + G + X - M \quad = \quad A + X - M\,, \tag{1}$$

where Y is aggregate output, C is consumption, I is investment, G is government purchases, X is exports, M is imports, and absorption or total final expenditures is defined as $A=C+I+G$.

To convert these nominal expenditures into inflation-adjusted or real counterparts, the accounting system uses a double-deflation procedure.[3] As an example, petroleum imports are valued at some fixed base-year price by dividing nominal expenditures by the oil price deflator. Real petroleum imports are combined with real imports for other goods and services to form real aggregate imports. The same process is repeated with a different set of prices for exports and the

[3] The system uses chained indexes and is explained in detail in U.S. Bureau of Economic Analysis (2006).

other major GDP components. The real expenditures for the various components are added (or in the case of imports, subtracted) to form real output,

$$y = a + x - m \tag{2}$$

where $m = M / p_m$, $x = X / p_x$, $a = A / p_a$ and p_m, p_x and p_a refer to the separate price indices (current prices divided by base-year prices) for imports, exports and absorption, respectively. The concept, y, is the real aggregate output effect featured prominently in most impact studies of oil price shocks.

Residents earn total income by selling this domestic production both internally and abroad. Their real income will be this nominal income (Y) deflated by the price of a numeraire good applicable to all sectors. Suppose that the national accountants decide to deflate nominal income by the price of total final expenditures (p_a). Beginning with the nominal GDP (Y) defined in Equation (1), real income would be computed as:

$$y^* = (Y / p_a) = a + (X / p_a) - (M / p_a) = a + [(p_x / p_a)\ x] - [(p_m / p_a)\ m] \tag{3}$$

Real income differs from GDP by subtracting (2) from (3):

$$y^* - y = [(p_x / p_a) - 1]\ x - [(p_m / p_a) - 1]\ m \tag{4}$$

If import prices rise faster than the prices of domestic consumption, the country will experience a deteriorating terms of trade and a decline in its real income. The nation must allocate more domestic production away from internal consumption in order to produce more exports for purchasing each unit of imports. Imports could be further disaggregated into petroleum and non-petroleum goods. A price rise in either import component will reduce its international real income, depending upon its relative importance in the economy as revealed by its share of m. Although petroleum imports account for only 1.3 percent of GDP in 2005, an oil price doubling would have first-order effects of approximately 1.3% of baseline GDP. For this reason, the small share of petroleum or aggregate imports in the total U.S. economy is not necessarily a reason to assume that this effect is minimal for large oil price shocks. Standard neoclassical welfare concepts link societal costs for an oil importer to oil price changes and oil import levels (the latter being the average of pre- and post-shock import levels in the basic consumer surplus approach). Thus, the missing terms-of-trade component for petroleum imports in conventionally measured real GDP is equivalent to the oil-wealth estimates derived by energy economists from the demand curve for net oil imports.[4]

Economists have offered a number of competing definitions for which price series should be used as the numeraire good, including either the import or export price, some composite of these two prices, or some general price index for gross domestic final expenditure as was done above. Since there is little agreement on which approach is preferable and the optimal choice depends upon the circumstances (Hamada and Iwata, 1984; United Nations, 2001), convention usually allows each nation to choose its approach.

In the United States, the custom in published data is to deflate the nominal exports by the implicit price deflator for aggregate imports (U.S. Bureau of Economic Analysis, 2006, p. 17). This approach results in the following difference between real income ($y\#$) and real product:

[4] Since these purchasing-power effects are in addition to the output (GDP) effects, Huntington and Eschbach (1987) suggest that the GDP effects should be augmented with separate terms of trade estimates. Rather than impose that assumption, the current paper seeks to estimate the total impact on real income directly.

$$y\#-y=(X/p_m)-(M/p_m)-(X/p_x-M/p_m)=(X/p_m)-(X/p_x) \qquad (5)$$

Nominal exports are deflated by import rather than the export prices.[5] If import prices rise relative to export prices, more production will be allocated towards exports and real income will decline.

3. Novel Oil Price Shocks

Measured output and income levels move closely with each other. As a result, any effort to explain the growth rate of real income must also incorporate the factors that explain the growth rate of real output. It is only when there are sharp changes in the price of traded commodities that their growth rates differ markedly from each other.

The next section will estimate the impact of oil price changes on real output (GDP) that will be used as a benchmark for further investigation of the impact of oil price changes on real income (command GNP) in following sections. This benchmark is based upon the vast literature on the oil-GDP relationship that has been adequately reviewed elsewhere (Brown and Yucel, 2002, 2004, and Jones, Leiby and Paik, 2004). Although this literature is not without its critics (e.g., see Barsky and Kilian, 2004), it is important for this analysis to begin with an approach that has been used by other researchers. If one believes that oil price shocks have not had an impact on aggregate output, the argument in this paper is substantially easier. The economic impacts will simply be the purchasing power effects discussed above. In the more general case where oil

[5] Nominal expenditures for final goods (A) are deflated by the same base price (p_a) in both the income and product series and hence do not contribute to ($y\#$-y).

price shocks may have had some impact on aggregate output, it is important to incorporate the possible effects on real product.

Numerous studies have empirically estimated that oil price shocks have reduced real GDP in the United States as well as other major oil-using countries[6]. Often, the impact on oil-exporting economies is similar to that on oil-importing countries, suggesting that the aggregate output effects do not depend critically upon whether oil is imported or not. The direction of the shock is critically important in these studies. Oil price increases reduce activity but oil price decreases tend to be insignificant.

Novelty is another characteristic of oil price shocks. Price increases over a range that has not been experienced recently are much different than price oscillations over a more familiar range. The combination of asymmetry and novelty means that unanticipated, surprise events create enough uncertainty that resources do not shift easily between sectors, resulting in idle capacity in major economic sectors. Although the U.S. crude oil prices increased more gradually in 1979 than they did in 1973 and 1991, they still increased much more rapidly than oil prices did in 2005. For example, oil prices were 96% higher 12 months after March 1979, while they were only 38% higher 12 months after December 2004.

Asymmetric and novel oil price shocks have been measured in different ways. The most common approaches are asymmetric shocks (positive versus negative), standardized shocks (relative to their recent deviations), or net price shocks where prices exceed a recent historical peak.[7] An asymmetric specification assumes that the responses to oil price increases and

[6] International studies include Mork, Mysen, and Olsen (1994), Huntington (2004), and Jimenez-Rodriguez and Sanchez (2005).

[7] Jimenez-Rodriguez and Sanchez (2005) discuss and compare the different approaches used by Lee, Kiseok and Ratti (1995), Mork (1989) and Hamilton (2003).

decreases differ from each other. If P_t represents the price in period *t*, the price increase (p+) and price decrease (p-) series would be computed as:

$$p_t^+ = \max\,[0, \ln(P_t) - \ln(P_{t-1})\,] \qquad \text{and} \qquad (6)$$

$$p_t^- = \min\,[0, \ln(P_t) - \ln(P_{t-1})]$$

The Hamilton net price series[8] (*s*) adopts a similar nonlinear approach and is computed as:

$$s_t = \max\,[0, \ln(P_t) - \max\{\ln(P_{t-1}), \ln(P_{t-2}), \ldots, \ln(P_{t-12})\}\,] \qquad (7)$$

where the current price must exceed the recent historical maximum over the last 12 quarters for the net price series to register a value (positive) other than zero.

The net price series is initially adopted because many researchers have used it. Since it behaves very similarly to the other price series investigated below, conclusions reached about Granger causality in the next paragraph apply to the other oil price series as well. Later, the analysis adopts a version of the standardized shock, which provides some additional useful insights. The construction of this variable is discussed later.

4. Oil Prices and Real Product

Applying the most recent U.S. data (1947:II-2005:IV) for the U.S. crude oil price and GDP variables[9] confirms that Hamilton's (2003) earlier results over the 1949:II-2001:III period persist. Table 1 contains a set of Granger causality tests confirming that oil price shocks

[8] Hamilton (2003) shows that the results based upon the net oil price series are very similar to an instrumental variables approach, where oil price shocks are first explained by sudden declines in oil supplies from several key countries in the Persian Gulf region.

[9] Estimates were based upon the EasyReg International econometric program (Bierens 2005). The U.S. Bureau of Economic Analysis publishes data on gross national product, command gross national product, and the price deflators for imported crude oil, imported non-petroleum imports and exports. The U.S. Bureau of Labor Statistics publishes data on the producer price index for domestic crude oil. The U.S. Energy Information Administration publishes data on the composite refiners' acquisition costs for domestic and imported crude oil.

precede or "Granger-cause" real output declines (or real command declines as discussed later), but that real GDP does not precede net oil price shocks (or crude oil prices as conventionally measured, which is not shown). The table also shows that oil price shocks do not precede changes in nominal GDP, which is likely to be influenced more by shifts in aggregate demand policy and conditions than by oil price shocks.

The Granger causality results show a weak form of exogeneity, where economic activity from prior periods provides no useful information for projecting net oil prices. Although this information is relevant for forecasting and for efforts to establish the conditional expectation of GDP growth on lagged GDP growth and lagged oil price changes, these tests do not satisfy the conditions of strong exogeneity. However, Hamilton (2003) has explored the exogeneity issue by employing an instrumental-variable technique where volumetric oil supply disruptions are used initially to explain the exogenous portion of crude oil prices. His results based upon this instrumental-variable specification are very similar to estimates using the net oil price series in the following reduced-form equation:

$$y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i y_{t-i} + \sum_{j=0}^{n} \beta_j s_{t-j} + \varepsilon_t \tag{8}$$

where y is the quarterly change in real GDP, s is the quarterly change in the net oil price series (including the contemporaneous change), n is the number of lagged quarters, and ε is the independently and identically distributed disturbance term. Other researchers (e.g., Mork, Mysen and Olsen, 1994) have also used similar specifications to develop initial insights about the economy's response to oil price changes.

The number of lags (n) was initially set for 8 quarters. Both the Akaike criterion and F-test concluded that the optimal lag specification would include 4 quarters, while the Hannan-Quinn and Schwarz criterion concluded a very much shorter lag of one quarter. The longer lag specification of four quarters was chosen to be consistent with previous studies. The biases created by including extra variables are considerably less serious than those caused by excluding relevant variables. Moreover, the standard F test is appropriate for a single-equation model (Enders, 2004, p. 357).

When the (logarithmic) change in real quarterly GDP is regressed on its first four lags and the current and first four lags of the net oil price series, the coefficients in Table 2's first column are also similar to estimates based upon Hamilton's earlier sample. When the net oil price series is based upon *domestic* crude oil prices, the sum of the price coefficients for the four previous quarters equals –0.082, which provides a cursory but useful benchmark for the approximate size of the impact.[10] The insignificant coefficient for the current oil price change is kept purely for illustrative purposes, but will be dropped in the next section. These results are of the same order of magnitude as those estimated by Hamilton (2003) on the earlier data, where the price coefficients that he reports sum to –0.105.[11] As reported in the bottom of this table, Breusch-Pagan tests did not reject homoskedastic errors and Breusch-Godfrey tests did not reject zero, first-order autocorrelation for any of the specifications.

Mork (1989) argued that the domestic crude oil price fails to capture the Nixon price controls beginning in the second quarter of 1971. He suggests that a better measure would be an average of imported and domestic crude oil prices. During this period, price controls kept domestic prices below imported prices, with refiners paying a marginal price equal to a composite of domestic and foreign prices because the regulations operated like a tax/subsidy system.

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[10] Various literature reviews (e.g., Jones, Leiby and Paik, 2004) have used the sum of the price coefficients as an approximation of the full effect of oil prices on the economy. More generally, the lagged effects of output changes and the other variables in the system will also influence the total effect.
[11] This sum is virtually the same (–0.104) based upon our database for the same period (1949:II-2001:III) and domestic crude oil price.

Quarterly data for a composite average price paid by U.S. refineries for all oil is available from the U.S. Energy Information Administration (2006c) only after 1973. However, annual data for the same series (U.S. Energy Information Administration, 2006b) indicates that the composite price exceeds its domestic counterpart by 2% or less for the 1968-73 period. A much larger price differential emerges in the 1974-80 period, ranging between 16 and 26 percent. Thus, starting the composite price series at the beginning of 1974 creates a very minimal bias compared to the observed bias associated with the 1974-80 period. To adopt the Mork refinement, a quarterly oil price series was developed by merging domestic crude oil prices before 1974 with composite refinery costs after 1973.[12] A new net oil price series was computed on the basis of this composite oil price.

When the net oil price series is based upon this composite U.S. price, their coefficients shown in Table 2's second column are reasonably similar to those based upon the domestic crude oil price. The main appeal of this equation is conceptual, although the first lagged price coefficient is now significant at the 10% level. The sum of the price coefficients declines slightly to -0.074. Overall, the first two specifications confirm that the lagged oil-price effects on aggregate output remain significant when the estimation period is extended beyond 2001 and when composite rather than the domestic crude oil prices are used.

The advantage of Hamilton's net price series is that it clearly differentiates between price increases that are moving into new frontiers (higher than recently) from those that are simply recovering from previous retreats. Price increases that are not novel are unlikely to generate the type of adjustment problems commonly attributed to oil price shocks. The main disadvantage of the series is that a price that begins to exceed the recent historical peak may not be all that

[12] This series is available from the author upon request.

surprising. A one percent increase above the recent maximum will register as a (much smaller) price shock in the same way that a hundred percent increase will.

Another problem is that the definition of an oil price shock may have changed dramatically over time. Often using an extremely long horizon, the studies assume that the economy responds to a given percentage increase in the oil price (above its recent maximum) the same way in the 1950s as in the 1980s or later. For example, the Suez Crisis raised U.S. oil prices at a quarterly rate of 7.6 percent during the first three months of 1957. This event was more than a 30% price increase on an annual basis at a time when the Texas Railroad Commission effectively kept oil prices very stable. That same increase in today's economy is unlikely to generate a similar concern, primarily because recent oil prices have been much more volatile. For example, crude oil prices increased at a quarterly rate of 7.9% during the second quarter of 2005, an amount substantially smaller than the 9.6% rate over the previous 8 quarters. It makes little sense to consider the Suez Canal crisis and the quarter immediately preceding the Katrina storm as constituting similarly sized oil price shocks.

To adjust for these widely different experiences, a new standardized price shock series is developed that incorporates the price volatility issue raised by Ferderer (1996). Net oil price shocks that are large relative to recent oil price movements are considered more damaging than ones that could be easily lost in the background of recently experienced price volatility. Price increases that dampen economic activity should be both novel and large relative to recent experiences. For easy reference, this series will be referenced as the *net shock* rather than *net price* variable, which is defined as:

$$s_t^* = \max\,[0, s_t - d_{t-1}] \qquad (9)$$

where s_t is the above net price series and d_{t-1} is the standard deviation of the oil price change around its mean (*u*) over the last *n* quarters immediately prior to period *t*, computed as

$$\mathrm{d}_{\mathrm{t\text{-}1}} = \left[\frac{1}{n-1} \cdot \sum_{j=1}^{n} \{(\ln(P_{t-j}) - \ln(P_{t-1-j}) - u_t)\}^2 \right]^{1/2} \tag{10}$$

As with the previous net price variable, the new series includes only oil prices that exceed recent historical levels, rather than those that are simply retracing their previous path. In addition, however, the price increase during the quarter must exceed the standard deviation of historical price increases over recent quarters. The *net shock* series includes the 7.6 percent increase during the Suez Canal but excludes three out of the 4 (much larger) price increases that the net price series registered for 2004. Although oil prices were moving above their recent historical peaks, they were increasing at a slower rate than in previous quarters.

Variations with standard deviations over 4, 8 and 12 quarters produced very similar oil price coefficients and equation estimates. The price coefficients for the *net shock* series based upon standard deviations over 8 quarters are displayed in the third column of Table 2. This specification improves the statistical fit of the price response terms; the first, third and fourth lagged price terms are significant at the 5% level. The equation's explanatory power also increases, whether it is measured by the adjusted R-squared or the F-statistic for zero slopes.

Although the sum of the price coefficients appears demonstrably larger in these specifications than with the *net price series*, the oil price variables are defined quite differently. The net price series defines price increases that exceed the recent historical maximum, while the net shock series defines price increases that must also exceed the recent standard deviations in price changes. If oil prices should increase by ten percent and the 8-quarter standard deviation in price changes is 5 percent (approximately the average for the last two quarters of 2005), the 5 percent *net shock* reduces real GDP by 0.9 percent below its baseline after 4 quarters (approximated by the sum of the price coefficients times 5%). If the 8-quarter standard deviation should decline to 0 percent (approximately the average just before the Suez Crisis), this same 10 percent oil price increase will reduce real GDP by 1.7 percent below its baseline level after 4 quarters.

The analysis now shifts to explaining the growth rate in real income, based upon what has been learned about the response of real GDP to oil price shocks. It should be emphasized that none of the conclusions about the impacts on real income depends upon whether one uses composite or domestic oil prices or defines novel price increases as net oil shocks or net oil prices. This section will define oil price shocks as the net oil shock variable (Table 2's column 3) because that definition seems to be the most consistent with the explanations offered by Hamilton and others and because its explanatory power appears to be more robust than other oil price variables.

5. Oil Prices and Real Income

If real income (as measured by command GNP) replaces real GDP in the previous specification, the lagged net price series will incorporate the effects of oil prices on aggregate output evaluated above. The shift to real income, however, must also incorporate an additional adjustment – the decline in the country's terms of trade. Equation (3) shows that this international purchasing power effect will be governed by the real prices of imported petroleum and non-petroleum products as well as the real price of exports. Consistent with that equation, these real prices have been computed by deflating each series by the price deflator for final purchases for consumption, investment and government (or total absorption).

The estimation equation for real income becomes:

$$y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i y_{t-i} + \sum_{j=1}^{n} \beta_j s_{t-j} + \sum_{j=0}^{k} \delta_j o_{t-j} + \sum_{j=0}^{k} \theta_j m_{t-j} + \sum_{j=0}^{k} \lambda_j x_{t-j} + \varepsilon_t \qquad (11)$$

where the economic activity variable (*y*) is now real income, *s* continues to represent oil price shocks, and the variables, *o, m* and *x*, refer to the real prices of petroleum imports,[13] non-petroleum imports and total exports, respectively. Reflecting restrictions on the availability of data for imported petroleum and non-petroleum prices, this equation was estimated for the 1967:2-2005:3 period.

The length of the lag for the real purchasing power effect (*k*) is unknown and requires testing. Table 3 reports F-statistics and various information criterion measures for determining the number of lags. All but the Schwarz information criteria suggest that the equation should include both the current and first quarterly lagged price terms for traded goods. Once again, the biases created by including extra lagged variables are less serious than those caused by excluding relevant lagged variables.

Replacing real GDP with real income does not change the effects of oil price shocks on economic activity. The sum of the oil price shock variables (s) is the same for the real income equation using the command series (in the first column of Table 4) as for the real output equation (in the third column of Table 2). In addition, however, changes in the real oil price (both decreases and increases) have another effect on real income. One would expect from equation (3) that this estimate would approximate the average value share of imported petroleum products

[13] The implicit price deflator for imported oil rather than the composite oil price variable is needed in order to measure the international terms-of-trade effects.

in U.S. GDP (about 1.2%) since 1967. After a doubling of oil prices in the previous quarter, the estimate in Table 4 shows that real income will decline by 1.7% below its baseline value. Although slightly higher than expected, this estimate has a 5% confidence interval [-.008,-.026] that includes -.012, the expected value. For this reason, the estimate appears reasonable given the relative importance of oil imports in the economy.[14]

Surveys of the empirical literature have emphasized that the economic impacts of oil price shocks from small empirically-based models (including various VAR specifications) are often substantially greater than those from large macroeconometric models. Policymakers are left to ponder whether the complexity of the larger models causes important misspecifications or whether the smaller models exclude too many important features of the economy. Although this issue is largely beyond the scope of this paper, it requires a brief comment.

Both government spending and monetary policy could have changed during the oil shock, thereby biasing the responses to the oil price shock. If aggregate demand policies attempted to control inflation by restricting output, the oil price variable could be incorporating some of the lost output due to the aggregate demand effect, and its negative impact on aggregate output will be overstated. If aggregate demand policies attempted to mitigate output losses without fears of raising inflation, the observed negative oil price effect will be understated.

A number of studies have included changes in nominal GDP to control for aggregate demand conditions in their tests of different macroeconomic perspectives, including new classical (Lucas, 1973), standard Keynesian (Schultze, 1984) and neo-Keynesian frameworks (Ball, Mankiw and Romer, 1988). As demonstrated in section 3, nominal GDP changes are not influenced (Granger-caused) by previous crude oil price changes. This approach will control for

[14] One of the referees suggested that the equation should be estimated by excluding the large oil shocks of the 1970s. This coefficient declines to –0.011 for the period after 1974 and to –0.012 for the period after 1979, but remains significant at the 1% level.

demand shocks, as long as the aggregate demand schedule is approximately unitary, as implied by estimates from, for example, Mankiw and Summers (1986). Although this approach would not be suitable for guiding macroeconomic policymakers, it provides intuition on the approximate size of the impact.

The second column of Table 4 repeats the same equation in the first column but includes the change in nominal GDP in the current quarter as a control for changes in aggregate demand conditions. Coefficients that are significant without the change in nominal GDP (in the first column of Table 5) remain significant when nominal income is included (the second column). The estimated values for the oil price change (o) and the sum of the shock effects (s) are about 60% as large as they were previously. These results suggest a weaker role for oil prices than would be inferred by excluding these demand conditions.

6. Conclusions

This analysis uses a broader measure of economic impact that includes changes in the U.S. international purchasing power. Just as a wage earner is interested in his purchasing power as well as the hours that he works, policy economists should be interested in not only the nation's output but also its real income in terms of the cost of the goods and services that it consumes. When a policy economist is interested in real income rather than real output, this broader measure should be used.

An oil price shock will reduce income through its lagged effect on real output. In addition, it will also reduce real income immediately through its effect on an oil-importing economy's terms of trade. Real GDP impacts will not incorporate these additional effects. Estimates of this excluded purchasing-power (PP) effect over the 1967-2005 period suggest that the real income may have declined by an additional 1.0%-1.7% below its baseline value in the quarter immediately after a doubling of the oil price. The PP impacts will be tied to oil import shares in the total economy. Government projections expect future US oil import shares to rise in the future (US Energy Information Administration, 2006a). Under these conditions, the future impacts on purchasing power could be higher than estimated here.

The analysis also suggests that oil price shocks need to be carefully measured. The net oil price series used in many studies captures when oil prices move above their recent range, but these episodes may not be true shocks if they occur against a background of considerable oil price volatility. The estimates in this paper offer some support for defining oil price shocks as price increases relative to recent oil price oscillations. Although the oil price shock associated with the Suez Canal was a surprise and unexpected, resulting in lower economic activity, the same price movement in today's economy with much more volatile prices would hardly be noticed.

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Table 1. Granger Causality Tests

Activity	Changes in oil price do not precede changes in activity	Changes in activity do not precede changes in oil price
Real GDP	20.75**	2.15
	(0.000)	(0.708)
Real Command GDP	21.61**	2.05
	(0.000)	(0.726)
Nominal GDP	3.77	3.84
	(0.438)	(0.428)

** F test rejects that lagged coefficients are zero.
Probability values appear in parentheses.

Table 2. Estimated Coefficients in Real GDP (y) Equation, 1947:2 - 2005:4

	(1)	(2)	(3)
y(-1)	0.239 **	0.234 **	0.217 **
	(0.066)	(0.066)	(0.065)
y(-2)	0.116 *	0.115 *	0.115 *
	(0.067)	(0.067)	(0.066)
y(-3)	-0.116 *	-0.119 *	-0.133 **
	(0.067)	(0.067)	(0.066)
y(-4)	-0.132 **	-0.127 **	-0.125 **
	(0.064)	(0.064)	(0.063)
s	-0.012	-0.008	-0.010
	(0.012)	(0.010)	(0.018)
s(-1)	-0.020	-0.019 *	-0.057 **
	(0.012)	(0.011)	(0.018)
s(-2)	-0.003	-0.002	-0.008
	(0.013)	(0.011)	(0.019)
s(-3)	-0.017	-0.017	-0.040 **
	(0.013)	(0.011)	(0.019)
s(-4)	-0.030 **	-0.028 **	-0.058 **
	(0.012)	(0.011)	(0.019)
sum(s)	-0.082	-0.074	-0.173
Adjusted R-square:	0.183	0.188	0.222
F test (zero slopes)	6.72 **	6.93 **	8.29 **
Breusch-Pagan test	10.95	10.87	12.92
Breusch-Godfrey test	0.170	0.108	0.173

** (*) Significant coefficient at 5% (10%) level.

Table 3. Test of Lag Length for Export and Import Prices in Real Income Equation

	F-tests	Akaike	Hannan-Quinn	Schwarz
4 Lags	4.45	-9.739	-9.543	-9.257
3 Lags	0.83	-9.723	-9.552	-9.302
2 Lags	3.63	-9.758	-9.611	-9.397
1 Lags	9.42 **	-9.762	-9.639	-9.461
0 Lags		-9.720	-9.622	-9.479
Optimal Lag	1	1	1	0

F test result measures the effect of removing each set of lags and is based upon heteroskedasticity consistent variance matrix because Breusch-Pagan test rejects homoskedastic errors.

** Zero coefficients are rejected at 5% level.

Table 4. Estimated Coefficients in Real Income (y) Equation, 1967:2 - 2005:3

	(1)		(2)	
y(-1)	0.102		-0.103	**
	(0.077)		(0.040)	
y(-2)	0.088		0.004	
	(0.097)		(0.041)	
y(-3)	-0.111		-0.032	
	(0.083)		(0.041)	
y(-4)	-0.032		-0.032	
	(0.083)		(0.036)	
s(-1)	-0.072	**	-0.025	**
	(0.017)		(0.009)	
s(-2)	-0.009		-0.022	**
	(0.019)		(0.009)	
s(-3)	-0.038	**	-0.027	**
	(0.019)		(0.008)	
s(-4)	-0.054	**	-0.031	**
	(0.022)		(0.008)	
po	-0.017	**	-0.010	**
	(0.005)		(0.002)	
po(-1)	0.002		-0.002	
	(0.005)		(0.003)	
pm	-0.005		-0.011	
	(0.060)		(0.025)	
pm(-1)	-0.184	**	-0.070	**
	(0.067)		(0.025)	
px	0.202	**	0.062	
	(0.092)		(0.039)	
px(-1)	0.175	**	0.082	**
	(0.079)		(0.039)	
yn			0.809	**
			(0.036)	
constant	0.010	**	-0.004	**
	(0.002)		(0.002)	
sum(s)	-0.173		-0.104	
Adjusted R-square	0.291		0.766	
F test (zero slopes)	5.37	**	33.49	**
Breusch-Pagan test	26.99	**	21.84	
Breusch-Godfrey test	0.731		#	

** (*) Significant coefficient at 5% (10%) level, based upon White's heteroskedasticity consistent variance matrix if Breusch-Pagan test rejects homoskedastic errors.

Breusch-Godfrey test =11.63 in OLS. Estimates are for equation with first-order autocorrelation.