Estimates of Oil Price Elasticity

By Robert Hoffman*

Introduction

This review is focused on research that attempted to quantify the impact of oil prices on GDP / GNP and specifically articles that provide a point estimate of this key elasticity. In general, the empirical research has generated an evolving impression about the magnitude of oil-price effects on aggregate economic activity.

Researchers found that during the period starting after World War II and extending through the 1970s oil price shifts had a very large impact on economic activity. Point estimates of oil price elasticity were as high as -0.29 – suggesting that a 10% increase in the price of oil would translate into a 2.9% decline in real GNP.

When data from the 1980s was added to the sample period, estimates of the elasticity fell sharply. In fact during the mid-1980s the structural relationship appeared to change and researchers began to entertain the possibility that oil prices had an asymmetric impact on economic activity. Oil price increases continued to have a negative (albeit smaller) impact on economic activity; however, large oil price declines failed to produce an economic boom.

Research conducted over the last decade note that oil prices have become more volatile while the impact on the economy appears to have continued to diminish. Point estimates of the elasticity based on macroeconomic model simulation where the impact of the shock can be isolated, produce results that are as low -0.02 in year 1 and -0.05 in year 2. In this instance a 10% increase in the price of oil would result in a year 1 decline in real GDP of just 0.2% and a year 2 decline of 0.5%.

Several authors have tried to explain the economy's reduced sensitivity to oil price spikes. One strand of this research emphasizes the response of monetary policy in determining the output and core inflation impacts of an oil price shock. These researchers used both VAR models and econometric model simulations and produced results confirming that central bank response to oil price shocks has fundamentally changed over the years and that this shift has mitigated much of the negative impacts on real GDP and contributed to the reduction in the oil price elasticity.

Estimates of the Oil Price Elasticity

James Hamilton

Two articles by Hamilton published in the early 1980s were very influential in convincing economists that oil price increases are important contributors to recessions. His articles relied on the statistical concept of Granger causality to test for directions of effect in the setting of recurrent shocks. He found that exogenous shocks to oil prices had significant effects on real activity in the United States in samples that end before 1973.

Hamilton's first article on the topic in 1983 took a simple approach, he estimated a log-linear relationship between GDP growth and lagged oil prices. For this investigation his full sample period was 1948 to 1980. To investigate the stability of the relationship he separated the full sample into two sub-periods: 1948 to 1972 and 1973 to 1980. He found a statistically significant relationship for both periods. In addition he found that estimation of the full period yielded smaller coefficients than either sub-period. For the period from 1949 to 1972, the oil-price coefficients at the second, third, and fourth lags are -0.082, -0.170, and -0.177. For the period 1973 to 1980, those coefficient values are -0.038, -0.078, and -0.115.

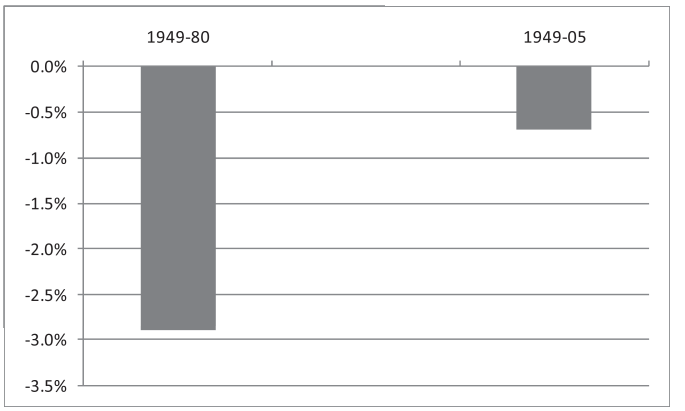

Figure 1
Real GDP Impact 4 quarters after a 10% Oil Price Increase

An article by Hamilton in 2000 provided clear evidence of an asymmetric relationship. He found that oil price increases are much more important than oil price decreases, and increases have significantly less predictive content if they simply correct earlier decreases.

In 2005 Hamilton updated some of his estimates and found that the statistical significance of the relationship falls as one adds more data. He found that a

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regression over the period from 1949 to 1980 would predict that GDP growth would be 2.9% lower (at an annual rate) four quarters after a 10% oil price spike. While the regression estimated over the period from 1949 to 2005 would predict only 0.7% slower growth. Hamilton interpreted his results to suggest a linear relationship is either mis-specified or unstable.

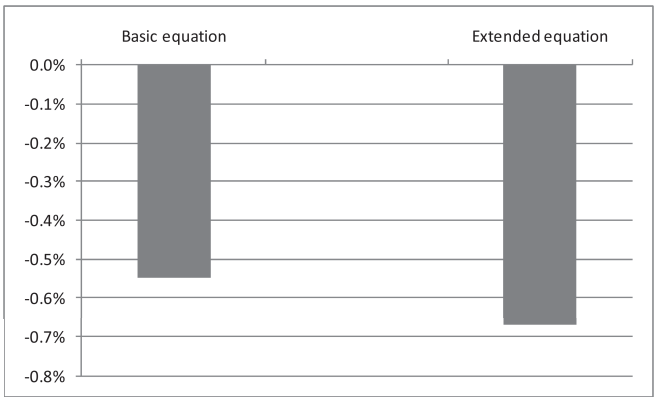

Figure 2
Real GNP Impact of a 10% Oil Price Increase

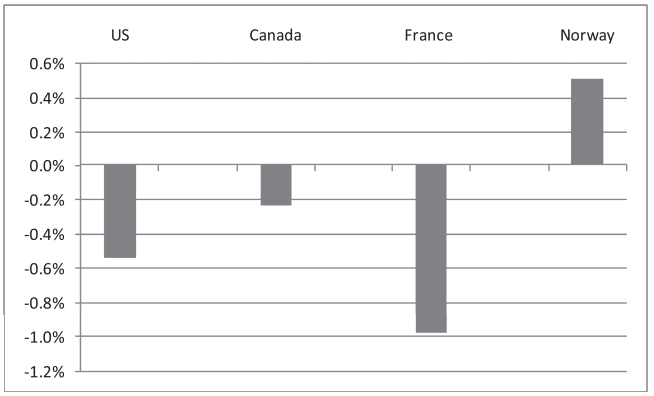

Figure 3
Real GDP Impact of a 10% Oil Price Impact for Various Countries

Javier Mory

His 1993 article explored the asymmetric macroeconomic responses to oil price changes. He estimated a simple regression of GNP on the oil price, with a one-year lag. Using a sample period of 1951 to 1990, he obtained a GNP elasticity of -0.0551 which was highly significant statistically. He did not, however, control for other influences in that regression.

In subsequent regressions (extended version) he included separate variables for oil price increases and decreases. He also controlled for government purchases and M2 money supply. In this case over the same period the GNP elasticity was somewhat larger at -0.0671 and was also statistically significant.

Knut Mork

In his 1994 article Mork extended Hamilton's original work and allowed oil price shocks to have asymmetric effects. His research findings inferred that oil price increases reduced real output while oil price declines had no effect. His estimate of the elasticity was -0.054 based on the period from 1967 to 1992 - very similar to the one produced by Mory. The elasticity for other OECD countries over the same period was quite different. For Canada the elasticity was about half the size (-0.024). It was considerably larger for France (-0.098). In the case of Norway the elasticity was positive at 0.051. Norway is a large producer and exporter of oil. In this case a 10% increase in oil prices is associated with a 0.5% increase in real GDP.

Mork's research also found a statistically significant negative elasticity for oil price increases and non-significant positive elasticity for price decreases.

Mark Hooker

Federal Reserve economist Mark Hooker (1996) concluded that the relationship uncovered by Hamilton had broken down in the mid-1980s when a large decline in oil prices did not result in an output boom. He explored data for the period from 1948 to 1994. He found a structural break-point in the relationship at 1973 - a drastically weakened relationship between oil prices and GDP, unemployment rate and the rate of overall inflation over the period 1973 to 1994. He found that neither GDP growth nor unemployment Granger-caused by oil prices in this later period. His efforts to explain this finding by possible endogeneity of oil prices and several versions of asymmetry hypotheses were negative - no macroeconomic variable Granger causes oil prices in the later period.

In a 2002 article Hooker analyzes empirically the changing weight of oil prices as an explanatory variable in a traditional Phillips curve specification for the U.S. economy. He finds that pass-through from oil to prices has become negligible since the early eighties, but cannot find evidence for a significant role of the decline in energy intensity, the deregulation of energy industries, or changes in monetary policy as a factor behind that lower pass-through.

Robert Rasche and John Tatom

Articles by Rasche and Tatom (1977 and 1981) estimated an aggregate Cobb-Douglas production function for the United States and several other OECD nations. The authors explain that energy price shocks alter the incentives for firms to employ energy resources and alter their optimal methods of production. Energy-using capital is rendered obsolete by an energy price increase and the optimal usage of the existing stock is altered and production switches to less-energy-intensive technologies. The reduced capacity output of the economy is usually referred to as a decline in potential or natural output.

The authors state that domestic aggregate demand is affected due to a change in net imports of oil. The direction and extent of effects depend on the country's net oil export status. Net oil exporting countries experience an increase (decrease) in aggregate demand when oil prices rise (fall). The effect on net oil importing countries is exactly the opposite. Net oil exporting countries like Canada and the UK receive a boost to aggregate demand and output / employment from a spike in oil prices.

The impacts on productivity tend to work in the same direction regardless of the oil trade status of the country. An increase in oil prices has a negative impact on productivity. The theory suggests that energy price shocks should affect the productivity of capital and labor resources similarly across countries. The authors' second article provides evidence for this using production function estimates for Canada, Germany, France, Japan and the UK.

The estimation period for their study was from 1949 to 1978. The estimated equations were based on the first-order condition for firms' profit maximization. They substituted the price of energy for its quantity, but used quantities for labor and capital. The estimated coefficient in this case is interpreted as the long-run elasticity. Their estimate of the energy price-GNP elasticity for the United States was -0.070. The estimated impact was highest in Japan (-0.171) and lowest in Germany (-0.019). Their other estimates included UK (-0.035), Canada (-0.044) and France (-0.041). The oil price elasticity is lower in Canada and the UK given their net oil exporting status.

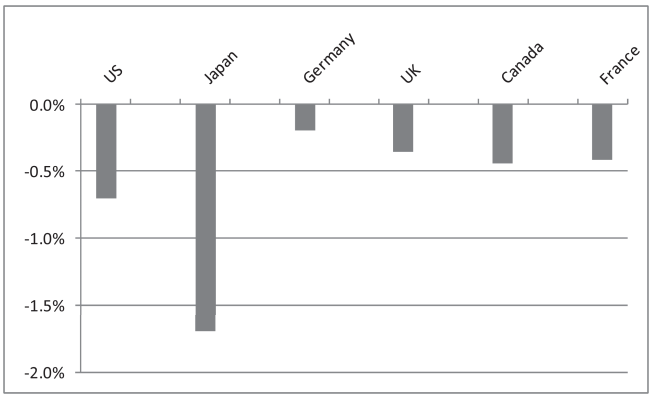

Figure 4
Real GDP Impact of a 10% Oil Price Increase for Various Countries

Rati Ram and David Ramsey

An article by Ram and Ramsey (1989) also took a production function approach (Cobb-Douglas specification) to estimating the elasticity. Their estimates for the United States are somewhat unique in that they distinguish between privately owned and publicly owned capital. A relative energy price variable is also incorporated and the estimation period is from 1948 to 1985. They obtained statistically significant energy price-GNP elasticity estimates that ranged between -0.074 and -0.069, depending on the disaggregation of public capital.

David Smyth

An article by Smyth (1993) investigates asymmetric impacts using a model of price 'rachet' effects. The basic equation structure also takes a Cobb-Douglas production function. The economy's response to three possible price movements is considered: price increases below the historic maximum price, price increases above the historic maximum price as well as price decreases. Three separate slope coefficients are estimated. In addition three separate intercept terms are allowed for. The inputs used are labor and private capital, and the price of energy. Annual observations over the period from 1952 to 1990 are used.

Smyth obtained a non-significant positive elasticity (0.020) for price decreases, a non-significant negative elasticity (-0.018) for price increases below the historic maximum price, and a significant negative elasticity (-0.052) for price increases above the historic maximum. He interprets the first two estimates as effectively zero. The overall results imply that energy price changes within the range of previous experience has no effect on aggregate output, however, oil price increases above that range have a sharp, negative impact on aggregate output.

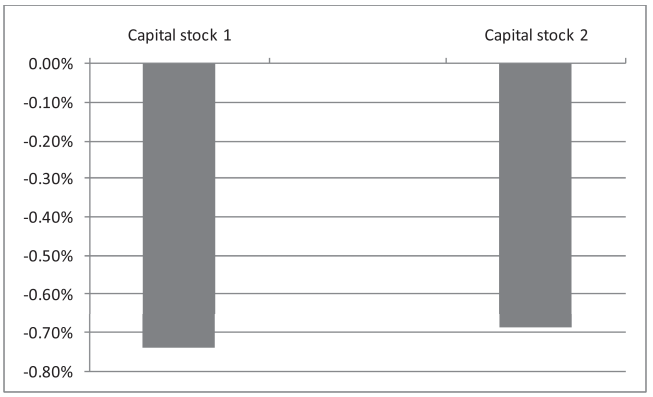

Figure 5
Real GNP Impact of a 10% Oil Price

Micha Gisser and Thomas Goodwin

Their 1986 article estimated equations involving real GNP, general price level, unemployment rate and real investment. They regressed each of those variables independently on contemporaneous and four lags of the M1 money supply, the high employment federal expenditure measure of fiscal policy, and the nominal price of crude oil. They use quarterly data over the period from 1961 to 1982. The coefficients

of the contemporaneous oil price and those of the third and fourth quarterly lags were highly significant in the GNP equation, negative in sign, cumulatively larger than the corresponding coefficients on fiscal policy and half the cumulative magnitude of the money supply coefficients. The oil price variables also had significant positive coefficients in the price level and unemployment rate equations and significant negative coefficients (contemporaneous and third and fourth lags) in the investment equation. The values of the significant oil price coefficients in the GNP equation were -0.020 (contemporaneous), -0.030 and -0.049 for the third and fourth quarterly lags, and -0.11 for the cumulative impact.

David Reifschneider, Robert Tetlow and John Williams

The January 1999 issue of the Federal Reserve Bulletin reported simulation results using the Federal Reserve Board's large-scale model (FRB/US) of a rise in oil prices on the U.S. economy. The authors simulated the effect on the U.S. economy from a $10 permanent increase in the price of a barrel of oil relative to the price of all other goods that gradually builds up over 1 year. They found that if the Fed were to keep the real federal funds rate constant, the level of GDP would be below its baseline trend by 0.2 percentage points after 1 year and by 0.4 percentage points after two years. In ten years the level of real GDP would be 0.3 percentage points below its baseline trend.

Jose De Gregorio, Oscar Landerretche and Christopher Neilson

In their 2007 article the authors provide a variety of estimates of the degree of pass-through from oil prices to inflation, and its changes over time, for a large set of countries. In addition to estimates of Phillips curves along the lines of Hooker (2002), they also provide evidence based on rolling VARs and focus exclusively on the effects on inflation. Their paper also examines a number of potential explanations, including a change in the response of the exchange rate (in the case of non-U.S. countries), and the virtuous effects of being in a low inflation environment.

Ben Bernanke, Mark Watson and Mark Gertler

This 1997 article starts with the idea that oil, and energy costs in general, are too small relative to the economy's total production costs to have the significant impact on economic activity that is found by other researchers. The authors posit that part of the recessionary impact of an increase in oil prices arise from the subsequent monetary contraction. The approach uses a VAR system with data from 1965 to 1995. The authors consider an oil price shock under two alternative scenarios - the first with, and the second- without a monetary policy response. They find that the absence of an endogenous restrictive monetary policy results in higher output and prices and the effects on output are quantitatively large. A non-responsive monetary policy manages to eliminate most of the output effects of the oil price shock within the first 8-10 months. This article provides analysis that suggests monetary policy has been the primary reason that oil price increases have had negative output effects in the U.S.

Nigel Gault

In 2011 Chief U.S. Economist for IHS Global Insight, Nigel Gault, used a macroeconomic model simulation to quantify the impact of a permanent $10/barrel increase in oil prices from the current price of about $100/barrel. The author finds that if this rise in the oil price is fully passed through, it will result in an increase of 24 cents in the price at the pump. The direct effects of a $10/barrel rise in crude oil prices is an increase in consumer price index of 0.38%, an increase in the consumption deflator of 0.28% and a decrease in disposable income of 0.26%. Assuming no change in the volume of gasoline purchased, the result is a $30 billion increase in the consumer gasoline bill.

Gault notes that if consumers cut spending on gasoline in response to the higher price, this reduces incomes elsewhere in the economy and this in turn decreases spending (the macroeconomic model's induced impacts). The first-year real GDP and real consumer spending impacts would be a decline of 0.21% relative to the baseline. In year two, the effect builds and real GDP and real consumer spending fall by 0.52% and 0.51% respectively (relative to baseline). This is consistent with an oil price elasticity of -0.021 in year 1 and -0.052 in year 2. Real disposable income falls by 0.40% in year one and 0.53% in year two, while the CPI rises by 0.46% in the first year and climbs a bit higher in the second year of the shock. Importantly, Gault assumed no policy response by the Federal Reserve so that the federal funds interest rate stays at its current very low setting in 2012.

Ben Hunt, Peter Isard and Doug Laxton

IMF economists employed the multi-country model MULTIMOD to analyze the macroeconomic

effects of oil price shocks in industrial countries. They distinguish between temporary, more persistent and permanent shocks. They focus on the key role of monetary policy in influencing macroeconomic outcomes. The article identifies five key channels through which oil price increases can pass through into core inflation and a possible explanation asymmetric relationship between oil prices and economic activity. The authors note that the MULTIMOD-based analysis of oil-price shocks hinges critically on the nature of wage/price behavior in a particular country and the monetary policy reaction function (monetary policy rule). MULTIMOD contains a real-wage catch-up relationship that is related to the bargaining process, it contains a key parameter that reflects the degree to which workers resist a reduction in their real consumption wage. The real-wage catch-up is a key parameter in determining the pass-through of an oil price shock to core inflation. It is unique for each country. The authors' findings suggest that if core inflation does not respond to oil price increases then there might be no need for monetary policy to tighten, in which case the effects on real economic activity could be minimal and this would reduce the oil price elasticity.

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