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Oil and the Macroeconomy

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Nine out of ten of the US recessions since the Second World War were preceded by an upward spike in oil prices. One way to inquire whether this might be just a coincidence is with a statistical regression of real GDP growth rates (quoted at a quarterly rate) on lagged changes in GDP growth rates and lagged logarithmic changes in nominal oil prices. The results from an ordinary least squares (OLS) estimation of this relation for $t =$ 1949:II to 1980:IV are as follows (standard errors in parentheses):

$$\begin{aligned} y_t = &\underset{(0.18)}{1.14} + \underset{(0.09)}{0.20}\, y_{t-1} + \underset{(0.09)}{0.05}\, y_{t-2} - \underset{(0.09)}{0.10}\, y_{t-3} \\ &- \underset{(0.09)}{0.19}\, y_{t-4} - \underset{(0.026)}{0.004}\, o_{t-1} - \underset{(0.026)}{0.027}\, o_{t-2} \\ &- \underset{(0.026)}{0.034}\, o_{t-3} - \underset{(0.027)}{0.065}\, o_{t-4}. \end{aligned}$$

The coefficient on the fourth lag of oil prices ($1o_t - 4$) is negative and highly statistically significant (t-statistic $= -2.4$), and an F-test leads to a rejection of the null hypothesis that the coefficients on lagged oil prices are all zero with a p-value of 0.005. Quite a few studies have tested and rejected the hypothesis that the relation between oil prices and output could just be a statistical coincidence, including Rasche and Tatom (1977, 1981), Hamilton (1983), Burbidge and Harrison (1984), Santini (1985, 1992), Gisser and Goodwin (1986), Rotemberg and Woodford (1996), Daniel (1997), Raymond and Rich (1997), Carruth et al. (1998), and Hamilton (2003).

Another possibility is that the correlation between oil prices and output results from common dependence on some third factor or factors that are the true cause of both the increase in oil prices and the subsequent recession. For example, something about the last stages of an economic expansion may often produce a surge in oil prices just before output is about to turn down, so that both the oil price increase and the subsequent recession result from the same business cycle dynamics. This is difficult to reconcile with the fact that, at least for the early post-war period, oil

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price changes could not be predicted from earlier movements in other macro variables (Hamilton 1983), and that most of the oil spikes can be attributed to exogenous events such as military conflicts (Hamilton 1985). However, Barsky and Kilian (2002, 2004) have recently developed challenges to the latter claim.

Predicted Size of Effects

Economic theory suggests that it is the real oil price rather than the nominal price that should matter for economic decisions. It does not make much difference in summarizing the size of any given shock whether one uses the nominal price o_t or the real price of oil, since in most of the shocks discussed here the move in nominal prices is an order of magnitude larger than the change in overall prices during that quarter. However, particularly in the early part of the sample, the nominal oil price would stay frozen for years and then adjust suddenly. To the extent that there is a difference between using nominal and real prices as the explanatory variable in such regressions, the real price results from the confluence of two forces: events such as the Suez crisis, which accounts for almost all of the movement in the nominal price between 1955 and 1965, and the quarter-to-quarter change in inflation, which is completely endogenous with respect to the economy and whose consequences for future output are likely to be quite different from those of an oil shock. In so far as the statistical exogeneity of the right-hand variables is important for interpreting the regression, many researchers have for this reason used the nominal oil price change rather than the real oil price change as the explanatory variable.

One simple framework for thinking about what the effects of energy supply disruptions should be comes from examining a production function relating the output Y produced by a particular firm to its inputs of labor N, capital K, and energy E:

$$Y = F(N, K, E).$$

Suppose that output is sold for a nominal price P dollars per unit, labour is paid nominal wage W, energy's nominal price is Q, and capital is rented at nominal rate r. The profits of the firm are given by

$$PY - WN - rK - QE.$$

A price-taking profit-maximizing firm would purchase energy up to the point where the marginal product of energy is equal to its relative price,

$$F_E(N, K, E) = Q/P,$$

where $F_E(N, K, E)$ denotes the partial derivative of $F(\,)$ with respect to E. If we multiply both sides of the above equation by E and divide by Y, we find

$$\frac{\partial \ln F}{\partial \ln E} = \frac{QE}{PY}.$$

In other words, the elasticity of output with respect to a given change in energy use can be inferred from the dollar share of energy expenditures in total output.

This dollar share for the economy as a whole is fairly small. For example, in 2000 the United States consumed about 7.2 billion barrels of oil. At a price of $30 a barrel, that represents only 2.2 per cent of a $9.8 trillion nominal GDP. With the rapid price increases of 2003–5, that share has risen to 3.8 per cent of GDP. Table 1 reports Hamilton's (2003) values for the size of the supply disruptions associated with the five most important oil shocks, calculated from the magnitude of the drop in production in the affected countries. Kilian (2005) has more modest estimates based on his inference that production might have fallen even in the absence of the indicated events, and neither Hamilton's nor Kilian's figures take into account the fact that typically production increased in other parts of the world to make up part of the gap. Even using the ten per cent figure and a four per cent crude oil share, however, such

Oil and the Macroeconomy, Table 1 Exogenous disruptions in world petroleum supply, 1956–90

Date	Event	Drop as % of world production	Change in US real GDP (%)
Nov. 1956	Suez crisis	10.1	−2.5
Nov. 1973	Arab–Israel war	7.8	−3.2
Nov. 1978	Iranian revolution	8.9	−0.6
Oct. 1980	Iran–Iraq war	7.2	−0.5
Aug. 1990	Persian Gulf war	8.8	−0.1

Source: Hamilton (2003)

shocks would by the above calculation be predicted to reduce GDP by only 0.4 per cent. Table 1 also reports the amount by which US real GDP declined between the date of the oil shock and the trough of the subsequent recession, which trough usually was reached a little over a year after the oil shock. Since the US economy would grow 3.4 per cent during a typical year, these numbers imply declines of real GDP relative to trend in excess of four per cent, an order of magnitude greater than predicted by the factor share argument. Furthermore, Bohi (1991) failed to find statistically significant evidence that industries with greater energy factor shares suffered more than others in response to the oil shocks of the 1970s.

One would arrive at a similar prediction if one thought of the oil shock as an exogenous change in the price of oil rather than a decrease in the quantity supplied. Faced with an increase in fuel costs, one option a given consumer would always have would be to keep on buying as much gas as before and just pay the higher price, decreasing other expenditures as needed. The value of what is lost by such behaviour is given by $E \cdot \Delta Q$; or, to express this relative to total income PY,

$$\frac{E \cdot \Delta Q}{PY} = \frac{QE}{PY} \cdot \frac{\Delta Q}{Q},$$

in other words, the percentage change in oil prices $\Delta Q/Q$ is again multiplied by energy's value share QE/PY. This actually places an upper bound on the value of what the consumer loses, because, in so far as the consumer opts to reduce E rather than hold E fixed, it must be because the latter strategy is in fact an inferior option.

If these oil shocks did contribute to economic downturns, this would have to be attributed to the movements they induced in other factors of production rather than to the value of the lost energy input per se. Some modest adjustments of other factors would be anticipated in a frictionless neoclassical model, but these appear to be small. Kim and Loungani's (1992) real business cycle analysis suggested that oil price shocks could explain only a modest component of the variance of US output growth.

One modification that can make a difference is to replace the assumption of perfect competition with mark-up pricing. Rotemberg and Woodford (1996) showed that this can induce a response of labour utilization to an oil price shock that greatly amplifies the effects, with simulations in which a ten per cent increase in energy prices could lead to a 2.5 per cent drop in output six quarters later.

Another important margin is the capital utilization rate, as emphasized by Finn (2000), who was able to arrive at similar quantitative effects as Rotemberg and Woodford even under the assumption of perfect competition.

Other Mechanisms

Another explanation offered for the correlation between energy prices and output has to do with the role of monetary policy. Barsky and Kilian (2002, 2004) argued that a monetary expansion was the cause of much of the 1973–4 oil price increase, and that this monetary expansion also set the stage for a subsequent decline in output. Bernanke et al. (1997) took the view that the oil shocks were exogenous, but the Federal Reserve responded to them by raising interest rates in order to control inflation, with this monetary contraction itself the principal cause of the downturns. Hamilton and Herrera (2004) argued that the Bernanke, Gertler and Watson conclusion was due primarily to the fact that these authors omitted the biggest effects of oil shocks corresponding to the coefficients on o_{t-3} and o_{t-4} in the regression above. Leduc and Sill (2004) added sticky prices to a theoretical model generalizing the approach considered by Finn (2000), and concluded that monetary policy makes only a modest contribution. More empirically oriented studies also concluding that the oil shocks were more important than any monetary contraction include Dotsey and Reid (1992), Hoover and Perez (1994), Ferderer (1996), Brown and Yücel (1999), and Davis and Haltiwanger (2001).

A different class of explanations emphasizes the frictions in reallocating labour or capital across different sectors that may be differentially affected by an oil shock. For example, one common consequence of an oil price shock is a sudden drop in demand for certain kinds of cars, which leads to lower capacity utilization at affected plants (Bresnahan and Ramey 1993). Because labour and capital cannot move costlessly to alternative productive activities, the result is idle resources that can significantly multiply the effects described above. Manufacturing of transportation equipment is one of the industries most affected by oil shocks in the United States but has one of the lowest energy intensities, and thus is part of the reason that Bohi (1991) found no connection between energy intensity and output decline. Lee and Ni (2002) found that oil price shocks tend to reduce supply in oil-intensive industries but reduce demand in other industries such as autos. Davis and Haltiwanger (2001) found oil shocks reduce employment the most in industries that are more capital intensive, more energy intensive, and have greater product durability. Keane and Prasad (1996) documented significant differences across industries in the effects of oil shocks on workers' wages.

Hamilton (1988) and Atkeson and Kehoe (1999) provided theoretical analyses of the way in which technological costs of adjusting capital or labour can result in magnification of the disruptive effects of oil shocks. One of the key predictions of such models is that, unlike the factor share stories, the response of output to oil prices would not be log-linear. When oil prices go up, consumers may postpone their car purchases, but when oil prices go down, they do not go out and buy a second car. In fact, it is a theoretical possibility that, as a result of the output that is lost from trying to reallocate capital and labour, the short-run effect of an oil price decrease would actually be a decline rather than an increase in output.

Linearity

If one estimates a log-linear relation between GDP growth and lagged oil prices, the statistical significance of the relation falls as one adds more data (Hooker 1996), suggesting at a minimum that a linear relation is either mis-specified or unstable. For example, when the regression described above is re-estimated with data through 2005:II, the result is

$$\begin{aligned} y_t = {} & \underset{(0.11)}{0.69} + \underset{(0.07)}{0.28}\, y_{t-1} + \underset{(0.07)}{0.13}\, y_{t-2} - \underset{(0.07)}{0.07}\, y_{t-3} \\ & - \underset{(0.07)}{0.12}\, y_{t-4} - \underset{(0.006)}{0.003}\, o_{t-1} - \underset{(0.006)}{0.006}\, o_{t-2} \\ & - \underset{(0.006)}{0.002}\, o_{t-3} - \underset{(0.006)}{0.015}\, o_{t-4}. \end{aligned}$$

Although the t-statistic on o_{t-4} remains statistically significant with a p-value of 0.02, an F-test of the null hypothesis that all four coefficients on lagged oil prices are zero would be accepted with a p-value of 0.11. The size of the effect is substantially smaller as well – whereas the 1949–80 regression would predict that GDP growth would be 2.9 per cent slower (at an annual rate) four quarters after a ten per cent oil price hike, the 1949–2005 regression would predict only 0.7 per cent slower growth.

A number of authors have concluded that this instability is due to the nonlinearity of the relationship, with a linear relationship breaking down empirically when the huge oil price drops of 1985 failed to produce an economic boom. Loungani

(1986) and Davis (1987a, b) were the first to report evidence of nonlinearity of these relations, which they interpreted as implying that the effects of oil shocks resulted from sectoral shifts with costly reallocation of resources. Mork (1989) estimated separate coefficients on oil price increases and decreases, and found that the latter were statistically insignificantly different from zero.

To the extent that the oil shocks are operating through an effect on demand for items such as less fuel-efficient cars, the influence would depend not just on the size of the oil price increase but also the context in which it occurred. Lee et al. (1995) found that much better forecasts of GDP growth were obtained if one divided the oil price increase by the standard deviation of recent price volatility. Hamilton (2003) used a flexible parametric model to investigate the nature of this nonlinearity, and found support for the Lee, Ni and Ratti formulation as well as an alternative that looks at how much the oil price might exceed its previous three-year peak; if it does not exceed the previous three-year peak, no oil shock is said to have occurred. An OLS regression of quarterly GDP growth (quoted at a quarterly rate) on lags of this net oil price measure for 1949:II to 2005:II results in the following estimates:

$$
\begin{aligned}
y_t = {} & \underset{(0.12)}{0.87} + \underset{(0.07)}{0.24}\, y_{t-1} + \underset{(0.07)}{0.11}\, y_{t-2} - \underset{(0.07)}{0.08}\, y_{t-3} \\
& - \underset{(0.07)}{0.13}\, y_{t-4} - \underset{(0.012)}{0.009}\, o^{\#}_{t-1} - \underset{(0.012)}{0.014}\, o^{\#}_{t-2} \\
& - \underset{(0.012)}{0.009}\, o^{\#}_{t-3} - \underset{(0.012)}{0.031}\, o^{\#}_{t-4}.
\end{aligned}
$$

Here an F-test of the null hypothesis that all coefficients are zero is rejected with a p-value of 0.006, and a ten per cent increase in oil prices above their previous three-year high is predicted to reduce quarterly GDP growth (quoted at an annual rate) by 1.4 per cent.

Similar evidence of nonlinearity, with oil price increases reducing real output growth, has also been reported for a number of other countries by Mork et al. (1994), Cuñado and Pérez de Gracia (2003), and Jimenez-Rodriguez and Sanchez (2005).

Other Factors and Consequences

As noted by Kilian (2005), civil unrest in Venezuela in December 2002 led to a drop in production of 2.3 million barrels a day, representing 3.4 per cent of world production at the time. The net oil price series $o^{\#}_t$ reflected a surge in crude oil prices 20 per cent above their previous three-year high. Nevertheless, there was no discernible drop in GDP. Another surge in $o^{\#}_t$ of 18 per cent occurred in 2004:III, accompanied by a 1.3 per cent increase in world production, and a third surge of 21 per cent in 2005:I, accompanied by a 0.2 per cent increase in production, with no recession as of the time of this writing (August 2005). It is clear from the last two examples in particular that demand increases rather than supply reductions have been the primary factor driving oil prices over recent years. In so far as these demand increases resulted from global income growth, one wouldn't expect to see the sharp drop in consumer spending on other key items that accompanied the episodes in Table 1. At a minimum, the failure of a recession to result as of the time of this writing from the oil price increases of 2003–5 suggests that there is not simply a mechanical relation, even a nonlinear one, between oil prices and output. The experience is consistent with the claim that the key mechanism whereby oil shocks affect the economy is through a disruption in spending by consumers and firms on other goods and that, if this disruption fails to occur, the effects on the economy are indeed governed by the factor share argument.

Another potential macroeconomic effect of oil price shocks is on the inflation rate. The long-run inflation rate is governed by monetary policy, so ultimately this is a question about how the central bank responds to the oil shock. Hooker (2002) found evidence that oil shocks made a substantial contribution to US core inflation before 1981 but have made little contribution since, consistent with the conclusion of Clarida et al. (2000) that US monetary policy has become significantly more devoted to curtailing inflation.

See Also

- ► Cost-Push Inflation
- ► Inflation
- ► Real Business Cycles

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