Shares, Gaps and the Economy's Response to Oil Disruptions

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Abstract

Most previous studies have focused on whether oil price shocks cause economic recessions but fewer studies have investigated whether the impact of an oil price shock can be different under alternative economic conditions. Using an international data set of industrialized economies, this paper explores whether an economy relying more on oil or operating closer to full employment may be more vulnerable to an oil disruption. Although the results for oil dependence are ambiguous, the analysis does find a significant relationship between the impacts of an oil shock and how closely the economy is operating to its full-employment level prior to the disruption.

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1. Introduction

Oil-related disruptions have again captured the attention of policymakers and the public. Although the world economy was already beginning a downward slide, the September 2001 terrorist attacks caused stunning drops in consumer confidence and expanding unemployment (Virgo, 2001). During much of 2002 and early 2003, the invasion of Iraq cast a shadow over the economy because relatively small physical disruptions could escalate into large price shocks and serious economic consequences (Nordhaus, 2002). Oil prices did not spin out of control in either event, because oil producers and consumers had confidence in Saudi Arabia's ability to stabilize oil markets under the most likely military conditions and offset any likely disruptions with excess capacity. Without a rapid and unexpected escalation in oil prices, these events were unlike previous oil shocks. However, they were disruptive to the economy and they harbinger a future with a much higher likelihood of other oil price shocks, if the major oil producers should fail to provide this much-needed petroleum safety net.

When OPEC embargoed oil supplies in 1973, the world experienced widespread recession and unemployment. The pervasiveness and severity of the problem prompted a number of economic studies searching to explain and document the economy's response.[1] These studies uncovered a number of interesting results including: most post-war recessions were preceded by an oil price shock (Hamilton 1982), the economy responded to upward price shocks but not to downward price cuts (Mork 1989), and surprise events rather than mere volatility were more important to the economy (Hamilton 1996). Most studies focused exclusively on the issue of whether oil shocks caused economic recessions, and most studies (but not all) extracted their conclusions from the U.S.

experience. Few of the studies confirming causality between oil prices and economic recessions attempted to explore how the underlying economic conditions at the time of the disruption could influence the response of the economy.

This paper explores how underlying economic conditions can influence the economy's response to an oil disruption by using an international data set. This broader international experience appears to support the research showing a significant causality between oil prices and the economy. The main objective of the analysis, however, is to consider whether any particular economy's response can be attributed to underlying economic conditions. In particular, the analysis focuses on oil's share in the economy and on the size of the gap between actual and potential gross domestic product (GDP).

Section 2 describes the data set and its stationary properties. Section 3 discusses the estimated coefficients from equations that specify a symmetric economic response to oil price increases and decreases. Section 4 considers the problem of asymmetric responses to oil price increases and decreases and explains how to test for these responses. Section 5 explains why oil shares and GDP gaps may be important factors in several alternative explanations for the economic impacts of oil shocks. The next two sections review the estimated coefficients from specifications that include these factors, while the last section concludes with a discussion about how another oil shock today might affect economic growth.

2. International Economic and Oil Price Data

The analysis is based upon an international data set of real gross domestic product (GDP) per capita for 14 major, industrialized economies[2] over the 1960-98 period that was constructed by the US Bureau of Labor Statistics (BLS). Based upon national statistics collected within each country, BLS computes a purchasing power concept for GDP per capita in each country. They also adjust these national statistics to be consistent across all countries. Their approach provides a consistent data set for more than 500 annual observations (39 years times 14 countries=546). It is larger than the quarterly data set used by Hamilton (2001) and others investigating the quarterly response of the U.S. economy to oil shocks. Hamilton's quarterly data set included 212 quarters for one country, the USA, over the 1949-99 period. Although annual data does not allow one to test the cyclical properties of oil shocks, these cyclical variations are not the primary focus in this analysis. By shifting to this annual data, the analysis can incorporate consistent data that measures GDP accurately in purchasing power parity terms and that adjusts for important national differences in reporting economic activity.

The US refiners' acquisition costs for imported crude oil represents the world crude oil price.[3] Following Mork, Mysen, and Olsen (1994), we use a single world price for all countries. Prior to 1968, the series was extended backwards to 1960 by using the first crude oil price for the United States. In 1968, the two prices were nearly identical so that this approximation appears justified.

Table 1 shows that the logarithm of crude oil prices is not stationary. Tests include a trend variable. However, the series is stationary when converted to first differences, excluding the time trend. In the next section, this price will be decomposed into components depending upon whether the price is rising to a new maximum, recovering from a previous dip, or falling. Finally, Table 1 shows that GDP for each country generally shows similar patterns. Only the US data appears stationary in logarithmic levels. However, all data but Japan appears stationary when expressed in first differences.

3. Symmetric Responses to Oil Price Changes

The (logarithmic) levels of GDP per capita and crude oil prices may still be included in an equation if they are cointegrated. However, the Johansen specification[4] did not confirm cointegration. One approach for handling these variables would be to estimate the relationship in first differences because the change in the variables do not display unit roots. Following previous studies cited earlier, we adopt this same approach.

Researchers estimating equations with quarterly data generally use four quarterly lags in their VAR equations. If a similar time pattern is adopted here, the equations for crude oil prices and GDP per capita would include only a yearly lag. A single pooled equation, with fixed country effects, was applied to the data and estimated in a first-difference, log-linear form:

$$dy_{i\,t} = \alpha_i + \beta\, dp_{it-1} + \delta\, dy_{i,t-1} + \varepsilon\,, \tag{1}$$

where dy refers to the logarithmic change in gross domestic product per capita, dp is the logarithmic change in world crude oil price, ε is the disturbance term, and *i* and *t* refer to country and year, respectively. The set of country-specific constants, α_i, allows each country to grow at a different rate.

The symmetric specification allows crude oil price changes to have the same effect on GDP regardless of whether they are rising or falling. The results in the first column of Table 2 show that this equation produces a first-year elasticity of –0.02. This initial effect is magnified by another 25 percent in the second year, as GDP in the second year declines in response to the fall in GDP in the first year.

4. Decomposing Oil Prices

Other researchers have used a variety of techniques to separate positive from negative oil price changes. Mork (1989) includes separate variables for price increases and decreases, while Hamilton (1996) defines a special variable that equals the price change when oil prices are sustained above their previous maximum level. A third approach is the method used in several studies of the price elasticities for agricultural supply and energy demand.[5] It separates price changes into various categories depending upon whether prices are increasing or decreasing and whether they remain above or below their previous maximum level. Gately (1992) and Gately and Huntington (2002) decompose the response to oil prices into three separate components: the responses to the highest maximum price level, to price cuts below the historical peak, and to price recoveries rising back towards the peak.

The most direct approach for implementing this price decomposition method in a first-difference equation would be to separate the price change variable into three separate components. The maximum price change (dP_{max}) would equal the price change if prices are pushing towards a new high level and would equal zero otherwise. Similarly, the price cut (dP_{cut}) and price recovery (dP_{rec}) variables would equal the price change if prices were falling or rising back towards the previous peak. Otherwise, they would be zero.[6] When summed, these three price components (in logarithms) would equal the original price series

$$dP_t = dP_{max,t} + dP_{cut,t} + dP_{rec,t}\ ; \qquad (2)$$

Note that GDP per capita should be inversely related to positive oil price increases or to negative oil price decreases. These decomposed price terms can be tested separately to determine their individual significance.

When the equation with asymmetric responses for the three different price components was estimated, we obtained a positive but insignificant price-cut coefficient. Dropping this variable did not change the coefficients for the other variables very much. The second column of Table 2 shows the results for the GDP equations using the two price series for maximum and recovering price increases. A Chi-square statistic of 0.277 in the Wald test cannot reject the hypotheses that the two remaining price increase variables have equal coefficients. As a result, these two series are replaced by a single price variable that equals the increase in oil prices, regardless of whether it is reaching a new maximum or recovery from a recent decline. These results are displayed in the third column of results under the label "positive". After the first year of a sustained 10 percent oil price increase, real GDP would be .32 percent lower than otherwise.

In more recent years, the oil price changes have been neither sudden nor exogenous events such as political or military turmoil. For example, oil prices rose strongly over the 1998-200 period as a result of strong economic growth. If oil prices are endogenously and positively correlated with economic growth, they will be positively correlated with the error term for the gross domestic product variable. Estimates of the oil price coefficient that do not control for exogenous events will tend to understate the negative response of GDP to exogenous oil prices.

Hamilton (2000) uses an instrumental-variable technique to control for exogenous oil price shocks, where the instrumental variable equals the shortage in world production at the beginning of a disruption. When his shortage variable is used to estimate oil price changes with our equations and the newly constructed oil price variable is then used to estimate the GDP response, the analysis shows a slightly better fit and a higher elasticity. The response is -.044 in the instrumental specification, -.032 in the asymmetric specification, and -.020 in the symmetric specification. Similar results were also obtained using a shortage variable based upon those reported by the U.S. Energy Information Administration[7], although Hamilton's variable is preferable because it measures the shock at the beginning of the disruption while the EIA variable measures the average shortage over the entire disruption. This latter measure will include any endogenous responses that occur in response to the initial disruption. Overall, the instrumental-equation results are not fundamentally different from those in the asymmetric specification, a result that Hamilton also found.

5. Shares and Gaps: Conceptual Issues

The previous equations follow the pattern established in previous studies of expressing changes in real GDP per capita as a function of changes in the price of crude oil. However, price shocks might have larger impacts when the economy is more dependent on oil or when it is operating closer to its full-employment level.

There are two leading explanations for the economywide impacts of an oil price shock that allow for an asymmetric effect between price increases and decreases. The first explanation relies upon downward price stickiness that temporarily prevents non-energy prices from falling when energy prices jolt upward unexpectedly. A higher aggregate price level reduces spending unless the nominal money supply is expanded. With a negative price shock, however, the other non-energy prices are not prevented by price stickiness from rising and thus offsetting the energy shock. This mechanism could explain the qualitatively different response to sudden energy price reductions.

If price stickiness and the increase in the aggregate price level are principal contributors to the resulting economic recession, an oil price shock will have a larger impact when the oil share of GDP is larger, *ceteris paribus.* Moreover, if laborers and firms pass through an external price shock based partly upon the excess labor and commodity conditions, these impacts will be larger when the economy is operating closer to full employment (Gordon 1975).

The second explanation for the economic impacts is that either oil shock increases or decreases create distortions in demand between products and sectors and that it is costly to transfer resources quickly (Hamilton 2000). Price increases will create adjustment costs that exacerbate the negative effects of oil price increases on production, whereas price decreases will create adjustment costs that partially offset the positive effects of oil price decreases on production.

If distortions in product demand and adjustment costs provide the mechanism for oil price changes, the size of the oil price dislocation measured partly by its relative importance in the economy will also be important. Moreover, it may be more costly to shift resources between sectors when resources are more fully utilized in a full-employment economy than when resources are slack at the time of the shock. Therefore, oil shares and GDP gaps may also influence the economic response with this explanation as well.

The analysis weights oil prices by the oil consumption share rather than the oil import share for several reasons. Although the import share was widely considered the relevant criteria after the first OPEC embargo, fewer economists today think of a petroleum disruption as a tax imposed by foreign oil owners. In addition, countries that produce some of their total oil used (e.g., the United States) and countries that export some oil (e.g., Norway and Great Britain) appear to suffer as badly as countries that import all of their oil.

Including the oil consumption share as an independent variable assumes that the economies do not differ markedly in their capacity to substitute other inputs for energy in response to higher oil prices. An oil disruption will not necessarily harm an economy with a higher consumption share more, if it also has more flexibility to substitute inputs than other countries. Big differences among countries in the elasticity of substitution between oil and other inputs are unlikely to be observed for the short term under investigation here, although the longer-run situation could be quite different.

6. Oil Shares: Estimation

The oil-share variable is constructed as

$$S\,dp = (Q/Y)\,dp\,, \tag{3}$$

where Q is total annual oil consumption per capita, Y is real GDP per capita, and dp is the logarithmic change in crude oil prices. This shares-weighted variable could be constructed only for the 1966-98 period due to the availability on oil consumption data.

When weighted oil prices enter the equation along with unweighted oil prices, the results in the first column of Table 3 show that it is difficult to separate the two effects. The weighted series is strongly collinear with the unweighted price variable. This collinearity results from the fact that oil price shocks are larger percent changes in the earlier part of the period (1973), when oil shares in each country were also higher, than they were later (1990). A long-term trend towards declining oil shares over time, perhaps accentuated by price shocks and government policies like automobile efficiency standards, tend to reduce the oil shares in each country.

The next two columns show the estimated coefficients when each price variable is entered separately. There is no solid support for preferring one specification over the other equation. Although the unweighted approach produces an equation with a slightly higher explanatory power, the differences are not large. Given the intuitive appeal of the shares approach, we will discuss the implications of the estimates in column (2) for the effect of oil prices on the economy, although the results do not necessarily support one interpretation over another.

7. GDP Gaps: Estimation

The International Monetary Fund (2000) provides estimates of the GDP gap for the 1970-98 period. The GDP gap is measured as the difference between actual and potential GDP (a negative number), divided by potential GDP.[8] Therefore, when actual

GDP grows relative to potential GDP, the measured gap becomes less negative and it therefore increases. Thus, the measured gap is directly related to actual GDP. Since the economy will be more responsive to oil shocks when total spending is higher, we expect a negative response between GDP and the gap-weighted oil price.

When the gap-weighted oil price variable is included with unweighted oil prices, both coefficients are significant and negative and the equation has a higher explanatory power than when either variable by itself is included. These results, shown in the last column of Table 3, indicate that oil price shocks retard economic growth and that its effect is greater when the difference between actual and potential GDP is less at the time of the disruption.

8. Implications

Sudden and exogenous oil price shocks have reduced economic activity in a range of industrialized countries over the last several decades. Our average estimates across all the countries suggest that GDP would be about 3.7% lower for a doubling of the oil price.

However, there are reasons to expect that the economic response may be greater if an economy relies more upon oil or if it is operating closer to full-employment conditions at the time of the shock. This analysis finds evidence for the latter hypotheses about GDP gaps but not necessarily for the former one about oil shares.

Since oil shares are lower and the gap between actual and potential GDP are higher today than they have been over the last several decades, the response to an oil shock given current conditions may be less than that implied assuming a constant-elasticity approach. Table 4 summarizes the impacts for each country assuming that the economic response depends upon oil shares and GDP gaps.[9] In each case, oil shares and GDP gaps are taken for 1998, the most recent year in our data sample. When oil impacts are related to oil's share, the GDP response in these countries would range from –1.1% to -2.8% for a doubling of oil prices and would equal –2.3% for the United States. When oil impacts are related to the initial GDP gaps, the GDP response in these countries would range from –0.5% to –3.6% for a doubling of oil prices and would equal –1.5% for the United States. All of these impacts are noticeably less than the -3.7% response computed without accounting for different oil shares and GDP gaps by country.

References

Brown, Stephen P. A. and Mine K. Yucel, "Energy Prices and Aggregate Economic Activity: An Interpretative Survey." *Quarterly Review of Economics and Finance*, 42 (2002), 193-208.

Bureau of Labor Statistics, *Comparative Real Gross Domestic Product Per Capita and Per Employed Person, Fourteen Countries, 1960-1998,* Washington, DC: U.S. Department of Labor, Office of Productivity and Technology (March 30, 2000).

De Masi, Paula "IMF Estimates of Potential Output: Theory and Practice," *Working Paper of the International Monetary Fund*, No. 97/177 (December 1997).

Gately, Dermot, "Imperfect Price-Reversibility of U.S. Gasoline Demand: Asymmetric Responses to Price Increases and Decreases," *Energy Journal* 13 (1992), 179-207.

Gately, Dermot and Hillard G. Huntington, "The Asymmetric Effects of Changes in Price and Income on Energy and Oil Demand," *Energy Journal* 23 (2002), 19-55.

Gordon, Robert J., "Alternative Responses of Policy to External Supply Shocks," *Brookings Papers on Economic Activity (1975, 1): 183-204.*

Hamilton, James D., "What is an Oil Shock?" *Journal of Econometrics* 113 (2003) 363–398.

Hamilton, James D., "This is What Happened to the Oil Price-Macroeconomy Relationship." *Journal of Monetary Economics* 38 (1996), 215-220.

Hamilton, James D. "Oil and the Macroeconomy Since World War II." *Journal of Political Economy* 91 (1983) 228-248.

International Monetary Fund, The World Economic Outlook (WEO) Database, September 2000. http://www.imf.org/external/pubs/ft/weo/2000/02/data/index.htm

Mork, Knut Anton, “Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton’s Results.” *Journal of Political Economy* 97 (1989), 740-744.

Mork, Knut Anton, Hans Terje Mysen, and Øystein Olsen “Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries.” *The Energy Journal* 15 (1994).

Nordhaus, William, "Economic Consequences of a War in Iraq," in *War With Iraq: Costs, Consequences and Alternatives,* Cambridge, MA: American Academy of Arts and Sciences (2002).

Traill, Bruce, David Colman, and Trevor Young, “Estimating Irreversible Supply Functions,” *American Journal of Agricultural Economics* 60 (Aug. 1978), 528-31.

US Energy Information Administration, *Annual Energy Review 2000*, (Washington, D.C.: US Government Printing Office, 2000).

Virgo, John M., “Economic Impact of the Terrorist Attacks of September 11, 2001,” *Atlantic Economic Journal* 29(4) (2001), 353-357.

Wolffram, Rudolf, “Positivistic Measures of Aggregate Supply Elasticities: Some New Approaches-Some Critical Notes,” *American Journal of Agricultural Economics* 53(2) (May 1971): 356-59.

Table 1: Summary of Unit Root Tests

Variable	Levels With Trend	First Differences, No Trend
Crude Oil Price	-0.975	-3.588 *
GDP per capita		
United States	-3.910 *	n.a.
Canada	-2.481	-3.594 *
Japan	-1.629	-1.846
Korea	-2.926	-3.441 *
Austria	-1.173	-3.285 *
Belgium	-2.001	-3.107 *
Denmark	-2.591	-4.874 *
France	-1.579	-2.804 *
Germany	-2.110	-5.259 *
Italy	-1.738	-4.205 *
Netherlands	-2.148	-3.251 *
Norway	-2.128	-4.464 *
Sweden	-2.418	-3.632 *
United Kingdom	-3.226	-4.446 *

* Significant at 95% level.

Table 2. Estimated Coefficients With Symmetric and Asymmetric Specifications
(Standard errors appear in parentheses)

	(1) Symmetric	(2) Asymmetric	(3) Positive	(4) Instrumental
Lagged GDP per capita	0.254 *	0.232 *	0.232 *	0.258 *
	0.043	0.043	0.043	0.042
Oil Price	-0.020 *		-0.032 *	-0.044 *
	0.004		0.005	0.005
Price-Maximum		-0.032 *#		
		0.005		
Price-Recovery		-0.029 *#		
		0.014		
Adjusted R-squared	0.253	0.276	0.277	0.301
Durbin-Watson	1.904	1.878	1.881	1.921

* Significant at 95% level.
# Price coefficients are not statistically significant from each other at 95% level (Chi-square=0.028).

Table 3. Estimated Coefficients for Specifications Incorporating Oil Shares and GDP Gaps

(Standard errors appear in parentheses)

	Oil Share			Gap
	(1)	(2)	(3)	(4)
Lagged GDP per capita	0.217 *	0.221 *	0.217 *	0.153 *
	0.046	0.047	0.046	0.050
Oil Price Increase	-0.046 *		-0.030 *	-0.019 *
	0.018		0.0047	0.0055
Weighted Increase	13.620	-23.610 *		-0.342 *
	15.207	3.950		0.121
Adjusted R-squared	0.293	0.284	0.293	0.279
Durbin-Watson	1.817	1.813	1.814	1.786

* Significant at 95% level.

Table 4. Inferred GDP Response to Oil Price Increase Based Upon 1998 Oil Shares and GDP Gaps

Country	Share	Gap
United States	-0.023	-0.015
Canada	-0.021	-0.008
Japan	-0.015	-0.026
Korea	-0.028	-0.036
Austria	-0.011	-0.016
Belgium	-0.023	-0.014
Denmark	-0.015	-0.021
France	-0.013	-0.010
Germany	-0.013	-0.017
Italy	-0.013	-0.013
Netherlands	-0.020	-0.019
Norway	-0.016	-0.035
Sweden	-0.016	-0.005
United Kingdom	-0.012	-0.021
Constant Response	-0.037	

Footnotes

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[1] Brown and Yucel (2002) survey the available literature.

[2] The countries are listed in Table 4 below.

[3] The source for refiner's acquisition costs and first crude oil price was US Energy Information Administration (2000).

[4] The two-step, error-correction approach of Engle and Granger also confirms this result.

[5] Wolffram (1971), Traill, Colman and Young (1978), Gately (1992), and Gately and Huntington (2002).

[6] The Gately-Huntington (2002) decomposition computed the *cumulative* changes in price in each category from the first year in the sample rather than the price change between the current and preceding periods for each component.

[7] The Energy Information Administration disruption estimates are available at http://www.eia.doe.gov/security/distable.html.

[8] Measured potential output and output gaps need to be interpreted carefully because they incorporate some degree of imprecision (De Masi, 1997). The IMF uses a production-function approach to estimate potential output rather than univariate techniques.

[9] The impacts are second-year responses and include the effect of lower GDP in the previous year on current GDP. The shares-adjusted effects are based upon the equation shown in counn 2 of Table 3. The gap-adjusted effects are based upon the equation shown in column 4 of Table 3.