Federal Reserve Bank
of San Francisco

Fall

1986

Economic Review

Number

4

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The Federal Reserve Bank of San Francisco's Economic Review is published quarterly by the Bank's Research and Public Information Department under the supervision of John L. Scadding, Senior Vice President and Director of Research. The publication is edited by Gregory J. Tong, with the assistance of Karen Rusk (editorial) and William Rosenthal (graphics).

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Oil Prices, Exchange Rates and the U.S. Economy: An Empirical Investigation

Bharat Trehan*

In general, research on the impact of oil price shocks on the U.S. economy has assumed that oil price changes are exogenous — determined almost exclusively by the actions of OPEC. This paper uses vector autoregressions to demonstrate that the foreign exchange value of the dollar has a substantial impact on the price of oil. Thus, the practice of using changes in the dollar price of oil as a measure of the underlying supply shocks is likely to exaggerate the effects of exogenous oil price changes.

Research on the effects of oil supply shocks on the United States' economy has assumed that changes in the price of oil are exogenous, determined largely by the actions of OPEC. Significant historical episodes seem to support this assumption. For instance, oil prices approximately tripled in both 1973 and 1979 as a result of OPEC's decision to curtail the supply of oil. This assumption of exogeneity is critical, because it permits researchers to associate changes in the price of oil with shocks to its supply. Researchers can then determine the effects of a shock to the supply of oil simply by looking at the response of the economy to a change in the price of oil.

In this paper, we demonstrate that it is incorrect to treat all changes in the dollar price of oil as exogenous. More specifically, we show that the foreign exchange value of the dollar has a substantial impact on the dollar price of oil. This result has important implications. First, exclusion of the exchange rate in any study of the impact of oil supply shocks will lead to incorrect estimates of the effect of oil price changes on the economy since some of the effects of exchange rate changes will be attributed to oil price changes. Second, the existence of exchange rate effects implies that changes in the price of oil cannot always be associated with exogenous supply shocks but must be recognized as the result of a mix of factors. Thus, changes in the price of oil should not be used as a measure of supply shocks.

We examine these issues using a statistical technique known as vector autoregressions (VARs). This approach is "atheoretical" in the sense that it does not use economic theory to impose any restrictions upon how different variables should interact with one another. In addition, it treats all variables as determined within the system itself — a feature whose importance will be evident below. This technique is well-suited for the issues at hand because shocks to oil supply affect the economy through several channels (see the discussion in Section II). Because of the multiplicity of channels and the lack of prior knowledge about their relative importance, the more conventional technique of placing specific restrictions upon the ways that a supply shock will affect the economy is likely to distort the empirical results.

A number of previous empirical studies have examined the relationship between oil price changes and the U.S. economy using VARs but none of them take the exchange rate into account.[1] For instance, Hamilton (1983) showed that the price of oil has predictive power for real GNP, the GNP deflator, and a host of other variables, but that the oil price is

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not affected by them. His results suggest that oil price changes are determined by considerations external to the U.S. economy, and that oil price increases have contributed significantly to business cycles in the U.S. in the post World War II period.[2,3] Burbidge and Harrison (1984) also present evidence supporting the view that oil prices have had a significant impact upon both industrial production and the consumer price index in the U.S.

Below, we present some empirical evidence on this issue. Section I focuses on the relationship between the exchange rate and the price of oil. It contains a discussion of why changes in the value of the dollar will have an effect on the price of oil, as well as some empirical tests of this relationship. Section II then demonstrates how the measured impact of oil price changes on the U.S. economy is sensitive to the inclusion of exchange rates. In that section, we first discuss what economic theory tells us about the impact of oil price shocks on the economy and what the historical experience has been in terms of both oil supply shocks and exchange rate changes. Empirical results follow. Section III contains the conclusions.

I. The Dollar and Oil Prices

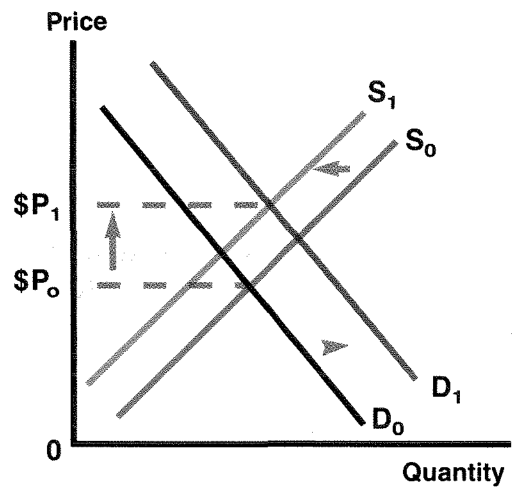
Crude oil traded in world markets is priced in dollars. This fact has important implications for the relationship between the value of the dollar and the price of oil because oil importers who do not use the dollar as currency must, in effect, obtain dollars to purchase oil. Thus, if the value of the dollar changes, the price they pay in terms of their own currencies will change. For similar reasons, oil exporters will also not be indifferent to fluctuations in the value of the dollar.

To understand the way in which a change in the value of the dollar affects the price of oil, consider the figure below. Assume that the curve labeled D_0 represents the demand for oil by the oil importers and the curve labeled S_0 represents oil supply. The world market for oil is then at equilibrium when the price of oil is $\$P_0$ per barrel.

Now suppose that the dollar falls in value against the currencies of other oil-importing nations and against the currencies of the oil exporters. If the dollar price of oil remains unchanged, the other oil-importing countries will find that the price of oil in terms of their own currencies has declined. Consequently, their consumption of oil will go up. In terms of the diagram, the demand curve for oil will shift to the right. It is worth pointing out that this increase in demand at an unchanged dollar price occurs only because oil is priced in dollars. If oil were priced in yen, for instance, a decrease in the value of the dollar would actually lead to a decrease in the U.S. demand for oil. The demand for oil by other oil-importing countries would not be affected.

A change in the value of the dollar affects the supply of oil as well. If the dollar falls, oil exporters will discover that the price of oil in terms of their own currencies has declined. Consequently there will be a contraction in the quantity of oil supplied at the prevailing dollar price.[4] In the diagram above, this is shown as a leftward shift in the supply curve for oil. To equate demand and supply, the dollar price of oil will then increase from P_0 to P_1. In the same way, increases in the value of the dollar would set into motion declines in the dollar price of oil.

The Effect of a Decline in the Value of the Dollar on the Price of Oil



There are, of course, other factors that determine the price of oil. The ability of the members of OPEC to act in concert was the primary reason that oil prices approximately tripled in both 1973 and in

1979. The preceding discussion is not meant to deny a role to OPEC, but to point out a role for the dollar. For instance, it is difficult to believe that OPEC does not take the value of the dollar into account when setting the dollar price of oil.

The discussion above has shown how changes in the value of the dollar affect the price of oil. While we have not discussed what factors influence the value of the dollar itself, this should not be taken to imply that the dollar is immune to developments in the U.S. and the rest of the world. In fact, the dollar reacts to factors such as differences in the rate of inflation between the U.S. and the rest of the world, interest rate differentials, and shocks to productivity. For example, many economists contend that an important reason for the depreciation of the dollar during the two periods 1971-72 and 1978-79 was the relatively loose monetary policy being followed by the U.S. during those years.

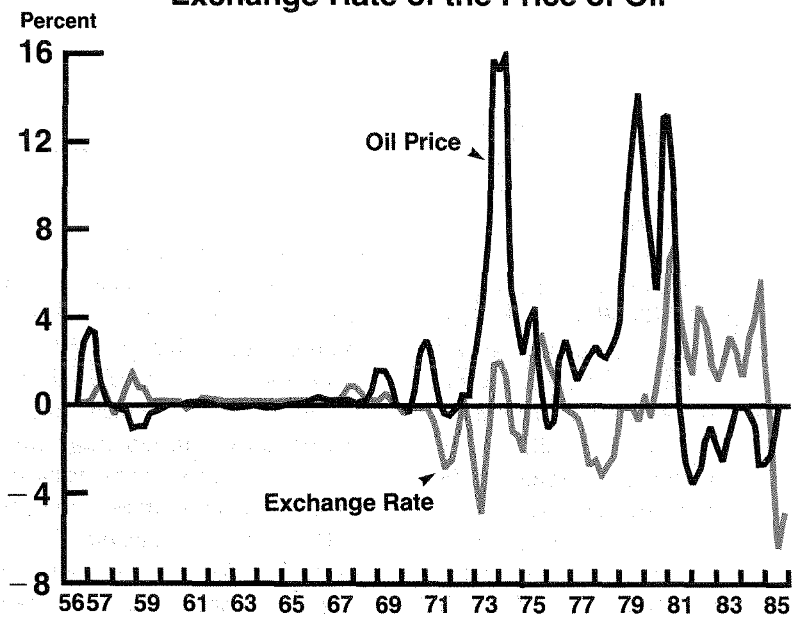
The Empirical Relationship

We now present some empirical evidence on the relationship between the dollar and the price of oil. We use the multilateral trade-weighted nominal exchange rate constructed by the Federal Reserve Board as our proxy for the value of the dollar.[5] This is not the precise empirical counterpart to the exchange rate in the discussion above. The exchange rate relevant to world oil demand would perhaps be one that used oil imports as weights. However, the data necessary to construct such an index is not readily available. Moreover, our results may not be very sensitive to the choice of index.[6] Consequently, the trade-weighted exchange rate is used here.

The measure of the oil price is the crude petroleum component of the producer price index. This measure is probably the most relevant to both real activity and inflation in the U.S. Both the exchange rate and the oil price measures have also been widely used in previous research on the U.S. economy.

Before examining the statistical relationship between oil prices and exchange rates, it seems useful to look at how the two variables have behaved over our sample period. Chart 1 shows the relation-

Chart 1
Quarterly Growth Rates* of the Nominal Exchange Rate of the Price of Oil



*3-quarter moving averages of the first difference of logs.

Vector Autoregressions

The techniques employed in this paper were developed by Christopher Sims to analyze interrelated variables. These techniques have been recommended as an alternative to traditional "structural" models, which restrict the relationships between different variables according to economic theory. Sims has argued that these restrictions are arbitrary because they are often imposed piecemeal and with a specific relationship in mind. As a result, structural models may sometimes distort the various interactions that exist in the data. A Vector Autoregression (VAR) imposes no restrictions on the dynamic relationships between different variables in the model, in effect allowing the data to speak for themselves.

Estimating a VAR is essentially a method of examining the relationship between a set of variables (a *vector*) and their past values (*autoregression*). Thus, estimating a two-variable VAR containing, say, the oil price and the exchange rate, involves estimating two equations: one for each variable, with each equation including past values of both variables on the right hand side. Notice that this implies that all variables in a VAR system are determined within the system. Provided certain assumptions are met, this method of estimation will lead to results with desirable statistical properties.

One issue that arises in estimation concerns the number of lags that must be included in the system. There are several tests available for determining the proper lag length, one of which is used in the text. However, alternative tests may not always provide the same answer. Data availability is sometimes an important constraint on lag selection as well, since the number of coefficients in a VAR increases rapidly as the lag length is increased. Consequently, econometricians may sometimes work with a small number of lags even if statistical tests suggest otherwise. Thus, selection of the number of lags to be included remains a subjective decision.

Statistical tests are used to check whether past values of a given variable are significant in a particular equation. For example, in the text, these tests are used to determine whether the lagged values of the exchange rate have predictive power in the oil price equation. If past values of the exchange rate are useful in predicting oil prices then the exchange rate is said to "Granger cause" the price of oil. The existence of Granger causality does not imply causation as it is commonly understood. Instead, it is possible for past values of one variable to have predictive power for another without the existence of a causal relationship.

The VARs estimated above are not easy to use in interpreting the dynamics of the system, often because of oscillating coefficients on the lags. A more useful way to study the dynamics is to examine how each variable responds to different disturbances to the system. But because the disturbance estimated from any one equation may affect several variables simultaneously, the measured disturbance cannot be treated as the disturbance to a particular variable. The researcher must choose a method to obtain disturbances that can be associated with specific variables.

The method employed in this paper is best illustrated in terms of a 3-variable VAR consisting of real GNP, the price of oil, and the GNP deflator. We first choose a particular ordering for the disturbance terms obtained from these equations. For instance, the disturbance to the oil price equation may be placed first, that to the GNP deflator second, and the disturbance to the real GNP equation last. Leaving the disturbance to the oil price equation unaltered,we then strip the disturbance to the GNP deflator equation of whatever variation it has in common with the first disturbance (that is, the oil-price disturbance). Next, we purge the third disturbance term (that is, the disturbance to the real GNP equation) of the variation it has in common with the first two disturbances.

The procedure outlined is one way of imposing a specific relationship upon contemporaneous values of the different variables in the VAR. In terms of the three variables in our example, it is equivalent to the assumption that an unpredicted change in the price of oil affects both real GNP and the GNP deflator in the same quarter, but that the price of oil is not affected by contemporaneous unpredicted changes in these two variables. Unpredicted changes in the GNP deflator (which is placed second) are allowed to affect real GNP in the current quarter, but unpredicted changes in real GNP have no contemporaneous impact on the GNP deflator.

Each of these modified disturbance terms can now be treated as the unpredicted change in one of the variables in the VAR. We then study how the different variables in the system react over time to these disturbances. The variables' responses are plotted in Charts 2 through 5 with one additional modification. To make it easier to compare the effect of different disturbances on a particular variable, the size of each disturbance has been set equal to its standard deviation over the sample period. Thus, each plot shows the dynamic response of a given variable to a particular standardized disturbance, with all other variables held fixed. For example, the left hand panel of Chart 2 shows the response of the price of oil over time to an unpredicted increase in the value of the dollar.

Clearly, the ordering imposed upon the disturbances is important. Reversing the ordering will change the disturbances obtained above, and, consequently, also change the estimated responses. Generally speaking, the results will be sensitive to whatever method the researcher uses to extract the "true" from the measured disturbances: the closer the relationship between the measured disturbances, the greater the sensitivity of the results to the method employed.

The tests discussed above provide a way to measure whether lagged values of a particular variable are significant in predicting any given variable. For example, one can test whether past changes in the price of oil are significant in predicting real output. However, even if they were found to be significant, the tests do not rule out the possibility that changes in the price of oil constitute only a small proportion of the total variation in real GNP. Useful information on this issue comes from the errors that the estimated VARs make in forecasting different variables. In particular, we look at how much of the forecast error for any variable in the VAR is due to a given disturbance.

The information obtained from this exercise is succinctly described by Sims (1982):

> A natural measure of the degree to which Granger causal priority holds is the percentage of forecast error variance accounted for by a variable's own future disturbances in a multivariate linear autoregressive model. In such a system, the k-step ahead forecast error for each variable is a linear combination of forecast errors 1 through k steps ahead in the variable itself and in other variables in the system. A variable that is optimally forecast from its own lagged values will have all its forecast error variance accounted for by its own disturbances.

In general, any variable that accounts for a large percentage of the forecast error variance of another variable will be useful in predicting the latter.

Early work using VARs is contained in Sims (1980) and Sargent and Sims (1977). For a technical introduction to VARs, the reader is referred to Hakkio and Morris (1984). For a critique of the VAR approach, see Cooley and LeRoy (1985).

ship between the growth rate of the oil price and the exchange rate using quarterly data from the second quarter of 1956 to the fourth quarter of 1985. Three-quarter moving averages have been used in the chart to smooth out fluctuations.

The chart shows that the price of oil was much more stable in the fixed exchange rate period than in the floating exchange rate period. Growth rates of both the exchange rate and the price of oil were close to zero prior to 1970 but have been much more volatile since then. In addition, both periods of extended drops in the dollar (approximately the periods 1970-73 and 1977-79 in the chart) were followed by substantial increases in the price of oil — the two oil price "shocks" — while the appreciation of the dollar in the first half of the eighties has been accompanied by falling oil prices. This pattern of co-movement between these two variables is

Table 1A

Summary Statistics
VAR Equations for Exchange Rates and Oil Prices

(Sample Period: 1959Q2 — 1985Q4)

Equation for:	Exchange Rate	Oil Price
F-test		
Explanatory Variables[1]	F-ratio (M.S.L.)[2]	F-ratio (M.S.L.)
Exchange Rates	1.44 (.16)	4.99 (.39 E-5)
Oil Prices	1.47 (.15)	1.67 (.09)
$R^2/\bar{R}^2$	.35/.15	.58/.46
SEE[3]	.0267	.039

[1]Regressions contain 12 lags of each variable.

[2]The F-statistic is calculated for the null hypothesis that the coefficients on all the lags of the variable in question are zero. M.S.L. is the Marginal Significance Level, which is the probability of finding an F-statistic greater than the computed statistic given that the null hypothesis is true. Conventionally used M.S.L.s are .05 and .10.

[3]SEE is the standard error of the estimate.

Table 1B

Decomposition of Variance

Forecasting Oil Prices

Percentage of variance of error due to disturbances to:

Quarters Ahead	Oil Prices	Exchange Rates
0	100	0
5	79	21
20	58	42

Forecasting Exchange Rates

Percentage of variance of error due to disturbances to:

Quarters Ahead	Oil Prices	Exchange Rates
0	9	91
5	15	85
20	23	77

what the analysis above would suggest.

The increase in the volatility of oil prices in the floating rate era is one piece of evidence supporting our hypothesis. Stronger confirmation is provided by the fact that periods of dollar depreciation have been followed by increases in the dollar price of oil, while an appreciation of the dollar has been followed by decreases in the dollar price of oil.

Results from VARs

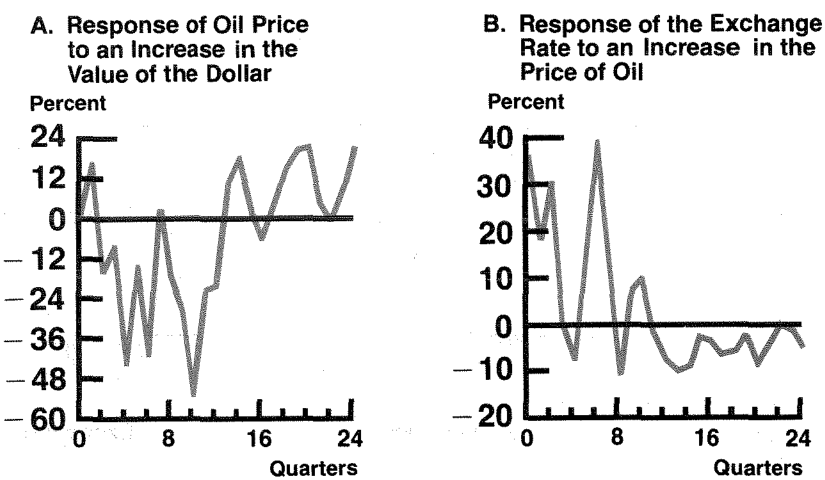
We now employ VARs to present some formal evidence for our hypothesis.[7] The results of the estimation are in Table 1A. They reveal that the exchange rate has predictive power for the price of oil, while the oil price is not very useful in predicting exchange rates. Approximately half of the variation in oil prices is unpredictable on the basis of past values of the exchange rate and the price of oil.

Chart 2 transforms the VARs in Table 1A and shows how exchange rates and oil prices react over time to a disturbance that could not have been predicted on the basis of their past values. The right hand panel, for instance, shows how the exchange rate reacts to a disturbance in the price of oil. One example of such a disturbance would be the Iran-Iraq war. The disturbances actually used in Chart 2 have been set equal to the standard deviation of the disturbances in each variable over the sample period. Thus, the plots represent the dynamic responses of each of the two variables to an "average" disturbance in the other variable.

The charts reveal that an unpredicted increase in the value of the dollar leads to a decline in the price of oil with a lag of approximately two quarters. The price of oil remains low for about three years after the shock, after which the response damps out. By contrast, the response of the exchange rate to a shock to the price of oil is relatively weak, although the dollar does show some evidence of appreciation.[8]

The evidence in Table 1A and Chart 2 demonstrates that changes in the dollar's value have a statistically significant impact on the dollar price of oil, and that an increase in the value of the dollar leads to a decline in the dollar price of oil. However, the results do not rule out the possibility that exchange-rate-induced changes in the price of oil constitute only a small proportion of the total varia-

Chart 2
Dynamic Responses
(Obtained from VARs in Table 1)



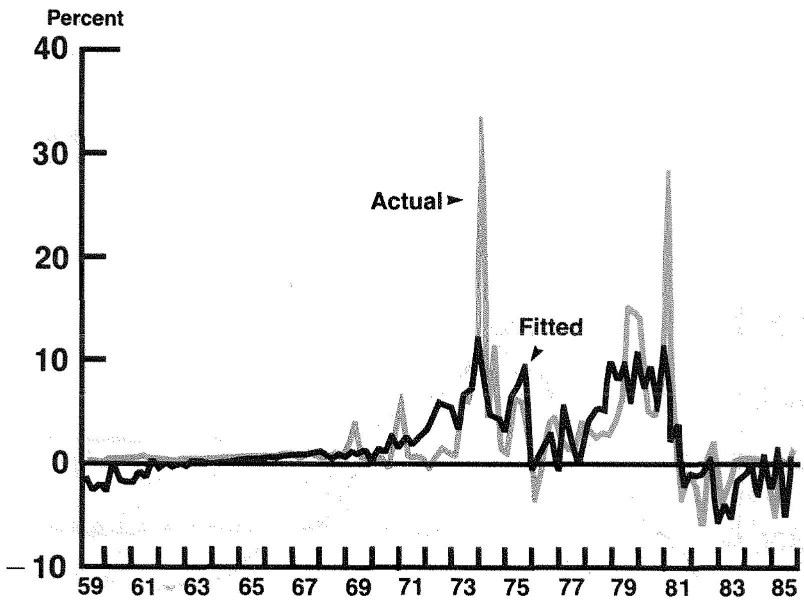
tion in the price of oil over the sample period. To examine this issue, consider the results in Table 1B. Disturbances to the exchange rate account for a progressively greater proportion of the variance of the error in forecasting the price of oil. At the twenty-quarter horizon, for instance, exchange rate disturbances account for 42 percent of the forecast error variance of oil prices.[9] These results imply that shocks to the exchange rate have been an important source of variations in the price of oil over the sample period.

Since exchange rate changes account for a substantial proportion of the changes in oil prices over the period sampled, it is natural to wonder about the role played by exchange rate changes during particular episodes within the period. More specifically, how much of the two oil price shocks of the 1970s can be predicted on the basis of past changes in exchange rates *alone*?

To answer this question, the growth rate of oil prices was regressed on past growth rates of the exchange rate.[10] Chart 3 shows the growth rate of oil prices and the fitted values obtained from estimating the equation over 1959Q2-1985Q4. The equation tracks changes in the growth rate of oil prices reasonably well. It reveals that oil prices would have been expected to increase over the periods 1973-74 and 1978-81 on the basis of the relationship between oil prices and exchange rates alone. Needless to say, the equation does not explain the entire increase in oil prices during those periods. The equation also suggests that oil prices should have declined over the period 1981-1985.

A common criticism of exercises of this sort is that the estimated equation has simply correlated changes in the two variables. Consequently, while such an equation provides a reasonable fit over the sample period, it is not likely to perform very well in explaining events beyond the period over which it was estimated. To test this proposition, the same equation was estimated from 1959Q2 to 1978Q4, that is, up to the year before the second "oil shock".[11] The coefficients from this equation and the actual values of the exchange rate from 1979Q1

Chart 3
Actual and Fitted* Values of the Growth Rate of the Price of Oil



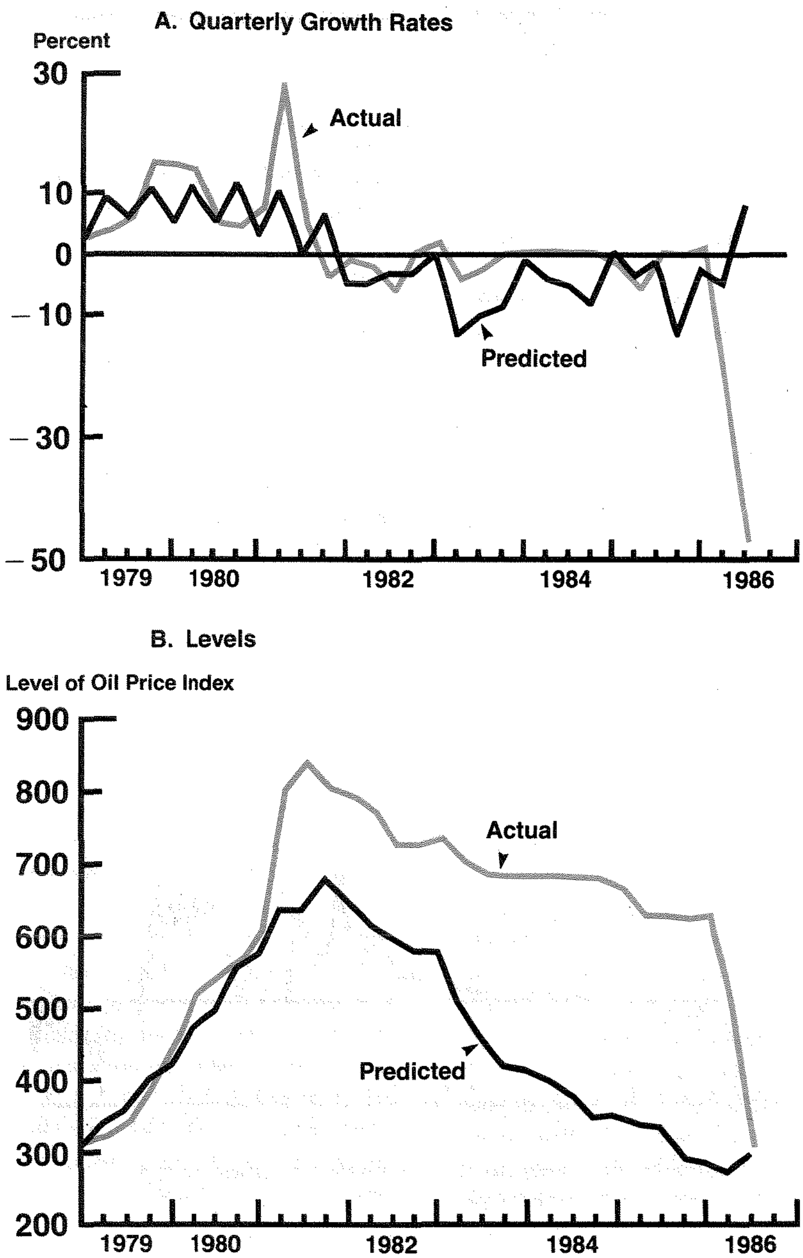
Fitted values obtained by regressing oil price on lags of exchange rate only.
See footnote 10 for details.

onwards were used to "predict" the price of oil through the second quarter of 1986.

Chart 4A shows the results of this exercise. The equation predicts increases in the price of oil through the end of 1981, and decreases in the price of oil through the first quarter of 1986. This pattern is consistent with the actual changes in oil prices over this period, although the equation does underpredict the increases in the pre-1982 period (most noticeably in the first quarter of 1981) and predicts sharper decreases in the price of oil than actually occurred in the three years afterward. The equation

Chart 4

Actual and Predicted* Values of the Price of Oil



also misses the large fall in oil prices in the second quarter of 1986, when it predicts a small increase.

Chart 4B transforms these results to express them in terms of the level of oil prices. The predicted values track the actual price of oil quite closely until the fourth quarter of 1980, but miss the large increase that took place in the first quarter of 1981. It is perhaps significant that the Iran-Iraq war began in September 1980. The equation correctly predicts declining oil prices from the third quarter of 1981 onwards, but a faster pace of decline than what actually occurred. The large drop in oil prices that took place over the first half of this year actually brings oil prices back into line with those predicted by the equation.

While these results should not be interpreted to imply that the exchange rate is the only variable that matters for the price of oil, they do offer strong evidence that the exchange rate is an important determinant of oil prices. Since it is well-known that the exchange rate itself is influenced by a host of developments both in the U.S. and abroad, the results imply that oil price changes cannot always be regarded as exogenous to economic developments.

II. Oil Prices and Economic Activity

The results demonstrating that changes in the exchange rate have a substantial effect on the price of oil have, in turn, important implications for studies that attempt to estimate the impact of oil supply shocks on the U.S. economy. They imply, first, that studies that omit exchange rates will mismeasure the impact that oil supply shocks have on the economy since some of the impact of exchange rate changes will be attributed to oil price changes. Second, they imply that it is incorrect to use changes in the price of oil as a measure of the underlying supply shock because some of these price changes are caused by other factors. Thus, studies that attempt to analyze the effects of oil supply shocks must first isolate the component of oil price changes that is not due to these factors. Before proceeding to an empirical examination of these issues, we review the channels through which a shock to the supply of oil will affect the economy.

Effects of Oil Supply Shocks

Along with labor and capital, energy is an input to the production process. Oil in turn is an important component of total energy sources. An increase in the price of oil due to an OPEC shock to supply will force business firms to economize on the use of oil. Since close substitutes for oil are not readily available, this will lead to a reduction in energy input and a consequent decline in aggregate supply.

There will be other effects as well. Analysts have often likened exogenous increases in the price of oil to a tax increase for consumers that leads to a reduction in demand. An increase in the price of oil also redistributes income between the U.S. and the rest of the world because the U.S. is a net importer of oil. Within industry, profits are redistributed from oil-consuming to oil-producing firms.

The last effect reveals an aspect that is potentially important when trying to determine the net impact of oil supply shocks on economy-wide output. Just as oil consuming industries react to an exogenous increase in the price of oil by reducing output, industries involved in the production of oil will react by increasing output. They do so because the higher price of oil makes it profitable to engage in both exploration and drilling for oil in locations where it was previously unprofitable to do so. An increase in the level of activity by firms directly engaged in the production of oil leads, in turn, to increased production in industries that supply these firms with inputs. Similarly, an exogenous decrease in the price of oil will force a contraction in the output of industries involved in producing oil.

Thus, the overall effects of any exogenous change in the price of oil on real output will depend upon the relative magnitude of the effects on the oil-consuming and oil-producing sectors. While previous research has focused upon the impact of exogenous oil price changes on oil-consuming sectors of the economy, recent evidence suggests that the impact upon the oil-producing sector may be substantial as well. In particular, experience over the short period since the oil price decline in early 1986 suggests that the immediate impact on oil producers may be large enough to outweigh the impact on oil consumers.

These considerations imply that using theory alone to predict the exact response of aggregate output to an exogenous change in the supply of oil would lead to a somewhat ambiguous answer. In contrast, the effect on the price level is unambiguous. An exogenous reduction in the oil supply leads to an increase in the price of oil and in the aggregate price level. (It is this increase in the price of oil that causes domestic oil producers to increase their output.)

We have contended that the omission of exchange rates will bias the measured impact that oil price changes have on the economy. To see what the precise effects will be, it is necessary to examine what economic theory tells us about the impact of exchange rate changes on the economy. Recall, first, that the sample period of this study includes two episodes of sharp increases in the price of oil. Oil prices almost tripled in 1973 and then again over the 1979-81 period. As Chart 1 indicates, both episodes were preceded by declines in the value of the dollar. The proximity of these dollar declines suggests that omitting the effects of the exchange rate changes would exaggerate the effect of oil price shocks.

For instance, theory tells us that an increase in the value of the dollar will lead to lower inflation. A higher dollar implies that the price of U.S. imports declines and that domestic producers must lower prices on goods sold in the U.S. In addition, if domestic producers are to remain competitive in world markets, they must reduce export prices as well. Similarly, when the dollar falls, the price of imports goes up. In addition to the direct impact on the price level, a decline in the dollar's value also allows domestic producers to raise prices on products that compete with imports. For our purposes, this implies that ignoring exchange rate effects will lead one to attribute the inflation that followed the dollar's depreciation in both the early and late 1970s largely to the oil price increases.[12]

Empirical Results

We now turn to a discussion of the formal empirical tests. In Table 2, we examine whether changes in the price of oil help predict changes in real output. To isolate the role played by different variables, we present a series of VARs. The first VAR looks at the relationship between real GNP and the price of oil alone and indicates that the price of oil is extremely significant in predicting real GNP. The reverse is true as well, that is, real GNP predicts the price of oil. Similarly, in the system consisting of oil prices and the GNP deflator, both variables "cause" each other. These conclusions hold up in the three-variable system as well, although in not as strong a form. The results reported in these VARs on the effect of oil prices on both real GNP and the price level are essentially similar to what has been reported in earlier studies.

To test our major hypothesis, we added the exchange rate to the VAR. The result of this addition is that the price of oil is no longer significant at conventional statistical levels in predicting real output. This finding is consistent with our discussion above since it demonstrates that the significance of the measured impact of oil price changes on real output depends on whether exchange rates are included in the VAR. While oil prices are still significant in predicting the GNP deflator, the dynamic response functions show that their impact is considerably smaller once exchange rates are included. These results are discussed below. Table 2 also reveals that both real GNP and the exchange rate provide information about future values of the price of oil.

A problem in interpreting the results above is that the dollar is a financial asset. Since financial markets react to new information much more rapidly than goods markets, results from causality tests often show that financial market variables have considerable predictive power for other variables in the model. (See Sims, 1982, for a discussion of this issue and an example.) Thus, it is possible that the exchange rate is significant in the above equations because it is "picking up" information about the future course of events in the economy.

In Section I, we showed that changes in the value of the dollar predict a reasonable percentage of the oil price increases in both 1973 and 1979. This result suggests that the relationship between the dollar and oil prices is not due to the anticipation by asset markets of increases in the price of oil because it is generally agreed that the dollar's depreciation prior to both these episodes was due to factors such as the difference between the policy stance of the

United States and other industrialized countries.

As a formal test of whether the exchange rate is falsely significant in the above equations, we replaced the exchange rate by the Standard and Poor's 500 stock price index in the VAR. The change does not alter the significance of the oil price variable in the real GNP equation at all (that is, it remains the same as in the three-variable VAR). Nor does the stock price index predict changes in the price of oil.[13]

As a final check, the last system shown in Table 2 adds the Standard and Poor 500 stock index to the VAR that also contains the exchange rate. If the exchange rate were significant only because the dollar is a financial asset, this experiment should reduce its predictive power. Table 2 reveals that the addition of the S&P index does not materially alter the significance of the exchange rate.[14] Together, the results from these tests suggest it is unlikely that the exchange rate is significant in the VAR simply because it is acting as a proxy for developments in the financial market.

The different VARs reported above appear to represent robust results. Slope dummies were used in order to test for stability. For each variable on the right-hand side of a given equation, another variable was created that takes the value of that particular variable up to 1973Q1 and zero after that. These new variables were then included in all equations in addition to the original variables.

TABLE 2

Causality Tests — Marginal Significance Levels

(Sample Period: 1959Q2 — 1985Q4)

Dependent Variable	Explanatory Variables*				
	Oil Price	Real GNP	GNP Deflator	Exchange Rate	S&P 500
Bivariate GNP system					
Oil Price	.00002	.008			
Real GNP	.004	.51			
Bivariate Deflator system					
Oil Price	.03	—	.006		
GNP Deflator	.008	—	.00004		
3-variable system					
Oil Price	.01	.02	.02		
Real GNP	.06	.56	.61		
GNP Deflator	.005	.17	.00002		
4-variable system					
Oil Price	.10	.02	.56	.004	
Real GNP	.19	.69	.26	.06	
GNP Deflator	.0007	.33	.004	.03	
Exchange Rate	.40	.83	.79	.003	
5-variable system					
Oil Price	.07	.03	.54	.007	.18
Real GNP	.26	.94	.28	.10	.03
GNP Deflator	.002	.34	.006	.03	.81
Exchange Rate	.46	.94	.59	.003	.84
S&P 500	.12	.3	.46	.18	.04

*Four lags of each variable are included in all the equations.

If the relationships under study changed between the periods 1959Q2-1973Q1 and 1973Q2-1985Q4, then including these variables would significantly alter the pattern of unpredicted changes in the variables (such as real GNP and oil prices) whose behavior is being explained. The tests show that there is no significant difference between the two periods for either the five-variable system or the four-variable system (which contains real GNP, the GNP deflator, the exchange rate, and the oil price).

However, when the exchange rate is dropped from the VAR, the test reveals a significant difference between the two periods. A second test involving an examination of the individual equations shows that the source of this difference lies in the oil price equation. This finding implies that there is a significant difference in unpredictable oil price changes between the two periods if exchange rates are excluded from the oil price equation but not when they are included.[15]

We now examine the responses of output and the price level to an oil price shock. Chart 5 shows how the responses of both these variables change when the exchange rate is included in the system. In the left-hand panel, we show that the effect of an increase in the price of oil on the GNP deflator becomes noticeably smaller once the exchange rate is included in the VAR. In particular, including the exchange rate reduces both the magnitude of the initial impact and the duration of the effect. The response of real GNP to an oil price shock changes in a similar manner. That is, including the exchange rate in the VAR reduces both the size as well as the duration of the real GNP response to an oil price shock. (Notice also that in the system excluding the exchange rate, an oil price shock leads to a contemporaneous increase in real GNP. This anomaly is removed when the exchange rate is added to the system.)

It is interesting to examine the implications of these results for specific episodes such as the 1973-1975 period of oil price increases. Using two of the VARs shown in Table 2, we examine the impact on real GNP.

Chart 6A shows the forecasts we would have made using the three-variable system containing real GNP, the GNP deflator, and the price of oil with the model used to generate these forecasts estimated

Chart 5
Dynamic Effects of an Increase in the Price of Oil
(Obtained from VARs in Table 2)

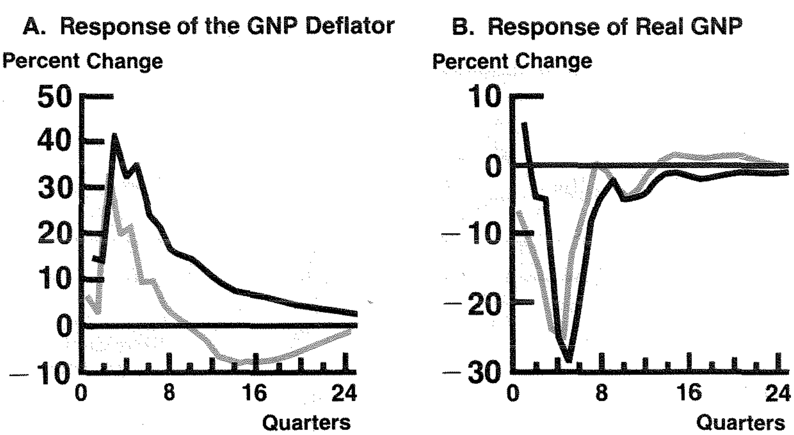
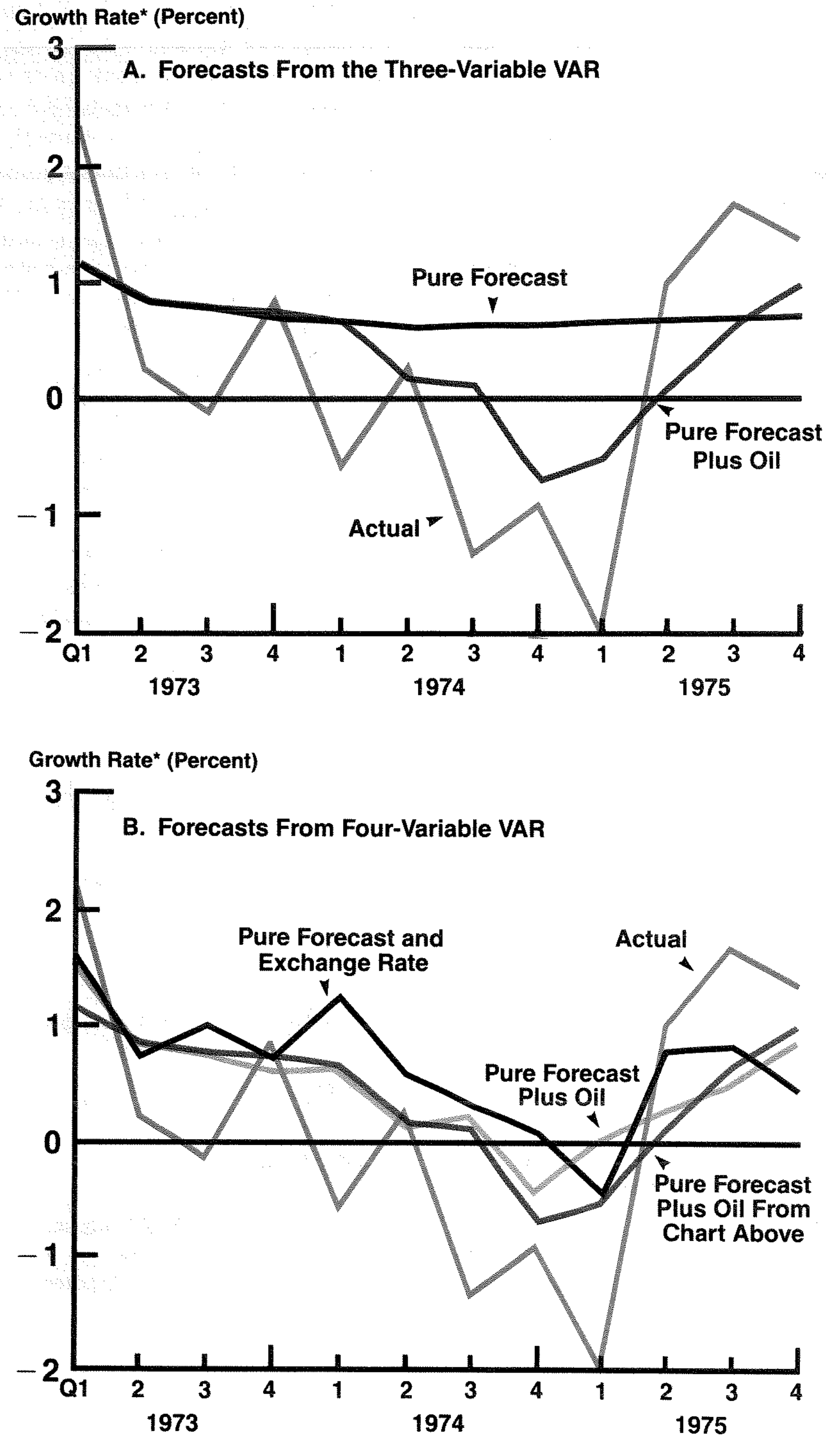


Chart 6
Actual and Forecast Real GNP Growth*



*Growth Rates are measured quarter over quarter.

using data up to 1985Q4. The line labeled "Pure Forecast" is the real GNP we would have predicted before any data for 1973 became available. The line labeled "Pure Forecast Plus Oil" adds the effects of the oil price shocks. We see that including the oil price shocks improves the forecast, most noticeably during the fourth quarter of 1974 and the first quarter of 1975 when real GNP was contracting.

Chart 6B shows the results from a similar exercise using the four-variable system consisting of real GNP, the GNP deflator, the price of oil, and the exchange rate. The line labeled "Pure Forecast Plus Oil" shows what we would have predicted at the end of 1972 had we known the behavior of oil prices over the next two years. The continuous line is reproduced from Chart 6A for comparison. Comparing the two lines reveals that the effect of the oil price shock on real GNP growth is smaller in the four-variable system, most noticeably in the first quarter of 1975. The smaller impact is due to unpredictable exchange rate changes, captured in the line labeled "Pure Forecast Plus Exchange Rate." This outcome supports our contention that omitting the exchange rate will cause the effect of exchange rate changes to be attributed to changes in the price of oil.

To obtain an idea of how much of the total variation in both real GNP and the price level over the entire sample period is due to oil price shocks, consider the results shown in Tables 3 and 4. Table 3 shows the results for real GNP. Once again, we first consider a system consisting of only real GNP and the price of oil and successively add the GNP deflator and the exchange rate.

While disturbances to the price of oil have a relatively large impact on real GNP when only these two variables are included in the VAR, the addition of other variables noticeably reduces their explanatory power. The results for the GNP deflator in Table 4 tell a similar story. Oil price disturbances do account for a relatively large percentage of the variance of the error made in predicting the GNP deflator in the first two systems. However, adding the exchange rate lowers their relative importance.

The results reported here maximize the role played by oil price shocks because only oil price

TABLE 3

Variance Decompositions — Forecasting Real GNP

(Sample Period: 1959Q2 — 1985Q4)

Percentage of variance of error due to:

	Quarters Ahead	Explanatory Variables*			
		Oil Price	GNP Deflator	Real GNP	Exchange Rate
2-variable system	0	0	—	100	—
	5	18	—	82	—
	20	19	—	81	—
3-variable system	0	0	1	99	—
	5	15	4	81	—
	20	15	7	77	—
4-variable system	0	0	0	99	0
	5	12	4	77	7
	20	11	5	65	20

*Variables are arranged according to their ordering in the VARs.

TABLE 4

Variance Decompositions — Forecasting the GNP Deflator

(Sample Period: 1959Q2 — 1985Q4)

Percentage of variance of error due to:

	Quarters Ahead	Explanatory Variables*			
		Oil Price	GNP Deflator	Real GNP	Exchange Rate
2-variable system	0	3	97	—	—
	5	26	74	—	—
	20	31	69	—	—
3-variable system	0	2	98	0	—
	5	24	72	4	—
	20	24	68	8	—
4-variable system	0	1	99	0	0
	5	11	58	1	29
	20	8	38	1	52

*Variables are arranged according to their ordering in the VARs.

shocks are allowed to affect everything else in the VAR contemporaneously. Removing the restriction on other variables noticeably reduces the response of both real GNP and the deflator to oil price shocks, especially when the exchange rate is included in the VAR. The effects of an oil price shock are also susceptible to an increase in the lag length used in the VAR. For instance, an increase in the number of lags in the VAR from 4 to 8 causes the real GNP response to an oil price shock to become even smaller (while the real GNP response to an exchange rate shock becomes somewhat larger).[16]

Finally, while the results are not shown, disturbances to the exchange rate account for a relatively large proportion of the variance of the oil price forecast error in the larger systems as well. For example, in the four-variable system, the percentage of the oil price forecast error variance due to exchange rate disturbances is 38 at the ten-quarter horizon and 40 at the twenty-quarter horizon.[17]

III. Interpretation and Conclusions

The empirical results in Section I above demonstrate that changes in the value of the dollar have a substantial impact upon the dollar price of oil. However, we must emphasize that the estimated equations do not explain all the variation in oil prices over the period studied. The results do not imply that OPEC was unable to increase oil prices above what they otherwise would have been. They do suggest that the dollar price of oil would have risen in the 1970s as the dollar depreciated and would have fallen in the 1980s as the dollar appreciated even without the existence of OPEC. This contradicts the common view that changes in the price of oil are generally exogenous. Such a view may have resulted from an excessive focus on the role of OPEC in setting oil prices and the belief that OPEC's decisions are made independently of economic developments.

The analysis suggests that a considerable proportion of the changes in the price of oil during the so-called oil price shocks were simply discontinuous price adjustments to changes in the economic environment. This discontinuity is probably the result of the cartel's mode of operation, which has been one of making large adjustments in output while adhering to a pre-announced dollar price.

Of particular interest in this context was the steep fall in oil prices in early 1986. While disagreements within the cartel were the proximate cause of the large decline in prices, it is likely that the appreciation of the dollar until early 1985 played an important part. The appreciating dollar tended to reduce non-U.S. demand for oil while increasing supply from countries other than OPEC. Since OPEC was trying to maintain a constant dollar price of oil, it was forced to make large reductions in output. Disagreements about how these reductions in output were to be allocated led to a collapse in OPEC's agreements. In all likelihood, the output reductions forced upon the cartel would have been smaller in the absence of the dollar's appreciation.

Viewed differently, the evidence (especially Chart 4) suggests that, during the early 1980s, the cartel succeeded in keeping prices above what the historical relationship between exchange rates and oil prices would suggest. However, pressures that arose from doing so led to a breakdown of the cartel. The large oil price decline in early 1986 then brought prices back to more "normal" levels.

While our analysis ignores other factors that may affect the price of oil, our interpretation is consistent with the behavior of other commodity prices. In general, commodity prices have been declining since the dollar began to appreciate. Were it not for the cartel, oil prices probably would have declined significantly more prior to 1986.

The relationship between oil prices and the value of the dollar is the basis for questioning studies that purportedly measure the impact of oil price shocks on the economy while ignoring either the impact of the exchange rate on the price of oil or the impact of the exchange rate on the economy. In Section II, we demonstrated that once the exchange rate is taken into account, changes in the price of oil no longer have a significant impact on real GNP. An examination of the 1973 "oil shock" episode also reveals that omitting the exchange rate exaggerates the contraction in real GNP following the oil price increase. Furthermore, the results in Table 3 suggest that output variations induced by oil price changes have not constituted a large proportion of the total variation in real output over the sample period as a whole. Taken together, this evidence suggests that the large decline in oil prices in the beginning of 1986 is not likely to provide as big a boost to real GNP as would be predicted on the basis of previous studies.

Finally, the results in Section II also show that inclusion of the exchange rate in the VAR reduces the impact of changes in the oil price on the GNP deflator. Most noticeable is the reduction in the length of time for which oil price changes continue to have an effect on the price level. Apparently, the effect of oil price changes is concentrated in the first few quarters following an oil price shock. This finding reinforces our point that omitting the exchange rate causes the oil price variable to pick up the inflation that may actually have been due to the dollar's depreciation.

FOOTNOTES

1. Structural models that take the exchange rate into account when studying the effects of oil shocks on the economy assume that the price of oil is determined exogenously (which is halfway between including and excluding exchange rates in the corresponding VAR). An exception is Hooper and Lowrey (1979), which studies the impact of exchange rate changes under two alternative assumptions: first, that exchange rate changes have no impact on the price of oil, and second, that half of the oil price increase in 1979 was due to the fall in the value of the dollar.

2. In view of the results to follow, it is interesting that he found that the price of imports (which reflects the value of the dollar) had a significant impact on the price of oil and yet dismissed the finding as inconsequential.

3. Gisser and Goodwin (1986) build upon the "exogeneity" results of Hamilton, and use the price of oil in a reduced form, St. Louis-type equation to show that the price of oil affects output, inflation, etc.

4. Oil exporters will be indifferent to changes in the value of the dollar only if the entire proceeds from the sale of oil are used to purchase dollar-denominated products — a condition that is hardly likely to be satisfied in practice.

5. An exchange rate index for the dollar measures the value of the dollar against a weighted average of a basket of currencies. A multilateral trade-weighted index uses the ratio of a country's total trade (exports plus imports) to the total trade of all countries in the basket as weights.

6. It appears that alternative dollar indices will move together as long as changes in these indices originate from changes in the value of the dollar. However, the indices will move differently if non-dollar currency realignments tend to be larger or more common. For our purposes, it is probably sufficient that the dollar depreciation during the early, as well as late 1970s, was not accompanied by large changes in the value of nondollar currencies against each other.

See Brown and Phillips (1986) for a study that uses oil consumption weights to construct an index for the dollar. They show that an increase in the value of the dollar leads to a decline in the dollar price of Saudi Arabian oil.

7. Sample size and data frequency were dictated by the availability of exchange rate data. Data on the Federal Reserve Board's trade-weighted exchange rate is available in quarterly average form starting in 1956.

All variables are included as the first difference of logs. All VARs include a constant and a time trend. Lag lengths were chosen as follows. I started with a specification of 12 lags. A likelihood ratio test was then used to compare this with lag lengths of 4, 8 and 16 lags. (The test used is discussed in Sims 1980, and includes a correction for the number of explanatory variables in each equation.) For the VAR containing the price of oil and the exchange rate, the tests reveal that the 12-lag specification is different from the 4- and 8-lag specifications at the 1 percent level, but is no different from the 16-lag specification. The lag of 12 quarters implies that estimation begins from 1959Q2. To keep the results comparable, all other VARs are estimated over the same period, even though each of them contains only four lags of each variable.

8. The moving average representations and the variance decompositions shown here — and in the rest of the paper — have all been obtained by placing oil prices first and exchange rates last in the ordering imposed upon the error terms. In other words, it is assumed that any shock common to oil prices and other variables in the VAR is due entirely to a change in oil prices. This ordering will, in general, maximize the role played by oil price shocks and minimize that of exchange rate shocks.

9. Placing exchange rates first in the ordering substantially increases the effect of exchange rate disturbances. Exchange rate shocks account for 33 percent of the forecast error variance of oil prices at the 5-quarter horizon, 51 percent at the 10-quarter horizon, and 54 percent at the 20-quarter horizon. The effect of oil price shocks becomes correspondingly and noticeably smaller. Oil prices shocks account for 5 percent of the forecast error variance of exchange rates at the 5-quarter horizon, 11 percent at the 10-quarter horizon, and 11 percent at the 20-quarter horizon.

10. The first difference of the log of the price of oil is regressed on 12 lags of the first difference of the log of the exchange rate. The equation also contains a constant and a time trend. The R^2 for the equation is .48, the adjusted R^2 is .41. The Standard Error is .041, and the Durbin-Watson statistic is 1.66.

11. The R^2 from this exercise is .47, the adjusted R^2 is .37. The Standard Error of the equation is .034 and the D.W. statistic is 1.86.

12. Theory also tells us that a fall in the value of the dollar will lead to an increase in output. However, the empirical results indicate that this increase is only temporary and that it is followed by a contraction in real output.

While this result is counterintuitive, it has been reported by other researchers as well. Simulations with the Board of Governors MPS model suggest that a fall in the value of the dollar first raises real output but then reduces it, so that two years later, the level of real GNP is below its initial level. An important assumption in their simulation is that monetary policy remains unchanged. In our analysis, the results are not significantly altered when the money supply is included in the VAR.

13. When the S&P 500 is included (and the exchange rate dropped from the VAR), the oil price has a marginal significance level (M.S.L.) of .06 in the real GNP equation, which is the same as when the VAR contains only real GNP, the real GNP deflator, and the price of oil. The S&P 500 has a M.S.L. of .11 in the oil price equation, .81 in the GNP deflator equation, and .02 in the real GNP equation. In the variance decompositions, the S&P 500 accounts for no more than (a) 7 percent of the forecast error variance of the oil price; (b) 4 percent of the forecast error variance of the GNP deflator, and (c) 10 percent of the variance of real GNP, at forecast horizons up to 20 quarters.

14. The variance decompositions reveal that the share of forecast error variances explained by the S&P 500 is no more than 4 percent for oil prices, 4 percent for the GNP deflator, and 9 percent for real GNP at any forecast horizon. Inclusion of either the 10-year or the 20-year Treasury bond rate also does not alter the significance levels of the

exchange rate in the VAR, although the long rates do explain a considerable proportion of the GNP deflator's forecast error variance. Finally, the nature of the results is unaffected by the inclusion of M1 in the VAR.

15. For the system stability tests, a likelihood ratio test, discussed in Sims (1980), was used. F-tests were carried out on the individual equations. For the 5-variable system in Table 2, the Chi-square statistic — calculated under the null hypothesis of no change between the two periods — had a marginal significance level of .85. For the 4-variable system, the computed Chi-square has a marginal significance level of .41. Finally, for the 3-variable system, the test statistic has a marginal significance level of .02. In this system, the oil price equation has a F(12,81) statistic of 2.5, which is significant at 5 percent.

16. The effect of increasing the lag length is especially noticeable in an examination of the 1973 "oil shock" episode. While the impact of the change in oil prices in the 3-variable VAR is more or less the same in both the 4 and 8 lag versions, it becomes much smaller once the exchange rate is included. Specifically, knowledge of the oil price shocks does not appear to be useful in "predicting" much of the decline in real GNP over 1974Q3-1975Q1.

17. To test the robustness of this result with respect to other output and inflation measures, a system containing industrial production and the producer price index was also estimated. While the oil price is significant at less than one percent in the industrial production equation when only oil prices and industrial production are included, its marginal significance level increases to .76 when both the producer price index and the exchange rate are added to the system.

In the variance decompositions, the oil price variable accounts for a maximum of 6 percent of the forecast error variance of industrial production even when it is placed first (in a four-variable VAR which included the exchange rate). With oil prices placed last, this number falls to 4 percent. In the same system, oil prices (when placed first) account for 13 percent of the variance of the error in predicting producer prices in the contemporaneous quarter. This falls to 8 percent at the ten-quarter horizon. When oil prices are placed last, they account for more than 5 percent of the forecast error variance of the PPI only once.

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