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## Faculty Working Papers

PREDICTING INFLATION RATES WITH CHANGING OIL  
PRICES

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Economics

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#545

College of Commerce and Business Administration  
University of Illinois at Urbana-Champaign



FACULTY WORKING PAPERS

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PREDICTING INFLATION RATES WITH CHANGING OIL  
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Summary:

This paper estimates the effect of higher crude-oil prices on the inflation rate in the U.S.

It does so by estimating a price equation, within a model of wage-price interaction, that contains a term to capture the inflationary impact of crude oil prices. This term is inserted using a third degree polynomial distributed lag of four quarters that allows not only for some immediate impact on the consumer price index (e.g. through gasoline prices), but also for a delayed impact as crude oil prices affect production costs, wage rates, and eventually final goods prices.

Since increase in crude oil prices appear to be a continuing source of exogenous shocks on the system, simulations are presented that estimate the net effect of these increases; in this case of the 14.5% increase announced by OPEC for 1979 on the remaining quarters in 1979 and 1980. If OPEC policies, Iranian developments, or domestic U.S. policies should raise crude oil prices by an additional 10%, the net effect is estimated to raise the inflation rate by .9% above what it would otherwise be.

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and Parkin (1976), Trevethick and Mulvey (1975), and H. Frisch (1977). There have also been demonstrations of the effect of changes in raw material costs on manufacturing prices prior to the time that oil and energy prices become a unique problem by Eckstein and Fromm (1968), and Siebert and Zaidi (1971), although these were not found very significant at higher levels of aggregation by Eckstein and Brinner (1972, p. 20).

Regression analysis will be used to test the hypothesis that crude oil prices have significant direct and delayed effects on the quarterly percent rate of change in the Consumer Price Index (CPI) using quarterly data from 1960 through the first quarter of 1977. Predictions then are generated using the parameter estimates obtained for the price equation for the remainder of 1977 and for 1978, and the accuracy of these predictions compared to the actual experience. Forecasts are also made of the inflation rate for 1979-80 under the assumption of alternative oil-price-increase policies, and some of the implications discussed.

#### I. THE DETERMINANTS OF INFLATION

The price equation used in this study differs from previous inflation models in that it includes variables used to capture the inflationary impact of higher crude oil costs. Beyond this, many of the 'traditional' variables are used, both to control for other affects while testing the oil price hypothesis and to produce a prediction equation useful for forecasts. The theory and past empirical tests suggest the following hypotheses:

1. During periods of excess demand, firms raise the selling price of their products, the collective effect being to increase the inflation rate (and visa versa).

## Predicting Inflation Rates with Changing Oil Prices

Douglas E. Goodman and Walter W. McMahon

The purpose of this paper is to examine the impact of higher oil prices on inflation rates in the U.S., irrespective of whether these higher oil prices are caused by OPEC policies or by discretionary U.S. domestic deregulation or tax policies. It is apparent that crude oil prices will continue to be raised, in part by OPEC, but also by some deregulation of crude oil and of by-products such as natural gas as well as by import and domestic taxes. The desired effects of the discretionary policies are to encourage more efficient use of oil, to encourage exploration, and to stimulate production of alternative forms of energy such as coal, nuclear, and solar power.

This paper will seek to measure an undesired side-effect of this increase in oil prices; the adverse overall effect on domestic inflation rates. The dilemma posed is clear; oil consumption must be reduced, and use of alternatives encouraged, yet policy prescriptions aimed at achieving this goal calling for higher oil prices add to the inflation rate. Potential policies to curb inflation, such as supply-management policies or taxed-based incomes policies (TIP), the latter providing tax incentives to encourage business and labor to moderate price and wage increases, offer a possible trade-off, but one that requires estimates of the impact of higher oil prices on the Consumer Price Index.

Recent work on the price equation concentrates on current and expected excess demand, demand change, labor cost, and productivity change as determinants of the price level, as reflected in the work by Laidler

2. Increased standard unit labor cost, (determined primarily by historical rates of change in labor cost), leads to increased prices.
3. Current unit labor cost changes exert an independent effect on prices.
4. Cyclical changes in productivity are inversely related to prices; i.e., higher current productivity relative to the trend rate of growth in productivity induces downward pressure on prices, and vice versa). And finally,
5. The cost of crude oil is positively related to the price index.

#### Excess Demand

The "demand pressure" variable is constructed by obtaining the ratio of unfilled orders to inventories. Unfilled orders measures demand directly, and can be hypothesized to be positively related to prices, whereas the size of the inventory stock is inversely related to prices. Hence, the ratio of unfilled orders to inventories can be expected to be positively related to prices.

#### Standard Unit Labor Cost

Following O. Eckstein and R. Brinner (1972), the standard unit labor cost is calculated using a scheme of declining weights on current and past rates of change in compensation per man hour, deflated by the trend rate of growth of productivity. Symbolically, the standard unit labor cost at time  $t$ ,  $\dot{w}_t$ , is defined as:

$$(1) \quad \dot{\bar{w}}_t = \bar{w}_t - Q_T,$$

where,

$$\bar{w}_t = .4(w_t) + .3(w_{t-1}) + .2(w_{t-2}) + .1(w_{t-3}),$$

where  $w_t$  is the quarterly percent of change in compensation per man hour for the nonfarm business sector, and

$Q_T$  = the quarterly trend rate of growth of productivity for the nonfarm business sector, a constant expressed as a percentage equal to .49.

### Current Labor Cost

In addition to standard unit labor cost, the price equation includes current labor cost defined here as the difference between the current rate of wage inflation, (deflated by the trend rate of growth in productivity), and the standard unit labor cost:

$$(2) \quad (w_t - Q_T) - \dot{\bar{w}}_t$$

which, when  $\dot{\bar{w}}_t$  is replaced by its definition in Eq. (1), reduces to

$$(2a) \quad w_t - \bar{w}_t$$

This variable permits evaluation of the impact of volatile, short run movements in wages for comparative purposes with the less volatile 'permanent' component captured by standard unit labor cost. The coefficient estimated for this variable measures the relative impact of recent wage changes above and beyond standard labor costs in the price equation.

### The Productivity Gap

Although the behavioral assumption of a mark-up over standard cost pricing is assumed in this paper, it is not inconsistent to believe that short-run productivity movements have an independent effect on prices. A productivity gap variable defined as the difference between short-run productivity changes and its trend value is used to test this hypothesis. Symbolically, the productivity gap variable is expressed as:

$$(3) \quad Q_{gt} = Q_t - Q_T$$

where,

$Q_t$  = the index of output per man hour for the nonfarm business sector, expressed as a quarterly percent rate of change, and

$Q_T$  = the quarterly trend rate of growth of productivity for the nonfarm business sector, .49, as above.

### The Oil Cost Index

In contrast with previous work dealing with price inflation, this study incorporates an index of energy cost based on the quarterly rates of change in the prices of domestically produced and imported crude oil. These rates of change are weighted according to the proportion of the total consumption of oil that is produced domestically and the proportion that is imported.

Specifying this measure of energy cost as a determinant of price inflation would appear to be warranted in view of OPEC oil policy since the early 1970s and the growing dependence of the United States on

imported oil. Although there were in addition temporary shocks from agricultural prices and devaluation, the escalating price of crude oil during the early 1970s was permanent and coincides with one of this nation's worst bouts of inflation, lending credence to the notion that the increased energy cost experienced by domestic industries has been reflected in permanently higher prices for virtually all goods and services.

The impact of oil cost changes on the CPI is hypothesized to be both immediate and lagged. To test the hypothesis that time is required for the full impact of current changes in oil cost to affect the price deflator, an Almon polynomial lag structure is employed, allowing present and lagged changes in oil prices to be evaluated as an explanatory variable in the price equation.

## II. THE PRICE EQUATION; EMPIRICAL RESULTS

The price equation is used to estimate the quarterly percent rate of change in the Consumer Price Index in which there is widespread interest. There are difficulties inherent in the use of this price index due to its lack of perfect correspondence with the nonfarm business sector and its degree of aggregation. Moreover, indices of compensation per man hour and of output per man hour are not available on an economy-wide basis. So it is necessary to obtain these for the nonfarm business sector, which does not correspond perfectly to the more aggregative economy-wide basis for which the CPI is computed. But the nonfarm business sector does represent the overwhelmingly largest share of the total economy and therefore its labor cost and productivity movements are a reasonable representation of these effects economy-wide.

Econometric Estimates of the Price Equation

The complete price equation, together with estimates of its coefficients and the corresponding t-statistics in parentheses, is as follows:

$$(4) \quad \begin{aligned} \dot{P}_t &= .767(UF/INV)_t + 1.059(\bar{w}_t - Q_t) + .179(w_t - \bar{w}_t) \\ &\quad (1.917) \quad (7.194) \quad (1.325) \\ &\quad - .065 Q_{gt} + .026 \dot{P}_{Et} - .925 \\ &\quad (-1.564) \quad (3.221) \quad (-2.417) \\ \bar{R}^2 &= .86 \quad D.W. = 1.79 \quad \rho = 0.21 \end{aligned}$$

where:

$\dot{P}_t$  = quarterly percent rate of change in the consumer price index,

$(UF/INV)_t$  = the ratio of unfilled orders to inventories, reflecting excess demand,

$(\bar{w}_t - Q_t)$  = standard unit labor cost, adjusted for productivity, as defined previously,

$(w_t - \bar{w}_t)$  = current wage changes in excess of increases in standard unit labor cost,

$Q_{gt}$  = the difference between the current rate of change in productivity and its trend rate of growth, and

$\dot{P}_{Et}$  = current and recent past changes in oil prices, expressed with a distributed lag.

The results of the price equation are consistent with all the hypotheses.<sup>1</sup> The excess demand, standard unit labor cost, current wage change, and crude oil price index variables each contribute positively to the rate of change in the CPI and all except current wage increases

are significant at the .05 level or better. The negative coefficient estimated for the productivity gap variable is also as expected--when short run changes in productivity are greater than the trend rate of growth in productivity, there is downward pressure on prices.

The results of the price equation were corrected for serial correlation and the rho value is reported beside the Durbin-Watson statistic. Thus, all coefficients are corrected for first order autoregression in the residuals by a Cochrane-Orcutt iterative procedure.<sup>2</sup>

The coefficient for  $\dot{P}_{Et}$  is the sum of the coefficients for the current and lagged values of  $P_E$  using a third degree polynomial distributed lag. This collected impact of crude oil cost using distributed lags was obtained through a LaGrangian Polynomial Interpolation.<sup>3</sup> More than one value for the degree of the polynomial and length of the lag distribution were tried before selecting the values which provided the best fit in terms of the standard error of the estimate.<sup>4</sup> The best results were obtained from a third degree polynomial with a lag of four quarters, constrained to zero at the most distant time point in the distributed lag (t-4) and at time point (t+1). The time form of the lagged response therefore provides for a positive impact immediately in the first quarter that increases in the second quarter and then diminishes to zero by the fourth quarter.

### III. PREDICTIVE ACCURACY OF THE MODEL

Predicted and actual inflation rates can be compared both within and for five quarters following the sample period, with the latter also compared to the inflation rates predicted by the published forecasts of the major econometric models.



### Comparisons Within the Sample Period

Figure 1 illustrates the path of actual and predicted values of the CPI within the 1960:1 through 1977:1 sample period. Predicted values do not lead or lag behind the upswings or downturns in the inflation rate, and are close to the actual. Predicted values do however have a tendency to be less volatile. However, the quarterly actual inflation rates contain some statistical noise from data collection procedures and rounding errors, so that some of the minor jogged fluctuations about the predicted values are a statistical artifact. The smoother predicted values could therefore be more accurate predictions of the underlying inflation rate than are the minor quarter-by-quarter fluctuations in the actual values.

### Accuracy of the Predictions in the Post-Sample Period

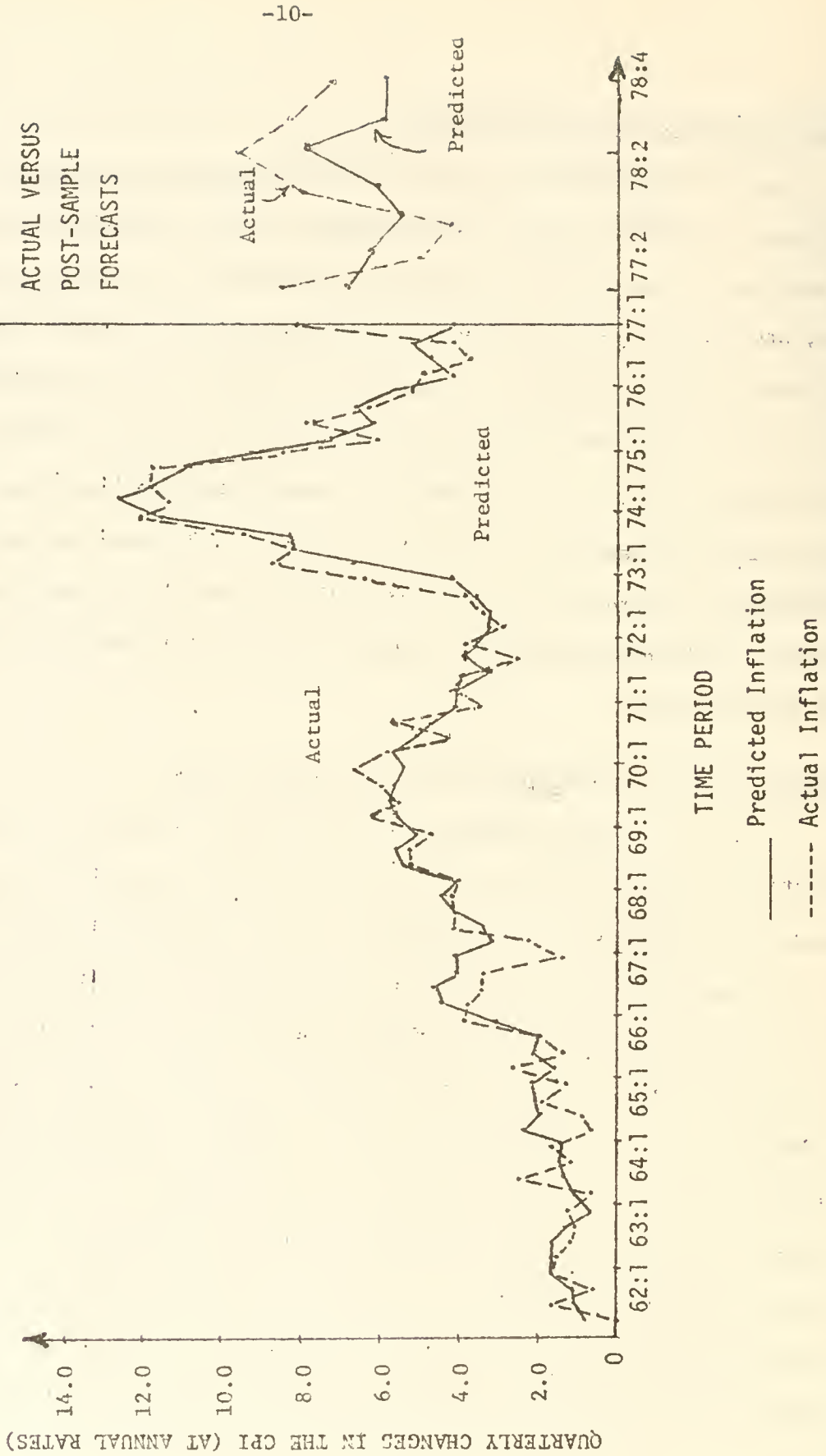
In the post-sample period which is also shown in Figure 1, predicted inflation rates again move in the same direction as the actual inflation rates. However they also underpredict the amplitude of the actual values.

The accuracy of the predictions is also evaluated in Table 1 by comparing the predictions using our price equation (Eq. 4) with the predictions made by three major national econometric models. Table 1 presents a comparison of the predictions made during the first quarter of 1977 for the period from 1977.2 through 1978.4 of the quarterly percentage increases (at annual rates) in the Consumer Price Index made by the Chase, Wharton, and Data Resources Inc. econometric models. The percentage point errors in these predictions in relation to the actual inflation rates (Col. (1)) are shown in Columns (3), (7), and (11). The degree

FIGURE 1

HISTORY OF PRICE INFLATION: PREDICTED AND ACTUAL EXPERIENCE 1961:1 - 1978:2

THE CONSUMER PRICE INDEX



of accuracy of each of the three models is remarkably similar, with all models underpredicting the amplitude, and more seriously, the average inflation rate for the period as a whole by 1.8%.

Predictions of prices by use of our price equation, using the forecasted values of the variables exogenous to the price equation (4) as given by the econometric model to which it is being compared are shown in Columns (4), (8), and (12). Our equation also underpredicts the amplitude, but it does do slightly better on the average in predicting the Consumer Price Index than does the more complicated price sector in each of these national models.

A major reason for the divergence between the actual and predicted inflation rates lies in the overestimation of the unemployment rates for 1978 by all of the models, leading in turn to the underestimation of the rate of wage and price inflation. In addition to this, the rate of increase in productivity was overestimated, contributing further (since productivity and prices are inversely related) to the underprediction of the inflation rate.

#### IV. SIMULATED EFFECTS UNDER ALTERNATIVE OIL PRICE POLICIES

Simulations under two alternative oil-price policies were implemented for the quarters from 1979:1 through 1980:4. The first predicts inflation rates for this period under conditions of no change in crude oil costs. The second predicts inflation rates assuming that crude oil costs rise at the 14.5% rate that has been announced by O.P.E.C. for 1979, and at a 10% rate during 1980.<sup>5</sup>

Table 1

Actual vs. Predicted Inflation: A Comparison with Other Models

Quarterly Percent Change at Annual Rates

Date	Chase (a)			Wharton-Penn. (b)			DRI (c)						
	Actual Experience (1)	Chase Model (2)	%-age Point Error (3)	Our Model (Chase Data) (4)	%-age Point Error (5)	Wharton Model (6)	%-age Point Error (7)	Our Model (Wharton Data) (8)	%-age Point Error (9)	DRI Model (10)	%-age Point Error (11)	Our Model (DRI Data) (12)	%-age Point Error (13)
77:3	4.9	6.9	2.0	6.3	1.4	5.8	.9	6.5	1.6	5.3	5.3	6.2	1.3
77:4	4.6	7.0	2.4	5.6	1.0	4.6	.0	5.5	.9	5.0	.4	5.2	.6
78:1	8.0	4.0	-4.0	5.3	-2.7	4.8	-3.2	5.1	-2.9	5.4	-2.6	5.2	-2.8
78:2	9.8	4.3	-5.5	5.0	-4.8	5.4	-4.4	5.3	-4.5	5.1	-4.7	5.1	-4.7
78:3	8.1	4.3	-3.8	4.9	-3.2	6.1	-2.0	5.4	-2.7	5.3	-2.8	5.2	-2.9
78:4	6.9	4.8	-2.1	4.6	-2.3	5.0	-1.9	5.6	-1.3	5.0	-1.9	5.2	-1.7
Average Percentage Point Error			-1.8		-1.7		-1.8		-1.5		-1.8		-1.7

(a) Chase Econometrics Association, January 25 (1977).

(b) Forecast made in January, 1977.

(c) Forecast made in January, 1977.

(d) Prediction-test of our price equation (4) as of 1977:1 incorporating data for the explanatory variables as given by the model to which the price predictions are being compared.

TABLE 2

FORECASTS OF INFLATION RATES UNDER ALTERNATIVE CRUDE OIL PRICE POLICIES<sup>a</sup>

Quarterly Changes Expressed in Annual Rates

Forecasts Using Equations 4 and 5

Date	No Change in Oil Prices	Oil Prices Increased by 14.5% in 1979 and 10% in 1980	Increment to Inflation Attrib- utable to OPEC	DRI Forecast	
	(1)	(2)	(3)	CPI	% Col. 2
1979:1	7.5	7.8	+3	5.8	74
1979:2	7.2	7.6	+4	6.2	82
1979:3	6.7	7.1	+4	6.3	89
1979:4	6.4	6.9	+5	6.4	93
1980:1	6.4	6.8	+4	6.0	88
1980:2	6.4	6.8	+4	6.2	91
1980:3	6.3	6.7	+4	6.1	91
1981:4	6.4	6.8	+4	6.2	91

<sup>a</sup>All forecasts are made in 1978:4.

### Measurement of the Explanatory Variables

The price equation requires data for each of the explanatory variables, all of which are endogenous in the more comprehensive macro-econometric models of the U.S. economy. The data used in the simulations therefore are the values for the explanatory variables as forecasted by the DRI model in its forecasts made at the beginning of 1978:3.<sup>6</sup>

To allow for wage-price interaction, as the price increases fueled by energy costs feed back on wages, the following wage equation was also used in these simulations:

$$(5) \quad W_t = 1.1649 (U^{-1}) + .4885 (P_t^e) - .3551 (W_{g,t})$$

Where  $W_t$  = the quarterly percent change in compensation per man hour for the nonfarm business sector,  $U$  = the unemployment rate, and  $P_t^e$  = the expected quarterly rate of change in the CPI. The latter is obtained by using a weighted lag structure consisting of the current inflation rate (as forecast by the DRI model) and three lagged rates of price change as estimated by our own price equation, Eq. (4).<sup>7</sup> The weights used for the distributed lag applied to the four quarterly rates of price inflation are 0.4, 0.3, 0.2, and 0.1.

### Simulations with Alternative Oil Price Changes

A summary of the effects of these alternative oil price changes is presented in Table 2. Col. (1) uses our two equation model, assuming no change in oil prices; Col. (2) assumes that oil price increases of 14.5% are phased in during 1979, and increases of 10% occur in 1980; Col. (3) gives the increment in the inflation rate attributable to the oil price

percentage point above where they would otherwise be in the absence of these OPEC and domestic oil price policies.

If the current incomes policy involving wage-price guidelines accompanied by sanctions (e.g., removal of government contracts, tariff cuts, sales out of government stockpiles) and by a tax incentive plan (TIP) is effective, actual inflation rates could be expected to be somewhat below those predicted by the simulations in Col. (2) of Table 2. The same is true if unemployment rates should rise above those expected. Independently of those factors, however, these results call attention to the conflict between domestic oil-price deregulation policies and the problem with inflation. The results also serve to document the importance of including oil price terms in the price equation.

increase; and Col. (4) presents the DRI price forecast of the Consumer Price Index as a basis for comparison.

Previous work that traces the effect of oil price and oil tax policies such as that by D. Jorgenson (1976, pp. 7-94) has tended to focus not on the effect on inflation rates, but instead on the effect on energy conservation within the context of an inter-industry model. Eckstein and Herr (1976, p. 365) have examined the effect on the GNP implicit price deflator of the whole energy package. But most of that energy package has been eliminated by the Congress, and there is a need for a more specific tool useful for estimating the effects of oil price policies.

The results using the price equation developed in this paper tend to predict higher inflation rates than the corresponding rates forecast by the DRI model. The rates are higher in most quarters roughly by the amount attributable to the crude oil price increases.

These results show that the announced increase in crude oil prices during 1979 and 1980 can be expected to hold the inflation rate about four tenths of a percentage point above where it would otherwise be.

For each additional percentage point of increase in crude oil prices based on Col. (3), the inflation rate could be expected to be .027 to .04 percentage points above where it would otherwise be. So, for example, if OPEC raises oil prices by 14.5%, and if a new oil price policy (through deregulation, or taxes, or both) should raise the price of crude oil an additional 10%, the results would be an increment of .9% to the inflation rate. That is, all inflation rates could be expected to be almost a



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Footnotes

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<sup>1</sup>Equation (4) was also estimated using the price deflator for the nonfarm business sector as the dependent variable with similar results. These latter results show the oil-price determinant to be even more significant and to have an even larger coefficient. These results are discussed in a separate manuscript available from the authors on request.

<sup>2</sup>Using the Cochrane-Orcutt technique, an initial estimate of rho ( $\rho$ ) is obtained from the residuals of the regression equation by the formula  $\hat{\rho} = \sum U_t U_{t-1} / \sum U_{t-1}^2$ . Next, the moments are transformed using  $\hat{\rho}$  and new estimates of the coefficients are obtained. After this adjustment is made, a second estimate of  $\rho$  is calculated from the residuals of the revised estimates of the coefficients. This procedure is repeated until two successive estimates of  $\rho$  differ by less than .001, or the number of estimates by this procedure exceeds 20.

<sup>3</sup>For a detailed description of the computations involved in this procedure see, S. Almon (1965).

<sup>4</sup>These other lag distributions, as well as simultaneous equation estimates are also covered in the manuscript available from the authors that is discussed above, but will not be discussed here in order to allow space for our focus here on the predictions.

<sup>5</sup>See the Wall Street Journal, December 18, 1978, page 3.

<sup>6</sup>This differs from Table 1, in that forecasts of the explanatory variables used there were those made during the first quarter of 1977.

<sup>7</sup>This is a similar approach to that used by Eckstein and Brinner to determine the expected rate of inflation. They use compensation per man hour less the expected quarterly percent change in the CPI, deflated by the trend rate of productivity growth for the nonfarm business sec-

tor, and lagged one quarter;  $W_{g,t} = [(W_t - P_t^e) - .49]_{t-1}$ , where

$W_{g,t}$  = the wage gap defined as the differences between the quarterly percent changes.

<sup>8</sup>First, the estimated price equation uses output per man hour for the nonfarm business sector; the DRI model provides a similar measure, but for the private nonfarm business sector. The latter sector overlaps the former except that it excludes government. To allow for this omission, the following equations were estimated.

$$(6) \quad Q_{bu} = .03 + .95Q_p$$

Where,  $Q_{bu}$  = the quarterly percent rate of change in output per man hour for the nonfarm business sector, and  $Q_p$  = the quarterly percent rate of change in output per man hour for the private nonfarm business sector.

Second, DRI forecasts do not include estimates for unfilled orders as used in the excess demand variable, but they do include forecasts of a variable frequently used to measure excess demand, capacity utilization rates. The equation used to bridge this gap is:

$$(7) \quad UF/INV = -.024 + 1.59 CU$$

Where, UF = unfilled orders, INV = inventories, and CU = capacity utilization rates.









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