THE PRICE OF OIL AND ECONOMIC ACTIVITY, A SHORT-RUN MODEL

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The study is the third in a sequence of studies by Fishelson ([1980a], [1980b]) that investigate the relationships between exogenous events in the energy market and the economic activity. This study differs from the other two in two respects. First, it is an empirical positive analysis of the post-1973 U.S. economy (Fishelson [1980] is a normative study of the Israeli economy). Secondly, the deriving force in this study is the exogenous change of the price of oil (not embargoes or quotas). The model is framed into a simultaneous equation system. It is aimed at detecting the short-run effects of oil prices on the economic activity. The economy is divided into three sectors, Residential (including commercial), Industrial (including agriculture and mining) and Transportation. Each sector is assumed to be affected to a different extent by oil prices and to affect the overall economic activity by a different extent than other sectors.

The Model

The model is an ad hoc one. The specified relationships follow intuitive argumentation (are not rigorously derived from basic behavioral objective functions that are optimized). The system is described by four equations. The first three each relates the energy consumed by the sector to the overall economic activity, (GNP), to previous energy consumption by the sector, to the price of oil and to a time variable. The fourth equation relates the GNP to the quantities of energy consumed by each sector, lagged GNP and a time trend variable.

A fifth equation that is recursive to the four mentioned above relates the quantity of energy consumed out of crude oil to the economic activity, a price of oil and a time variable. Another version of the fifth equation is that here the quantity of oil is related to the quantities of energy consumed by the various sector, a lagged quantity of oil and time. The first four equations can be estimated independently of the fifth one. The first three equations are over-identified (the rank criteria) while the fourth is just identified. Given this situation the two-stage least squares procedure is used for estimation.

The relationships are:

(1) RESE = f(RESE(-1), GNP, PE, T)

(2) INDE = f(INDE(-1), GNP, PE, T)

(3) TRNE = f(TRNE(-1), GNP, PE, T)

(4) GNP = f(GNP(-1), RESE, INDE, TRNE, T)

(5) OIL = f(OIL(-1), GNP, PE, T)

or

(5') OIL = f(OIL(-1), RESE, INDE, TRNE, T)

where

GNP - GNP, billions of dollars, at 1972 prices.

RESE - Energy consumed by the Residential sector, 10^{15} Btu.

INDE - Energy consumed by the Industrial sector, 10^{15} Btu.

TRNE - Energy consumed by the Transportation sector, 10^{15} Btu.

PE - Real price of a composite (domestic and import) barrel of crude oil (adjusted by CPI*).

T - Time where the first quarter of 1973 take the value of 1, the second of 2 and so on.

OIL - The energetic value of crude oil consumed, 10^{15} Btu.

All the variables listed above are measured on a quarter basis. Hence, the estimated model is a quarterly model.

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*We do not have strong arguments to prefer CPI over the GNP implicit price index. We did not try both indices in the estimations. The correlation between the two indices is above .9.

The sectoral equations are not to be strictly viewed as the sectors demand functions for energy, since they also serve as a proxy for the sectors output. If viewed as a derived demand for an input--energy--prices of other inputs are also to be present. We did not introduce these prices implying that in the short-run the production function is close to fix proportion (the short-run elasticities of substitution among the inputs are very small) and that the real prices of the other inputs were relatively constant over the analyzed period. The inclusion of GNP as an argument in the sectorial energy "demand" equations is a substitute for the output of the sector variable (in the industrial and the transportation sectors, i.e., output is proportional to GNP) and as a measure of income in the residential sector (energy is a consumption good).

The GNP equation (following the definition of GNP) should have been the sum of the added values of the producing sectors. We proxied the value added by the energy consumed. The energy consumed by the residential sector is to be viewed as a demand shifter for various goods and services produced in the economy. The time variable is present in all equations in order to allow for technological changes (neutral).

Another variable included in each equation is that of the first quarter of 1974 which was unique due to the oil embargo, and oil shortages which might not have been reflected in price changes. The basic underlying assumption of the model is that the specified system reflects market equilibrium by consumers and by producers. We doubt about the validity of this assumption at least for the first quarter of 1974.

The lagged endogenous variables stand for physical restrictions on the production capacity, consumers habit formation and costs of adjustments.* We view the model as the smallest but of sufficient coherent to replicate the mechanism that links economic activity to energy prices. One should actually view each of the structural equations in our model as

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*In the simultaneous equation framework that we analyze the lagged variables are the equation specific exogenous variables which facilitate the identification of the relationships.

a reduced form equation of a more elaborated detailed simultaneous equation model where each equation stands for a specific economic or technical relation (supply, demand, production function, etc.). The task of formulating the full scale model is still ahead.

Estimation and Results

Before entering the estimation stage we did our own adjustment for seasonal effects of the energy consumption variables. To start with, the GNP data at 1972 prices were seasonally adjusted while the energy data were not. Such a mix would generate meaningless results in the simultaneous equation framework.

The cleaning up of the energy data from the seasonal effects was achieved by estimating the seasonal effect for each sector in the relation

$$E_{jk} = e^{\alpha_1 D_1 + \alpha_2 D_2 + \alpha_3 D_3 + \alpha_4 D_4 + \alpha_5 D_{174}} ,$$

where E_j is the consumption of energy by sector j in the k quarter $k = 1 \ldots 4$.

D_k - $k = 1 \ldots 4$ are the quarters dummy variables

D_{174} is the dummy variables for the first quarter of 1974.

$\overline{E}_j - \hat{\alpha}_k$ is the k's quarter effect in sector j, where $\overline{E}_j$ is the quarterly average energy consumption by sector j in the 1973:1 to 1980:2 period.

The equations were estimated using the two stage least squares procedure (White [1978]).* We experimented some modifications with the variables the price of oil and time. The model is formulated in logarithm. We, however, introduced time once in logs and once in its level. With regard to the price of oil two versions were tried. Once

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*White, K.J., "A General Computer Program for Econometric Methods, SHAZAM," Econometrica, 1978.

using the current real price, the second using the lagged real price jointly with (log of) the relative change of oil prices.

Table 1 contains the set of equations we consider to be the best in terms of explaining the system and consistancy with expectations of signs. In this system current real oil prices represent the effect of changing oil prices. Time is introduced in a logarithmic transformation (constant elasticity). By further testing, it was found that the price of oil does not affect GNP directly but only through its effect on energy consumption by the various sectors. It turns out (as expected) that the main (and only significant) effect of the price of oil is on energy consumption by the transportation sector. Also note that the elasticity of GNP with respect to the transportation sector is the largest (relatively to the residential and industrial).*

The effect of time (energy saving technological progress) turns out to be significant. The time elasticity of GNP is .012. To interpret this number recall that the last observation used is the second quarter of 1980 for which T = 30. A ten percent increase of time, three quarters, will result is a .12 percent increase in GNP (energy consumption by all sectors being constant). Since time affects the sectors energy consumption the total effect of time is somewhat higher (found from the reduced form equations, Table 3) about .19 percent for three quarters.

The effect of time on energy consumption is positive on the residential and transportation sectors and negative on the industrial sector. This might indicate the energy saving induced technological progress in the industrial sector none of which took place (yet) in the other sectors. This declining energy consumption trend over time was entirely assigned to the time variable and none to the price of oil. In the reduced form equation (Table 3) price actually turns to have a positive sign. The energy consumption by the transportation sector is outstanding with respect to the effect of the price of oil. The elasticity is about -.2. We

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*When TRNE is dropped from the GNP equation, PE is found to affect GNP directly.

already noted that the transportation sector affects GNP as the residential and industrial sectors jointly. Hence, the major effect of the increase in oil price on the economy is transmitted via the transportation sector.

Energy consumption by the transportation sector fluctuated around 25 percent of total energy consumed.* It declined during the fifties to 25 percent in 1959, 22 percent in 1966 and increased back to 25 percent in 1973-4 and 27 percent in 1975-78. Since 1976 the absolute consumption by the transportation sector was about stable. Hence, the negative effect of the increase in the price of oil was compensated by the positive time effect. If further increases in oil prices would occur the time effect would not be sufficient to compensate for it. The effect on GNP would then be negative to an extent dependent on the price rise.

The dependence of GNP on energy used in transportation stands for more than just energy. It is a proxy for the activity of the automobile industry and its multiplier effect on the other sectors and the economy. Thus a structural shift to small cars which is to be reflected in lower energy consumption might have a major negative effect on the economy unless the smaller cars are made in the U.S. rather than imported (in the 1977-80 period the production of U.S. cars declined while import of small cars increased). Also, although the model is a short-run model and new innovations are not relevant for this time span (by definition of a short-run) one might consider the structural effect of introducing electric vehicles on the energy consumed by the transportation sector and the rolling effect on GNP.

Energy used in the industrial sector realized a trough in 1975. It was stable in 1977-79 in spite of a negative time effect. This stability was reached by expanding production activities.** A negative

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*U.S. Department of Energy, EIA 1979 Annual Report, Washington, D.C., 1980.

**For the industrial sector the time and price effects are of the opposite sign of that found for the other sectors (see also the coefficients in the reduced form equations, Table 3).

effect on GNP would be experienced if real output declines such that net energy consumption declines and with it the GNP. Energy consumption by the residential sector is on a continuous upward trend. The very small coefficient of oil price in the structural equations is somewhat misleading. From the reduced form equations (Table 3) it seems that the price of oil is very significant. "Luckily," its upward trend lately was not felt because of the steep time effect which compensated for most of it (increase in GNP was the other reason).*

The demand for oil was investigated in several directions (Table 2). The variations were single equation (OLS) vs. simultaneous equation (2SLS). The price of oil was introduced once in its current real value and once jointly of the lagged price and relative price change.

Equations (1), (OLS) and (2) (2SLS) relate oil to lagged consumption, GNP and oil price. The 2SLS results imply larger elasticities of all variables especially of time and the price of oil, although from the statistical significance it is of lower quality (GNP is considered endogenous). Splitting the price of oil to lagged price and relative increase did not improve the OLS results. The 2SLS estimation results in an elasticity of GNP above unity (not significant even not from zero). This might be a warning to policy-makers which worry about the increasing imports of oil. Note, however, that the very strong effect of time (equation (2)) is practically eliminated.

The OLS equation that relates oil consumption to sectorial energy consumption seems to be very reasonable. If, however, energy consumption increases equally (1%) oil consumption will increase by a larger proportion (about 1.3%). The 2SLS equation for these variables (equation (6)) is unreasonable all over.

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*In the reduced form equations it was the lagged value of GNP which is exogenous but behaves as GNP if the latter is trended monotonically.

Table 1

GNP and Sectorial Energy Consumption

(A Simultaneous Equation Model)*

$$GNP = \underset{(.92)}{-\,1.30} + \underset{(.12)}{.750GNP(-1)} - \underset{(.06)}{.071D_{174}} + \underset{(.066)}{.082RESE} + \underset{(.07)}{.090INDE} + \underset{(.07)}{.182TRNE} + \underset{(.006)}{.012T}$$

$$RESE = \underset{(4.96)}{1.405} - \underset{(.12)}{.081RESE(-1)} + \underset{(.18)}{1.230D_{174}} - \underset{(.22)}{.003PE} + \underset{(.73)}{.275GNP} + \underset{(.10)}{.059T}$$

$$INDE = \underset{(4.75)}{1.454} - \underset{(.18)}{.136INDE(-1)} - \underset{(.17)}{.289D_{174}} + \underset{(.21)}{.034PE} + \underset{(.68)}{1.263GNP} - \underset{(.09)}{.132T}$$

$$TRNE = \underset{(1.64)}{6.053} - \underset{(.23)}{.151TRNE(-1)} - \underset{(.05)}{.040D_{174}} - \underset{(.07)}{.197PE} + \underset{(.23)}{.422GNP} + \underset{(.028)}{.056T}$$

*The exogenous variables are GNP(-1), D_{174} T, PE, RESE(-1), INDE(-1) and TRNE(-1). The values in parentheses are the standard errors of estimate.

Table 2

Consumption of Oil Equations

$$(1)\quad OIL = \underset{(1.30)}{4.318} + \underset{(.20)}{.065OIL(-1)} + \underset{(.07)}{.006D_{174}} - \underset{(.06)}{.157PE} + \underset{(.22)}{.504GNP} + \underset{(.024)}{.050T}, \quad R^2 = .679$$

$$(2)\quad OIL = \underset{(2.97)}{6.138} - \underset{(.46)}{.312OIL(-1)} + \underset{(.23)}{.371D_{174}} - \underset{(.14)}{.299PE} + \underset{(.47)}{.648GNP} + \underset{(.06)}{.118T}$$

$$(3)\quad OIL = \underset{(1.47)}{4.244} + \underset{(.20)}{.063OIL(-1)} + \underset{(.06)}{.013D_{174}} - \underset{(.07)}{.152PE(-1)} - \underset{(.14)}{.177\Delta PE} + \underset{(.25)}{.520GNP} + \underset{(.028)}{.048T}, \quad R^2 = .679$$

$$(4)\quad OIL = \underset{(3.44)}{2.757} - \underset{(.52)}{.273OIL(-1)} + \underset{(.45)}{.582D_{174}} - \underset{(.16)}{.057PE(-1)} - \underset{(.76)}{1.097\Delta PE} + \underset{(.78)}{1.202GNP} + \underset{(.06)}{.015T}$$

$$(5)\quad OIL = \underset{(1.06)}{2.463} + .046OIL(-1) - \underset{(.05)}{.535D_{174}} + \underset{(.07)}{.002T} + \underset{(.05)}{.515RESE} + \underset{(.05)}{.333INDE} + \underset{(.11)}{.428TRNE} \quad R^2 = .923$$

$$(6)\quad OIL = \underset{(22.7)}{-10.094} - \underset{(6.3)}{2.290OIL(-1)} + \underset{(2.7)}{.406D_{174}} + \underset{(.21)}{.071T} + \underset{(.58)}{.586RESE} + \underset{(.98)}{.626INDE} + \underset{(8.03)}{3.425TRNE}$$

Table 3

Reduced Form Equations

Coefficients of Price of Oil and Time*

	GNP	RESE	INDE	TRNE	OIL
PE	- .0413	- .6805	.6682	- .2385	- .2878
	(.02)	(.12)	(.11)	(.06)	(.05)
T	.0188	.2268	- .2677	.0729	.0877
	(.007)	(.04)	(.04)	(.02)	(.002)
R^2	.980	.952	.866	.697	.863

*All variables are in logs. The values in parentheses are standard errors of estimates.

Conclusions

A compact model linking energy price and GNP was suggested and its parameters estimated. The advantage of a simultaneous equation system is that it enables the embodying of structural changes that were not a priori considered (since they were not present) as well as of those variables included in the model. Hence, the effect of an increase in the price of oil on GNP can be predicted directly from the reduced form equation of GNP on PE (Table 3) or using the structural equations (Table 1 (.082 (-.003) + .090 (.034 + .82 -(.197)) = -.0324) to be about -.4 percent for 10 percent increase in price. This, however, will be offset somewhat by the time variable. One quarter is 3.3 percent (T = 30). Thus the effect of time on GNP is + .04% (.012 + .082 .059 + .090 (-.132) + .056 .182) * 3.3). Hence, the net effect would be a decline in GNP of about 1/3 of one percent. If, however, the residential energy consumption GNP relationship remains but RESE declines by 10 percent within a quarter (seasonally adjusted) GNP would decline by .8 percent of which .04 percent is restored by time. Thus, GNP will decline by about 3/4 of 1 percent. The same 10 percent increase of oil price would lower oil consumption by 2.9 percent out of which .3 will be offset by the positive time effect. Hence, a decline within a quarter of 2.6 percent of oil consumption will be observed.

The study left some unanswered issues. The most important is the unexpected signs of the time and price in the industry equation. Also since only 29 observations are available (one was lost because of using lagged variables) we utilized all for estimation. The deviation of the predicted values from the observed ones did not exceed 5 percent in more than 35 percent of observations. Yet the main test would be when future quarters are predicted.

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