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BY

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Introduction

This study examines the effects of price incentives on the availability of petroleum. Although only three percent of the total domestic consumption of petroleum is used in agriculture, agricultural production is highly dependent on petroleum. Virtually all mobile power units operate on petroleum products and their continued use depends on an adequate supply of petroleum (Pagoulatos and Timmons). The availability of low cost energy to fuel mobile power units has been the major force behind the mechanical revolution that has taken place within agriculture. The continued availability of fertilizers, insecticides and herbicides is dependent upon the availability of petrochemical bases. Furthermore, although the capital stock of U. S. agriculture can be shifted to a system less heavily dependent on petroleum, the shift will be expensive and will have massive impacts on food costs, land use and production intensity for American society.

Agriculture department officials are aware of the importance of petroleum and petrochemicals for the continued productivity of U. S. agriculture, and provide input into economic policies that affect petroleum supplies. Nonetheless, congress and the administration will design energy policy dealing with the total energy supply for all sectors of the U. S. economy, not just for agriculture. While the newly created cabinet level energy office will look to agriculture officials for advice concerning the special needs for petroleum in agriculture, this

office must be concerned with the petroleum situation for the entire U. S. economy. Hence, in assessing the impact of national policy on the availability of petroleum products for agricultural uses, the economic forces affecting the total petroleum extraction system must be considered.

This study presents a model useful for examining the effects of Selected price policies by the federal government on petroleum production. We attempt to determine if adjustments in the pricing mechanism for domestic crude oil will improve the demand-supply situation for oil in the U. S. Price policies examined include: (a) equalization of the domestic wellhead price for crude oil at the world price, (b) constant money wellhead prices for crude oil, (c) constant real wellhead prices, and (d) equalization of domestic wellhead prices with the 1976 world price with increases thereafter equal to the change in the domestic wholesale price index.

Model Structure

While agricultural economists have already been concerned with the effects of increased energy costs on the availability of fuels and chemicals, on the mix of crops produced, and on the shifts in producer and consumer welfare, they have not dealt with the more general problem of the effect of government policy on the petroleum extraction system (cf. Adams, King and Johnston, Heady and Dvoskin, Carter and Youde, and Klepper et. al.). In an effort to delineate areas of energy research for agricultural economists, Whittlesey and Butcher argue for research

dealing not only with impacts of the changing energy situation on agriculture but for more involvement by agricultural economists in the national situation of supply, demand and policy for energy resources.

Studies by Epple, Khazzoom, Carter, Fisher, Adams and Griffin, and Erickson, Millsaps and Spann, have all dealt with the oil discovery problem. However, these studies have not analyzed the impact of economic policy on the total oil production system, but rather focused on specific facets of the industry. MacAvoy and Pindyck did develop an integrated economic model, but their study was designed to assess the effects of alternative regulatory policies on the natural gas, not crude oil industry.

In this paper, a theoretical model that captures the total system regulating the generation and extraction of crude oil is developed. The model is explicitly designed to test the responsiveness to price incentives of petroleum exploration, reserves generation and extraction. Figure 1 illustrates the conceptual relationships comprising the structure of the model. The model consists of three major components: (a) a petroleum exploration submodel, (b) a reserves generation submodel, and (c) a submodel generating oil for refined products.

Petroleum Exploration

The petroleum exploration component of the model consists of four stochastic equations and one identity (Table 1). The supply of new domestic oil is determined by the product of the number of exploratory wells drilled (TED) and (ADSZ) the average discovery size per well (Equation 1). The number of exploratory wells drilled (TED) depends

upon the interrelationship between expected returns from oil and gas, costs of production and risk (Equation 2).[1] Because of the time-lag between investment outlays and the accrual of revenues, the interest rate is included.

The search for oil and gas is carried out jointly, and new oil discoveries (ADSZ) are associated with discoveries (SZNG) of natural gas (Equations 3-4). The higher the ratio of past gas discoveries to past oil discoveries, the higher the probability of finding oil. However, as Fisher points out, there are many more small, less risky, petroleum prospects still to be discovered than there are large, more risky prospects. Hence, the average discovery size will be reduced as the finite stock of oil and gas is depleted. The success ratio (SUC), defined as the ratio of productive to total new wells drilled, is a function of previous discoveries of oil and gas and the depth at which exploration is taking place (Equation 5).

The price of crude oil (P) is a function of the price of close substitutes (natural gas and imported crude oil) and the extent of refinery capicity utilization (Equation 6). A distributed lag of the sales of refined products rather than actual sales is used, because a sustained increase in sales of refined products must occur if the price of crude oil is to increase.

Reserves Generation

The reserves generation component of the model consists of two stochastic equations and one identity (Table 2). Total proven reserves

of crude oil (TR) are equal to the sum of reserves remaining in the previous period, (R_{t-1}), new discoveries (DC), new extensions of reserves (EC) and revisions to existing reserves (RC) for any time period (Equation 7).[2]

Extensions of previously discovered oil (EC) depend upon expected prices, which are given by a distributed lag (see Griliches), as well as the amounts of crude previously discovered (Equation 8). Economic incentives result in the adoption of new technologies on extraction and make possible the use of secondary and tertiary recovery methods. Revisions of established reserve levels (RC) do not respond to economic or technological variables and are assumed to be proportional to changes in reserve levels (Equation 9).

Oil for Refined Products

The final submodel focuses on oil for refined products (Table 3). The primary inputs to the petroleum refining industry are domestic crude oil and lease condensate (S), natural gas liquids (NG) and oil imports (M). To arrive at the total quantity of products from the refinery, (DISTR), the processing gain realized in the refineries (GA) is also included (Equation 10).

Because petroleum producers attempt to balance annual flows with reserve levels, the supply of domestic production (S) is determined by the marginal cost of developing existing reserves (Equation 11). Hence, marginal production costs will depend on reserve levels relative to domestic production. As the reserve to production ratio declines,

marginal costs rise exponentially. Development of new production sites will be undertaken only if the expected price of oil covers all costs including a normal return on investment and a risk allowance. A short-term glut may send current prices down. If the glut was expected to be temporary, and long-run price expectations were high enough, development might continue even at low current prices.

Price expectations and the opportunity cost of investing in petroleum production are expressed as distributed lags of past prices and the difference between net price and the rate of interest.[3]

Imports of crude petroleum are assumed to respond to domestic economic policy as well as the price of imported crude oil (Burrows, Adelman). Current imports (M) are viewed as demand for foreign crude oil and respond to the utilization of domestic refining capacity which acts as a constraint on the domestic supply of crude, since import quotas were set on the basis of domestic output (Equation 12).

The amount of natural gas liquids (NG) added in the refinery process, because of economic and technological factors, has been steadily increasing over time (Equation 13). Natural gas liquids have been a relatively small proportion of total inputs (averaging about 14 percent of total supply over the period 1959-1972) and have been directly related to the price ratio of crude to natural gas liquids.

The processing gain (GA) represents the expansion of fuels due to some refining processes such as reforming and cracking, and is the final component of the total amount of refined liquids.[4] The quantity of processing gain increases in direct proportion to the amount of

crude oil and lease condensate run through stills, and declines in proportion to the amount of natural gas liquids added for refining (Equation 14).

Estimation and Validation

The complete econometric model consists of 11 stochastic equations and 3 identities. Some of the parameters of the structural relationships are simultaneously determined. Two stage least squares and three stage least squares were used to estimate model parameters. Estimates obtained via the three stage least squares method were somewhat more efficient than the two stage least squares estimates. Three stage least squares results are presented in Tables 1-3. Estimates were obtained using sample data from 1959 to 1972.

A major effort was devoted to the validation of the model using quantitative measures suggested in Theil (1966). The model was first validated with respect to its ability to predict endogenous variables within the range of the sample data over the time period 1959 to 1972. Predicted values for endogenous variables were obtained for reduced forms from the first stage of estimation (the Unrestricted Reduced Form or URF estimates). Predicted values generated from the structural equations of both the second and third stage (the Restricted Reduced Form or RRF estimates) of the model were also generated. The predicted values from each of the three estimation methods (URF, two stage RRF, and three stage RRF) were used in conjunction with sample data to calculate Theil coefficients, correlations between actual and predicted

values, root mean square errors, and error decomposition measures (Theil, 1966). None of the prediction methods were found to be clearly superior to the others based on these validation measures (Steckler). Table 4 summarizes calculated values for the validation measures using predictions obtained from the structural equations of the third stage. Calculated values suggest that the model largely does an adequate job of predicting endogenous variables within the range of the sample data.

Old Theil coefficients based on predicted and realized changes in endogenous variables ranged from .164 to .793 while new Theil coefficients ranged from .248 to 1.063. Simple correlations between actual and predicted values were above .88 except for the equation generating the average size of natural gas discoveries. Regression coefficients of actual data on predicted values were all near one. Root mean square errors are all low relative to the magnitude of raw data values.

To further scrutinize the model's efficacy as a predictive device, predictions for endogenous variables were calculated for the years, 1973, 1974, 1975 and 1976 using actual data for predetermined variables for those years. Comparison of actualy observed values of endogenous variables for 1973, 1974, 1975 and 1976 with values obtained from the equations based on the 1959 to 1972 data provide a very critical test of the ability of the model to predict beyond the range of the sample data. Results using the RRF three stage least squares parameter estimates are presented in table 5. Predicted values for the years 1973-1976 all track very closely historical data for the same time period (see Figure 2-4).

Using the Oil Model in a Policy Setting

Given the lags from price changes to exploration, development, and production changes, it might be expected that very little additional supply would be forthcoming in the next three years from increased crude oil prices. The demand conditions of the 1980's can be described in a number of ways, varying from quite expansive (continued increases in petroleum product demands due to strict regulation of crude oil prices) to quite restrictive (because of higher crude oil prices and new coal and solar energy technologies).

The approach taken here is not to choose an extreme set of values of the exogenous variables to be inserted into the model. Rather, a set of values was chosen that follows from "median" conditions likely to prevail in energy markets in the near future. Demand for crude petroleum is expected to increase at the rate of 2.2 percent per annum under constant present prices and at the rate of 2.0 percent per annum under world prices.[5] It is expected that natural gas prices will increase at a rate of 9 percent per annum in current dollar terms and that the average drilling cost will increase at 7 percent per annum.[6] These values were then inserted into the econometric model to produce simulated values of additions to reserves, total proven reserves and production out of reserves for the time period 1977 to 1985. Impacts of the four price policies on additions to reserves, proven reserves and production out of reserves are summarized in Figures 2-4.

Domestic production and reserves under world prices

Domestic price increases at the rate of world price rises would have only a slight impact on new discoveries of reserves over the 1977 to 1979 period.[7] This is due to the assumption of a decreasing success ratio and to the lagged response of exploration to economic incentives. Total additions to reserves are expected to increase by 25 percent in 1978 over 1977 and surpass 3 billion barrels in 1982 (Table 6). Total additions to reserves do not necessarily track closely the new discoveries due to the increased production levels over the 1977 to 1982 period (Figure 2).[8]

Price incentives in exploration coupled with a decreasing success ratio yield total additions to reserves which are lower than the amounts of extracted oil at these prices. Total additions to reserves reach 7 billion barrels a year by 1985. This is approximately 5.5 billion barrels greater than the new additions to reserves for 1977, expected prior to the series of price increases.

Higher crude oil prices at the wellhead would make it profitable to increase production by more than 2 billion barrels during the period 1978 to 1985. The increased production out of reserves reduces the reserve-production ratio from 9:1 in 1977 to 3:7 in 1985 as a larger proportion of existing reserves is removed in response to the price incentive.

The result of a deregulated domestic price is to substantially increase domestic production and greatly reduce the magnitude of the crude oil shortage. This is sufficient to meet 88 percent of expected

U. S. consumption from domestic sources by 1980. The domestic production shortage is eliminated and an excess supply results by 1985. Excess supplies occurring after 1983 may lead to rebuilding of the reserves base and to some price softening on new field contracts.

Constant real wellhead prices

Continuation of present regulations is envisioned as a maintenance of "ceiling" prices on "old" oil at a higher level than currently used and continued deregulation of "new" oil prices. The increase in the price of crude oil at the wellhead is hypothesized to be increasing at an average rate of 5 percent per annum corresponding to the expected inflation.

The increments of total additions to reserves are shown in Table 7; total additions each year fall short of those for Table 6. The supply of production out of reserves is steadily decreasing after 1978 with a doubling of the excess demand by the year 1985. The lower wellhead price does not provide enough incentive for exploration and production out of reserves, but stimulates a higher level of demand in the economy. Furthermore, the price incentives coupled with the decreasing success ratio account for lower additions to reserves compared to the amounts extracted, with reserves decreasing to 23 million barrels in 1985.

Imports increase by 29 percent by 1980, and domestic crude oil constitutes only 50 percent of the total U. S. consumption. Because of the relatively lower profitability, the reserve-production ratio remains higher than before. Proven reserves decrease to 23.1 billion barrels and production out of reserves to 2 billion barrels in 1985.

Constant wellhead prices

Under the assumption of constant wellhead prices, additions to reserves decline very rapidly with no new oil being discovered after a 5 year period (1977-1982). Import levels would increase by 62 percent by 1980, and only 45 percent of total U. S. consumption will be supplied by domestic oil. The supply out of reserves also decreases, due to the lack of economic incentives. Excess demand reaches 5.5 billion barrels in the year 1985. As expected, the reserve production ratio increases as more oil is kept in the ground (Table 8).

Extended price controls

Under this plan, price controls on the price of crude petroleum at the wellhead are to change as follows: a) the price of newly discovered oil will be allowed to rise over a 3 year period to the 1976 world price, adjusted thereafter for domestic price increases; b) the current $5.25 and $11.28 price ceilings for previously discovered oil will be allowed to rise at the rate of domestic price increases; c) incremental tertiary recovery from old fields would receive the world price. Finally, a crude oil equalization tax equal to the difference between the controlled domestic price and the world price would be used to raise the price of domestically consumed oil to the world price.

This scheme of pricing domestic oil at the wellhead seems to provide adequate economic incentives for increased efforts in exploration and extraction of crude oil (Table 9). Total additions to reserves

double within a five year period (1977-1981) and supply out of reserves increases by about 40 percent over the same period.[9] Domestic production by 1980 will constitute 82 percent of total domestic consumption. Imports will be cut by one half compared with current levels. Excess demand reduces to zero by 1983 (within a 6 year period) and reserve-production ratios are fairly low. Although the reserve-production ratios are higher than the ratios under world prices for domestic producers, the incentives for extracting oil are substantial.

Conclusions

We have developed an econometric model which examines the responsiveness of petroleum exploration to prevailing oil prices. The model consisted of 11 stochastic equations and 3 identities, and the model was estimated via three stage least squares and validated with a variety of numerical measures. The behavior of the model beyond the sample period appeared to be quite good. Statistical results suggest that producers respond to expected sustained price increases and that if our nation's proven reserves of oil are to increase, we must be willing to pay a higher price.

Preliminary indications from the simulations of this study indicate that rising crude oil prices provide the necessary incentive to the U. S. petroleum industry for intensifying the exploration effort. Higher prices increase the number of new exploratory wells drilled and the use of the secondary and tertiary recovery methods. Although a time

lag exists between the exploration stage and the development of wells, higher prices also induce more production out of reserves. Consequently, the market mechanism by itself appears to be capable of bringing about the necessary adjustments in the domestic reserves of crude oil as well as the supply of domestic crude to the refineries. However, high prices tend to induce comparatively lower reserve to production ratios as the amounts extracted from the ground are larger than the additions to reserves, given the assumption of a decreasing success ratio in exploration.

Equalization of the domestic price of crude oil at the wellhead with the world price provides enough incentive to domestic producers to increase exploration and extraction. Although under this policy the U. S. could become self sufficient in a period of six years after implementation, sizeable windfall profits would be secured by the producers. A constant price or constant real price with base year 1976 would provide insufficient incentive for domestic producers. But a policy of constant real 1976 world price for the domestic producers would result in sufficient incentives for an increased oil flow, which eventually would make the U. S. self-sufficient within a seven year period.

Crude petroleum shortages for agriculture will occur when market distortions affect the flow of petroleum to producers of agricultural inputs and hence affect the seasonal flow of petroleum products to farmers. If domestic oil prices are set at less than 80 percent of market prices, a potential seasonal shortage of petroleum products may occur.

However, the potential for shortages is not the major issue. Primary concern rather should be directed toward technological adjustments that need to take place within agriculture in response to certain higher prices for petroleum and petroleum products.

Footnotes

[1]For the derivation of the estimated equation see Pagoulatos, Pagoulatos and Debertin, MacAvoy and Pindyck, Lintner, Mossin and Sharpe.

[2]Proven reserves according to the American Petroleum Institute are the estimated quantities of crude oil which geological and engineering data demonstrate with reasonable certainty to be recoverable from known reservoirs under existing economic and operating conditions. Although proven reserves are known with a probability of one at any given time, indicated and inferred reserves can be considered given lower probabilities. Also, the percentage of oil recovered from any given deposit has been increasing with cumulative recovery efficiency rising from 25 percent in 1955 to 33 in the 1970's. Secondary and tertiary recovery with expectations for higher prices as they become more economical will be increasing the cumulative recovery efficiency, thus increasing the extensions of proven reserves as well as the revisions. About 50 percent of the oil from the reservoirs discovered to date is still in the ground (Risser).

[3]The equilibrium path that the price of a nonrenewable resource should follow to the point of exhaustion is such that net price is increasing exponentially at a rate corresponding to the interest rate, unless technological progress affects production (Adelman, Epple, Hotelling, Nordhaus, and Solow).

[4]The processing gain represents approximately 3 percent of the total supply of refined products over the 1959-1972 period.

[5]The Energy Policy and Conservation Act provides for a Strategic Petroleum Reserve in order to reduce the impact of disruptions in

supplies of petroleum products. The Act requires storage of at least 150 million barrels of petroleum products and crude oil by December 22, 1978, and authorizes the storage of up to 1 billion barrels by December 22, 1982. These amounts of crude oil will have to be added in our calculations of demand.

[6] The assumption of a decreasing success ratio is conservative in that despite the past trend, future offshore leasing may stimulate larger average discovery sizes per well drilled. Furthermore, over the sample period the success ration increased at a rate of 0.5 percent per annum.

[7] World prices are assumed to increase at an average rate of 10 percent per year. More recent moderate stands taken by OPEC cast some doubt on the likelihood of this scenario.

[8] The figures include the 9.6 billion barrels located in Prudhoe Bay, Alaska, in 1968.

[9] Our calculations are based on the 1976 world price and an increase thereafter of 6 percent per year.

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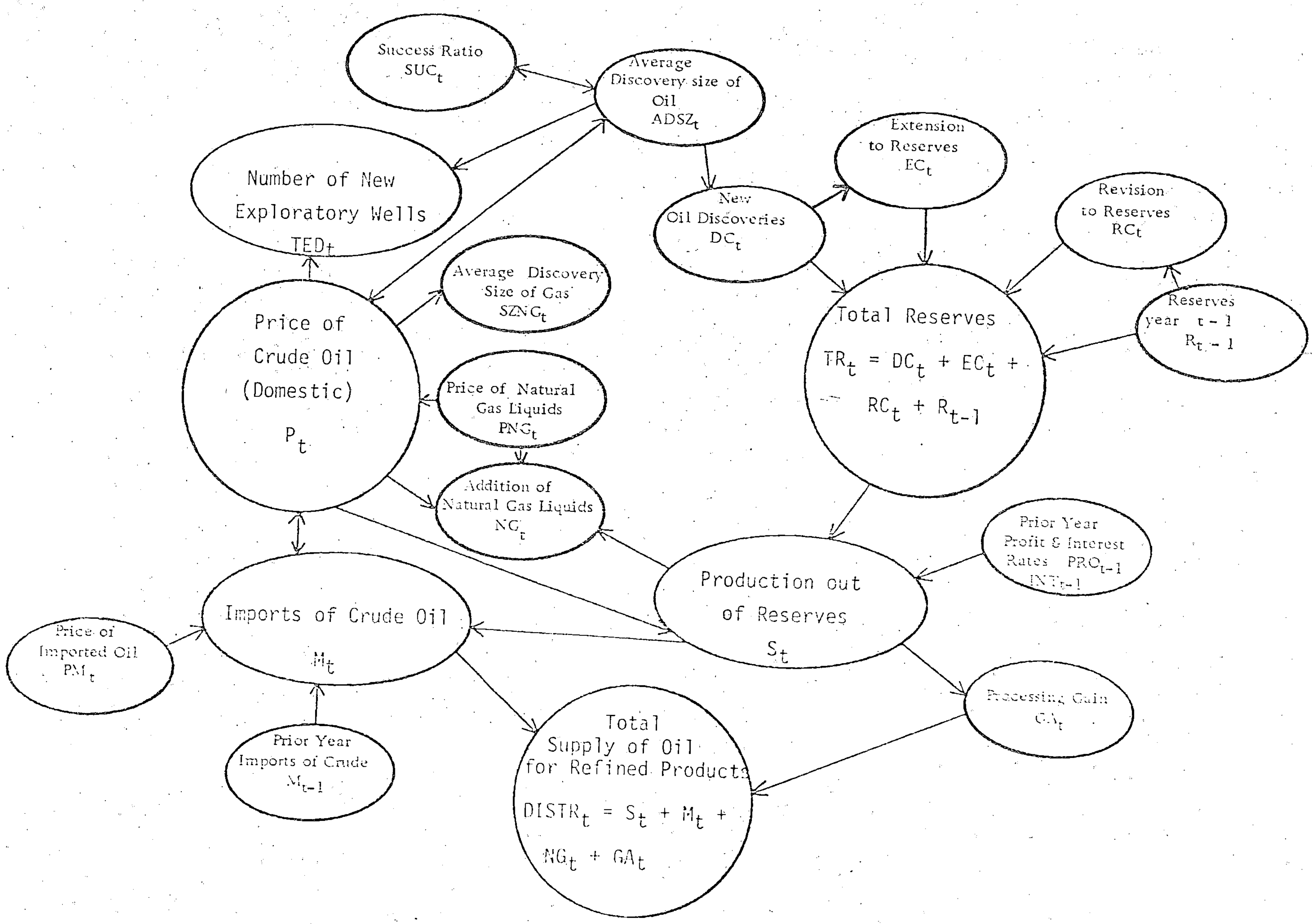

Figure 1.--Causal flow diagram of the petroleum model.

Table 1. Petroleum Exploration[a]

New oil discoveries

(1) $\hat{DC} = \hat{ADSZ} \times \hat{TED}$

New exploratory wells

(2) $TED_t = 77747.5 - 69778.8\, ACW_t - 2581.9\, INT_t + 0.0066\, [4\sigma_0^2\, ADSZ_t^2\, (P_{t-1} + P_{t-2} + P_{t-3})^2/9 + 4\sigma_G^2\, SZNG_t^2\, (PNG_{t-1}$

(3142.4) (6577.0) (562.2) (0.0014)

$+ PNG_{t-2} + PNG_{t-3})^2/9] - 0.00114\, [\hat{ADSZ}_t\, (P_{t-1} + P_{t-2} + P_{t-3}/3) + SZNG_t\, (PNG_{t-1} + PNG_{t-2} + PNG_{t-3}/3]$

(0.00025)

Average discovery size of oil

(3) $\ln ADSZ_t = -74.75 - 0.0815 \ln ADSZ_{t-1} + 15.30 \ln SUC_{t-1} - 1.45 \ln SZNG_{t-1} - 0.441 \ln \hat{P}_t - 1.31 \ln PNG_t$

(12.8) (0.0353) (2.41) (0.08) (0.449) (0.27)

Average discovery size of gas

(4) $\ln SZNG_t = -54.29 - 0.245 \ln SZNG_{t-1} + 10.08 \ln SUC_{t-1} - 0.0235 \ln ADSZ_{t-1} + 0.911 \ln PNG_t + 1.74 \ln \hat{P}_t$

(29.93) (0.176) (5.19) (0.0078) (0.819) (3.84)

Success ratio

(5) $\ln SUC_t = 2.48 - 0.432 \ln SUC_{t-1} - 0.0148 \ln ADSZ_{t-1} - 0.0148 \ln SZNG_{t-1} + 0.610 \ln DEP_t$

(0.60) (0.140) (0.0022) (0.0046) (0.043)

Price of crude oil

(6) $\ln P_t = -5.25 + 0.0000013 \ln PNG_t - 0.120 \ln REF_{t-1} + 0.0000015 \ln [1.1 (0.65\, DISTR_{t-1} + 0.35\, DISTR_{t-2})] + 0.702 \ln PM_t$

(1.07) (0.0000008) (0.028) (0.00000008) (0.102)

Definition of variables

DC = new oil discoveries, measured in 42-gallon barrels. Source: (American Petroleum Institute, API).

TED = number of new exploratory wells drilled (total productive and dry holes drilled each year). Source: (API).

SUC = success ratio (ratio of productive to total new wells drilled).

ADSZ = average size of new oil discoveries (ratio of new discoveries to total productive and dry holes).

SZNG = average size of new natural gas discoveries (ratio of new discoveries to total productive and dry holes). Source: (API).

ACW - average cost per exploratory well drilled (in dollars). Source: (API).

INT = interest rate (price of commercial paper 1 to 6 months). Source: (Federal Reserve).

PNG = price of natural gas liquids at the well head (dollars per barrel). Source: (U.S. Bureau of Mines, USBM).

P = price of crude oil at the well head (dollars per barrel). Source: (USBM).

DEP = average depth of new exploratory wells (in feet). Source: (API).

REF = refining capacity utilization. Source: (API).

DISTR = sum of domestically supplied refined products, net of imports, exports and change in petroleum stocks (42-gallon barrels). Source: (USBM).

[a](Standard errors are in parentheses).

Table 2. Reserves generation

<u>Total reserves</u>

(7) $\hat{TR}_t = R_{t-1} + \hat{DC}_t + \hat{EC}_t + \hat{RC}_t$

<u>Extensions of reserves</u>

(8) $\ln EC_t = 5.82 - 0.0623 \ln DC_{t-1} - 0.201 \ln DC_{t-2} + 9.83 \ln[1.05 (0.75 P_{t-1} + 0.2 P_{t-2} +$
(1.64) (0.0346) (0.035) (1.10)

$0.05 P_{t-3})]$

<u>Revisions of reserves</u>

(9) $RC_t = 1018942.79 + 0.095 \Delta R_{t-1}$
(166043.42) (0.033)

<u>Definition of variables</u>

TR = total reserves, beginning of year (in 42-gallon barrels). Source: (API).

R = crude petroleum reserves (proved reserves at the end of the year), measured in 42-gallon barrels. Source: (API).

EC = extensions of oil reserves, in 42-gallon barrels. Source: (API).

RC = revisions of established reserves (42-gallon barrels). Source: (API).

Table 3. Oil for Refined Products

Total refined liquids

(10) $DISTR_t = \hat{S}_t + \hat{M}_t + \hat{NG}_t + \hat{GA}_t$

Production out of reserves

(11) $S_t = \underset{(4744257.7)}{26796754.3} + \underset{(3783596.7)}{14919184.5}\, ln[0.5\, P_{t-1} + 0.3\, P_{t-2} + 0.2\, P_{t-3})] + \underset{(5.80)}{45.05}\, \hat{TR} - \underset{(80744.7)}{1222577.01}$

$\{1.05\, [0.35\, (PRO_{t-1} - INT_{t-1}) + 0.25\, (PRO_{t-2} - INT_{t-2}) + 0.2\, (PRO_{t-3} - INT_{t-3}) - 0.2\, (PRO_{t-4} - INT_{t-4})]\}$

Imports of crude oil

(12) $lnM_t = \underset{(2.88)}{18.58} + \underset{(0.12)}{0.95}\, lnM_{t-1} + \underset{(0.30)}{1.26}\, ln\hat{S}_t - \underset{(0.185)}{0.299}\, lnPM_t - \underset{(0.65)}{4.28}\, lnREF_t$

Addition of natural gas liquids

(13) $lnNG_t = \underset{(0.583)}{12.74} - \underset{(0.0590)}{0.0976}\, ln(\hat{P}_t/PNG_t) + \underset{(0.026)}{0.332}\, lnT^2$

Processing Gain

(14) $lnGA_t = \underset{(32.65)}{-36.49} - \underset{(2.61)}{3.93}\, ln\hat{NG}_t + \underset{(3.66)}{6.39}\, ln(\hat{S}_t + \hat{M}) + \underset{(0.46)}{1.95}\, lnT^2$

Definition of variables

S = production of crude oul (thousands of 42-gallon barrels). Source: (API)

PRO = profit rate on equity of petroleum industry. Source: (First National City Bank).

M = imports of crude petroleum (S.I.T.C.: 334.01). Figures converted to thousands of 42-gallon barrels from metric tons. Source: (United Nations).

PM = import unit price (value f.o.b.). Source: (United Nations).

NG = natural gas liquids added (thousands of 42-gallon barrels). Source: (API).

GA = processing gain (thousands of 42-gallon barrels). Source: (API).

T = linear time trend.

Table 5.--Historic Simulation and Projection of Selected Variables

	Total Additions to Reserves[a]		Total Reserves[a]		Supply of Production[a]		Reserve Production Ratio	
Year	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated
1959	3,666	3,427	31,719	31,411	2,574	2,417	12.3	12.9
1960	3,365	2,340	31,613	31,369	2,574	2,581	12.2	12.1
1961	2,657	2,527	31,758	31,954	2,621	2,529	12.1	12.6
1962	2,180	2,320	31,389	31,275	2,676	2,641	11.7	11.8
1963	2,174	2,343	30,969	31,439	2,752	2,662	11.2	11.8
1964	2,664	2,434	30,990	30,901	2,786	2,972	11.1	10.4
1965	3,048	3,272	31,352	31,100	2,848	3,074	11.0	10.1
1966	2,964	3,162	31,452	31,193	3,027	3,169	10.4	9.8
1967	2,962	2,951	31,376	30,964	3,215	3,179	9.7	9.7
1968	2,454	2,282	30,707	30,556	3,329	3,178	9.2	9.6
1969	2,120	2,258	29,631	29,320	3,371	3,494	8.7	8.4
1970	12,688	10,163	39,001	36,196	3,517	3,387	11.0	10.7
1971	2,317	2,277	38,062	35,056	3,453	3,417	11.0	10.3
1972	1,557	1,459	36,399	33,068	3,459	3,447	10.5	9.6
1973	2,145	2,100	35,299	31,808	3,360	3,287	10.5	9.6
1974	1,993	2,000	34,249	30,595	3,202	3,213	10.6	9.5
1975	1,318	1,312	32,682	28,719	3,052	3,188	10.7	9.0
1976	3,094	3,121	32,400	29,008	2,825	2,832	11.4	10.2

[a] Figures are ten thousand barrels.

[b] Simulated values are projections using coefficients derived from the 1959-72 sample data.

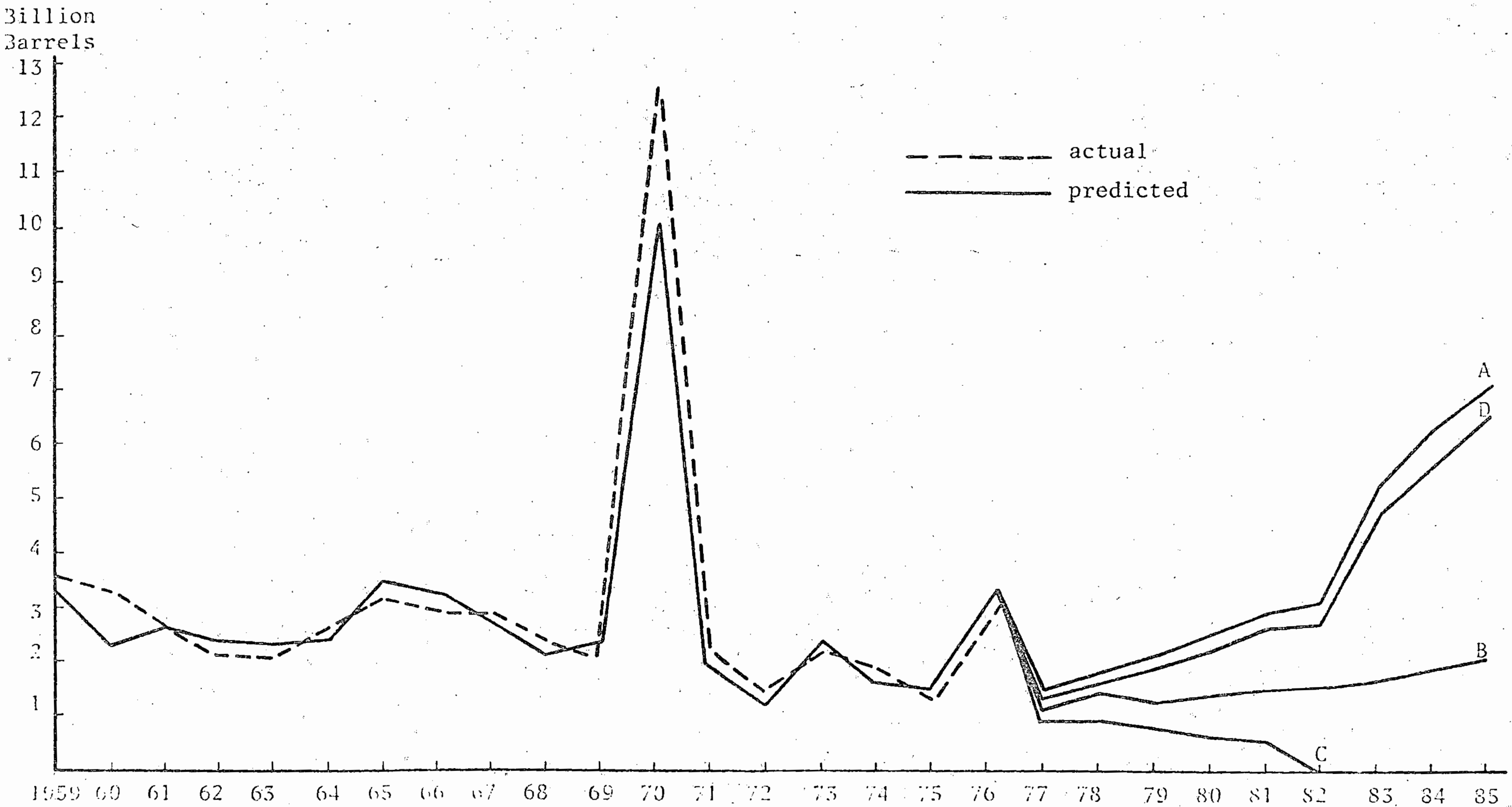

Figure 2. Impact of alternative price policies on additions to reserves

A - world prices
B - constant real prices
C - constant prices
D - extended price controls

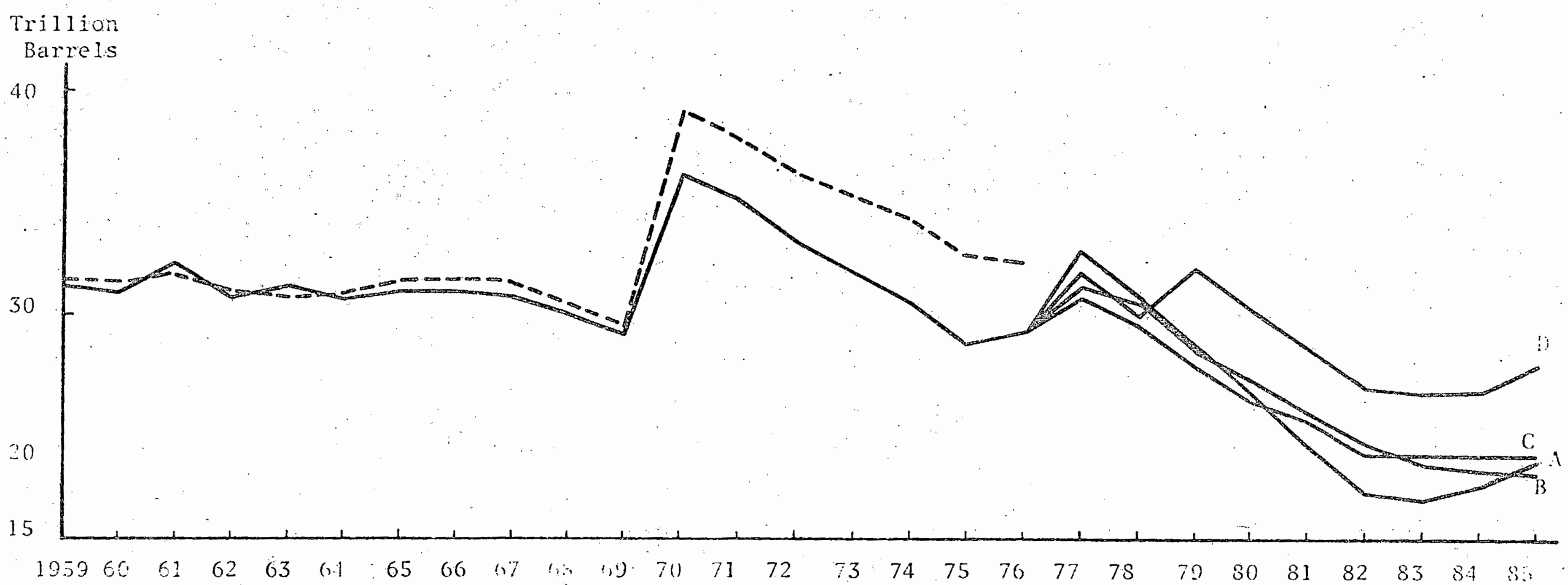

Figure 5. Impact of alternative price policies on reserves

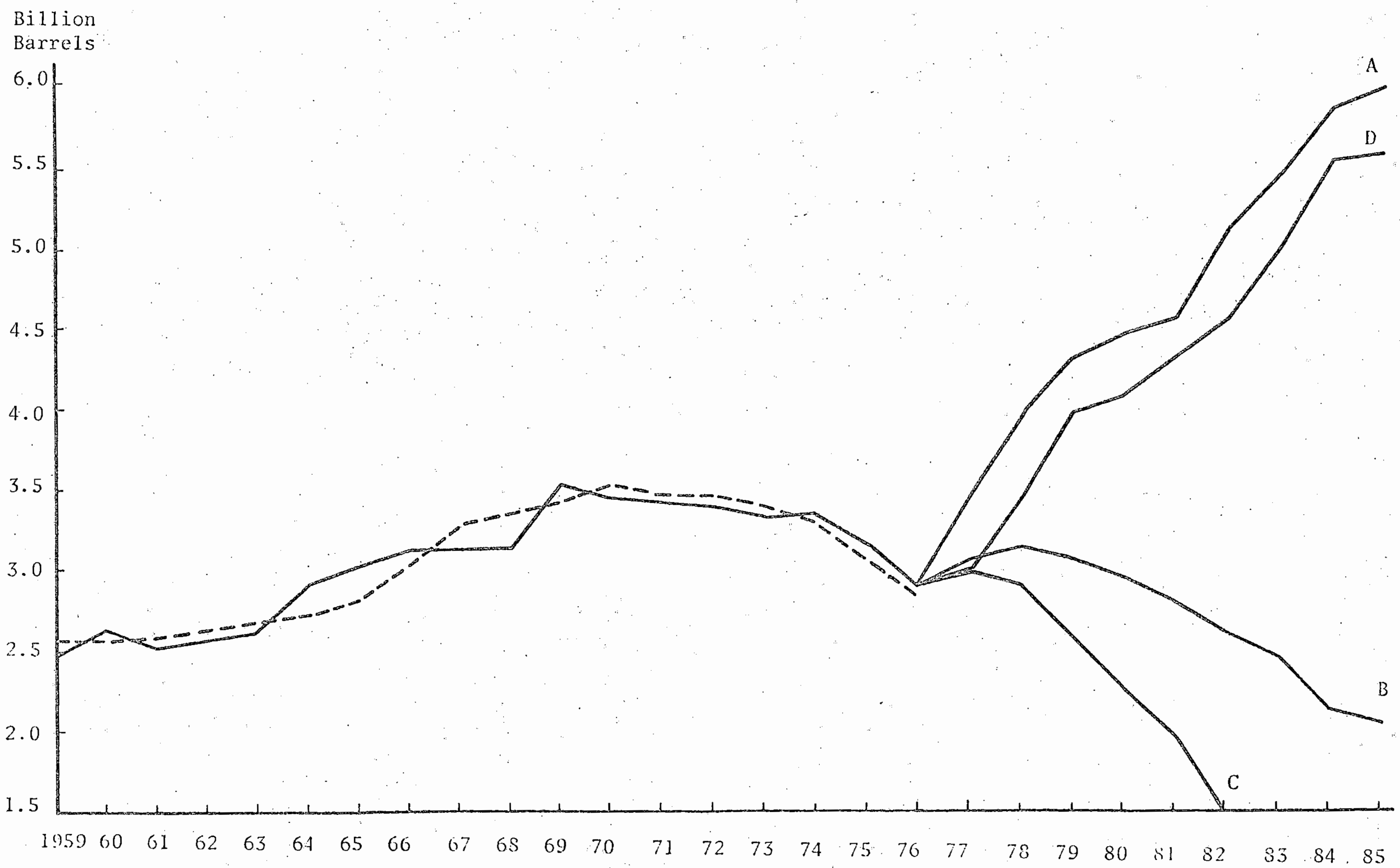

Figure 4. Impact of alternative price policies on production out of reserves.

Table 6.--Impact of Raising Domestic Crude Oil Prices at the Wellhead to World Prices, 1977-1985

Year	Total additions to Reserves[a]	Total Reserves[a]	Supply of Production[a]	Excess Demand[b]	Reserves Production Ratio
1977	1,497	32,797	3,450	1.3	9.5
1978	1,876	30,783	3,890	1.0	7.9
1979	2,103	28,570	4,317	0.6	6.6
1980	2,530	26,665	4,435	0.6	6.0
1981	2,922	24,017	4,590	0.4	5.2
1982	3,100	22,101	5,018	0.1	4.4
1983	5,256	21,910	5,447	-0.2	4.0
1984	6,370	22,315	5,965	-0.7	3.7
1985	7,106	23,393	6,028	-0.7	3.9

[a]Million barrels.

[b]Billion barrels.

Table 7.--Impact of Raising Wellhead Prices Five Percent Per Year, 1977-1985.

Year	Total additions to Reserves	Total Reserves	Supply of Production	Excess Demand	Reserve Production Ratio
1977	1,195	31,996	3,050	1.7	10.5
1978	1,365	30,258	3,103	1.7	9.7
1979	1,238	28,473	3,023	1.9	9.4
1980	1,303	26,877	2,899	2.2	9.2
1981	1,372	25,462	2,787	2.4	9.1
1982	1,475	24,300	2,637	2.6	9.2
1983	1,692	23,509	2,483	2.8	9.4
1984	1,853	23,176	2,186	3.2	10.6
1985	2,065	23,185	2,056	3.5	11.2

Table 8.--Impact of Constant Wellhead Prices, 1977-1985

Year	Total additions to Reserves	Total Reserves	Supply of Production	Excess Demand	Reserve Production Ratio
1977	1,129	31,300	3,013	1.7	10.4
1978	1,077	29,512	2,865	2.0	10.3
1979	933	27,838	2,607	2.3	10.6
1980	809	26,369	2,278	2.7	11.5
1981	703	25,193	1,879	3.4	13.4
1982	--	23,774	1,419	3.8	16.7
1983	--	23,700	--	5.3	--
1984	--	23,700	--	5.4	--
1985	--	23,700	--	5.5	--

Table 9.--Impact of Extended Price Controls, 1977-1985

Year	Total additions to Reserves	Total Reserves	Supply of Production	Excess Demand	Reserve Production Ratio
1977	1,385	31,996	3,150	1.7	10.4
1978	1,650	30,156	3,490	1.5	8.6
1979	1,890	32,046	3,995	0.9	8.0
1980	2,410	30,273	4,183	0.9	7.2
1981	2,708	28,617	4,364	0.6	6.6
1982	2,887	26,825	4,679	0.4	5.7
1983	4,950	26,605	5,170	--	5.1
1984	5,700	26,670	5,635	-0.3	4.7
1985	6,780	27,800	5,650	-0.3	4.9