PAPERS PRESENTED AT
A CONFERENCE ON
ENERGY PRICES, INFLATION AND ECONOMIC ACTIVITY

NOVEMBER 7 - 9, 1979

MIT ENERGY LAB WORKING PAPER No. MIT-EL 79-065WP

NOTE: All of these papers were distributed as discussion points for the conference, and should thus be considered only as discussion drafts.

A Brief Introduction to Papers Presented at the M.I.T. Center for Energy Policy Research Conference, November 7-9, 1979

The relationship between energy price increases and economic activity has drawn increased attention recently, and public policy debates have begun to consider this as one of the fundamental questions. The M.I.T. Center for Energy Policy Research has funded research into this question for the past two years, and the results from those investigations have occasioned considerable interest.

To further understanding of this question, CEPR held a conference November 7-9, 1979, bringing together other researchers, and individuals from government, industry, and public interest organizations. The purpose was not to reach consensus, but to understand better what were perceived to be the critical elements of both research activity, and public policy initiatives.

To set a framework for these discussions, participants spent the first two sessions reviewing the world oil market situation, and what likely developments there would be. The materials relating to these sessions are included here, and were sent in advance to participants.

The other papers here (following the tab) were prepared for the second part of the conference, dealing with Energy Prices, Inflation and Economic Activity. Dohner's paper gives an introduction to the subject of the conference, and surveys the issues and the research related to energy supply shocks. As an introductory survey paper, this was not actually presented at the conference, but was sent in advance to the participants.

The remaining papers were presented in three sessions at the conference. The first section, entitled Macroeconomic Analysis of Energy Price Shocks, featured papers by Mork and Hall, Eckstein, and Thurman and Berner. Mork and Hall's research is carried out at the Energy Laboratory, with CEPR and NSF funding. Their paper presents a broad outline of their model. Its most significant feature is stated as its integrated treatment of long-term supply issues on the one hand and short run macroeconomic disturbances, related to aggregate demand, on the other. The paper also reports on an application of the model to the 1979 oil price increase. Eckstein's paper gives a summary account of the role of energy in the DRI model and reports some significant recent changes in the model. The Core Inflation Model, an integrated part of the DRI model, is also presented in some detail. The paper then goes on to analyze the effects of the energy price increases in 1973-74 and in 1979. The quantitative results are similar to those of Mork and Hall. Thurman and Berner's paper reports the results of analyzing the effects of energy price changes in the MPS model, which is utilized by the Staff of the Federal Reserve Board. They describe the transmission channels for energy in the model. For their analysis of the 1979 energy price shock, they give a detailed calculation of the effects of decontrol policy. Since they assume a larger price increase as a result of decontrol, their estimate of energy-induced reduction in GNP over this period is somewhat larger than that of Eckstein and Mork and Hall.

The second session dealt with Macroeconomic Policy Responses to Energy Price Shocks. Papers were presented by Eckstein, Mork and Hall, and Pindyck. For the former two, the policy analysis was closely tied to their papers in the first session. Eckstein analyzes the level of general demand restraint needed to counteract the energy-induced inflation, and finds this policy to have a rather large impact on employment. Mork and Hall discuss the pros and cons of monetary versus fiscal expenditure policy. They express a preference for modest monetary expansion, because of its favorable effect on investment, although it will increase inflation in the long run. They also obtain encouraging results for payroll tax cuts and in increase in the investment tax credit, which encourage investment as well. Pindyck discusses alternative frameworks for analysis of policy after an energy shock, including the desirability of accommodative policy, and particularly how fast one wants to accommodate. The answer is found to depend on policymakers' preferences in regard to inflation and unemployment.

In the third session, Macroeconomic Analysis of Energy Price Shocks, papers were presented by Goettle (Dale Jorgenson Associates) and Schink

(Wharton Econometrics), based on the models of their respective institutions. Goettle analyzes the real economic cost of conservation policies versus development of alternative energy policies to reduce oil imports. His general equilibrium analysis shows the former alternative to be cost superior. Schink presents an analysis of Carter's energy plan, with respect to energy saving and security, balance of payments issues, and economic efficiency. He finds this plan to hurt efficiency in the form of reduced economic activity. On the other hand, significant gains are reported in the form of an improved balance of payments and a strengthened dollar.

Loren C. Cox
Executive Director
CEPR

SCHEDULE

NOVEMBER 7

5:30 - 7:00 p.m.	Varied arrivals and check-in at Sonesta Hotel, Cambridge, MA
6:00 - 7:00 p.m.	Open Bar (Charles River Suite A - Upper Lobby)
7:00 - 7:45 p.m.	Dinner (Charles River Suite A)
8:00 - 10:00 p.m.	World Oil Session (Charles River Suite A) "Interpreting Recent History - Demand Adjustments and Market Behavior" Presentation: Morris Adelman Comments: Warren Davis Moderator: Loren Cox

NOVEMBER 8

7:15 - 8:00 a.m.	Breakfast (Charles River Suite A)
8:00 - 10:00 a.m.	World Oil - "Condition of the International Financial System" (Charles River Suite B) Presentation: James Paddock Comments: Scott Pardee Moderator: Loren Cox
Coffee Break	Foyer
10:15 - 12:15	World Oil - "The Outlook for Capacity and Price" Presentation: Henry Jacoby Comments: John Mitchell Moderator: Loren Cox
12:15 - 1:00 p.m.	Lunch (Charles River Suite A) Presentation to participants of CEPR sponsored research on Energy Prices, Inflation and Economic Activity
1:00 - 2:30 p.m.	Macroeconomic Analysis of Energy Price Shocks Presentation: Robert Hall Knut Mork Moderator: Loren Cox

NOVEMBER 8 (Cont.)

Coffee Break — Foyer

2:45 - 4:00 p.m. — Macroeconomic Response to Energy Price Shocks
- Presentation: Robert Hall/Knut Mork
- Moderator: Loren Cox

4:00 - 5:15 p.m. — Macroeconomic Analysis of Energy Policies
- Presentation: Robert Hall/Knut Mork
- Moderator: Loren Cox

6:30 - 7:00 p.m. — Cocktails (Charles River Suite A)

7:30 - 8:30 p.m. — Dinner (Charles River Suite A)

(Evening free)

NOVEMBER 9

7:30 - 8:00 a.m. — Breakfast (Charles River Suite A)

8:00 - 10:15 a.m. — Macroeconomic Analysis of Energy Price Shocks (Charles River Suite B)
- Presentation (30 min.): Otto Eckstein
  - Robert Hall, Knut Mork
  - Richard Berner, Stephan Thurman
- Opening Discussion (30 min.): Robert Gordon
  - Alan Blinder
  - Robert Solow
- General Discussion: Moderator: Loren Cox

Coffee Break — Foyer

10:30 - 12:15 — Macroeconomic Response to Energy Price Shocks
- Presentation (30 min.): Otto Eckstein
  - Robert Hall, Knut Mork
  - Robert Pindyck
- Opening Discussion (30 min.): Franco Modigliani
  - George Perry
  - Stephen McNees
- General Discussion: Moderator: Loren Cox

12:15 - 1:15 p.m. — Lunch and Check Out (Charles River Suite A)

NOVEMBER 9 (Cont.)

1:15 - 2:45 p.m. Macroeconomic Analysis of Energy Policies

Presentation (20 min.): Richard Goettle
George Schink

Discussion (30 min.): Bill Hogan
Ray Scheppach
Denny Ellerman

General Discussion: Moderator: Loren Cox

3:00 p.m. Conclusion/Departure

ATTENDEES OF NOVEMBER 7 - 9 CONFERENCE ON ENERGY PRICES, INFLATION AND ECONOMIC ACTIVITY

Morris A. Adelman	Professor of Economics Massachusetts Institute of Technology
Ben C. Ball, Jr.	CEPR Liaison Gulf Oil Corporation
Paul Basile	Research Analyst Subcommittee on Energy and Power Committee on Interstate and Foreign Commerce U.S. House of Representatives
Richard Berner	Economist, Board of Governors Federal Reserve System
Phillip Blakeley	Petroleum Services ICI Limited
Alan Blinder	Professor of Economics Princeton University
Ralph Bristol, Jr.	Chief, Econometric Analysis Staff, OTA Office of the Secretary of the Treasury
George S. Broussard	Planning Manager Panhandle Eastern Pipe Line Company
William Carson	Chief, Crude Oil Pricing Branch Economic Regulatory Administration Department of Energy
E. Anthony Copp	Vice President Salomon Brothers, Inc.
Loren C. Cox	Executive Director, CEPR Energy Laboratory Massachusetts Institute of Technology
Eliot R. Cutler	Associate Director, Natural Resources, Energy and Science Office of Management and Budget The White House
Warren B. Davis	Chief Economist Gulf Oil Corporation
John V. Deaver	Manager, Economic Department Ford Motor Company

John Deegan	Vice President Consolidated Edison of New York
George Dowd	Counsel Energy Resources and Materials Production U.S. Senate
Theodore R. Eck	Chief Economist Standard Oil Company (Indiana)
Otto Eckstein	Professor of Economics Harvard University
A. Denny Ellerman	Secretary for Policy Analysis Department of Energy
John C. Fisher	Consultant, Research and Development Research and Development Center General Electric Company
Ted H. Fones	Director Research Department Caterpillar Tractor Company
Richard Goettle	Economist Dale Jorgenson Associates
Robert J. Gordon	Professor of Economics Northwestern University
Joshua Gotbaum	Executive Assistant to the Advisor to the President on Inflation The White House
Mariano Gurfinkel	Petroleos de Venezuela Corporation Vice President Commercial and Suministro Department
David E. Gushee	Chief, Environmental and Natural Resources Policy Division Congressional Research Service Library of Congress
Ernst R. Habicht, Jr.	Director, EDF Energy Program Environmental Defense Fund
Robert E. Hall	Professor of Economics Stanford University
Robert Halvorsen	Associate Program Director for Economics National Science Foundation
James W. Hanson	Chief Economist Corporate Planning Department Exxon Corporation

Jack Hartshorn	Director and Vice President Eastern Hemisphere Jensen Associates, Inc.
William W. Hogan	Director of Energy and Environment Policy Center Professor of Political Economy Harvard University
Henry D. Jacoby	Professor of Management Sloan School of Management Director of CEPR, Energy Laboratory Massachusetts Institute of Technology
Larry Jacobson	Economist, Board of Governors Federal Reserve System
Daniel Kanyr	Economic Analyst Caterpillar Tractor Company
Bruce Kelley	Assistant Director of Research Caterpillar Tractor Company
I. C. Kerridge, Jr.	Vice President Stockholder Relations and Economist Hughes Tool Company
John Kraft	Directorate of Applied Science and Research Applications National Science Foundation
Charles P. Kindleberger	Professor of Economics Massachusetts Institute of Technology
Kunisada Kume	Ministry of Foreign Affairs Government of Japan
Daniel Luria	Research Associate Research Department United Auto Workers
Michael McKee	Staff Economist Council of Economic Advisors
Stephen McNees	Vice President and Economist Federal Reserve Bank of Boston
John V. Mitchell	Head, Policy Review Unit British Petroleum
Franco Modigliani	Professor of Economics Massachusetts Institute of Technology

W. David Montgomery	Deputy Assistant Secretary, Policy and Evaluation Department of Energy
James S. Moose	Deputy Assistant Secretary International Market Analysis Department of Energy
Knut A. Mork	Sponsored Research Staff Massachusetts Institute of Technology
Thomas L. Neff	Sponsored Research Staff Massachusetts Institute of Technology
Clarence Nelson	Vice President and Economic Advisor Federal Reserve Bank of Minneapolis
J. Madison Nelson	Development Manager Energy Materials Department E. I. DuPont de Nemours and Company
Charles C. Nicholson	Vice President B. P. North America, Inc.
Hisashi Owada	Ministry of Foreign Affairs Government of Japan
James L. Paddock	Research Associate and Lecturer Massachusetts Institute of Technology
Scott E. Pardee	Senior Vice President Foreign Trading Department Federal Reserve Bank of New York
George L. Perry	Senior Fellow Brookings Institution
Donald H. Peters	Corporate Director of Information Systems E. G. & G., Inc.
Perry Phillips	Demand Branch Manager British Petroleum
Robert S. Pindyck	Professor of Management Massachusetts Institute of Technology
William F. Pounds	Dean, Sloan School of Management Massachusetts Institute of Technology
Dorothy K. Powers	Energy Chairperson League of Women Voters of the United States

Patricia Revey	Economist Foreign Trading Department New York Federal Reserve
George Schink	Director of the Annual Model Wharton Econometrics Forecasting Associates
Walter W. Schroeder	Executive Assistant to the Chairman Federal Energy Regulatory Commission
Gordon Shearer	Senior Business Analyst Cabot Corporation
Allen Sheldon	Vice President Environment and Energy Resources ALCOA Corporation
Cornelius Shields	Vice President Public Policy Sun Company
Robert M. Solow	Professor of Economics Massachusetts Institute of Technology
John S. Sorice	Director Energy Planning Olin Corporation
Peter H. Spitz	President Chem Systems, Incorporated
David Sternlight	Chief Economist Atlantic Richfield Company
Andrew Stratton	Corporate Research & Technology Department ICI Limited
Michael Telson	House Budget Committee U.S. House of Representatives
Stephan Thurman	Economist, Board of Governors Federal Reserve System
Philip K. Verleger	Senior Research Scholar School of Organization and Management Yale University
John A. Walsh	Vice President, NEPSCO New England Electric System
Jack W. Wilkinson	Chief Economist Sun Company

David O. Wood	Associate Director of Energy Laboratory Massachusetts Institute of Technology
Martin Zimmerman	Assistant Professor Sloan School of Management Massachusetts Institute of Technology

Background Materials for Discussion of

THE WORLD OIL SITUATION

prepared by

M. A. Adelman, H. D. Jacoby and J. L. Paddock

November 7 - 9, 1979

The materials presented here are drawn from the work of the M.I.T. World Oil Project. The Project is financed primarily by the National Science Foundation Grant No. DAR78-19044; the application of financial analysis to particular exporting countries is supported by the Department of Energy.

The World Oil Situation--Discussion Outline

1. INTERPRETING RECENT HISTORY--DEMAND ADJUSTMENTS AND MARKET BEHAVIOR

As preparation for looking forward, we want to begin with a review of what has happened in the last few years. This comes in two parts: the 1973-78 evolution, and the 1979 turbulence. During each period, we need to look at demand and supply separately.

Table 1 shows the response of demand to the 1973-74 increases. (The estimate of real prices in the OECD is for 1976, but there was little net change in 1976-78; in some OECD areas there were even some decreases.)

The growth of oil consumption has been the joint effect of: (a) GNP growing at 2.5 percent per year, (b) energy use per GNP unit declining at about 1.5 percent per year, (c) oil use per GNP unit decreasing at an average 2 percent per year. As Note 1 attached shows, this would be broadly consistent with the demand model constucted by the M.I.T. World Oil Project, assuming a delayed response to the 1973-74 price changes, with its half life about 7 to 9 years. If the trend continues, non-Communist consumption in 1988 will be about 54 MBD. Table 2 compares these results with other studies.

These observations lead to several questions about the demand history:

(1) Have we overlooked some important factor that would explain the consumption record? For example, the RFF group (Dunkerley et al.) have found an energy-GNP relation above 1.0 which would imply a stronger price effect than that calculated in Note 1.

(2) The 1973-78 experience shows a small but significant substitution of non-oil for oil. Is this a transitory phenomenon or does it have some years to run before being played out?

(3) Why has LDC consumption risen much faster than that of OECD? Will limits on borrowing constrain it?

The core OPEC nations (Persian Gulf, now excluding Iran) can export more than is demanded, to put down prices. Or they can export less, to raise prices. To see which seems more likely, we look back on the price history. Table 3 gives movements in list prices since 1970, and Figure 1 shows the relation between list prices and spot prices and net backs. Figure 2 shows the details of the past year. The figures indicate how the two big price increases have been brought about by production cutbacks, which made spot prices rise, which then drew contract prices after them. In the 1974-78 interim, there were modest price rises imposed by the OPEC nations, by changing the value of the marker crude. But during 1979, the marker crude has not been a representative list price. In Figure 1, therefore, we have supplemented it with the value of Iranian Light, whose intrinsic value is very close to Arab Light.

The recent picture has been further confused by several developments. First, the producing nations have practically ousted the multinational companies from the marketing of crude. They have put much more into the spot market, and now into the contract market, we cannot say how much. One would expect that with more going into the spot market, and particularly since current production has for some months exceeded consumption, spot prices would be falling swiftly toward contract, while contract would be rising slowly toward spot, with approaching convergence. But this has not happend. Even when spot prices were weakening in mid-Summer 1979 they stayed far above contract prices, and recently they have strengthened. The persisting uncertainty about near-term supply, and the desire to add to inventory even at very high prices, would explain it.

It has recently become clear that contract prices have moved substantially above the OPEC "list prices", and both OPEC and non-OPEC nations are charging them.

Tables 4 and 5 show the production behavior of key producers during the Iranian shortfall. And Tables 6 and 7 indicate the level of excess capacity held by OPEC throughout these events. Table 6 uses PIW figures for capacity, Table 7 is based on the more conservative CIA figures. These capacity estimates are further elaborated in Tables 8 and 9. As Tables 6 and 7 show, considerable excess capacity has existed over the past year, even during the worst of the Iranian crisis.

How are we to explain the restrained production of the Persian Gulf countries? There seem to be three main types of hypothesis:

Political. These countries are displeased with U.S. policy, particularly the Camp David agreements. Thus the U.S. Embassy in Jiddah: if we agreed to Saudi demands on Palestinian rights, "they would let us have all the oil we needed, and at very good prices."

Technical. Saudi Arabia no longer has spare capacity with which to expand output and keep down prices. Kuwait and Abu Dhabi don't care to help.

Economic. It is argued that Saudi Arabia and others in OPEC have not yet gotten price up to the wealth-maximizing level, and this is being achieved by capacity controls and exploitation of disruptions to ratchet the price up. Commissioner Brunner of the E.E.C. has stated that the objective of Saudi Arabia and neighbors is to maintain a constant small deficit, and calls this "economic brinkmanship". The path toward optimal revenue is along a backward-bending supply curve, an idea which has gained a distinguished adherant (British Petroleum) in a recent publication.

In the debate over these hypotheses, Saudi capacity has become a controversial subject. The CIA credits them with only 9.5 MBD (Tables 7 and 9), although they actually produced 10.5 in the first half of January. In any case, the CIA does not estimate the well capacity, but rather the narrowest bottleneck above ground.

There are persistent reports of technical difficulties, lower pressure, rising gas-oil ratios, especially in the Ghawar field. If we read the annual reports in the International Petroleum Encyclopedia, and in World Oil, there is no hint of any such problem. There are repeated estimates of Saudi capacity in the 11-12 MBD range. In early 1978, the Saudis were planning an early expansion to 12 or more MBD; this appears to have been shelved. The wells have actually produced nearly 13 MBD in a single day, according to some Saudi sources.

(4) Is anything known about capacity which is more precise than what the trade press or U.S. Government sources give us? In particular, we must distinguish among: (a) what the wells can safely produce at any given moment, (b) the capacity of above-ground installations, which may be greater or less, and (c) what additional capacity could be supplied in any given number of months?

(5) Given our understanding of the technical and economic issues of capacity, which of the three hypotheses above (which are not mutually exclusive) seems most accurate in explaining behavior over the past year?

All these are hypotheses of adjustment to a rapidly changing Iranian industry. Our perspective is a gloomy one. Past work of the World Oil Project has indicated that the Iranian industry is more than usually vulnerable to under-maintenance. Capacity was expected to be maintained only by a massive gas injection project, which has been suspended, and cannot be resumed without the expelled foreign personnel. There is also continuing unrest among the ethnic Arabs of Khuzistan province.

(6) Is there anything at all promising which we have not discerned?

Further background data on oil operations and primary stocks are provided in Tables 10 and 11.

2. THE CONDITION OF THE INTERNATIONAL FINANCIAL SYSTEM

In the face of the recent and continuing oil price increases, there is renewed concern about the world financial system. The role and capacity of the international financial system are key factors in facilitating world trade and economic growth. Therefore we need to examine the strengths and weaknesses of that system as they relate to oil trade.

Accomodation of an oil-importing country's trade by international financial markets has a direct impact on its rate of growth. A country's oil imports may be less responsive to a rising oil price if international financial transactions are possible, and thus the financial adjustment mechanism will allow a higher growth rate of GNP than would otherwise be the case. Simultaneously, however, a greater amount of oil imports may have an adverse effect on the importer's balance of payments, at least in the short-run. This effect may induce contractionary monetary and fiscal policies, or cause international capital markets to restrict lending to the country. Likely, the implications are different for industrialized countries than for LDCs.

Since the 1973 oil cutback and price jump, the international financial system has functioned adequately to handle the increased flows of payments. The absorptive capacity and responsiveness of the system has been able to accomplish the primary and secondary recycling demands[1] including portfolio investments of the OPEC "surplus." Most of these financial functions were carried out by private institutions, such as the

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[1] "Primary recycling" refers to direct payments for oil; "secondary recycling" refers to payments made with the help of loans from third countries.

Euromarkets. For example, the amount of loans outstanding to non-OPEC LDCs by commercial banks more than tripled between 1974 and 1978. (See Table 15). Much of the planned government involvement (e.g., the Kissinger "safety net") apparently was not needed unless simply to inspire confidence, which then allowed the private sector to function. Of course the IMF oil facility has been used.

Financial market transactions probably were not a constraint on oil trade or growth for most developed countries. For some LDCs, however, there may have been some inhibiting effects on economic growth, though they are difficult to estimate. Undoubtedly, some adjustment to higher oil prices took place through other markets as well, e.g., unemployment. The predicted massive surpluses on OPEC current account which would somehow seriously disrupt the international economic system never materialized. For example, the OPEC cumulative surplus will be approximately $308 billion in 1980 versus $68 billion in 1974. (See Tables 12 and 13). Of course, a substantial wealth transfer has taken place nonetheless.

Now we face a significant increase in the expected OPEC surplus over the near term, as shown in Tables 12, 13, and 14.

(1) Are there points of stress in the world's financial system which could have disruptive and/or differential effects on the growth rates of the world's economies? For example, there is a growing concern that the debt capacity of LDCs has been pushed to near its limit (see Tables 15b and 15c). Interest rates also have increased dramatically, as shown in Table 16.

(2) What is the financial system's shock absorbing ability in case of sharp price jumps? What future conditions or constraints may cause strain and damage to that international system?

It is often claimed that payments for the large imports of oil into the U.S. have direct depressing effects on the growth rate of U.S. GDP and on the value of the U.S. dollar. These effects are presumed to come from sources such as higher inflation rates, "excess" dollars for investment by OPEC countries, an increase in the supply of dollars as the U.S. "issues" more of them to pay for its oil imports, and an immediate "worsening" of the U.S. balance of payments due to its increased oil bill. For example, see Tables 17 and 18. The result will be lower U.S. economic growth, less confidence in the dollar as a reserve currency, and a decreased role for the U.S. as "banker to the world." On the other hand, if this flow of dollar credits has facilitated international financial intermediation, then perhaps a substantial decrease in U.S. oil imports would have a negative effect on world credit availability, oil trade, and, therefore, growth.

(3) To what extent are these monetary factors directly OPEC/oil related, and how much have they affected inflation rates and economic growth? What is the contribution of these factors to the rising differentials between U.S. economic growth rates and those of other industrialized countries?

(4) Can the U.S. deficit on current account really be blamed on our "large oil bill"--what about the counter-examples of West Germany and Japan?

(5) If the dollar remains "weak," what implications will that have for OPEC policy regarding the denomination of oil prices in dollars? Has the U.S. somehow been subsidizing the growth of West Germany and Japan as the real cost of dollar-denominated oil falls to those countries as their currencies rise against the dollar? (See Tables 3 and 18).

3. THE OUTLOOK FOR CAPACITY AND PRICE

Tables 6 and 7 show the excess capacity in OPEC over the period October 1978 through July 1979. The prospects for future price movements depend importantly on likely developments in capacity, and on market behavior in the face of supply interruptions, or changes in oil policy, in key supplier states.

(1) What are the prospects for expansion in Saudi capacity over the next 5 to 10 years?

(2) What is known about the deterioration of Iranian field capacity and other facilities, and what is the likely overall technical capacity to export over the next few years?

In the period of the Iranian interruption, several nations had excess capacity that was not used in the period of perceived shortage (see Tables 6 and 7). One may suppose that they had no interest in going very far out of their way to <u>restrain</u> the price ratchet. Indeed, many producers have an incentive to cut back during these periods, as they are experiencing increasing revenues--and perhaps expect higher revenues in future months, after the disruption is over and the price ratchet complete.

(3) Should we consider that there <u>always</u> will be this hesitancy to push to the limits of capacity in a short-term disruption? For financial reasons? For political reasons? Even in the face of severe price crisis? If so, does this mean that excess capacity means little in the face of these kinds of events?

(4) What kind of worldwide excess would there need to be (and be used) to <u>avoid</u> a price ratchet in the face of a loss of, say, 3 million barrels per day for a period of a few months?

As a result of the Iranian events, there appears to be a shift in expectations on the part of many observers: they expect more disruptions and consequent price increases, and they have a higher estimate of the long-term price--say, on a ten to fifteen year horizon.

(5) What effect are increased oil price levels, and changed expectations, having on capacity plans in non-core countries such as Mexico, U.K., Norway, etc?

With markets kept tight, the expectations for still more price rises may well be realized over the next year or two. But, as noted above, demand adjustment to price is well under way. And, as we will discuss later in the conference, the pressure of rising price is taking a toll in growth. Thus the price ratchet cannot go on without end. At some point, the demand effects are so great that significant excess capacity again appears.

In April, Sheik Yamani said a price of $40 (presumably in 1979 prices) was conceivable. The staff of the Joint Economic Committee wrote a worst-case scenario in which they put the price at $130 in 1979 prices. Mr. Laoussine of Algeria has called the synthetic production cost, which he thinks to be in the $30-$40 range, the natural ceiling to the world oil price. The one safe generalization is that nobody seems to think the maximum has been reached, nor that it would be less than $30.

(6) If we assume that the OPEC nations will not raise the price of crude oil so high as actually to decrease revenues, where is the neighborhood of that profit-maximizing price? Can we say that the numerous models which estimated an optimum OPEC price of $15 or less have been discredited by recent events? Or is

there any reason to think the producing nations have made a bad mistake in raising the price?

(7) What is a reasonable expectation for the price increases that can be sustained (or expected) over the period from now to 1990 or 1995?

(8) Is this expected path substantially different if policy measures (say in the U.S.) could cut demand by 1 or 2 million barrels per day below that which would result from the effects of rising prices and current policy? What effect would a U.S. reduction of 5 MBD (say, due to a synfuels program) have if it could be reached by 1990?

NOTE 1. ROUGH ESTIMATE OF PRICE ELASTICITY OF DEMAND, AND 1988 ENERGY CONSUMED PER UNIT OF GNP

Assumed relation: $Q = a\ G^{1.0}\ b\ P^{E}$

Assuming a one-time price change, after t years:

$$\frac{Q_t/Q_o}{G_t/G_o} = \left(\frac{P}{P_o}\right)^{E_t}$$

In the OECD, after 5 years: (see Table 1)

$$.927 = 1.38^{E_t}$$

$$E_t = -.235$$

Assume E_t approaches long-run elasticity as the capital stock is replaced. According to the Department of Commerce, Bureau of Economic Analysis, capital stock project, average service life of corporate assets is 18 years. Then if capital disappears exponentially, half-life is 11 years. Our estimate should be lower than the half-life because of retrofitting and net growth of the capital stock. If we alternatively take 7 years and 9 years as half-life, then the effect of the price change may be assumed to decay exponentially at such a rate that $e^{-7c} = .5$, or $e^{-9c} = .5$; hence, $c = .09$ or $C = .077$ and

$$E_\infty = -.235/(1-e^{-.5}) = .601, \underline{\text{or}}$$

$$E_\infty = -.235/(1-e^{-.4}) = .735$$

Such results are broadly consistent with the estimates of the M.I.T. World Oil Project.

Assuming the lower elasticity, in 1988, t = 15,

$$E_{15} = .601\ (1-e^{-15c}), \text{ and } \frac{Q_{15}/Q_o}{G_{15}/G_o} = 1.38^{-.47} = .86$$

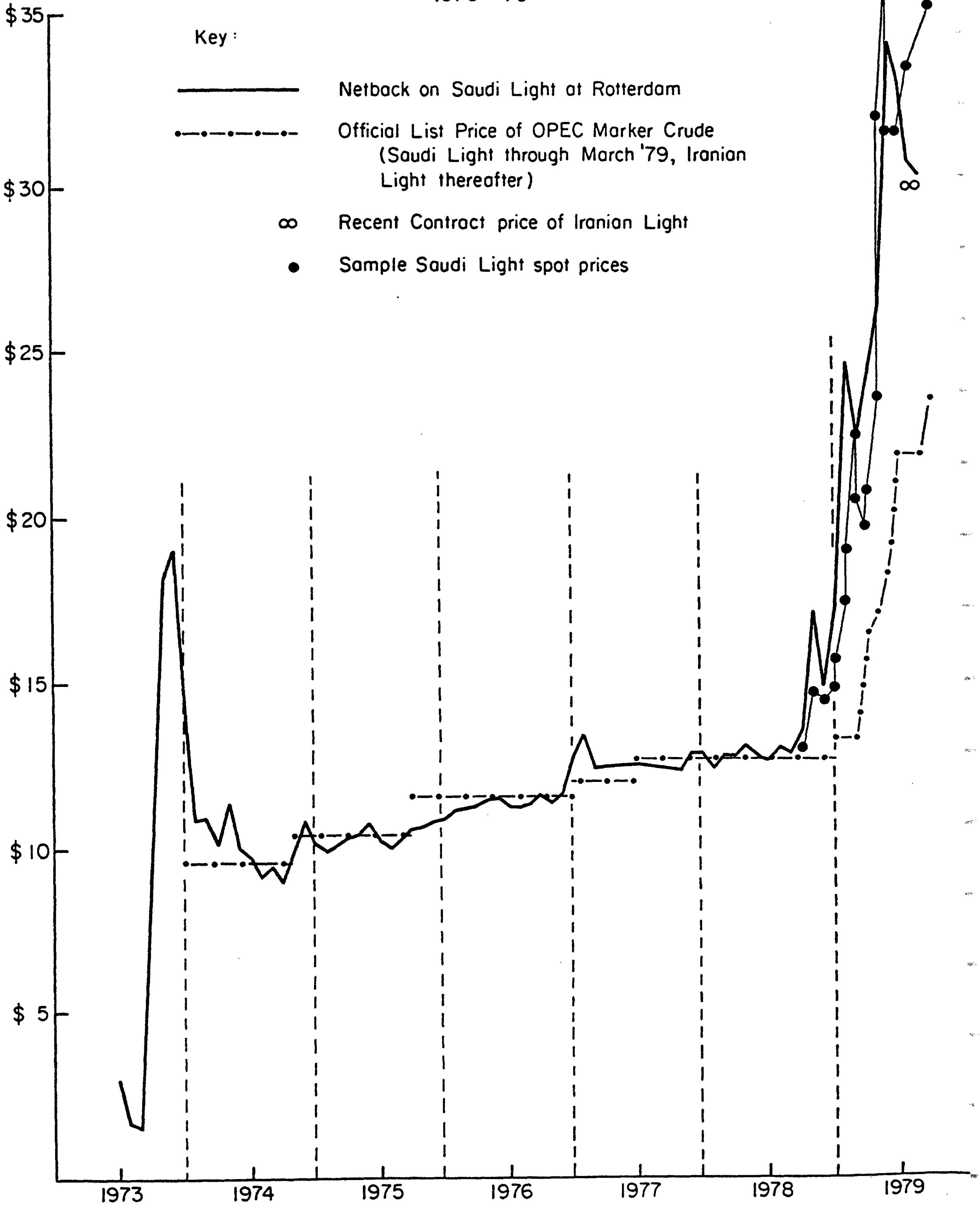
The real increase in the crude oil price in 1979 will be about (\$21/\$12) /1.15 = 1.52. If we suppose the increase in the real consumer energy price will be about 30 percent, and that the response will be about as in 1973-1978, then $E_{10} = 0.6\ (1-e^{-(10 \times .099)} = .38$, and the lowered energy consumption per unit of GNP should be:

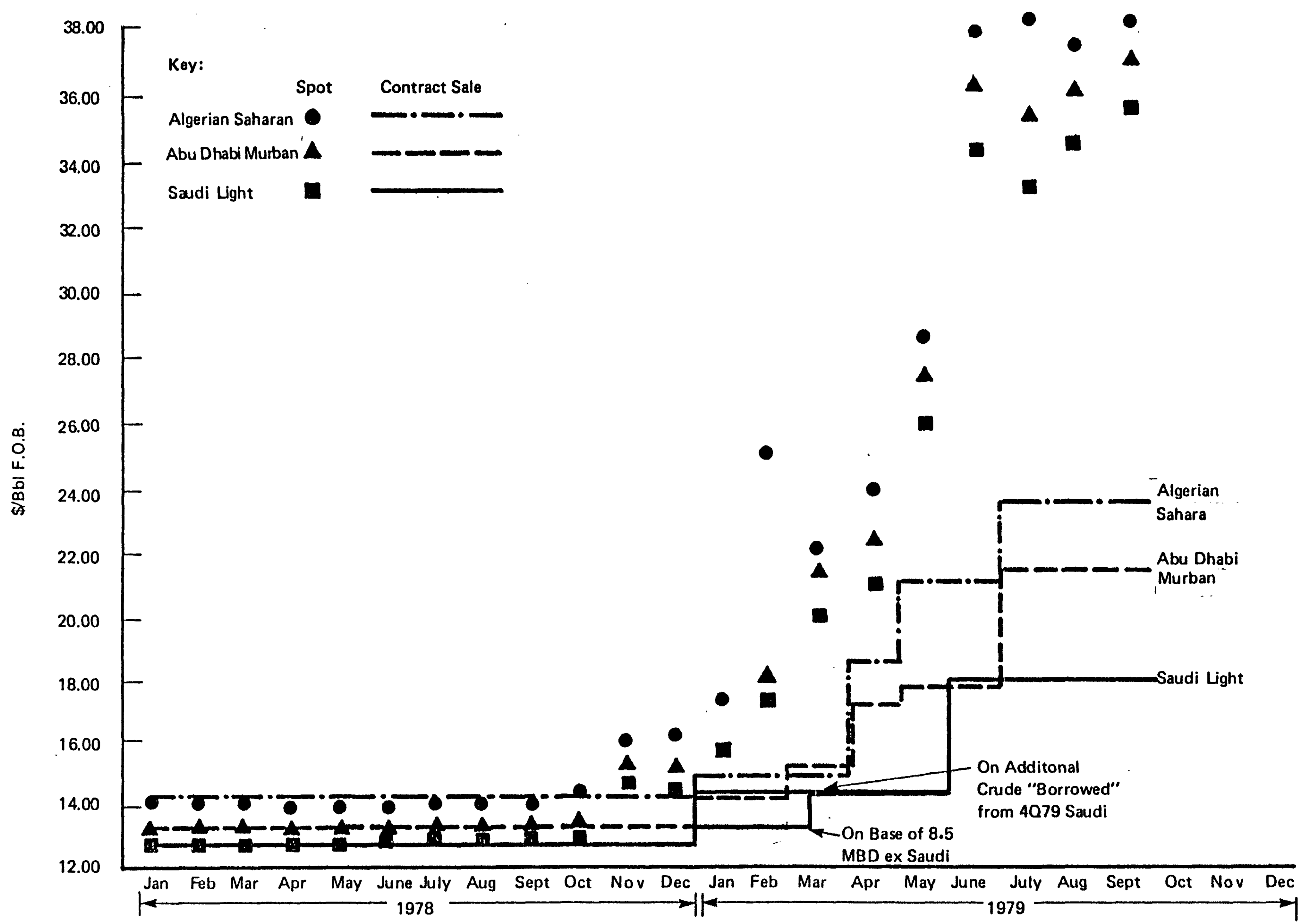
$$\frac{Q_{10}/Q_o}{G_{10}/G_o} = 1.30^{-.38} = .905$$

Reckoning together the 1973 and the 1979 round, we would expect Q_{88}/G_{88} to equal (.905 x .860) or .78 of the 1973 level. This is 84 percent of the 1978 level. At a uniform percentage rate, this would be a decrease of 1.7 percent per year, a little faster than the 1.5 percent in 1973-1978.

FIGURE I

OPEC PRICES, NETBACKS, AND SPOT PRICES
1973 - 79





Source: Petroleum Intelligence Weekly

FIGURE 2

SELECTED CRUDE PRICES, 1978-1979

TABLE 1

INDICES OF ENERGY, OIL, PRICES, AND REAL GNP IN 1978

(1973 = 100)

		OECD	U.S.
ENERGY AND GROWTH			
(1)	Real GNP	112.7	112.1
(2)	Total energy consumption	104.5	104.9
(3)	Residential & commercial	*	107.5
(4)	Industrial	*	99.6
(5)	Oil consumption	102.5	108.7
(6)	Energy/GNP ratio	92.7	93.6
(7)	[Decrease, %/yr.]	[1.5]	[1.3]
(8)	Oil/ GNP ratio	91.0	97.0
(9)	[Decrease, %/yr.]	[1.9]	[0.6]
REAL PRICES			
(10)	Total Energy	138	133
(11)	Households	*	122
(12)	Industries	*	144

* not available

Sources:

(1) Economic Report of the President

(2), (5) BP Annual Statistical Review

(3), (4) Monthly Energy Review, U.S. Department of Energy

(10) Dunkerley, et al, unpublished estimate

(11), (12) Economic Report of the President (BLS)

TABLE 2a

SOURCES OF NON-COMMUNIST OIL CONSUMPTION

(MBD)

			Non-OPEC Supply						
Year	Consumption, Non-Commun. World (excl. OPEC)[c]		U.S. & Canada	Latin America	Western Europe	Communist Exports	All Other Non-OPEC	Total Non-OPEC	Net Demand on OPEC (Exports)
1973[f]	46.2		13.1	1.8	0.4	0.9	1.3	17.5	28.7
1978[f]	48.8		11.8	2.8	1.8	1.8	3.2	21.4	27.4
1985	52.6[a]	EIA[d]	12.3	N/A	4.1	0	9.3	25.7	26.3
1985	52.6[a]	MIT[e]	8.9	7.7	2.6	0	3.1	22.3	29.7

a. Assumes same rate of change as 1973-78.

b. Includes some non-OPEC at Persian Gulf.

c. OPEC internal consumption estimated: 1973, 1.6 mbd; 1978, 2.2 mbd.

d. Mid-mid-forecast, EIA Annual Report to Congress, 1978.

e. Assumes development drilling increases at 5%/year.

f. Figures for 1973 and 1978 from British Petroleum, "Statistical Review of World Oil Industry", 1978.

TABLE 2b

MAJOR FORECASTS OF OIL SUPPLY-DEMAND BALANCE
(MBD)

	1980				1985					1990			1995
	Exxon[1]	CIA[2]	EPRI-PIRINC[3]	MIT[4] Model	Exxon	CIA	EPRI-PIRINC	EIA[6]	MIT Model	Exxon	EIA	MIT Model	EIA
World Consumption[5]	57	56	53-56	52.3	65	70	57-66	60.4	53.4	72	68.4	58.4	77.9
Non-OPEC Supply[5]	22	22	21	23.3	25	25	24-25	25.7	23.9	28	28.7	23.9	35
Net Exports of Centrally Planned Economies	N/A	0	1	0	N/A	(4)	0-1	0	0	N/A	0	0	0
Net Demand on OPEC	35	34	31-34	29.0	40	49	33-41	34.7	29.4	44	39.7	34.5	42.9
OPEC Capacity	N/A	42	N/A	33.6	N/A	38	N/A	N/A	36.1	N/A	N/A	34.6	N/A

Sources

1. World Energy Outlook, Exxon, April 1978.
2. U.S. Central Intelligence Agency, The International Situation: Outlook to 1985, April 1977.
3. Outlook for World Oil into The 21st Century, prepared for EPRI by the Petroleum Industry Research Foundation, Inc., May 1978.
4. Assumes: Constant real oil price of $20/bbl; moderate growth rates of countries' GNP; and development drilling increases at 5%/year.
5. Excludes centrally-planned economies.
6. Energy Information Administration, Annual Report to Congress, 1978.

TABLE 3

WORLD OIL PRICE, NOMINAL AND REAL (1970-79)

	(1) List price Saudi Light ($/bbl)	(2) U.S. GDP Deflator	(3) Real Saudi Light Price to U.S. (in 1970 US$)	(4) German GNP Deflator	(5)** Real Saudi Light Price to Germany (in 1970 DM Prices)	(6) List Price Iran Light ($/bbl)	(7) List Price Libya ES Sider ($/bbl)
1970	1.35	1.00	1.35	1.00	4.91	1.36	2.09
1971	1.75	1.05	1.67	1.07	5.33	1.76	2.80
1972	1.90	1.09	1.74	1.14	5.33	1.91	2.80
1973-Jan. 1	2.10	1.12	1.88	1.16	5.79	2.11	3.10
Dec. 1	3.60	1.19	3.03			3.75	6.45
1974-Jan. 1	9.60	1.22	7.87	1.23	21.07	10.63	14.30
Nov. 1	10.46	1.32	7.92			10.67	12.43
1975-Jan. 1	10.46	1.35	7.75	1.35	18.59	10.67	11.98
Oct. 1	11.51	1.42	8.11			11.62	12.21
1976-Jan. 1	11.51	1.43	8.05	1.41	21.38	11.62	12.21
July 1	11.51	1.46	7.88			11.62	12.40
1977-Jan. 1	12.09	1.51	8.01	1.46	19.54	12.81	13.74
July 1	12.70	1.55	8.19			12.81	14.00
1978-Jan. 1	12.70	1.60	7.94	1.52	17.54	12.81	13.80
July 1	12.70	1.67	7.60			12.81	13.68
1979-Jan. 1	13.39	1.71	7.83	1.57	15.52	13.45	14.52
April 1	14.55	1.76*	8.27			16.57	18.09
June 1	14.55	1.79*	8.13			18.47	21.09
July 1	18.00	1.81*	9.94			22.00	23.28

* Assumes 13% annual inflation rate over 1st half of 1979

** Calculated by dividing the nominal price of oil in terms of German mark by German GNP deflator.

TABLE 4

CRUDE OIL PRODUCTION INCREASES (DECREASES) FROM 3rd QUARTER 1978 LEVELS

(Thousands of barrels per day [tbd])

	Oct.78	Nov.78	Dec.78	Jan.79	Feb.79	Mar.79	Apr.79	May 79	Jun.79	July 79	Aug.79
Iran	(395.7)	(2391.7)	(3514.7)	(5440.7)	(4790.0)	(3140.0)	(1890.0)	(1390.0)	(1590.0)	(1690.0)	(1990.0)
Saudi Arabia	1627.4	2600.1	2752.3	2137.5	2127.2	2124.2	1141.8	1131.6	1130.8	2125.0	2123.0
Kuwait	(187.4)	352.7	(96.3)	317.7	310.6	(4.0)	(45.2)	(6.0)	(7.1)	(37.8)	(64.1)
Iraq	350.0	450.0	450.0	450.0	640.0	640.0	640.0	640.0	840.0	840.0	840.0
OAP[1]	0.0	(39.5)	81.6	35.6	44.9	(152.0)	(63.4)	42.6	(52.7)	(27.7)	(19.8)
Total Mideast	1394.3	971.6	(327.1)	(2499.9)	(1467.3)	(531.8)	(216.8)	416.5	321.0	1209.5	889.1
Nigeria	86.9	248.6	372.6	412.6	370.0	377.0	357.8	339.8	342.0	323.3	242.0
Venezuela	51.7	(3.4)	56.2	8.5	87.8	168.3	126.0	123.0	(9.3)	72.2	70.0
Libya	(24.9)	110.7	133.7	33.7	20.9	70.8	74.1	55.3	46.6	88.3	(1.3)
Other OPEC	0.5	21.7	2.0	52.0	25.0	9.1	(15.1)	(186.3)	(98.3)	(151.3)	(120.5)
Total OPEC[2]	1508.5	1349.2	237.4	(1993.1)	(963.6)	93.4	326.0	748.3	602.0	1542.0	1079.3
Non-OPEC[3]	193.0	530.0	697.0	705.0	766.0	765.0	947.0	965.0	1201.0	1241.0	N/A
Total World:[4] Incl. Iran	1701.5	1879.2	934.4	(1288.1)	(197.6)	858.4	1273.0	1713.3	1803.0	2783.0	N/A
Excl. Iran	2097.2	4270.9	4449.1	4152.6	4592.4	3998.4	3163.0	3103.3	3393.0	4473.0	N/A

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[1] Other Arabian Peninsula (including Oman and Bahrain).

[2] Includes Oman and Bahrain.

[3] Excluding Centrally Planned Economies.

[4] Assumes no change in exports of Centrally Planned Economies.

SOURCE: Petroleum Intelligence Weekly and Oil and Gas Journal.

TABLE 5

Non-OPEC Production Increases (Decreases) From 3Q78 Levels

	Oct.78	Nov.78	Dec.78	Jan.79	Feb.79	March 79	April 79	May 79	June 79	July 79
WESTERN HEMISPHERE										
U.S.	18	25	1	(16)	(106)	33	14	(32)	(47)	0
Mexico	60	88	129	152	158	154	158	163	174	177
Canada	139	268	291	202	326	311	265	216	282	273
Others	12	12	(15)	(56)	(67)	(52)	(51)	(51)	(19)	(19)
	229	393	406	282	311	446	386	296	390	431
WESTERN EUROPE										
Norway	(16)	(12)	(12)	(8)	(2)	(9)	26	11	(11)	9
UK	61	187	255	364	407	342	361	545	645	608
Others	(3)	3	4	9	9	16	16	10	11	11
	42	178	247	365	414	349	403	566	645	628
MIDDLE EAST	(14)	(12)	(8)	(13)	(16)	(10)	(5)	(3)	2	(1)
ASIA-PACIFIC	(21)	15	5	22	23	4	102	56	102	118
AFRICA	(43)	(44)	47	49	24	69	60	50	52	52
COMMUNIST										
China	83	83	83	183	183	183	233	183	183	183
Rumania	0	0	0	90	0	0	0	0	(40)	(40)
USSR	159	209	174	159	159	109	189	(141)	139	172
Others	0	0	0	0	0	0	0	0	0	0
	242	291	257	432	342	291	422	42	282	315
Non-OPEC TOTAL	435	822	954	1137	1099	1149	1368	1007	1473	1543

TABLE 6

OPEC CRUDE OIL PRODUCTIVE CAPACITY AS ESTIMATED BY PIW, AND EXCESS CAPACITY FOR OCTOBER 1978 THROUGH AUGUST 1979.

(Thousands of barrels per day [tbd])

	Capacity[1]						Excess Capacity					
		Oct.78	Nov.78	Dec.78	Jan.79	Feb.79	Mar.79	Apr.79	May 79	Jun.79	July 79	Aug.79
Saudi Arabia[2]	10,840[3]	1,562	579	436	1,052	1,063	1,066	2,049	2,060	2,061	1,067	1,069
Kuwait[2]	3,340	1,229	689	1,136	724	739	1,053	795	755	758	789	816
UAE	2,495	653	660	649	663	666	677	749	636	626	661	664
Qatar	650	145	177	67	101	96	282	102	110	195	131	117
Iraq	4,000	1,000	900	900	900	700	700	700	700	500	500	500
Libya	2,500	427	397	411	362	369	320	436	455	464	422	511
Venezuela	2,400	94	149	57	137	52	(28)	14	17	149	68	70
Nigeria	2,500	386	224	116	59	72	65	84	102	100	119	200
Indonesia	1,800	211	215	198	195	181	170	192	231	188	191	200
Algeria	1,225	0	0	0	0	0	0	0	0	0	0	0
Other	475	43	24	48	3	15	17	33	65	10	70	30
Subtotal[4]	32,225	5,750	4,014	4,018	4,196	3,953	4,350	5,154	5,131	5,051	4,018	4,177
Iran	6,990	1,450	3,496	4,619	6,545	6,290	4,640	3,390	2,890	3,090	3,190	3,490
Total OPEC[4]	39,215	7,200	7,510	8,637	10,741	10,243	8,990	8,544	8,021	8,141	7,208	7,667

NOTES:

[1] "This capacity is estimated maximum production achievable and sustainable for several months without regard to government restrictions." Petroleum Intelligence Weekly, October 8, 1979.

[2] Includes 340 tbd from Divided Zone.

[3] Revised downward by 1,000 tbd (from 11,840 tbd) from PIW, March 12, 1979.

[4] In the totals, any country producing above the PIW estimate of capacity (figures shown in parenthesis) is credited with zero excess.

TABLE 7

OPEC "MAXIMUM SUSTAINABLE" CRUDE OIL CAPACITY AS ESTIMATED BY THE CIA, AND EXCESS CAPACITY FOR OCTOBER 1978 THROUGH AUGUST 1979.

(Thousands of barrels per day [tbd])

	Capacity[1]	Excess Capacity										
		Oct.78	Nov.78	Dec.78	Jan.79	Feb.79	Mar.79	Apr.79	May 79	Jun.79	July 79	Aug.79
Saudi Arabia[2]	9,800[4]	1,022	39	(104)	512	523	526	1,509	1,320	1,321	27	29
Kuwait[2]	2,800[5]	789	249	696	284	299	613	355	215	218	325	276
UAE	2,360	518	525	514	528	531	542	614	501	491	526	529
Qatar	600	95	127	17	51	46	232	52	60	145	71	67
Iraq	3,000	0	(100)	(100)	(100)	(300)	(300)	(300)	(300)	(500)	(500)	(500)
Libya	2,200	127	97	111	62	69	20	136	155	164	122	211
Venezuela	2,400	94	149	57	137	52	(28)	14	17	149	68	70
Nigeria	2,400	286	124	16	(41)	(28)	(35)	(16)	2	0	19	100
Indonesia	1,650	61	65	48	45	31	30	42	81	38	41	50
Algeria	1,100	(125)	(125)	(125)	(125)	(125)	(125)	(125)	(125)	(125)	(125)	(125)
Other	450	18	(1)	23	(22)	(10)	(8)	18	40	(15)	45	5
Subtotal[3]	28,760	3,010	1,275	1,466	1,619	1,551	1,963	2,740	2,391	2,525	1,244	1,337
Iran	5,500[6]	1,060	3,106	4,229	6,155	5,900	4,250	3,000	1,400	1,600	1,700	2,000
Total OPEC[3]	34,260	4,070	4,381	5,695	7,774	7,451	6,213	5,540	3,791	4,125	1,944	3,337

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[1] "Maximum sustainable or operational capacity is the maximum production rate that can be sustained for several months; it considers the experience of operating the total system and is generally some 90-95 percent of installed capacity. This capacity concept does not necessarily reflect the maximum production rate sustainable without damage to the fields." CIA *International Energy Statistical Review*, October 3, 1979.

[2] Includes 300 tbd from Divided Zone.

[3] In the totals, any country producing above the CIA estimate of capacity (figures shown in parentheses) is credited with zero excess.

[4] Estimate decreased from 10,300 to 10,100 in May 1979, and further decreased to 9,800 in July 1979; excess capacity was calculated on a basis of 10,300 tbd capacity through April, 10,100 from May to June, and 9,800 from July on.

[5] Estimate decreased from 2,900 to 2,800 in May 1979; excess capacity was calculated accordingly.

[6] Estimate was 6,600 until early May, 5,500 thereafter when estimated additional capacity loss was factored in; excess capacity was calculated accordingly.

TABLE 8

OPEC Output Dips Despite 'Extra' Saudi Oil

Total OPEC crude oil production slipped 460,000 b/d from July to 31.4-million b/d in August, as Saudi Arabia's efforts to improve world supplies were eroded by cuts other producers made. Iran's production fell an estimated 300,000 b/d, its third consectuive monthly drop, reflecting continued political turmoil. Nigeria and Libya each cut back by over 80,000 b/d, claiming the reduction was for technical reasons.

On the other hand, Iraq was at record levels, and Kuwait still producing far in excess of its output ceiling. Ecuador's output rebounded and Sharjah's tiny production was at a 1979 high.

Jan.-Aug. production was up 5% from a year earlier when world supplies exceeded demand.

	——August——		Previous Two Months		——Jan.-Aug.——		†Output
	Volume	% Chg	July	June	Volume	% Chg	Capacity
MIDEAST OPEC:	1,000 b/d	v'78	Volumes In 1,000 b/d		1,000 b/d	v'78	1,000 b/d
Saudi Arabia	9,771.1	+36.0	9,773.1	8,778.9	9,384.2	+22.8	10,840
Aramco*	9,500.0	+37.0	9,500.0	8,500.0	9,100.0	+22.3	10,500
Divided Zone	‡271.1	+8.7	273.1	278.9	284.2	+42.8	340
Iran	3,500.0	–39.7	3,800.0	3,900.0	2,817.5	–49.9	6,990
Iraq*	3,500.0	+32.1	3,500.0	3,500.0	3,350.2	+37.9	4,000
Kuwait	*2,524.0	+7.3	r2,551.3	2,582.0	2,573.6	+31.9	3,340
Kuwait	*2,250.0	+7.3	r2,275.0	2,300.0	2,286.2	+30.5	3,000
Divided Zone	§274.0	+6.7	276.3	282.0	287.4	+44.1	340
Abu Dhabi, UAE	1,454.4	–0.1	1,454.2	1,490.3	1,451.3	+0.6	2,075
ADCO	867.3	+0.9	864.6	863.4	861.6	+1.3	1,035
ADMA	491.2	–3.1	489.8	524.8	493.3	–1.1	630
Others	95.9	+6.6	99.8	102.1	96.4	+4.0	140
Dubai, UAE	362.2	–0.9	368.8	366.8	363.4	+0.9	365
Sharjah, UAE	14.0	–40.4	10.9	12.0	12.6	–49.2	55
Qatar	533.3	–1.3	519.0	455.1	507.8	+9.3	650
Onshore	232.3	–9.2	217.8	226.6	242.7	+7.2	350
Offshore	301.0	+5.8	301.2	228.5	265.1	+11.2	300
Mideast OPEC	21,659.0	+6.3	r21,978.3	21,085.1	20,460.6	+2.6	28,315
OTHER OPEC:							
Venezuela	2,330.0	+5.7	2,332.2	2,250.7	2,340.2	+11.3	2,400
Nigeria	*2,300.0	+11.6	r2,381.3	*2,400.0	2,399.2	+36.7	2,500
Libya	1,988.7	–3.7	r2,078.3	r2,036.3	2,066.2	+7.8	2,500
Indonesia	*1,600.0	–0.7	1,609.2	1,612.2	1,606.1	–3.1	1,800
Algeria*	1,125.0	–8.2	1,125.0	1,125.0	1,174.4	–4.1	1,225
Gabon*	225.0	0.0	225.0	225.0	225.0	0.0	250
Ecuador	220.0	+11.1	180.0	230.0	212.7	+6.4	225
OPEC Total	31,447.7	+5.0	r31,908.3	r30,964.3	30,484.4	+5.1	39,215
NON-OPEC MIDEAST:							
Oman	290.5	–6.1	293.6	297.3	299.7	–5.4	...
Bahrain*	*50.0	–5.3	50.0	50.0	50.3	–6.2	...

†This capacity is estimated maximum production achievable and sustainable for several months without regard to government restrictions. ‡Includes 193,000 b/d offshore and 78,135 b/d onshore. §Includes 193,000 b/d offshore and 81,035 b/d onshore. *Estimated. r Revised.

Source: Petroleum Intelligence Weekly, October 8,1979.

TABLE 9

OPEC: Crude Oil Productive Capacity

Thousand b/d

	Capacity			Production	
	Installed[1]	Maximum Sustainable[2]	Available[3]	Latest Post-Embargo Peak	Current
Total	**40,750**	**34,260**	**31,515**		
Algeria	1,200	1,100	1,100	1,100 (Jun 79)	900 (Jul 79)
Ecuador	250	225	225	260 (May 74)	180 (Jul 79)
Gabon	250	225	225	230 (Dec 77)	210 (Jul 79)
Indonesia	1,800	1,650	1,650	1,740 (Mar 77)	1,610 (Jul 79)
Iran	7,000	5,500[4]	4,000[5]	6,680 (Nov 76)	3,750 (Jul 79)
Iraq	3,400	3,000	3,000	3,100 (Dec 78)	3,000 (Jul 79)
Kuwait[6]	2,900	2,500	2,000	2,990 (Dec 76)	2,300 (Jul 79)
Libya	2,500	2,200	2,200	2,210 (Mar 77)	2,080 (Jul 79)
Neutral Zone[7]	680	600	600	670 (Dec 76)	550 (Jul 79)
Nigeria	2,500	2,400	2,160[8]	2,440 (Jan 79)	2,380 (Jul 79)
Qatar	650	600	600	610 (Dec 75)	520 (Jul 79)
Saudi Arabia[6]	12,500[9]	9,500	9,500[10]	10,090 (Dec 78)	9,500 (Jul 79)
United Arab Emirates	2,520	2,360	1,855		
Abu Dhabi	2,100	1,965	1,460	1,830 (Jul 75)	1,455 (Jul 79)
Dubai	390	370	370	370 (Apr 79)	370 (Jul 79)
Shariah	30	25	25	60 (Dec 74)	10 (Jul 79)
Venezuela	2,600	2,400	2,400	2,950 (Jun 74)	2,330 (Jul 79)

[1] Installed capacity, also called nameplate or design capacity, includes all aspects of crude oil production, processing, transportation, and storage. Installed capacity is generally the highest capacity estimate.

[2] Maximum sustainable or operational capacity is the maximum production rate that can be sustained for several months; it considers the experience of operating the total system and is generally some 90-95 percent of installed capacity. This capacity concept does not necessarily reflect the maximum production rate sustainable without damage to the fields.

[3] Available or allowable capacity reflects production ceilings applied by Abu Dhabi, Kuwait, Iran, and Saudi Arabia. These ceilings usually represent a constraint only on annual average output, and thus production may exceed the ceilings in a given month.

[4] The precise loss in sustainable capacity remains uncertain.

[5] This figure represents the upper end of the range of available capacity, according to government statistics.

[6] Excluding share of capacity in the Neutral Zone, shown separately.

[7] Capacity and production is shared about equally between Kuwait and Saudi Arabia.

[8] Estimated production ceiling effective 1 August 1979 based on announced average 10 percent cutback.

[9] In Saudi Arabia, the concept of "facility," rather than "installed" capacity, is used. Facility capacity refers to the total installed capacity of gas-oil separating plants, main trunk pipelines, and oil-load terminals; it does not include the capacity of salt water-oil separators or flow lines.

[10] The Saudi Arabian production ceiling for 1st Qtr. 1979 was 9.5 million b/d, 8.5 million b/d for 2d Qtr, and is 9.5 million b/d for 3d Qtr 1979.

Source: U.S. Central Intelligence Agency, International Energy Statistical Review, 3 October 1979.

TABLE 10

Worldwide oil and gas at a glance

COUNTRY	ESTIMATED PROVED RESERVES 1-1-1978		OIL PRODUCTION			No. of ref.	REFINING Capacity (b/cd) January 1, 1979			
	Oil (1,000 bbl)	Gas (10^9 cu ft)	Producing wells July 1, '78	Estimated 1978 (1,000 b/d)	% change from 1977		Crude	Catalytic Cracking	Thermal Cracking	Reforming
ASIA-PACIFIC										
Australia	2,100,000	31,000	375	430.0	......	12	708,100	121,225		156,500
Bangladesh	......	8,000	......	......	......	1	31,200	......		1,720
Brunei	1,480,000	8,000	558	210.0	+5.0		......	......		......
Burma	45,000	150	429	25.0	......	2	26,000	......	1,700	......
Rep. of China (Taiwan)	*12,000	700	66	*4.3	−15.0	2	425,400	9,040	......	49,760
Guam	......	......	......	......	......	1	29,500	......	......	......
India	2,900,000	3,500	1,600	230.0	+9.5	10	625,750	51,800	62,984	26,318
Indonesia	10,200,000	24,000	3,644	1,650.0	−2.1	9	527,700	19,500	30,000	34,400
Japan	60,000	500	542	10.0	......	45	5,479,602	325,885		557,009
Korea, South	......	......	......	......	......	4	542,000	......	......	25,640
Malaysia	2,800,000	17,000	154	210.0	+5.0	3	140,000	......	......	8,000
New Zealand	*110,000	6,000	10	*13.0	−13.4	1	74,000	......	......	24,000
Okinawa (R.I.)	......	......	......	......	......	3	195,967	......	......	11,905
Pakistan	200,000	16,000	17	9.3	−7.0	3	110,140	......	......	5,210
Philippines	100,000	......	......	......	......	3	253,300	24,900	......	38,300
Singapore	......	......	......	......	......	4	917,650	......	48,000	20,000
Sri Lanka	......	......	......	......	......	1	38,000	......	12,500	3,750
Thailand	200	5,000	12	2	......	4	160,657	7,000	12,700	23,178
Total Asia-Pacific	20,007,200	119,850	7,407	2,791.8	+1.0	108	10,284,966	559,350	167,884	985,690
WEST EUROPE										
Austria	150,000	420	1,250	35.0	......	1	280,000	16,500		22,600
Belgium	......	......	......	......	......	7	971,900	77,400		109,250
Cyprus	......	......	......	......	......	1	15,000	......	......	2,400
Denmark	300,000	2,500	18	10.0	......	3	215,000	......	45,400	37,700
Finland	......	......	......	......	......	2	336,000	9,500	12,000	54,800
France	56,000	6,500	293	21.0	+5.0	23	3,468,625	190,500	43,700	441,050
Germany, West	310,000	6,300	2,933	102.0	−4.8	32	3,102,982	178,800	208,935	439,778
Greece	150,000	4,000	......	......	......	4	411,000	......	......	30,200
Ireland	......	1,000	......	......	......	1	56,000	......	......	14,500
Italy-Sicily	650,000	8,000	120	28.0	−6.8	32	4,196,850	251,250	36,300	422,110
Netherlands	70,000	62,000	416	36.0	+20.0	9	1,857,250	75,000	157,100	199,600
Norway	5,900,000	24,000	50	350.0	+25.0	4	264,000	......	46,000	30,000
Portugal	......	......	......	......	......	3	360,780	......	12,600	52,932
Spain	80,000	200	25	20.0	+25.0	10	1,424,944	......	13,000	179,382
Sweden	......	......	......	......	......	6	410,900	......	33,000	74,500
Switzerland	......	......	......	......	......	2	137,300	......	24,000	24,500
United Kingdom	16,000,000	27,000	109	1,100.0	+43.2	19	2,526,805	168,575	78,000	452,235
Yugoslavia	300,000	1,340	NA	80.0	......	6	293,278	1,960	6,100	46,296
Total W. Europe	23,966,000	143,280	5,208	1,782	+30.6	165	20,328,614	969,485	716,135	2,632,833
MIDDLE EAST										
Abu Dhabi	30,000,000	20,000	240	1,450.0	−12.9	1	15,000	......	......	2,800
Bahrain	250,000	7,000	233	56.0	......	1	250,000	34,200	19,000	15,200
Dubai	1,300,000	1,600	71	360.0	+12.9		......	......	......	......
Iran	59,000,000	500,000	551	5,250.0	−7.3	5	920,500	36,000	42,800	60,845
Iraq	32,100,000	27,800	250	2,500.0	+12.9	7	168,500	......	......	5,000
Israel†	10,000	60	25	10.0	+900.0	2	195,000	......	39,000	24,500
Jordan	......	......	......	......	......	1	30,300	4,410	......	928
Kuwait	66,200,000	31,300	586	1,900.0	+6.7	5	712,000	......	......	21,600
Lebanon	......	......	......	......	......	2	53,000	7,250	......	7,300
Divided (Neutral) Zone	6,480,000	5,000	455	420.0	+15.1		......	......	......	
Oman	2,500,000	2,000	100	320.0	−6.2		......	......	......	......
Qatar	4,000,000	40,000	95	480.0	+10.3	1	10,500	......	......	1,420
Saudi Arabia	165,700,000	93,900	875	7,800.0	−13.6	3	487,332	......	2,530	45,386
Sharjah	16,000	......	4	24.0	−14.3		......	......	......	......
South Yemen (Aden)	......	......	......	......	......	1	142,857	......	......	9,524
Syria	2,080,000	1,500	442	170.0	−16.3	2	223,040	......	20,679	16,975
Turkey	360,000	500	380	50.0	−7.4	4	338,000	38,260	......	29,875
Total Middle East	368,998,000	730,660	4,307	20,790.0	−8.2	35	3,546,029	120,120	124,009	241,353

EDITOR'S NOTE: All reserve figures except those for the U.S.S.R. are proved reserves recoverable with present technology and prices. U.S.S.R figures are "explored reserves," which includes proved, probable, and some possible.

*Condensate. †Includes Israeli-occupied portion of Gulf of Suez. ‡Estimates based on capacity 1/1/78 plus known 1978 expansions. Catalytic cracking, thermal cracking, and reforming figures converted to b/cd from b/sd (b/sd x 90% = b/cd). §Includes Bulgaria, Rumania, Czechoslovakia, East Germany, Poland, Hungary, Cuba, North Korea, Mongolia, Viet Nam, and Albania.

TABLE 10 (continued)

COUNTRY	ESTIMATED PROVED RESERVES 1-1-1978		OIL PRODUCTION			No. of ref.	REFINING Capacity (b/cd) January 1, 1979			
	Oil (1,000 bbl)	Gas (10⁹ cu ft)	Producing wells July 1, '78	Estimated 1978 (1,000 b/d)	% change from 1977		Crude	Catalytic Cracking	Thermal Cracking	Reforming
AFRICA										
Algeria	6,300,000	105,000	989	1,260.0	+15.5	3	122,400			23,600
Angola-Cabinda	1,115,000	1,200	182	130.0	−33.0	1	32,100			1,900
Cameroon	50,000	......	13	10.0	......					
Congo Republic	315,000	2,260	107	28.0	−15.2		......			......
Egypt	3,200,000	3,000	430	490.0	+20.1	4	251,000			7,000
Ethiopia	......	......	......	......	......	1	14,430			1,890
Gabon	1,970,000	2,400	211	170.0	−24.4	1	20,000		7,200	1,400
Ghana	......	......	......	......	......	1	26,000			4,750
Ivory Coast	......	......	......	......	......	1	39,000			5,900
Kenya	......	......	......	......	......	1	95,000			9,000
Liberia	......	......	......	......	......	1	15,000			2,300
Libya	24,300,000	24,200	817	2,050.0	−0.7	5	137,100			14,500
Madagascar	......	......	......	......	......	1	11,440			1,610
Morocco	125	30	1	.1	......	2	72,000	5,600		9,200
Mozambique	......	......	......	......	......	[illegible]	16,000			......
Nigeria	18,200,000	42,000	1,322	1,800.0	+9.3	2	159,000	26,000		6,000
Senegal	......	......	......	......	......	1	20,138			2,114
Sierra Leone	......	......	......	......	......	1	10,000			
Somalia	......	......	......	......	......	1	10,000			
South Africa	......	......	......	......	......	4	478,000	81,400	58,500	65,500
Sudan	......	100	......	......	......	1	26,000			1,800
Tanzania	......	50	......	......	......	1	17,000			4,200
Togo	......	......	......	......	......	1	20,000			3,020
Tunisia	2,300,000	6,000	76	100.0	+11.0	1	34,000			3,300
Zaire	142,000	50	12	20.0	......	1	17,000			3,000
Zambia	......	......	......	......	......	1	25,000			5,600
Total Africa	57,892,125	186,290	4,160	6,058.1	−3.1	37	1,667,608	113,000	65,700	177,584
WESTERN HEMISPHERE										
Argentina	2,400,000	12,000	6,020	450.0	+4.7	12	655,039	95,082	39,930	36,846
Bahamas	......	......	......	......	......	1	500,000			
Barbados	500	......	19	.7	+130.0	1	3,000			
Bolivia	250,000	6,000	286	30.0	−14.3	4	74,300			13,800
Brazil	1,200,000	1,500	1,522	160.0	......	12	1,209,200	216,400		21,600
Chile	400,000	2,500	425	20.0	......	2	144,000	34,500	8,800	9,000
Colombia	750,000	4,800	1,980	130.0	−6.5	6	173,500	52,000	18,000	
Costa Rica	......	......	......	......	......	1	12,000			1,500
Dominican Republic	......	......	......	......	......	2	46,461			9,550
Ecuador	1,170,000	4,000	979	200.0	+11.0	4	92,815	12,600	12,600	2,780
El Salvador	......	......	......	......	......	1	17,000			3,000
Guatemala	16,000	......	1	.7	......	1	14,000			3,000
Honduras	......	......	......	......	......	1	14,000			1,800
Jamaica	......	......	......	......	......	1	32,600			3,000
Martinique	......	......	......	......	......	1	14,000			3,100
Mexico	16,000,000	32,000	4,145	1,270.0	+24.2	9	1,243,500	217,000	82,000	96,000
Netherlands Antilles	......	......	......	......	......	2	842,000	42,000	298,000	15,000
Nicaragua	......	......	......	......	......	1	14,900			2,800
Panama	......	......	......	......	......	1	100,000			7,500
Paraguay	......	......	......	......	......	1	5,000			
Peru	560,000	1,150	2,567	150.0	+74.4	5	170,100	23,390		1,760
Puerto Rico	......	......	......	......	......	3	284,000	47,000	20,000	76,000
Trinidad & Tobago	500,000	8,000	3,284	240.0	+4.4	2	461,000	26,500		27,000
Uruguay	......	......	......	......	......	1	43,000	4,000		3,000
Venezuela	18,000,000	41,000	11,909	2,150.0	−3.8	12	1,445,500	53,400	73,700	21,900
Virgin Islands	......	......	......	......	......	1	728,000	......	......	80,000
United States	28,500,000	205,000	508,340	8,660.0	+5.9	285	‡17,150,000	‡5,050,000	436,000	‡3,840,000
Canada	6,000,000	59,000	25,800	1,300.0	−1.3	37	‡2,225,000	‡550,000	‡42,900	‡450,000
Total W. Hemisphere	75,746,500	376,950	567,283	14,761.4	+4.5	410	27,713,915	6,423,872	1,031,930	4,729,936
Total Non-Communist	547,607,825	1,557,010	588,365	46,183.3	−0.8	755	63,541,132	8,185,827	2,105,658	8,767,396
COMMUNIST AREAS										
U.S.S.R.	71,000,000	910,000	(N.A.)	11,400.0	4.5	31	10,478,000	NA	NA	NA
China	20,000,000	25,000	(N.A.)	2,000.0	11.1	20	1,578,000	NA	NA	NA
Other§	3,000,000	10,000	(N.A.)	410.0	......	37	2,692,000	NA	NA	NA
Total Communist	94,000,000	945,000	(N.A.)	13,810.0	5.3	88	14,748,000	NA	NA	NA
TOTAL WORLD	641,607,825	2,502,010		59,993.3	0.6	843	78,289,132	......	......	

TABLE 11

Selected OECD Countries: Oil Stocks

Thousand Barrels, End of Month

		United States[1]	Japan[4]	Canada	Belgium	Denmark	France	Ireland	Italy
1973	Sep	1,057,911[2]	308,000	113,193	N.A.	N.A.	N.A.	N.A.	N.A.
1974	Mar	995,365[2]	265,000	116,060	N.A.	N.A.	N.A.	N.A.	N.A.
	Jun	1,102,467[2]	333,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Sep	1,156,105[2]	367,000	148,305	N.A.	N.A.	N.A.	N.A.	N.A.
	Dec	1,115,916[2]	342,000	142,233	N.A.	N.A.	N.A.	N.A.	N.A.
1975	Mar	1,076,360	302,000	133,805	45,968	34,770	N.A.	7,636	136,890
	Jun	1,071,150	322,000	140,617	44,983	34,887	N.A.	7,899	142,335
	Sep	1,147,338	339,000	147,939	51,644	44,333	254,296	7,716	152,490
	Dec	1,111,810	335,000	138,462	51,538	43,836	222,051	6,293	142,153
1976[3]	Mar	1,060,489	303,000	121,490	42,340	36,281	191,245	5,913	117,260
	Jun	1,108,703	333,000	132,174	47,187	35,033	202,684	6,563	132,882
	Sep	1,191,450	374,000	135,020	48,165	42,033	239,265	6,570	141,496
	Dec	1,111,810	366,000	125,934	40,077	41,296	231,133	6,008	140,773
1977	Mar	1,086,808	337,000	123,757	41,508	36,354	209,868	5,840	135,692
	Jun	1,195,272	372,000	138,808	49,589	39,456	201,130	7,066	162,381
	Sep	1,303,685	386,000	142,660	57,371	46,340	225,592	6,979	163,958
	Dec	1,311,900	390,000	143,545	51,618	46,107	234,629	7,023	159,972
1978	Mar	1,167,740	371,000	128,476	42,961	39,259	194,640	6,512	135,692
	Jun	1,185,228	382,000	127,777	42,756	40,610	187,632	7,840	140,240
	Sep	1,263,105	377,000	130,086	43,121	45,698	213,715	8,030	156,943
	Dec	1,277,940	397,000	121,459	43,508	47,056	198,166	8,045	150,164
1979	Mar	1,145,996	368,000	110,430	36,989	38,478	184,347	7,818	123,187
	Apr	1,169,888	378,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	May	1,182,700	396,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Jun	1,194,800	372,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Jul	1,233,800	396,000	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

		Luxembourg	Netherlands	Norway	Portugal	Spain	Switzerland	Turkey	United Kingdom	West Germany
1973	Sep	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1974	Mar	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Jun	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Sep	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	Dec	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1975	Mar	569	82,724	12,534	N.A.	61,393	27,638	9,636	N.A.	148,832
	Jun	504	82,738	11,921	N.A.	58,845	28,368	10,957	N.A.	151,424
	Sep	548	83,614	13,563	6,541	61,743	30,332	11,271	N.A.	170,083
	Dec	511	80,059	13,702	5,876	59,181	30,565	6,979	N.A.	184,004
1976	Mar	438	71,336	16,958	8,556	57,874	28,360	10,424	145,555	165,783
	Jun	584	71,744	18,980	7,680	66,211	29,375	10,103	156,417	172,244
	Sep	584	84,315	17,162	7,008	68,240	30,580	9,870	163,323	190,858
	Dec	606	80,190	17,454	9,176	66,897	32,230	11,680	163,111	204,787
1977	Mar	650	75,438	14,133	8,838	77,760	32,018	8,475	146,518	203,342
	Jun	620	83,388	15,936	9,629	81,694	34,500	14,089	155,884	201,677
	Sep	606	86,819	17,009	9,132	77,701	35,222	10,614	157,768	216,971
	Dec	650	79,935	18,805	11,147	77,833	35,573	N.A.	145,985	222,110
1978	Mar	657	68,094	15,717	8,198	67,759	34,522	N.A.	138,204	203,743
	Jun	591	69,686	15,739	N.A.	76,650	34,536	N.A.	139,800	204,933
	Sep	496	68,846	18,965	N.A.	80,344	36,157	N.A.	140,664	216,747
	Dec	664	78,584	16,549	N.A.	74,467	36,945	N.A.	144,671	224,606
1979	Mar	577	69,642	15,089	N.A.	70,846	37,558	N.A.	128,232	221,073

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[1] US stocks include Strategic Petroleum Reserves (SPR). According to DOE, the SPR held approximately 88.8 million barrels as of 31 July 1979.

[2] Estimated.

[3] As of January 1977, US Bureau of Mines changed the reporting of crude oil stocks to include foreign crude oil not yet received at refineries. Figures beginning in 1976 have been computed on the new basis.

[4] Japanese stocks include government-owned strategic stockpiles estimated at about 33 million barrels.

Source: U.S. Central Intelligence Agency, International Energy Statistical Review, 3 October 1979.

TABLE 12

OPEC TRADE AND CURRENT ACCOUNT BALANCE (BILLIONS DOLLARS)

	1973	1974	1975	1976	1977	1978	1979^p	1980^p
CURRENT PRICES								
Exports of goods	42.25	115.25	107.25	132.25	145.25	143	209	252
Imports of goods	-20.75	-38.75	-58	-67.75	-83.75	-100	-108	-125
Services & Private Transfers(net)	-12.5	-15	-19.25	-26	-30	-35	-38	-44
Official Transfers(net)	-1.25	-2.5	- 3	-2.5	-2.25	-2	-2	-2
Current Account	7.75	59.5	27.25	36.5	29	6	61	81
Cumulative Current Account	7.75	67.25	94.5	131	160	166	227	308
"Low Absorbers" Exports	19.75	55	52	67.25	73.25	70.5	105	123
"Low Absorbers" Current Account	7	35.5	25.25	29.25	27.5	16.75	59	73
"Low Absorbers" Cumulative Current Account	7	42.5	67.75	97	124.5	141.25	200.25	273.25
1975 PRICES								
Exports	58.4	129.1	107.25	130.3	132	112.5	150.6	164.7
Current Account	10.7	66.6	27.25	36.0	26.4	4.7	43.9	52.9
Cumulative Current Account	10.7	77.3	104.6	140.6	167.0	171.7	215.6	268.5

p = projected

Notes to Table 12

(1) Current prices data from 1973 to 1978 are all from OECD, Economic Outlook, July 1979. Data for 1979 are also from this source except for exports of goods. Here we have assumed oil exports of 28.5 mbd at an average price of $19.00 a barrel. (The C.I.A. estimate of production for the first 5 months of 1979 is 30.5 mbd and we allow 2 mbd for OPEC internal consumption.) Non-oil exports of goods are projected to be $11 billion in 1979 by Morgan Guaranty. For 1980 we assume exports of 28.5 mbd at an average price of $23 per barrel and non-oil exports of goods of $13 billion. In 1980 imports of goods and net service imports are assumed to increase by 15% in value terms.

(2) The "Low Absorber" group is made up of the following countries: Bahrain, Kuwait, Libya, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

(3) The series in 1975 prices were constructed by deflating the current prices series by a unit value index for the export of manufactures from OECD countries. This unit value was constructed from data provided in various issues of OECD: Economic Outlook.

TABLE 13

POSSIBLE OPEC OIL AND NGL REVENUES (REV) AND SURPLUS ON CURRENT ACCOUNT (SCA), 1979 AND 1980

(Billions of Dollars)

Price of Oil		Quantity of Oil Exported 30 mbd	28.5 mbd	27 mbd	25.5 mbd	24 mbd
	Rev.	186.2	176.8	167.5	158.2	148.9
$17.00	SCA '79	49.2	39.8	30.5	21.2	11.9
	SCA '80	28.2	18.8	9.5	0.2	-9.1
	Rev.	208.1	197.6	187.2	176.8	166.4
$19.00	SCA '79	71.1	60.6	50.2	39.8	29.4
	SCA '80	50.1	39.6	29.2	18.8	8.4
	Rev.	230.0	218.6	207.0	195.5	184.0
$21.00	SCA '79	93.0	81.6	70.0	58.5	47.0
	SCA '80	72.0	60.6	49.0	37.5	26.0
	Rev.	251.9	239.3	226.7	214.1	201.5
$23.00	SCA '79	114.9	102.3	89.7	77.1	64.5
	SCA '80	93.9	81.3	68.7	56.1	43.5
	Rev.	273.8	260.1	246.4	232.7	219.0
$25.00	SCA '79	136.8	123.1	109.4	95.7	82.0
	SCA '80	115.8	102.1	88.4	74.7	61.0
	Rev.	295.7	280.9	266.1	251.3	236.5
$27.00	SCA '79	158.7	143.9	129.1	114.3	99.5
	SCA '80	137.7	122.9	108.1	93.3	78.5

(1) Constituents of the current account, other than oil exports, are assumed to sum to -$137 bill and -$158 bill in 1979 and 1980 respectively. These figures reflect the same sources as those of Table 12.

(2) The C.I.A. estimates of OPEC production for the first five months of 1979 average 30.5 mbd. Assuming OPEC consumption of 2 mbd yields the export figure of 28.5 mbd used in Table 12.

TABLE 14

OPEC SURPLUS ON CURRENT ACCOUNT IN RELATION TO OECD GDP AND TRADE

(Billions of Dollars)

	1973	1974	1975	1976	1977	1978	1979^{P}	1980^{P}
Current Account(a) Surplus of OPEC	7.75	59.5	27.25	36.5	29	6	61	81
OECD GDP(b)	3243	3594	4039	4377	4921	5875	6580	7369
OECD Trade(c)	408	563	583	660	748	873	1015	1143
OPEC Curr. Acc. as % of OECD GDP	0.2	1.7	0.7	0.8	0.6	0.1	0.9	1.1
OPEC Curr. Acc. as % of OECD Trade	1.9	10.6	4.7	5.5	3.9	0.7	6.0	7.1

(a) See Table 12.

(b) Source OECD, Main Economic Indicators, July 1979 for 1973-78. Figures for 1979 and 1980 both assume increases in nominal GDP of 12% over previous year.

(c) Average of total imports and total exports of OECD countries. Source: National Institute Economic Review, May 1979.

TABLE 15

Table 15a

The current account deficit of non-OPEC LDCs[a] and its financing

in billions of dollars

	1973	1974	1975	1976	1977	est. 1978	proj. 1979
Current account deficit	8.6	28.0	36.6	25.2	22.0	27.5	35.0
(of largest 20 countries)[b]	(4.0)	(19.9)	(26.4)	(16.5)	(13.2)	(17.1)	(22.5)
Increase in international reserves	8.0	2.5	—2.0	11.2	11.1	13.2	3.0
(of largest 20 countries)[b]	(6.9)	(1.4)	(—3.0)	(9.7)	(7.9)	(13.8)	(2.2)
Net official transfers received	3.4	5.4	5.9	5.2	5.7	6.8	7.7
(of largest 20 countries)[b]	(0.5)	(0.5)	(0.6)	(0.8)	(0.6)	(0.8)	(0.9)
Net direct investment inflows	3.5	3.7	4.4	4.2	4.0	4.8	5.5
(of largest 20 countries)[b]	(2.3)	(2.5)	(3.3)	(3.3)	(3.1)	(3.7)	(4.3)
Net foreign borrowing	9.7	21.4	24.3	27.0	23.4	29.1	24.8
(of largest 20 countries)[b]	(8.1)	(18.3)	(19.5)	(22.1)	(17.4)	(26.4)	(19.5)

[a] non-OECD, non-OPEC countries excluding Israel and Communist block, but including Turkey

[b] in terms of the value of their external trade: Argentina, Brazil, Chile, Colombia, Egypt, India, Ivory Coast, Kenya, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Singapore, Taiwan, Thailand, Tunisia, and Turkey

Table 15b

Key external financing statistics for twenty selected non-OPEC LDCs[a]

in billions of dollars

	1973	1974	1975	1976	1977	est. 1978	proj. 1979
Current account deficit	4.0	19.9	26.4	16.5	13.2	17.1	22.5
as % of GDP	1.0%	4.1%	5.1%	2.8%	2.0%	2.3%	2.6%
External debt[b]	72.2	89.2	110.0	133.6	158.0	186.8	207.3
as % of GDP	18.9%	18.3%	21.1%	22.6%	24.2%	25.1%	24.3%
External debt net of international reserves	48.7	64.3	88.1	102.0	118.5	133.5	151.8
as % of GDP	12.7%	13.2%	16.9%	17.2%	18.2%	17.9%	17.8%

[a] see Table 5 for countries included in this group

[b] total external debt for Argentina, Brazil, Chile, Mexico, Philippines, and Turkey; total long-term external debt for Colombia, Korea, and Thailand; public and publicly-guaranteed long-term external debt for the remainder

Table 15c

The external position of commercial banks in major industrial countries vis-à-vis the non-OPEC LDCs[a]

in billions of dollars, end-of-period

	1974	1975	1976	1977	Sep 1978
Claims on non-OPEC LDCs	33.5	60.0	78.8	96.2	109.2
as % of total foreign claims	10.2%	13.6%	14.4%	13.9%	13.6%
Liabilities to non-OPEC LDCs	30.4	33.8	45.7	56.0	65.6
as % of total foreign liabilities	8.5%	7.6%	8.4%	8.3%	8.6%
Net claims on non-OPEC LDCs	3.1	26.2	33.1	40.2	43.6

[a] as reported by the Bank for International Settlements; data are not strictly comparable from year to year because of improvements in coverage

Table 15d

Industrial countries and non-OPEC LDCs: estimated dependence on oil and OPEC in 1978

	Net oil imports[a]				*Exports to OPEC[a]*	
	% of domestic oil consumption	*% of total energy consumption*	*% of total merchandise imports*	*% of GNP*	*% of total merchandise exports*	*% of GNP*
All industrial countries	65	36	15.0	2.2	8.9	1.4
United States	42	22	24.5	2.0	11.6	0.8
Japan	100	73	32.0	2.6	14.4	1.4
France	100	60	15.4	2.5	8.6	1.4
Germany	100	53	10.6	2.0	8.7	1.9
Italy	100	68	16.5	3.3	12.5	2.7
United Kingdom	50	21	5.5	1.3	12.4	2.7
All non-OPEC LDCs	40	20[b]	9.0	1.7	8.4	1.4

[a] all trade data are in U.S. dollars, customs basis

[b] based on 1977 data

Source: Morgan Guaranty, World Financial Markets, May 1979

TABLE 16

EUROCURRENCY DEPOSIT RATES

	U. S. Dollar		Pound Sterling	
	One Month	Twelve Month	One Month	Twelve Month
June 1973	8.75	8.75	10.38	10.00
Dec. 1973	9.87	9.38	17.19	15.00
June 1974	13.88	11.88	12.06	14.13
Dec. 1974	9.06	9.56	18.00	15.50
June 1975	6.00	7.63	10.00	11.75
Dec. 1975	5.25	7.00	10.63	11.50
June 1976	5.00	7.13	14.50	14.13
Dec. 1976	5.13	5.56	17.00	14.38
June 1977	5.62	6.25	7.75	10.13
Dec. 1977	6.87	7.67	6.50	7.37
March 1978	7.13	7.88	7.00	8.25
June 1978	8.06	9.13	10.75	12.13
Sept. 1978	9.37	9.50	12.38	12.75
Dec. 1978	10.87	11.87	12.00	13.00
March 1979	10.25	10.56	12.38	11.63
June 1979	10.81	10.19	14.25	12.63
Sept. 1979	12.88	12.19	14.00	13.63

*Prime bank bid rates in London, on the last trading day of each month.
Source: <u>Financial Times</u>, London.

TABLE 17

U. S. G.N.P. AND CURRENT ACCOUNT, ANNUALIZED FIGURES
(Billions of Dollars)

		G.N.P. 1972 $	Real G.N.P. % Growth Rate	G.N.P. Current Dollars	Current Acc. Surplus	Merchandise Trade Surplus
1973	I	1228.	9.1	1265.	-4.82	-3.77
	II	1231.	1.1	1288.	-3.73	-0.99
	III	1236.	1.7	1318.	2.30	2.88
	IV	1243.	2.0	1355.	6.34	5.52
1974	I	1230.	-3.9	1373.	-5.20	-0.59
	II	1225.	-1.9	1400.	-7.96	-5.94
	III	1217.	-2.5	1430.	-6.38	-9.36
	IV	1200.	-5.6	1452.	-0.57	-5.58
1975	I	1170.	-10.0	1453.	12.67	5.83
	II	1190.	6.9	1499.	21.12	13.14
	III	1220.	10.1	1564.	18.43	8.32
	IV	1228.	2.6	1598.	21.55	8.90
1976	I	1256.	9.0	1650.	6.97	-5.40
	II	1267.	3.8	1683.	8.68	-6.22
	III	1277.	3.1	1716.	1.47	-11.25
	IV	1288.	3.4	1756.	1.30	-14.32
1977	I	1316.	8.6	1820.	-13.74	-30.67
	II	1331.	4.7	1876.	-9.82	-26.26
	III	1354.	6.8	1931.	-11.63	-26.75
	IV	1361.	2.2	1971.	-21.20	-36.82
1978	I	1368	1.9	2011.	-27.74	-47.60
	II	1395	8.0	2104.	-13.70	-31.63
	III	1407.	3.5	2160.	-12.90	-32.05
	IV	1427	5.5	2235.	-1.25	-25.48
1979	I	1431.	1.1	2292.	0.62	-24.39
	II	1422.	-2.4	2329.		

Source: Survey of Current Business

TABLE 18

U. S. DOLLAR EXCHANGE RATES

(Units of foreign currency per dollar)

		D. Mark	Sterling	Yen	Swiss Franc	Effective Exchange Rate May 1970=100
1973	I	3.01	0.413	284.1	3.45	86.0
	II	2.74	0.395	265.0	3.15	82.1
	III	2.39	0.403	265.0	2.93	79.3
	IV	2.55	0.420	274.6	3.13	81.8
1974	I	2.73	0.439	292.3	3.21	85.7
	II	2.50	0.417	279.1	2.97	82.6
	III	2.61	0.426	294.6	2.98	84.3
	IV	2.52	0.429	300.0	2.76	84.0
1975	I	2.34	0.418	293.3	2.49	81.3
	II	2.35	0.430	292.4	2.52	81.4
	III	2.55	0.470	298.0	2.67	85.2
	IV	2.60	0.490	303.6	2.65	86.2
1976	I	2.57	0.500	302.4	2.58	86.9
	II	2.56	0.553	299.2	2.50	88.1
	III	2.53	0.566	291.1	2.48	87.7
	IV	2.41	0.606	293.6	2.45	88.0
1977	I	2.40	0.584	285.6	2.52	88.0
	II	2.36	0.582	275.2	2.51	87.4
	III	2.31	0.576	266.2	2.40	86.8
	IV	2.22	0.551	247.1	2.18	84.7
1978	I	2.08	0.519	237.6	1.93	81.9
	II	2.08	0.545	220.8	1.92	80.7
	III	2.01	0.518	192.8	1.68	76.6
	IV	1.87	0.504	190.6	1.63	75.2
1979	I	1.85	0.496	201.5	1.68	76.1
	II	1.89	0.481	217.7	1.71	77.8

Source: I. M. F. International Financial Statistics.

MACROECONOMIC ANALYSIS OF PRICE SHOCKS

Paper presented at the Conference on Energy Prices,
Inflation and Economic Activity

Sponsored by

The Center for Energy Policy Research, Energy Laboratory,
Massachusetts Institute of Technology
Cambridge, Mass.

by

Otto Eckstein, President, Data Resources, Inc., and
Paul M. Warburg Professor of Economics, Harvard University

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Energy has become a macro topic. Energy, along with industrial capacity, is the effective supply constraint of the economy, frequently decisive for inflation, growth and employment performance, and therefore at the very center of macro policy.

As a result, the major macro economic models used for forecasting and policy analysis have incorporated energy sectors designed to permit a tracing of energy and related supply effects on the economy. This paper summarizes the energy analysis embodied in the structure of the DRI Model of the U.S. Economy, an 800-equation construct used for both short-and long-term studies. Because it is the goal of the model to represent the economic process in considerable detail, the energy sector traces through numerous micro effects.

There is always the danger of losing sight of the forest for the trees, and so I have recently developed a small model which is largely recursive in its relation to the U.S. macro model and therefore benefits from the full detail, but is easier to interpret and to relate to macroeconomic theory. The model is used to analyze the impact of the two energy shocks, 1973-74 and 1979-80, on the economy. The companion paper extends the analysis to policy choices of the 1980s.

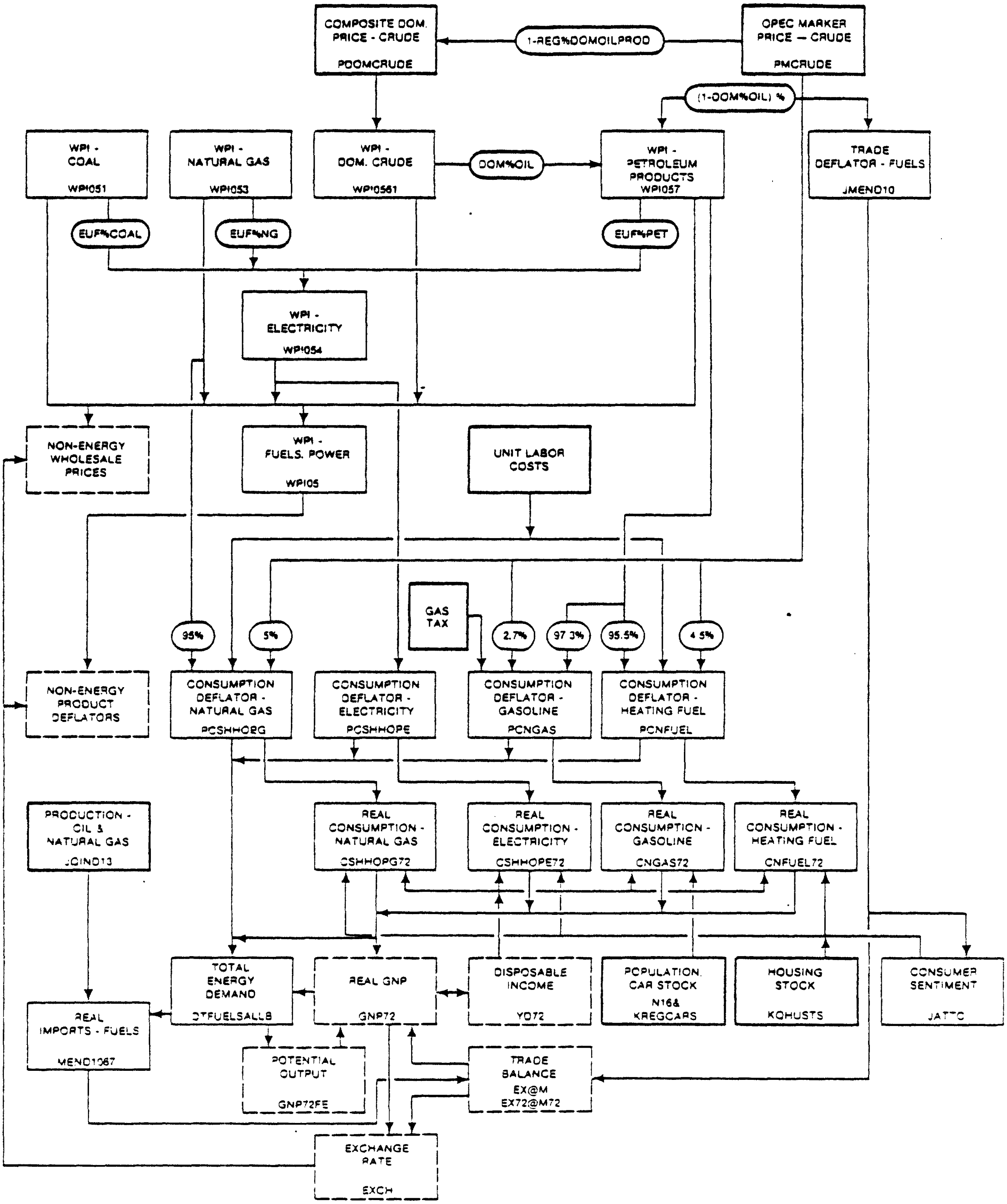
The Energy Sector in the DRI Model of the U.S. Economy

The detailed structure of the energy sector can be seen from Chart 1. The exogenous variables are an index of the OPEC marker price, production of domestic oil and natural gas, major tax rates levied by the various levels of government on gasoline, crude oil, electricity, etc., and the price control schedules on the various domestic sources. In addition, the macro model treats as exogenous energy supplies derived from solutions of DRI's energy models, including the breakdown of electricity generation by source according to coal, natural gas, petroleum and the domestic production of oil, gas, and coal. On the cost side, the model traces the prices of imported and domestic oil into the final energy products bought by consumers, such as retail prices of gasoline, electricity, natural gas and heating oil. Prices of the basic energy sources are traced through stage-of-processing equations to the various wholesale prices for different industries, and into retail prices generally. On the demand side, household demand is derived from consumption functions which include relative price terms, as well as the household stocks to which energy use is related, such as housing and automobiles adjusted for their efficiency ratings.

On the supply side, energy is one of four factors in the model's aggregate production function, along with capital, labor and the stock of research and development. Indirectly, energy also affects other supplies, of course. Industry investment equations include the energy sector, and help determine aggregate investment and the physical capital stock. The growth rate of the residential construction stock depends upon the rental price of housing, which includes energy among the operating costs. The supply of finance to the economy as a whole is affected by energy both through the general impact of prices on the financial system as well as the particular capital requirements of the energy industries.

Chart 1

THE ENERGY SECTOR OF THE DRI U.S. MACRO MODEL
MAJOR LINKAGES



KEY

——— INPUTS WHICH ARE BASICALLY EXOGENOUS TO SECTOR

– – – PRIMARY IMPACT POINTS OF ENERGY ON REST OF MODEL

⬭ INDICATE PERCENTAGE OF COST TERMS DERIVING FROM DIFFERENT SOURCES

There are various other indirect effects of energy on the economy. Consumer sentiment, one of the determinants of consumption, contains energy prices as a separate term, and should (but does not yet) also contain a term for energy disruption. The exchange rate in the model is affected by the trade balance, which is, of course, heavily determined by oil imports.

The model calculates the aggregate demand for energy in terms of quadrillion Btus (quads). In the case of the household demands, the separate consumption functions are the input to calculate energy requirements directly. In the case of industrial, transportation, commercial and other demands, the equations are very simple, relying on activity levels at relative energy prices, leaving it to the DRI energy model to provide the more detailed estimates. The two models can then be solved simultaneously to insure consistency. Thus, the total energy demand estimates of the macro model are mainly for the purpose of simulation exercises and for the identification of the oil import problem.

The oil import bill is calculated as a residual in the current version of the DRI Model. Given total energy demand and exogenous domestic energy supplies, the import requirement is simply a residual. It then becomes a matter of further analysis to assess whether OPEC will, in fact, make the calculated supplies available and at what price.

A more technical account of the energy sector in the DRI macro model is presented in the Technical Appendix[1] to this paper.

THE CORE INFLATION MODEL

An aggregate conceptual framework has been developed as a near-recursive component of the DRI Model to improve understanding of the inflation process. This model distinguishes three kinds of inflation: demand inflation, shock inflation and core inflation. The core rate originates in the long-term expectations of

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[1] The version of the energy sector described here was developed by Frank Cooper, Douglas Rice, and Virginia Rogers.

inflation in the minds of households and businesses, and in the contractual arrangements which sustain the wage-price momentum. Core inflation can be made better or worse by the particular circumstances of any short period, but can only be modified gradually. No brief experience will undo the cumulative effects of previous reality on expectations.

Chart 2 shows the core inflation rate since the late 1950s. It can be seen that it improved early in the period and was nearly eliminated by 1964. Since then it has deteriorated steadily, even in the years when the measured inflation rate showed dramatic improvement.

The conceptual structure can be set out as follows. The total inflation rate of a period is equal to the sum of the three separate inflation sources: demand, shock, and the core.

$$(1) \quad \dot{p} = \dot{p}_c + \dot{p}_s + \dot{p}_d,$$

where:

$\dot{p}$ = inflation rate

$\dot{p}_c$ = core rate

$\dot{p}_s$ = shock rate

$\dot{p}_d$ = demand rate

The core rate of inflation can be viewed as the rate that would occur on the economy's long-term growth path, provided the growth path were free of shocks, and the state of demand were neutral in the sense that markets were in long-run equilibrium. The core rate reflects those price increases made necessary by increases in the trend costs of the inputs to production. The cost increases in turn, are largely a function of underlying price expectations. In a competitive Cobb-Douglas economy with Hicks-neutral technological change, the long-term equilibrium price, p_c, can be written as,[2]

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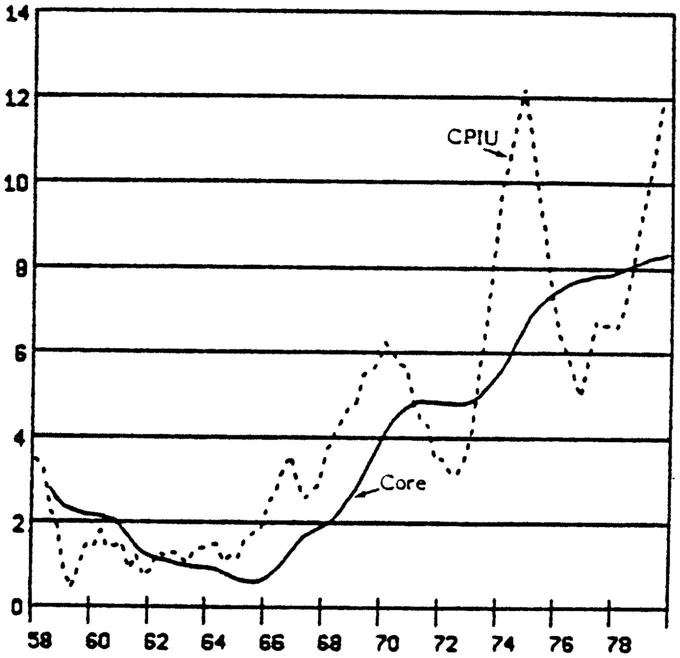
[2] For a fuller theoretical treatment of equilibrium price, see William D. Nordhaus, "Recent Developments in Price Dynamics," in Otto Eckstein, ed., The Econometrics of Price Determination, Federal Reserve Board, 1972, pp. 28-30.

Chart 2

The Core Inflation Rate Compared to
the Consumer Price Index
(Year-over-year percent)



$$p_c = A q^{a_1} w^{a_2} e^{-ht}, \tag{2}$$

where q is the rental price of the capital required per unit of output in a base period, w is the wage rate of the unit labor requirement, h is the aggregate factor productivity rate of technological progress, and a_1 and a_2 are the Cobb-Douglas factor share weights which, under the assumption of constant returns to scale, must sum to unity.

The core inflation rate is the change in the long-term equilibrium price along the balanced growth path. It can be written

$$\dot{p}_c = a_1 \dot{q} + a_2 \dot{w} - h. \tag{3}$$

The rental price of capital depends on the relative price of capital goods, depreciation and tax parameters, interest rates and equity rates of return. Let

$$q = \alpha(r, J), \tag{4}$$

where r is the market cost of financial capital and J is the tax variable. Financial cost is determined by the long-term inflation expectations embodied in nominal interest rates and equity yields, so that

$$\dot{q} = \alpha(\dot{p}^e_q, J). \tag{5}$$

Similarly, wages on the equilibrium path are determined by the price expectations underlying wage claims, or are based on

$$\dot{w} = \beta(\dot{p}^e_w). \tag{6}$$

Therefore, the core rate of inflation depends on long-term price expectations in labor and capital markets, tax provisions and factor productivity,

$$\dot{p}_c = a_1 \alpha(\dot{p}^e_q, J) + a_2 \beta(\dot{p}^e_w) - h. \tag{7}$$

Price expectations are formed on the basis of inflation experience, as measured by distributed lags on actual prices, and need not be the same for bond buyers as for workers. Thus,

$$(8) \quad p_c = a_1 \alpha \left(\sum_{j=0}^{-\infty} \lambda_j \, {}^*\dot{p}_j \, J \right) + a_2 \beta \left(\sum_{j=0}^{-\infty} \mu_j {}^*\dot{p}_j \right) - h.$$

The demand inflation rate will depend on utilization rates of resources. Presumably both unemployment and the operating rate of capital are pertinent, and the effects are nonlinear.

The shock inflation rate is, by definition, exogenous to the analysis. While, in fact, such shocks as OPEC and food prices are in part endogenous, with aggregate demand playing the conventional price-lifting role, they are considered to be determined primarily by non-controllable conditions here: OPEC political-economic decisions in one case, weather and crop conditions in the other. Government shocks, such as payroll taxes, are considered exogenous because they are policy levers which can be controlled.

The various inflation components must be pursued further into their own root causes. The core inflation rate is partly determined by the productivity trend, which depends upon the rate of capital formation, human resource investment and technological progress. The capacity utilization rate affecting demand inflation incorporates supply considerations including the tax system, as well as the level of demand created by fiscal and monetary policies and private spending propensities. A theory of investment is needed for capital supply, a theory of labor force participation for labor supply.

In effect, to fully trace the three components of inflation to root causes requires a full description of the economy such as is represented in a complete macroeconomic model. As will be seen in discussion of the empirical treatment below, the actual implementation of the core inflation model is drawn almost entirely out of the 800-equation DRI Quarterly Econometric Model of the U.S. Economy. Thus, there is no need to develop a special purpose theoretical or empirical model to conduct a full core inflation analysis.[3]

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[3] The core inflation analysis can also be treated as a stand-alone analytical device in which its inputs—the level of aggregate demand, the shock rate, the rental price of capital, the rates of wage and productivity increase are treated as exogenous.

The large DRI macro model is an eclectic, detailed empirical representation of the economy. The core inflation analysis could as easily be tied into a monetarist model, in which aggregate spending is driven exclusively by the monetary factor. Apart from the particular decomposition of the problem into its three components to provide analytical focus, the core model makes strong empirical statements only in one crucial regard—the formation of price expectations for determining long-run capital and labor costs is a gradual learning process rather than a quick response to policies or other particular events. The theory is consistent with the rational expectations viewpoint that price expectations are free of bias, but it is inconsistent with the viewpoint that these price expectations are formed quickly from particular policy or other events.

Energy and Core Inflation

Chart 3 shows the historical role of energy in the inflation process. Until 1973, energy was, if anything, helpful to the economy's cost structure. Thereafter, the energy component of shock inflation has been very large. Gradually, via the expectations of workers and investors, it converted itself into core inflation. The chart shows the actual record of core inflation and contrasts it with a hypothetical path in which energy prices continue their previous moderate behavior, with average increases of just 5½% a year.

The comparison shows not only the importance of energy in core inflation, but also indicates that there is far more to the recent inflationary experience than this one factor. The core inflation rate had risen from its brief near-zero levels of the mid-sixties to 5% by the time the OPEC actions began, and would have continued to worsen anyway. By the end of 1978, whereas the actual core inflation rate was 8.1%, the "No Energy" scenario would have had the core rate at 7.2%, still a very serious figure.

The Impact of Energy on the Economy—A Fuller View

While the core inflation analysis focuses on the fundamentals of the inflation problem, a full economic analysis, including the impact on real activity of capital formation, requires a full macro model simulation. Tables 1 through 3 contrast a historical tracking simulation of the DRI model with a hypothetical historical solution in which energy prices rise only 5.5%. The solution without the energy

Chart 2
The Core Inflation Rate (Percent)

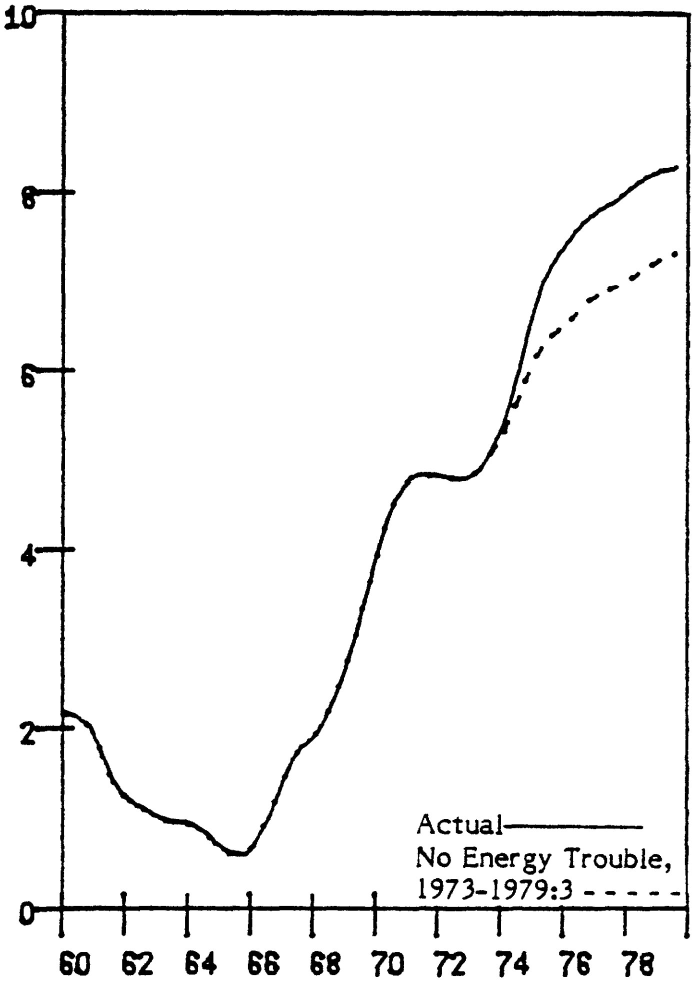

Table 1
Summary of Tracking Simulation of the U.S. Economy
(Percent change)

	1973	1974	1975	1976	1977	1978
Core Inflation Rate	5.0	5.9	7.1	7.6	7.9	8.1
Shock Inflation Rate	2.9	3.9	1.1	0.6	0.8	1.1
Demand Inflation Rate	-1.9	1.1	1.0	-2.4	-1.8	-1.0
Real GNP (1972 Dollars)	5.5	-1.4	-1.3	5.9	5.3	4.4
Total Consumption	4.7	-0.9	1.8	5.9	5.0	4.5
Nonres. Fixed Invest.	12.3	-0.3	-13.2	5.0	8.8	8.5
Invest. in Res. Structures	-4.0	-24.9	-13.8	23.4	20.9	4.0
Net Exports ($bil)	7.6	15.8	22.5	15.8	10.3	10.8
Government Purchases	-0.2	2.0	1.9	0.2	2.0	1.7
Imported Fuel Price	44.5	242.7	11.0	7.6	7.7	2.5
Personal Consumption Deflator	5.5	10.9	8.1	5.1	5.7	6.8
Output per Hour	1.8	-3.3	1.9	3.6	1.8	1.0
Potential GNP	4.2	3.3	3.2	2.7	2.6	3.0
Unemployment Rate (rate)	4.8	5.6	8.5	7.7	7.0	6.0

Table 2
Summary of No Energy Trouble (1973-1979) Scenario
(Percent change)

	1973	1974	1975	1976	1977	1978
Core Inflation Rate	5.0	5.6	6.3	6.7	6.9	7.1
Shock Inflation Rate	2.6	1.1	0.3	0.4	0.3	0.9
Demand Inflation Rate	-1.9	1.2	1.2	-1.7	-1.1	-0.5
Real GNP (1972 Dollars)	5.6	-0.4	1.3	6.0	4.4	4.4
Total Consumption	4.7	-0.2	3.8	6.3	4.6	4.7
Nonres. Fixed Invest.	12.5	1.5	-8.5	5.9	6.4	8.0
Invest. in Res. Structures	-3.5	-19.7	-4.6	13.6	13.7	8.2
Net Exports ($bil)	9.1	17.7	25.9	19.0	12.6	9.9
Government Purchases	-0.2	2.2	2.5	0.9	2.5	1.9
Imported Fuel Price	4.2	5.5	5.5	5.5	5.5	5.5
Personal Consumption Deflator	5.1	7.8	5.9	4.1	4.9	6.2
Output per Hour	2.1	-1.2	2.2	2.6	1.8	1.0
Potential GNP	4.2	3.4	3.6	3.2	3.1	3.4
Unemployment Rate (rate)	4.8	5.4	7.5	6.4	6.3	5.5

Table 3
Economic Impact of First Round of OPEC Price Increases: No Energy Trouble (1973-1979) Compared to Tracking Simulation

	1973	1974	1975	1976	1977	1978
Difference in rate of change						
Core Inflation Rate	0.0	-0.3	-0.7	-0.9	-1.0	-1.0
Shock Inflation Rate	-0.3	-2.7	-0.9	-0.3	-0.5	-0.2
Demand Inflation Rate	0.0	0.0	0.3	0.7	0.8	0.5
Percent Difference						
Real GNP (1972 Dollars)	0.1	1.1	3.8	4.0	3.1	3.1
Total Consumption	0.0	0.7	2.7	3.1	2.7	2.9
Nonres. Fixed Invest.	0.2	1.9	7.4	8.4	6.0	5.4
Invest. in Res. Structures	0.5	7.5	19.0	9.6	3.2	7.3
Net Exports	19.3	12.1	15.2	20.3	22.1	-8.0
Government Purchases	0.0	0.2	0.7	1.4	1.9	2.0
Imported Fuel Price	-27.9	-77.8	-78.9	-79.3	-79.7	-79.1
Personal Consumption Deflator	-0.4	-3.1	-5.1	-5.9	-6.6	-7.1
Output per Hour	0.2	2.4	2.7	1.7	1.6	1.7
Potential GNP	0.0	0.1	0.5	1.0	1.6	2.0
Unemployment Rate*	0.0	-0.2	-1.0	-1.3	-0.8	-0.5

*Difference in rate

crisis portrays a significantly different outcome. The energy crisis was not the only factor pushing the economy off its equilibrium path in 1973-74. However without it, the economy would have suffered no worse than a year of a small GNP decline in 1974, and would have seen 1975 as the first year of recovery. By 1976, real GNP would have been 4% higher than in the historical tracking simulation. The energy crisis was also largely responsible for the poor investment and productivity results of the last five years. In the "No Energy" case, investment averages 4.9% higher and productivity 1.7% higher between 1973 and 1978. This helps boost the potential output of the economy by 2% in 1978.

This analysis is a repetition of the work reported in greater detail in my recent book, The Great Recession, Chapter 9, but performed on the current version of the DRI Model. During the last three years, the model has become considerably more elaborate through the inclusion of the full energy sector as well as through various new supply formulations and a heightened sensitivity of the wage-price block. Despite various changes, the results are very similar to the figures reported in the earlier book.[4]

Effects of the Second OPEC Shock

In January 1979, the industrial world experienced the second OPEC shock. As Table 4 shows, the total magnitudes of the current round are very similar to the 1974 experience.

To assess the impact of the second OPEC shock, the most recent DRI macro forecast and the recent history are contrasted with the hypothetical history shown by a solution which assumes continuing moderate energy price behavior. Tables 5 through 7 show the second OPEC shock has worsened the economic outlook very considerably. Inflation in the years 1979-81 is higher by an average of 1.8% a year, and the core inflation rate, the legacy we leave to the future, is worsened from 7.7% to 8.3% by the end of 1981. Real activity is curtailed, and unemployment is boosted from 6.7% to 7.5% for the years 1980-81.

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[4] The paper by Mork and Hall, analyzing the same experience, also has very similar results. See Knut Mork and Robert E. Hall, "Energy Prices, Inflation, and Recession, 1974-75," Energy Laboratory Working Paper, May 1979.

Table 4
Energy Price Inflation After Two Rounds of OPEC Price Increases
(Compound annual percent change)

	1st OPEC Shock 1973-76	DRI Forecast 1978-81
OPEC Marker Price	60.0	28.0
(Change, $/barrel/yr.)	2.90	4.64
Avg. U.S. Import Price	53.9	29.1
Wholesale Prices		
Fuels and Power	25.5	24.2
Coal	19.1	8.7
Gas Fuels	31.3	23.9
Electric Power	17.1	12.7
Crude Petroleum	26.2	31.0
Refined Petroleum	29.0	29.2
Real Fuels and Power	11.0	11.1
All Industrial Commodities	13.1	11.7
Consumption Deflators		
Household Energy Prices	15.2	21.5
Gasoline and Motor Oil	14.7	26.3
Fuel Oil	22.3	30.0
Electricity	12.6	11.6
Gas	16.2	16.2
Real Energy Prices	6.7	11.5
All Consumer Prices	8.0	8.9

Table 5
Summary of Tracking Simulation (1979:1 - 1979:3) and DRI Six-Year Forecast (1979:4 - 1985)
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.3	8.4	8.3	8.5	9.0	9.3	9.2
Shock Inflation Rate	2.2	1.8	1.5	1.2	1.0	1.0	1.0
Demand Inflation Rate	-0.2	-0.7	-0.9	-0.5	-0.5	-0.3	0.2
	10.3	9.5	8.9	9.2	9.5	10.0	10.4
Real GNP (1972 Dollars)	2.0	-1.3	3.3	4.6	4.3	2.8	2.4
Total Consumption	2.3	0.0	3.0	3.8	3.9	3.1	3.1
Nonres. Fixed Invest.	5.1	-4.4	1.1	8.4	8.3	3.3	0.3
Invest. in Res. Structures	-6.1	-13.6	8.2	17.1	10.9	3.3	-2.1
Net Exports ($bil)	17.4	22.3	22.6	21.8	20.8	22.2	25.0
Government Purchases	0.1	0.9	1.5	2.0	2.3	2.4	2.3
Imported Fuel Price	36.6	35.9	13.0	12.7	14.6	13.8	8.6
Personal Consumption Deflator	8.9	9.1	8.6	8.1	7.8	7.8	7.4
Output per Hour	-0.8	-1.5	1.6	2.4	2.3	1.5	1.6
Potential GNP	2.7	2.8	2.8	2.8	2.8	2.8	2.8
Unemployment Rate (rate)	5.8	7.3	7.7	7.1	6.5	6.3	6.4
	12.3	8.2	12.2	13.8	13.8	12.8	12.8

Table 6
Summary of No Energy Trouble (1979-1985) Scenario
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.2	8.0	7.7	7.9	8.3	8.4	8.5
Shock Inflation Rate	1.3	0.4	0.7	0.7	0.5	0.6	0.6
Demand Inflation Rate	-0.2	-0.5	0.0	0.8	0.6	0.5	1.2
	9.3	7.9	8.4	9.4	9.4	9.5	10.3
Real GNP (1972 Dollars)	2.2	0.7	5.4	4.1	3.7	3.7	3.6
Total Consumption	2.2	1.2	4.5	3.8	3.7	3.7	3.8
Nonres. Fixed Invest.	5.4	-1.4	5.1	7.7	5.7	4.0	2.7
Invest. in Res. Structures	-4.6	-2.1	12.5	6.8	6.9	9.0	2.1
Net Exports ($bil)	18.2	25.3	25.7	24.6	24.5	27.1	31.2
Government Purchases	0.2	1.8	2.9	2.9	2.8	2.7	2.8
Imported Fuel Price	3.4	5.5	5.5	5.5	5.5	5.5	5.5
Personal Consumption Deflator	7.7	6.6	6.9	7.1	7.0	6.9	6.5
Output per Hour	-0.1	0.4	1.7	1.7	1.9	2.3	2.2
Potential GNP	2.7	2.9	3.2	3.3	3.3	3.1	3.0
Unemployment Rate (rate)	5.8	6.8	6.5	5.9	5.8	5.6	5.3
	11.5	8.6	13.8	13.5	13.1	13.2	13.9

Table 7
Economic Impact of Second Round of OPEC Price Hikes: No Energy Trouble (1979-1985) Compared to DRI Six-Year Forecast

	1979	1980	1981	1982	1983	1984	1985
	Difference in rate of change						
Core Inflation Rate	0.0	-0.3	-0.5	-0.6	-0.7	-0.8	-0.8
Shock Inflation Rate	-0.9	-1.4	-0.7	-0.5	-0.4	-0.4	-0.4
Demand Inflation Rate	0.0	0.2	0.8	1.3	1.1	0.8	0.9
	Percent Difference						
Real GNP (1972 Dollars)	0.1	2.2	4.2	3.7	3.1	4.0	5.2
Total Consumption	-0.1	1.1	2.6	2.6	2.3	2.8	3.6
Nonres. Fixed Invest.	0.3	3.4	7.5	6.8	4.3	5.0	7.6
Invest. in Res. Structures	1.7	15.3	19.9	9.4	5.4	11.2	16.0
Net Exports	4.4	13.6	13.7	12.8	17.3	21.8	24.8
Government Purchases	0.1	1.0	2.4	3.3	3.8	4.1	4.7
Imported Fuel Price	-24.3	-41.2	-45.1	-48.6	-52.7	-56.1	-57.4
Personal Consumption Deflator	-1.1	-3.4	-4.9	-5.8	-6.4	-7.2	-8.0
Output per Hour	0.6	2.6	2.7	2.0	1.7	2.5	3.1
Potential GNP	0.0	0.2	0.5	1.0	1.5	1.8	2.0
Unemployment Rate*	0.0	-0.4	-1.3	-1.2	-0.7	-0.7	-1.1

*Difference in rate

A simulation has also been developed which calculates the effects of the entire energy revolution, including both OPEC shocks and domestic price decontrol. Tables 8 through 9 summarize the results. By 1985, the cumulative effects of the energy crisis have cost 10% of real activity and 5% of potential output, and have added almost 15% to the price level. The core inflation rate is worsened from 8.7% to 9.2%.

This exercise completes the review of the historical record and the account of the technical apparatus that has been used to analyze it. The succeeding paper takes a more elaborate look ahead and explores a few of the macro policy choices.

Table 8
Summary of No Energy Trouble (1973-1985) Scenario
(Percent change)

	1978	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	7.1	7.3	7.3	7.2	7.5	8.0	8.4	8.7
Shock Inflation Rate	0.9	1.2	0.3	0.8	0.7	0.6	0.6	0.6
Demand Inflation Rate	-0.5	0.7	0.2	0.4	1.1	0.8	0.7	1.3
	7.5	9.2	7.8	8.4	9.3	9.4	9.7	10.6
Real GNP (1972 Dollars)	4.4	2.3	1.2	5.3	4.2	4.4	4.2	3.3
Total Consumption	4.7	2.4	1.4	4.4	3.7	4.1	4.1	3.7
Nonres. Fixed Invest.	8.0	5.9	-0.8	5.1	7.4	6.1	4.5	2.2
Invest. in Res. Structures	8.2	-2.8	-3.0	8.7	7.7	10.4	8.9	0.6
Net Exports ($bil)	9.9	13.7	21.2	22.1	22.2	24.8	28.4	32.2
Government Purchases	1.9	0.6	3.5	3.2	3.1	2.9	2.8	2.8
Imported Fuel Price	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Personal Consumption Deflator	6.2	7.5	6.3	6.8	7.2	7.1	7.2	6.9
Output per Hour	1.0	0.2	0.6	1.6	1.9	2.3	2.4	2.0
Potential GNP	3.4	3.5	3.1	3.2	3.4	3.3	3.2	3.1
Unemployment Rate (rate)	5.5	5.4	6.4	6.0	5.5	5.3	4.8	4.6
y	11.9	11.5	9.0	13.7	13.5	13.8	13.9	13.9

Table 9
Economic Impact of Entire Energy Revolution:
No Energy Trouble (1973-1985)
Compared to DRI Six-Year Forecast

	1979	1980	1981	1982	1983	1984	1985
Difference in rate of change							
Core Inflation Rate	-0.9	-1.0	-1.1	-1.0	-0.9	-0.9	-0.6
Shock Inflation Rate	-1.0	-1.4	-0.7	-0.5	-0.4	-0.4	-0.4
Demand Inflation Rate	0.6	0.6	1.0	1.3	1.0	0.6	0.7
Percent Difference							
Real GNP (1972 Dollars)	3.3	6.0	8.0	7.5	7.7	9.1	10.1
Total Consumption	3.0	4.4	5.9	5.7	5.9	6.9	7.6
Nonres. Fixed Invest.	6.3	10.2	14.5	13.4	11.2	12.5	14.6
Invest. in Res. Structures	11.1	24.7	25.3	15.3	14.8	21.0	24.3
Net Exports	-19.6	-3.1	-0.6	4.2	22.6	32.5	33.4
Government Purchases	2.6	5.3	7.0	8.1	8.7	9.2	9.8
Imported Fuel Price	-83.9	-87.5	-88.3	-89.1	-89.9	-90.7	-90.9
Personal Consumption Deflator	-8.4	-10.7	-12.3	-13.0	-13.5	-14.1	-14.5
Output per Hour	2.6	4.8	4.7	4.2	4.2	5.1	5.6
Potential GNP	2.4	2.6	2.9	3.5	4.0	4.4	4.7
Unemployment Rate*	-0.4	-0.9	-1.7	-1.7	-1.3	-1.5	-1.9

*Difference in rate

TECHNICAL APPENDIX

Energy Linkages in the DRI U.S. Macro Model

The 1979-C version of the DRI U.S. Macro Model contains a significant expansion of energy-related detail and linkages. The price disaggregation is much greater, and more precise, than in previous versions; the role of energy quantities is enhanced, with a modeling of domestic demand and production permitting the calculation of imports endogenously; the modeling of energy-related consumption categories has been altered to more accurately reflect the post-OPEC energy world.

The macro model now contains the following energy-related concepts (asterisks denote new variables):

- The OPEC marker price for light Arabian crude oil, including the average surcharge after 79:1 (PMCRUDE*);
- The unit value index for imported fuels and lubricants (JMEND10);
- The domestic wellhead price for crude oil (PDOMCRUDE*);
- Five components of the wholesale price index for fuels and related products and power (WPI05): coal (WPI051*), natural gas (WPI053*), electricity (WPI054*), crude oil (WPI056*), and petroleum products (WPI057*);
- Price deflators for consumer purchases of gasoline and motor oil (PCNGAS), home heating fuel (PCNFUEL), electricity (PCSHHOPE), and natural gas (PCSHHOPG);
- Total domestic energy demand, in BTU equivalents (DTFUELSALLB*):
- Domestic oil and natural gas production (JQIND13*);
- Imported quantity of fuels and lubricants (MEND1067).

The major exogenous levers are the domestic and imported crude prices (PDOMCRUDE and PMCRUDE), domestic production (JQIND13), and the non-oil wholesale energy price components (WPI051, WPI053, and WPI054). Each of these concepts is modeled by a simulation rule, wherein the primary determining variable is an exogenous counterpart. Equations derived from applicable theory rather than regression analysis cause the answers for these variables to differ from their exogenous counterparts when important related factors, such as the overall economy's inflation rate, change.

Other exogenous levers include, for electricity prices, the share of coal, petroleum, and natural gas as source fuels in electricity production (EUF%COAL, EUF%PET, and EUF%NG); for domestic crude prices, the proportion of domestic crude oil production which is subject to price regulation (REG%DOMOILPROD); for petroleum product prices, the domestically-produced share of domestic oil demand (DOM%OIL); for retail gasoline prices, the average governmental tax per gallon on gasoline (GASTAX), and for oil imports, the share of petroleum and natural gas in aggregate domestic energy demand (PET&NG%ENERGY).

THE PRICE BLOCK

Determination of primary energy prices is largely exogenous. Attempts to model their behavior through regression analysis proved problematical because a) OPEC actions and regulatory developments are not easily captured, and b) the energy sector is in a period of rapid structural change, which regression techniques cannot handle adequately. Consequently, the current DRI approach uses exogenously determined values for key prices, with simulation rules (non-stochastic equations) used to capture the impact on energy prices of other prices, regulatory developments, mix changes, and structural changes.

Petroleum Prices - Oil prices are primarily determined by appropriate weighting of domestic (PDOMCRUDE) and imported (PMCRUDE) crude prices.

The imported price variable is the OPEC price, expressed in dollars per barrel (PMCRUDE). Through 1979:1 the data is set at the pre-transportation price for Saudi Arabian marker (light) crude. The March 26, 1979 OPEC meeting effectively changed the marker crude price from a ceiling price to a base price. Therefore, after the first quarter of 1979, adjustments are made to PMCRUDE to reflect the base price plus an average surcharge. The values are still meant to capture the price of a crude of similar quality to the Saudi light for consistency with the historical data. Since it is difficult to separate premium differentials from surcharges, the price value becomes a best approximation and not an actually quoted price.

This variable (PMCRUDE) is now the lever for simulating OPEC price increases. Use of this lever, rather than JMEND10 (as in previous model versions) or PMCRUDEEXO, will ensure that changes flow through appropriately. (Changes made to JMEND10 will affect the trade deficit, and thus GNP, without affecting energy prices; changes to PMCRUDEEXO will affect energy prices without affecting the trade deficit).

PMCRUDE is determined exogenously, with a simulation rule to reflect changes in domestic demand prices:

$$\text{PMCRUDE} = \text{PMCRUDEEXO}*\text{PC\&I\&G}/\text{PC\&I\&GEXO},$$

where PC&I&G is the composite implicit price deflator for domestic demand (consumption, investment, and government purchases), and PMCRUDEEXO and PC&I&GEXO are exogenized counterparts of the corresponding variables. This formulation assumes that OPEC prices are determined partially by U.S. inflation developments. Their prices are not assumed to respond to exchange-rate changes, since OPEC prices are, at least in the short run, denominated in dollars.

In standard DRI solutions, PC&I&GEXO, an exogenous variable, is set equal to the value of PC&I&G, so that the last two terms on the right-hand side of the equation cancel, and PMCRUDE equals PMCRUDEEXO.

A simple bridge equation is employed to translate the imported crude oil price into the unit value index for imported fuel (JMEND10). This index is used in deriving the fuel import bill in the trade sector (MEND10). It forms no other linkages with the macro economy, since PMCRUDE is the channel through which all other links are defined. There are several important considerations about the nature of the data for JMEND10 which should be clarified:

- JMEND10 is obtained from the Bureau of the Census publication FT900, banked in @USCEN and derived as follows:

$$\%\Delta \mathrm{JMEND10} = \%\Delta(\mathrm{MPETNS}/\mathrm{MQPETNS})$$

where MPETNS = value of U.S. petroleum imports, F.A.S. , $/quarter
MQPETNS = quantity of U.S. petroleum imports, mmbd/quarter

- Movement in JMEND10 captures the movement in prices of all the fuels we import. Hence quality and mix changes will be included, in contrast to PMCRUDE, which captures just the movement in prices of a particular grade of crude oil.

- The imports are valued F.A.S.; hence prices will be slightly higher than the transaction cost reflected in PMCRUDE, but lower than if valued C.I.F. or on a refiners' acquisition basis. Recent data for JMEND10 were consistent with the following prices per barrel:

	1977	1978
$/barrel	13.31	13.31
(%)	9.4	-0.1

- The import category "10" includes all fuel imports. Hence, in the future, rising natural gas imports, with price movements that may not parallel oil price movements, may provide another source of discontinuity between JMEND10 and PMCRUDE.

An approach similar to that for PMCRUDE is utilized for domestic wellhead crude prices, except that the inflation factor is separated out: the regulated portion of domestic production can, in a simulation, change only when domestic inflation changes, since the regulations generally set ceiling prices which are a function of a base price and an inflation markup. The nonregulated portion, on the other hand, moves at the world oil price (approximated by PMCRUDE). The exogenous share variable REG%DOMOILPROD, which represents the controlled share of domestic production, controls how much the composite domestic crude oil price will change with respect to both domestic price inflation and world oil prices:

$$\mathrm{PDOMCRUDE} = \mathrm{PDOMCRUDEEXO}*(\mathrm{REG\%DOMOILPROD}*\mathrm{PC\&I\&G}/\mathrm{PC\&I\&GEXO} + (1-\mathrm{REG\%DOMOILPROD})*\mathrm{PMCRUDE}/\mathrm{PMCRUDEEXO}).$$

Domestic wholesale crude oil prices (WPI0561) are determined by simulation rule from the composite domestic crude oil price:

$$\mathrm{WPI0561} = \mathrm{WPI0561EXO}*\mathrm{PDOMCRUDE}/\mathrm{PDOMCRUDEEXO}.$$

Domestic petroleum product prices (WPI057) are determined by simulation rules from domestic wholesale crude oil prices, and the OPEC marker price for crude. The exogenous share variable DOM%OIL determines the proportion of petroleum product prices which reflects pass-through of OPEC prices, and the proportion which reflects pass-through of domestic crude oil prices. The simulation rule assumes a distributed lag adjustment of refined product prices to crude oil input prices:

$$WPI057 = WPI057EXO*$$

$$\sum_{i=0}^{3} a_i \left(DOM\%OIL_{-i} * \frac{WPI0561_{-i}}{WPI0561EXO_{-i}} + (1-DOM\%OIL_{-i}) * \frac{PMCRUDE_{-i}}{PMCRUDEEXO_{-i}}\right)$$

$$a_i = .2, .4, .3, .1 \qquad \Sigma a_i = 1.0$$

Consumer gasoline prices (PCNGAS) are estimated net of federal, state, and local taxes. According to DOE, approximately 2.7% of U. S. gasoline is imported; therefore, an input cost term is constructed by weighting wholesale refined petroleum product prices (WPI057) and imported crude oil prices (PMCRUDE):

$$gascost = .973*WPI057 + .027*PMCRUDE/1.710$$

where the 1.710 term converts the dollar-per-barrel PMCRUDE term to a 1967-based index for consistency with the WPI term. The gas price equation is then estimated as

$$\log\left(\frac{gasprice}{gasprice_{-1}}\right) = \underset{(0.002)}{0.00102} - \underset{(0.004)}{0.00703}*DMYPRICE$$

$$+ \underset{(0.047)}{0.731} * \log\left(\frac{gascost}{gascost_{-1}}\right)$$

$\bar{R}^2 = .7981$ (normalized on PCNGAS, $\bar{R}^2 = .9982$)

D.W. = 2.05

S.E.E. = 0.016 (normalized on PCNGAS, S.E.E. = 0.014)

with gasprice defined as

$$gasprice = PCNGAS-GASTAX/36.130,$$

where 36.130 is the average price, in 1972 cents, of one gallon of gasoline, and GASTAX is the average tax per gallon, in cents.

Consumer home heating fuel prices (PCNFUEL) are estimated in rate of change form from an input cost term derived from domestic petroleum product prices, (WPI057), imported petroleum product prices (proxied by PMCRUDE), and unit labor costs (TEMP@JULCNF):

fuelcost = 0.8*(0.955*WPI057+0.045*PMCRUDE/1.7)+0.2*TEMP@JULCNF

The weights for domestic and imported product prices were derived from DOE, and represent the shares of domestic and imported petroleum products in home heating fuel supplies. The estimated equation is

$$\log\left(\frac{PCNFUEL}{PCNFUEL_{-1}}\right) = \underset{(0.028)}{0.952} * \log\left(\frac{fuelcost}{fuelcost_{-1}}\right)$$

$\bar{R}^2$ = .8732 (normalized on PCNFUEL, $\bar{R}^2$ = .9988)

D.W. = 1.61

S.E.E. = 0.013 (normalized on PCNFUEL, S.E.E. = 0.020)

Coal Prices - Wholesale spot coal prices (WPI051) are determined exogenously, with a simulation rule which effects a 100% feed-through of domestic inflation:

WPI051 = WPI051EXO*PC&I&G/PC&I&GEXO.

The price used in construction of the index by the Bureau of Labor Statistics is the spot price. Coal moving under contract is not considered. Coke prices (WPI052NS in DRI's central data banks), which form a very small part of the total fuel price index, are not explicitly modeled. In input-output calculations of fuel cost indexes for other industries, and in the calculation of the aggregate index (WPI05), the weights which would accrue to WPI052 were assigned instead to coal prices (WPI051).

Natural Gas Prices - - Wholesale wellhead natural gas prices (WPI053) are determined exogenously, with a simulation rule which effects a 100% feed-through of domestic inflation:

WPI053=WPI053EXO*PC&I&G/PC&I&GEXO.

This simulation rule captures the tie-in of price ceilings, established under the Natural Gas Deregulation Act, to the inflation rate.

Consumer natural gas prices (PCSHHOPG) are determined from wholesale prices (WPI053) and unit labor costs (TEMP@JULCNF):

$$\log\left(\frac{PCSHHOPG}{PCSHHOPG_{-1}}\right) = \underset{(0.001673)}{-0.000396} + \underset{(0.146)}{0.583}*\log\frac{TEMP@JULCNF_{-1}}{TEMP@JULCNF_{-2}}$$

$$+\sum_{i=0}^{3} a_i * \log\frac{WPI053_{-i}}{WPI053_{-i-1}}$$

a_i = .0996, .1133, .1012, .0635

$\Sigma a_i = \underset{(0.042)}{0.378}$

$\bar{R}^2$ = 0.7545 (normalized on PCSHHOPG, $\bar{R}^2$ = .9992)

D.W. = 1.67

S.E.E. = 0.0086 (normalized on PCSHHOPG, S.E.E. = 0.011)

Electricity Prices - Wholesale electricity prices (WPI054) are determined by the costs of the three primary input fuels (coal, petroleum, and natural gas), and the proportions of generation fuel accounted for by each source. The exogenous weight EUF%COAL applies to the coal spot price WPI051; the exogenous weight EUF%NG applies to the natural gas price WPI053; the exogenous weight EUF%PET applies to the petroleum product price WPI057. The weights sum to less than one, reflecting the remaining sources of fuel (primarily nuclear and hydro). The simulation rule which generates wholesale electricity prices is based on a distributed lag formula:

$$\frac{WPI054}{WPI054EXO} = \sum_{i=0}^{3} w_i*\left(EUF\%COAL_{-i}*\frac{WPI051_{-i}}{WPI051EXO_{-i}}\right.$$

$$+ EUF\%NG_{-i} * \frac{WPI053_{-i}}{WPI053EXO_{-i}} + EUF\%PET_{-i} * \frac{WPI057_{-i}}{WPI057EXO_{-i}}$$

$$\left. + (1 - EUF\%COAL_{-i} - EUF\%NG_{-i} - EUF\%PET_{-i})\right)$$

$w_0 = 0.2$, $w_1 = 0.4$, $w_2 = 0.3$, $w_3 = 0.1$

Consumer electricity prices (PCSHHOPE) are determined by the wholesale price. A dummy variable was used in the estimation to account for the effects of price controls during the Nixon administration.

$$\log\left(\frac{PCSHHOPE}{PCSHHOPE_{-1}}\right) = \underset{(0.080)}{0.633} * \log\left(\frac{WPI054}{WPI054_{-1}}\right)$$

$$+ \underset{(0.0779)}{0.0957} * \log\left(\frac{WPI054_{-1}}{WPI054_{-2}}\right)$$

$$\underset{(0.0020)}{-0.00345} * DMYPRICE$$

$\overline{R}^2 = 0.7295$ (normalized on PCSHHOPE, $\overline{R}^2 = .9985$)

D.W. = 1.63

S.E.E. = 0.0077 (normalized on PCSHHOPE, S.E.E. = 0.011)

Aggregate Wholesale Price Index (Fuels) - The use of variable weights by the BLS in the construction of the wholesale price index for fuels and related products and power (WPI05), combined with the absence of an explicit modeling of coke prices (WPI052) caused problems in the attempt to find a satisfactory method of modeling the aggregate index from its components. The method adopted was the result of experimentation. The relative importance figures of each of the five components from BLS's wholesale price index release were translated into their base period relative weights. Then, assigning the weight for coke prices to coal prices (WPI051), the following equation was estimated:

$$WPI05 = \underset{(0.0019)}{-0.0201} + \underset{(0.0038)}{0.995} * weightedsum$$

$$+ \underset{(0.00077)}{0.00315} * \log(t) * weightedsum$$

$\overline{R}^2 = 1.0000$

D.W. = 0.52

S.E.E. = 0.0042

where weightedsum = 0.05281*WPI051+0.11341*WPI053+

0.28158*WPI054+0.09466*WPI0561+0.47452*WPI057

and t = TIME-60 is a time trend.

THE DEMAND BLOCK

The energy demand block centers on four consumption equations—gasoline, home heating fuel, electricity, and natural gas—and a total energy demand equation.

Gasoline - Gasoline consumption is estimated on a per-capita basis in log-linear form. The determining variables are real per-capita disposable income, with a four-period linear lag structure; a four-period moving average of the per-capita automobile stock; the average miles-per-gallon achieved by new model-year cars; and the relative price of gasoline, with a four-period linear lag structure:

$$\log\left(\frac{CNGAS72}{N}\right) = \underset{(0.36)}{-1.94} + \underset{(.145)}{0.485} * \log\left(\sum_{i=0}^{3} w_i * \frac{YD72_{-i}}{N_{-i}}\right)$$

$$+ \underset{(.168)}{0.733} * \log\left(\frac{1}{4*N} * \sum_{i=1}^{4} KREGCARS_{-i}\right)$$

$$\underset{(.0537)}{-0.0769} * \log(AVGMPG)$$

$$- \sum_{j=0}^{4} w_j * \log\left(\frac{PCNGAS_{-j}}{PC_{-j}}\right)$$

$w_i = .4, .3, .2, .1$ $\qquad \Sigma w_i = 1.0$

$w_j = .104, .083, .062, .042, .021$ $\qquad \Sigma w_j = 0.312\ (0.069)$

$\bar{R}^2 = .9802$ (normalized on CNGAS72, $\bar{R}^2 = .9882$)

D.W. = 0.47

S.E.E. = 0.028 (normalized on CNGAS72, S.E.E. = 0.558)

The relevant elasticities are thus .485 for income, .73 for the car stock, -.1 for relative price in the short run, and -.3 for relative price in the long run.

Heating Fuel - Home heating fuel consumption is estimated on a per-housing-unit basis, in log-linear form. The determining variables are real disposable income, with a low elasticity (0.21), the relative price, with a long-run elasticity of -.34, and consumer sentiment. The small size of this data series, relative to the precision to which the data are reported, and the (unmeasurable) effects of weather on heating fuel consumption, make accurate modeling difficult and R-squareds low; however, the standard error is a very modest $0.25 billion.

$$\log\left(\frac{CNFUEL72}{KQHUSTS_{-1}}\right) = \underset{(0.23)}{-3.77} + \underset{(.036)}{.209} * \log\left(\sum_{i=0}^{3} w_i * YD72_{-i}\right)$$

$$+ \sum_{j=2}^{4} (w_j * \log(JATTC_{-j}))$$

$$- \sum_{k=0}^{4} \left(w_k * \log\left(\frac{PCNFUEL_{-k}}{PC_{-k}}\right)\right)$$

$w_i = .4, .3, .2, .1$ $\qquad \Sigma\, w_i = 1.0$

$w_j = .101, .151, .117$ $\qquad \Sigma\, w_j = .368\ (.059)$

$w_k = .112, .090, .067, .045, .022$ $\qquad \Sigma\, w_k = .336\ (0.040)$

$\overline{R}^2 = .7028$ (normalized on CNFUEL72, $\overline{R}^2 = .7841$)

D.W. = 1.22

S.E.E. = .046 (normalized on CNFUEL72, S.E.E. = 0.254)

Electricity—Electricity consumption is modeled as a per-housing unit function of income, relative price, and consumer sentiment, in log-linear form. Transfer income is separated out from non-transfer income; the resulting response of electricity consumption is more immediate for transfer income. The estimated price elasticity is a modest 0.21.

$$\log\left(\frac{CSHHOPE72}{KQHUSTS\&MH_{-1}}\right) = \underset{(0.07)}{5.85} + \underset{(0.014)}{0.394} * \log\left(\sum_{i=0}^{3} w_i \left(\frac{YD_{-i} - VG_{-i}}{PC_{-i}}\right)\right)$$

$$+ \underset{(0.011)}{0.332} * \log\left(\frac{VG_{-1}}{PC_{-1}}\right)$$

$$- \sum_{j=0}^{4} \left(w_j * \log\left(\frac{PCSHHOPE_{-j}}{PC_{-j}}\right)\right)$$

$$+ \sum_{k=1}^{5} (w_k * \log(JATTC_{-k}))$$

$w_i = .4, .3, .2, .1$ $\qquad \Sigma\, w_i = 1.0$

$w_j = .071, .057, .043, .028, .014$ $\qquad \Sigma\, w_j = .213\ (.030)$

$w_k = .034, .031, .027, .020, .011$ $\qquad \Sigma\, w_k = .123\ (.033)$

$\bar{R}^2$= .9896 (normalized on CSHHOPE72, $\bar{R}^2$ = .9921)

D.W.= 1.40

S.E.E. = .022 (normalized on CSHHOPE72, S.E.E. = .290)

Natural Gas - Natural gas consumption is modeled as a per-housing unit function of disposable income, relative price, and consumer sentiment. The income elasticity is a modest 0.38; the long-run price elasticity is -0.34. The explanatory power of the equation is limited, like the heating fuel equation, by the size and imprecision of the series, and the lack of an appropriate weather variable.

$$\log\left(\frac{CSHHOPG72}{KQHUSTS_{-1}}\right) = \underset{(0.23)}{-4.95} + \underset{(0.036)}{0.387} * \log\left(\sum_{i=0}^{3} w_i * YD72_{-i}\right)$$

$$- \sum_{j=0}^{4} w_j * \log\left(\frac{PCSHHOPG_{-j}}{PC_{-j}}\right)$$

$$+ \sum_{k=1}^{4} w_k * \log(JATTC_{-k})$$

w_i= .4, .3, .2, .1 Σw_i = 1.0

w_j = 0.113, 0.090, 0.068, 0.045, 0.023 Σw_j = 0.339 (0.042)

w_k = 0.060, 0.054, 0.042, 0.024 Σw_k= 0.180 (0.063)

$\bar{R}^2$ = .6887 (normalized on CSHHOPG72, $\bar{R}^2$ = .8852)

D.W.= 1.30

S.E.E. = 0.050 (normalized on CSHHOPG72, S.E.E. = 0.295)

Total Energy Demand - Total U.S. energy demand is modeled in BTU equivalents, as a function of consumer energy demands, industrial activity, and relative price. The consumer demand term is defined as

$$\text{consumerdemand} = CNGAS72 + CNFUEL72 + CSHHOPE72$$
$$+ CSHHOPG72 + a * CSTRANS72,$$

where a is a constant representing the share of transportation services which is energy-related. This share is estimated as a function of a linear and logarithmic time trend. Specifying industrial demand for energy as a function of industrial production in manufacturing (JQINDM), mining (JQINDMI), and utilities (JQIND49&G), and the relative price term as the ratio of the wholesale price index for fuels and related products and power (WPI05) to the aggregate wholesale price index (WPI), we estimate total demand for energy, in quadrillion BTU (DTFUELSALLB) as follows:

$$
\begin{aligned}
\log(\text{DTFUELSALLB}) = {} & \underset{(0.252)}{1.744} \\
& + \underset{(0.066)}{0.613} * \log(\text{consumerdemand}) \\
& + \underset{(0.025)}{0.101} * \log(\text{JQINDM}) \\
& + \underset{(0.050)}{0.087} * \log(\text{JQIND49\&G}) \\
& + \underset{(0.055)}{0.114} * \log(\text{JQINDMI}) \\
& - \sum_{i=1}^{5} w_i * \log(\text{relativeprice}_{-i})
\end{aligned}
$$

$w_i = 0.023, 0.019, 0.014, 0.009, 0.005 \qquad \Sigma w_i = 0.070\ (0.010)$

$\overline{R}^2 = .9974$ (normalized on DTFUELSALLB, $\overline{R}^2 = .9970$)

D.W. = 1.18

S.E.E. = 0.009 (normalized on DTFUELSALLB, S.E.E. = 0.601)

The coefficients on the relative price terms cannot be directly interpreted as elasticities, since the consumer demand term already has price elasticity effects built in. Similarly, the full-system elasticities on the industrial production terms are not equal to the corresponding coefficients except for movements in the particular index which are independent of movements in the other two indexes and in the consumer energy demand categories.

THE SUPPLY BLOCK

The energy supply block takes domestic crude oil and natural gas production (JQIND13) as exogenous, and calculates oil and gas imports (MEND1067) as a residual type of energy supply. That is to say, an increase in domestic energy demand will, in the short run, be met primarily by the importation of additional foreign oil.

Domestic Supply - Production of oil and natural gas is represented by the variable JQIND13, from the Federal Reserve Board's Industrial Production series. It is a subset of the mining composite, comprising 69.2% of all mining and 4.4% of all industrial production. It includes the following major components:

	% of JQIND13	% of JQIND
Oil and Gas Extraction (JQIND13)	100.0	4.4
Crude Oil	66.7	2.9
Natural Gas Liquids	6.8	0.3
Natural Gas	15.2	0.7
Oil and Gas Drilling	11.3	0.5

In the model, JQIND13 is forecast exogenously; a simulation rule allows for a small (.05) short-run and moderate (.44) long-run supply elasticity, based on domestic wellhead crude oil prices:

$$\log\left(\frac{JQIND13}{JQIND13EXO}\right) = \sum_{i=0}^{24} w_i * \log\left(\frac{PDOMCRUDE_{-i}}{PDOMCRUDEEXO_{-i}}\right)$$

$w_i = .01$ for $i = 0 - 4$, $i = 10$, and $i = 24$

$w_i = .01$ for $i = 11$, $i = 23$

$w_i = .03$ for $i = 12 - 22$

$w_i = 0$ for $i = 5 - 9$

$\Sigma w_i = .44$

Import Supply -Energy imports to the U.S. are captured by the Bureau of the Census value, in 1967 dollars, of all imports of fuels and lubricants (MEND1067). Although primarily crude oil and petroleum products, the series does include natural gas, other fuel imports and lubricants. This fact must be remembered when translating oil imports or mmbd into constant-dollar imports (MEND1067). The Census data are often at odds with either the levels or the movement in levels of oil import quantities available from the Department of Energy and the American Petroleum Institute. For reference, the following benchmark figures for the oil import quantities associated with MEND1067 may be helpful:

Oil Imports
(mmbd)

	1977	1978	78:1	78:2	78:3	78:4
Census	8.72	8.14	7.99	7.87	8.38	8.32
API	8.59	8.15	8.02	7.68	8.07	8.82
DOE	8.79	8.03	8.08	7.50	8.21	8.31
Strategic Storage	.02	.16	.12	.13	.19	.21

It should be noted that the Census figures include imports for strategic storage, whereas the API figures do not; DOE provides estimates both with and without strategic storage. Furthermore, the sampling techniques and timing differ among the three estimates. None of the figures includes imports to the Virgin Islands (there appear in the statistical discrepancy to the trade accounts, STATM67).

The equation for imports of fuels and lubricants (primarily crude oil, refined petroleum products, and natural gas) is derived from total demand and total production. Total demand can be approximated historically by adding domestic production and imports, scaling the two concepts so that they are in equivalent units:

$$\text{domestic (realized) demand} = a * \frac{\text{JQIND13}}{\text{JQIND13}[t]} + b * \frac{\text{MEND1067}}{\text{MEND1067}[t]}$$

where a is the domestic supply in some time period t, in mmbd, and b is the equivalent import supply. Choosing any year t, and the corresponding values for a and b, domestic demand is defined in barrel equivalents.

A relationship is then assumed between this concept of domestic demand, and total energy demand (DTFUELSALLB), multiplied by the petroleum and natural gas share of total energy demand (PET&NG%ENERGY):

$$\log(\text{domestic demand}) = a_0 + a_1 * \log(\text{DTFUELSALLB} * \text{PET\&NG\%ENERGY})$$
$$a_2 * \text{TIME} + a_3 * \log(\text{TIME}) - a_4 * \log(\text{relative price})$$

where the relative price is the cost of oil- and natural gas-related fuels relative to the cost of all fuels. This can be approximated by constructing a measure similar to WPI05, but excluding coal and the nonpetroleum/natural gas share of electricity:

$$\begin{aligned}\text{cost oil/ng} = (&.153*\mathrm{WPI053} + .214*(\mathrm{EUF\%NG} + \mathrm{EUF\%PET})*\mathrm{WPI054}\\ &+ .087*\mathrm{WPI0561} + .478*\mathrm{WPI057})/\\ &(.718 + .214*(\mathrm{EUF\%PET} + \mathrm{EUF\%NG}))\end{aligned}$$

The equation was then estimated as:

$$\begin{aligned}\log(\text{domestic demand}) = {} & \underset{(3.884)}{7.725} + \underset{(0.250)}{0.972} * \log(\mathrm{DTFUELSALLB}\\ & * \mathrm{PET\&NG\%ENERGY})\\ & + \underset{(0.012)}{0.038} * \mathrm{TIME}\\ & - \underset{(1.239)}{3.429} * \log(\mathrm{TIME}) - \sum w_i \log(\text{relative price})\end{aligned}$$

w_i= .022, .043, .061, .078, .092, .105, .115, .124, .131, .136, .139, .140, .139, .136, .131, .124, .115, .105, .092, .078, .061, .043, .022 $\Sigma w_i = 2.23$ (.51)

$\bar{R}^2 = .9411$ (normalized on MEND1067, $\bar{R}^2 = .9706$)

D.W. = 1.34

S.E.E. = .0240 (normalized on MEND1067, S.E.E. = 0.333)

Given the definition of domestic demand (above), this estimated relationship can be rearranged to solve for MEND1067.

The sum of the coefficients on the relative price term cannot be interpreted directly as a price elasticity because the numerator and denominator are not sufficiently independent; the true price elasticity is quite small.

Macroeconomic Analysis Of
Energy Price Shocks:
The M.I.T. Energy Lab Energy-Macro Model

by

Knut Anton Mork

M.I.T. Energy Laboratory

and

Robert E. Hall

Stanford University

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1. Introduction

In less than a decade, the U.S. economy has absorbed two large sudden shocks in the world price of oil. The first of these resulted in a severe dislocation of the domestic economy in the form of extraordinarily high rates of inflation and a severe recession. The full results of the second shock still remain to be seen, but the outlook for 1980 is discouraging according to most current forecasts.

These unhappy events have clearly demonstrated the need for economists to pay explicit attention to energy price shocks. This seems so much more important as the models in existence before 1974 seemed unable to account satisfactorily for the macroeconomic effects of these shocks.

In our view, a successful analysis of an energy price shock must integrate two equally important aspects. On the one hand, the long term effects of energy substitution must be incorporated. This is done in most general equilibrium energy-economy models [1], but these are long-term growth models and not intended for analysis of short-term problems. All the existing large short-run macroeconomic models lack this feature to our knowledge.

On the other hand, the short run effects on price level, financial markets, and employment must be taken into account. As equilibrium models of the real economy, the energy-economy growth models naturally abstract from these phenomena. Short-term macroeconomic models include them, or can be modified to include them. However, a fully satisfactory treatment of the problem requires an integration of the long- and short-run mechanisms.

We have constructed an energy-macro model which we believe satisfies these criteria. It has been kept deliberately at a relatively small scale,

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[1] Cf. in particular Hudson and Jorgenson (1977)

consisting of about ten equations. Although many interesting and important aspects of the economy are necessarily overlooked this way, the compactness of the model has the definite advantage that the effects of a shock can be traced relatively easily through the model.

The model assumes that goods and services are produced by labor, capital, and energy. The demand for inputs to production is modeled according to the modern theory of production. The macroeconomic structure of our model includes a financial system, which enables us to study various aspects of inflation and monetary policy. The model incorporates the hypothesis of rational expectations, but it is also somewhat Keynesian in treating money wages as predetermined in the short run. In a purely classical economy where wages clear the labor market instantaneously, an unexpected energy price increase would reduce the level of output as a way of substituting away from energy. Because of an accelerator effect on investment, this impact would be larger in the short than in the long run. However, there would be no effect on employment or prices. When the price of one factor, energy, increases, the price of other factors, especially the wage, would fall to offset it. Full employment should always prevail, and the price level should be linked directly to the money stock. In our model, on the contrary, wages respond slowly to unexpected changes in energy prices (and to all other surprises in the economy). During the period following an energy price increase but before the accommodating change in the wage, labor is priced too high for full employment. Furthermore, with wages sticky, an energy price increase increases the price level, so that the real money supply is lowered, which has an additional contractionary effect on the economy. Our model deals explicitly with these aspects of the effect of an energy price shock; investment and interest rates play an important role in the relation between the sticky wage rate and the resulting levels of prices, output, and employment.

When energy is partly imported, as in the U.S. of the 1970s, another consideration links output and employment to an unexpected increase in energy prices -- higher prices make the U.S. poorer and so reduce the level of consumption in real terms. Often this is compared to the imposition of a tax on U.S. consumers with the proceeds going to foreigners. As the U.S. is made poorer, energy-supplying nations become richer. They acquire claims upon the U.S. and face the choice of accumulating the claims (as government or corporate bonds, stocks, direct investments and so on) or cashing them in for goods produced in the U.S. Our model does not attempt to explain the choices of oil producers in this regard, but uses a guess that oil producers spend a relatively small fraction of their new income on U.S. goods. This seems consistent with observations on actual behavior in recent years.

Our work follows in the footsteps of a number of innovative earlier studies. One of the first to predict the recession as a result of the energy shock seems to have been Robert Gordon (1974). A number of later studies have followed. Some of these have made important theoretical contributions, like Gordon (1975a), E. Phelps (1978), Solow (1978), and Findlay and Roderiques (1977). Others have employed quantitative models to simulate the 1974-75 experience. These include Pierce and Enzler (1974), Berner et al. (1975), Perry (1975a, b), Eckstein (1978), Fair (1978), Klein (1978), and from a slightly different perspective Hudson and Jorgenson (1978). Contributions of the more informal type include Haberler (1976), Serot (1978), and Okun

(1975). Our own effort is, to our knowledge, the first attempt to give a unified treatment of the issues associated with factor substitution on the one hand and monetary and general macroeconomic aspects on the other.

The present paper gives a non-technical introduction to our model. The model is outlined in some detail in the next section. Section 3 applies the model to a study of the effects of this year's increase in oil prices. A compact mathematical statement of the model is contained in the Appendix.

2. The Model

Our model was constructed on the basis of the one used by Hall (1978a), but contains some important extensions and revisions. The present model treats the economy as having two sectors, goods and energy. Only the goods sector is fully represented in the model. Energy is used as an input to the goods sector and is thought of as primary energy, such as crude oil, natural gas at the wellhead, and coal at the minemouth. For simplicity, there is a single price of energy, though it should be recognized that this is only a rough approximation.

The goods sector combines labor, capital, and energy to produce goods. The term "goods" covers all sorts of goods and services and includes finished energy products such as gasoline and electricity. Total goods production is allocated among consumption, investment in the goods sector, government expenditures, net export of goods, and deliveries to the energy sector. It differs from real GNP by the amount of the last item, which is small, and net energy imports.

Input Markets and the Supply of Goods

The supply of goods is modeled as a production possibility frontier represented in the form of a unit cost function with the following properties. The own price elasticity of energy demand is about -0.3, and the partial elasticities of substitution are about zero for capital and energy, unity for capital and labor, and around one half for energy and labor. These are long-run elasticities; short-run behavior is modeled by specifying the capital stock as predetermined. The low value for the own elasticity of energy in the aggregate is supported by evidence by Mork (1978) and by casual reading of post-1973 data. The unitary elasticity of substitution between capital and labor is strongly supported by the evidence of Berndt (1976) and many other authors. For the corresponding elasticity between capital and energy, strikingly different estimates can be found in various parts of the literature.[1] Despite new insights and attempted reconciliations,[2] the issue seems to remain a subject of controversy. Our choice of a zero elasticity is partly based on the evidence of Hudson and Jorgenson (1978). Although their model has capital-energy complementarity for the manufacturing sector, substitutability in service industries and interindustry shifts in final demand gives a net effect on capital intensity of the 1973-74 energy price increase that is very close to zero. We hope to pursue this issue at a later stage.

Under the assumption of cost minimization, the demand for labor, energy, and capital is derived from the production possibility model.

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[1] Cf. e.g., Berndt and Wood (1975) and Griffin and Gregory (1976).

[2] Cf. Berndt and Wood (1979) and Field and Grebenstein (1977, 1978).

The derivation of energy demand is straightforward. The price of energy is viewed as exogenous, and what cannot be supplied by the domestic energy sector is imported. The price elasticity of domestic energy supply need not be considered for our purposes.

The demand and supply of labor is a bit more complicated. The supply of labor is assumed inelastic and grows exponentially at a constant rate. Wages are thought of as committed in advance as in formal labor contracts. When wages are set, they clear the labor market, or come as close as they can given current information about future demand for labor. When unexpected events occur, such as a sudden increase in the price of energy, the wage rate is partly determined by past commitments and adjusts to the new equilibrium only gradually as wages are renegotiated. Immediately after the shock, the demand function for labor determines the level of employment, which may be well below supply, so that unemployment may occur. This can be interpreted as a characterization of the Keynesian hypothesis of wage rigidity and is an attempt to embody the view that the labor market achieves equality of supply and demand in the long run but that the process takes time. It implies a kind of Phillips curve for the economy. However, in place of the expected inflation term that has been the source of so much instability and conceptual ambiguity in the literature on the Phillips curve, expectations of future labor demand are formed using the model itself. In particular, feedback from prices to wages occurs in the model to the extent that price increases signal current or future increases in the demand for labor (as they typically do).

This formulation, set forth by Hall (1978a), has been extended in two directions. First, a cost of living increase has been added to the precommitted wage rate. Specifically, for each percentage point of unexpected price inflation, the committed wage rate is raised by 0.25 percent in the same year and another 0.25 percent in the year after. Roughly, this corresponds to a 50 percent escalation clause with a six month lag, assumed to reflect the time needed for data collection. The inclusion of this feature is justified by the widespread occurrence of such clauses in the U.S. labor contracts (cf. Mitchell (1978)) as well as the theoretical argument by Hall and Lilien (1979) that efficient labor contracts will have this feature. Furthermore, it allows for a positive feedback from energy prices to wages in the short run. Since it turns out that an energy price increase lowers the demand for labor permanently, however, this positive feedback is counteracted by a tendency towards lower wages in the longer run.

The other extension is an adjustment in the committed wage rate to incorporate cyclical movements in labor productivity. This feature makes the model obey Okun's law but has few other implications and thus will not be discussed in detail here.

Cost minimization also determines the desired stock of productive capital. Part of investment is assumed to be determined by past commitments, so that the stock of capital will adjust to unexpected events with a lag. The specific form of the investment lag in the model is discussed below.

The Demand for Goods

Consumption in the model is determined by permanent income. Consumers are viewed as looking into the future to evaluate their future incomes, and then choosing a growth path of consumption that is the highest feasible given expected future income. The behavior of consumption has the character described by Hall (1978b) -- consumers always plan a constant growth rate for consumption. When new information arrives, they make an immediate once-and-for-all adjustment to the level of consumption. We assume that consumption is unaffected by real interest rates, in the sense that the rate of growth of planned consumption does not depend on the interest rate. Note that the assumption in Hall (1978a) that consumption is unresponsive to all economic events is replaced by an explicit dependence on permanent income. The model makes no distinction between durable and non-durable consumption goods. We consider this an oversimplification and plan to change it at a later stage. Stock adjustment of consumer durables are introduced <u>ad hoc</u> in simulations of the present version of the model.

Investment demand is derived from the demand for capital. However, in the short run, the model assumes that the economy's ability to adjust the capital stock is limited. Part of the investment in the next few years is already committed today and cannot be adjusted in response to new information. Specifically, this is modeled by treating capital as an aggregate of m categories, such that the quantity of category j needs to be determined j - 1 years in advance. Each category enters symmetrically in the technology model; but the categories are imperfect substitutes in production, since otherwise all investment would be concentrated in the category with the shortest lead time. In the year of the energy shock, investment in m - 1 categories is committed already, whereas investment in the last category is determined by the demand for capital of that category as determined by present and expected future prices and demand. The next year, another category becomes "flexible" until all capital and investment is determined by post-energy shock forces after four years. This formulation, which is adapted from Hall (1978a), does justice to the physical lags in the investment process without introducing arbitrary lags for expectation formulation.

Government expenditure and net export of goods are taken to be exogenous. Among other things this means that, rather than modeling the behavior of petroleum exporting countries, we use an outside estimate of their demand for U.S. goods. We are currently working on a revision which will incorporate this aspect into the model.

Financial Sector

The model has only two assets, money (supplied exogenously by the government) and ownership of physical capital. This allows the description of this sector to be compressed into one equation, the money demand function. In this equation, the major issue is the specification of the variable that measures the dollar volume of transactions. The use of nominal gross national product for this purpose is one of the many reasons that macroeconomic models in existence in 1973 were unable to deal effectively with the energy price shock (cf. the remarks by Pierce and Enzler, op. cit., p. 16) -- nominal GNP subtracts imports and so cancels out much of the effect of higher energy prices. We use the dollar volume of output from the goods sector as a proxy for transactions. This variable makes sense in view of the fact that much of the money stock is in the hands of consumers, not businesses. We neglect the small contribution to the demand for money that might come from the energy sector (recall that all energy passes through the goods sector on its way to final demand).

The money demand equation is supplemented by an identity relating the nominal interest rate to the real return to capital. One of the terms in this identity is the expected rate of inflation, which we take to be the rate predicted by the model.

Price Level Determination

The price level is defined as the money price of goods. It is determined in the model by a price equation which equates price to unit cost. For this purpose, unit cost is derived from the same function as in the technology model, but the arguments are slightly different. First, fluctuations in the unit cost of labor due to cyclical variations in productivity are excluded from the price equation whereas the technology model includes them. Secondly, the capital price used in the price equation is a long-run average of the real rental price of capital times the price level rather than the current nominal capital price. When the real price of capital changes permanently in response to a shock, the capital price in the price equation is assumed to adjust with a lag. This formulation corresponds to the following important findings of the price equation literature: (1) Apart from the effect via wages, fluctuations in demand have little or no effect on the price level;[1] (2) prices show no sensitivity to cyclical fluctuations in productivity;[2] and (3) transitory fluctuations in interest rates do not affect prices.[3] In addition, this specification seems to give a sensible estimate of the partial impact on the price level of an energy price increase, namely the share of energy in variable cost.

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[1] Cf. Gordon (1970, 1971, 1977), Nordhaus (1972), Hall (1979).

[2] Gordon (1975b)

[3] Cf. e.g. Gordon (1975b), pp. 643-44.

This model of price level determination is compatible with the hypothesis that inflation is determined by money supply in the long run. In the short run, however, wage rigidity may allow substantial deviations from this rule.

3. An Example: The 1979 Energy Price Shock

We have used this model to carry out an analysis of the current energy price shock. It rests on the following assumptions:

1. The world price of crude oil increased from $12.50 in 1978 to $21.50 in the second quarter of 1979.
2. The price will remain at $21.50 for the rest of 1979.
3. The dollar price of oil will rise another 14 percent at the beginning of 1980, so that the average price in 1980 will exceed the average price for all of 1979 by 25 percent.
4. In 1981 and beyond, the world price of oil will remain constant in dollars adjusted for inflation.
5. The prices of other forms of primary energy--coal and natural gas--will rise by half as much as the percentage increase in the price of oil.
6. The combination of long-term contracts and regulation of utilities and other energy markets introduces a lag in the pass-through to the consumer of increases in primary energy prices. We assume the pass-through to be 80% in 1979 and complete in 1980 and later years.

All these assumptions imply that, relative to the 1978 level, the price of primary energy in the U.S. will have increased by 30 percent in

1979 and 63 percent in 1980. Of this, we assume that 9 percent per year increase was expected before the shock. Our analysis treats the rest as an unanticipated increase.

The results of the analysis are summarized in Table 1 and presented in detail in the Appendix. The effects of the energy shock on inflation and real output will be significant, but a good deal less than in 1974-75. Almost two percentage points are expected to be added to the inflation rate this year (some of which has already been observed) and about 1.3 percentage points in 1980.

With respect to real economic activity, we find that the U.S. economy is probably already in a recession, with a shortfall in real output of 15 billion 1972 dollars or one percent this year, and as high as 55 billion or almost four percent in 1980. Again the largest decrease is in investment activity, but not until 1980 with a shortfall of 28 billion, and reaching its bottom level in 1981 with a shortfall of 34 billion 1972 dollars. Consumption decreases by two and a half to three percent. Government expenditure is assumed to follow its past trend, whereas net export of non-energy goods is expected to rise by 3 billion 1972 dollars as oil-rich nations spend part of their new wealth on U.S. goods. It is assumed, however, that this increase does not take effect until 1981, as the recession will slow down export demand from other countries. Unemployment is expected to increase, not so much this year, but by a little more than a percentage point for 1980. Wages do not seem likely to change very much in nominal terms, which means a decrease in real wages of two to three percentage points. All of this adds up to another severe dislocation of the U.S. economy because of an energy shock.

Table 1

Summary of Projected Effects of Energy Shock

	Year 1979	 1980	 1981
Extra inflation (percentage points per year)	1.8	1.3	0.1
Extra growth in real GNP (percentage points per year)	-1.1	-2.8	0.4
Extra investment (percentage of level in absence of shock)	3.6	-12.6	-14.8
Extra consumption (percentage of level in absence of shock)	-2.6	-2.9	-2.3
Extra unemployment (percentage points)	0.4	1.2	0.9

We see the energy price shock as affecting the economy via two principal channels. First, there is a permanent lowering of the long-run growth path of the economy because the energy price increase induces more labor-intensive methods of production. Since the supply of labor is largely fixed, the substitution requires lower output. As the economy adjusts its stock of productive capacity to the new growth path, investment drops temporarily. Secondly, wages rise somewhat in response to the shock, so the combined effect is a substantial jump in the price level. As money supply is not increased in nominal terms, interest rates rise and induce a further decline in investment. Another major component of aggregate demand, consumption, falls because the higher energy bill depresses real income, as does the recession itself. The decline in aggregate demand is assumed to be offset a little by an increase in export demand as energy-rich nations spend part of their new wealth on U.S. goods, but this is offset in the short run by reduced export demand from energy importing countries. The net effect is a large decline in aggregate demand for U.S. goods.

4. Concluding remarks

Our model of the U.S. economy suggests it is vulnerable in an important way to unexpected increases in the world oil price. An oil shock drives down investment and pushes employment below its full-employment level. These shorter-run, business cycle responses are economically inefficient--they involve the under-utilization of the productive capacity of the economy. In addition, U.S. consumers have suffered a loss in real income which makes them reduce consumption. This response is inescapable and would occur even in an economy that was able to respond to the oil shock in a fully efficient way.

The key feature of our model that makes it respond in a cyclical way to the shock is the rigidity of money wages in the short run. In this respect, our model is distinctly Keynesian. By contrast, in a fully classical model, money wages would decline in response to an increase in oil prices, and full employment would be maintained. It is an interesting challenge to economists to explain why money wages are so unresponsive, in view of the very substantial cost the economy pays for the unresponsiveness. An even greater challenge is to find ways of reforming the economy to make it less vulnerable to price shocks.

Appendix

Compact Mathematical Statement of the Model

Capital Accumulation:

$$\hat{K}_t = \hat{I}_t + (1 - \delta)[(b_{t-1}/b_t)\hat{K}_{t-1} + ((b_t - b_{t-1})/b_t)\overline{K}_{t-1}], \tag{M.1}$$

$$\overline{K}_t = \overline{I}_t + (1 - \delta)\overline{K}_{t-1} \tag{M.2}$$

Demand for Capital:

$$\hat{K}_t = (P_{Kt}/\hat{P}_{Kt})\ \phi_K(e^{-\mu_1 t}\ w_t,\ P_{Et},\ P_{Kt})Y_t \tag{M.3}$$

$$\overline{K}_t = (P_{Kt}/\overline{P}_{Kt})\ \phi_K(e^{-\mu_1 t}\ w_t,\ P_{Et},\ P_{Kt})Y_t \tag{M.4}$$

$$P_{Kt} = \hat{P}_{Kt}^{\ b_t}\ \overline{P}_{Kt}^{\ 1-b_t} \tag{M.5}$$

Demand for Labor:

$$\hat{L}_t = (w_t/\hat{w}_t)e^{-\mu_1 t}\ \phi_L(e^{-\mu_1 t}\ w_t,\ P_{Et},\ P_{Kt})Y_t, \tag{M.6}$$

$$\overline{L}_t = (w_t/w_t^*)\ e^{-\mu_1 t}\ \phi_L(e^{-\mu_1 t}\ w_t,\ P_{Et},\ P_{Kt})Y_t \tag{M.7}$$

$$w_t^0 = \hat{w}_t^{\ f_t}\ w_t^{*\ 1-f_t} \tag{M.8}$$

$$w_t = w_t^0(w_t^*/\hat{w}_t)^{h(1-f_t)} \tag{M.9}$$

$$w_t^* = [1 + \gamma(\frac{1}{2}\ \frac{P_t - \overline{P}_t}{\overline{P}_t} + \frac{1}{2}\ \frac{P_{t-1} - \overline{P}_{t-1}}{\overline{P}_{t-1}})]\overline{w}_t \tag{M.10}$$

Supply of Labor:

$$\hat{L}_t = \hat{L}_0 e^{nt}, \quad n = 0.017 \tag{M.11}$$

Demand for Energy:

$$E_t = \phi_E(e^{-\mu_1 t}\ w_t,\ P_{Et},\ P_{Kt})Y_t \tag{M.12}$$

Supply of Energy:

$$P_{Et} \text{ exogenous} \tag{M.13}$$

Consumption Function:

$$C_t = C_0 e^{gt}\ ,\ g = n + \mu_1,\ C_0 \text{ chosen so as to attain steady state for real economy in the long run} \qquad (M.14)$$

Distribution of Output in goods market:

$$Y_t = C_t + b_t \hat{I}_t + (1 - b_t)\bar{I}_t + X_t + G_t \qquad (M.15)$$

X_t, G_t exogenous

Price Equation:

$$(1 - \tau)P_t = \phi(e^{-\mu_1 t}\, w_t^o,\ P_{Et},\ P\bar{v}), \qquad (M.16)$$

$\bar{v}$ long run average of P_{Kt}/P_t

Money Market Equilibrium:

$$\ell n(P_t Y_t/M_t) = \psi_0 + \psi_1 t_t + \mu_2 t,\ \ M_t = M_0 e^{mt},\ m = 0.058 \qquad (M.17)$$

Equality of Nominal Return to Capital and Nominal Interest Rate:

$$r_t = v_t/(1 - d_t) - \delta - \theta + \ell n((1 - d_{t+1})P_{t+1}) - \ell n((1 - d_t)P_t),$$

$$v_t = \hat{P}_{Kt}/P_t \qquad (M.18)$$

TABLE A1

Details for Table 1

	Real Gross Output		Real Growth		Price Level	Inflation		Investment		Consumption	
	Abs. diff.	% diff.	Level	Diff. in % pts.	% diff.	Level	Diff. in % pts.	Abs. diff.	% diff.	Abs. diff.	% diff.
1979	-15.1	-1.1	1.2	-1.1	1.6	10.9	1.8	7.9	3.6	-23.0	-2.6
1980	-54.7	-3.8	-0.2	-2.9	2.9	10.4	1.3	-28.2	-12.6	-26.5	-2.9
1981	-51.9	-3.5	3.2	0.3	3.0	9.1	0.1	-33.8	-14.8	-21.1	-2.3
1982	-46.2	-3.1	3.4	0.5	2.8	8.8	-0.2	-27.5	-11.7	-21.8	-2.3
1983	-38.9	-2.5	3.8	0.6	2.7	8.8	-0.1	-19.6	-8.0	-22.4	-2.3

	Employment		Unempl. Rate		Wage Rate	Price of Energy (1972 = 1)		Net Export of Goods and Gvt. Expenditure	
	Abs. diff.	% diff.	Level	Diff. in % pts.	% diff.	Level	% diff.	Abs. diff.	% diff.
1979	-0.4	-0.4	6.6	0.4	0.3	3.833	19.2	0.0	0.0
1980	-1.5	-1.6	7.4	1.2	0.3	4.810	37.2	0.0	0.0
1981	-1.1	-1.2	7.1	0.9	0.3	5.242	37.2	3.0	1.0
1982	-0.7	-0.7	6.7	0.5	-0.0	5.703	36.9	3.1	1.0
1983	-0.3	-0.3	6.3	0.2	-0.2	6.205	36.8	3.2	1.0

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Analysis of Oil Price Shocks in the MPS Model

by

Stephan Thurman and Richard Berner [*]

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[*] Economists, Board of Governors of the Federal Reserve System. The views expressed in this paper are solely those of the authors and do not necessarily represent the views of the Board or its staff.

Introduction

Another round of large oil price increases has hit the U.S. and world economies. The first large oil price increases, in 1973-74, were in part responsible for the severity of the recession and inflation of 1974-75. The U.S. is apparently at a weak stage in the business cycle again, and the oil price increases will almost surely slow real growth and increase inflation. To decide on the appropriate fiscal and monetary policy responses to the price increase requires thorough analysis of its macroeconomic effects.

In this paper we focus on the unique characteristics of energy price shocks within the U.S. economy and simulate the experienced and projected macroeconomic effects of OPEC price increases with the MIT-PENN-SSRC (MPS) econometric model. The standard channels of transmission of external inflationary shocks also operate in this instance. These are discussed only briefly here since they have been analyzed at length in previous MPS model studies by Pierce and Enzler [11], Berner, Clark, Enzler and Lowrey [3], and Thurman and Kwack [16]. 1/

1/ The results of these studies are broadly consistent with the empirical studies by Eckstein [4], Klein [7], Mork and Hall [8], and Perry [10].

In the analysis that follows we consider carefully three types of energy prices: imported oil prices, domestic oil production prices, and the wholesale price index for energy. Average imported oil prices in the U.S. are calculated as a weighted average of prices charged by OPEC and non-OPEC oil exporting countries. Domestic oil production prices are calculated from upper tier, lower tier, marginal, and noncontrolled oil production level prices at the wellhead. Domestic wholesale energy prices, net of imported petroleum prices, are BTU equivalent output weighted average prices of domestic oil, coal, natural gas and other energy prices. 1/

The three prices are plotted as indexes (1972 = 100.) in Graph I where the extension beyond 1979 Q2 incorporates the announced (in June 1979) OPEC schedule for oil import prices. Beyond 1979, this schedule is arbitrarily extended at a 10 percent annual rate of growth. The two domestic price paths are closely linked to that for imported oil. These linkages will be discussed in detail in what follows.

Two salient features of this graph are the discrete jumps in the world oil price in the 1974 and 1979 periods and the paths of domestic energy prices which are regulated below world energy prices in the 1974-1979 period and then phased up to world price levels in the period 1979-1981. Domestic wholesale energy prices react slowly to the world and domestic oil price increases due to long-term contract lags in the domestic non-oil energy producing industries. Domestic refined petroleum product prices, which are also a component of the

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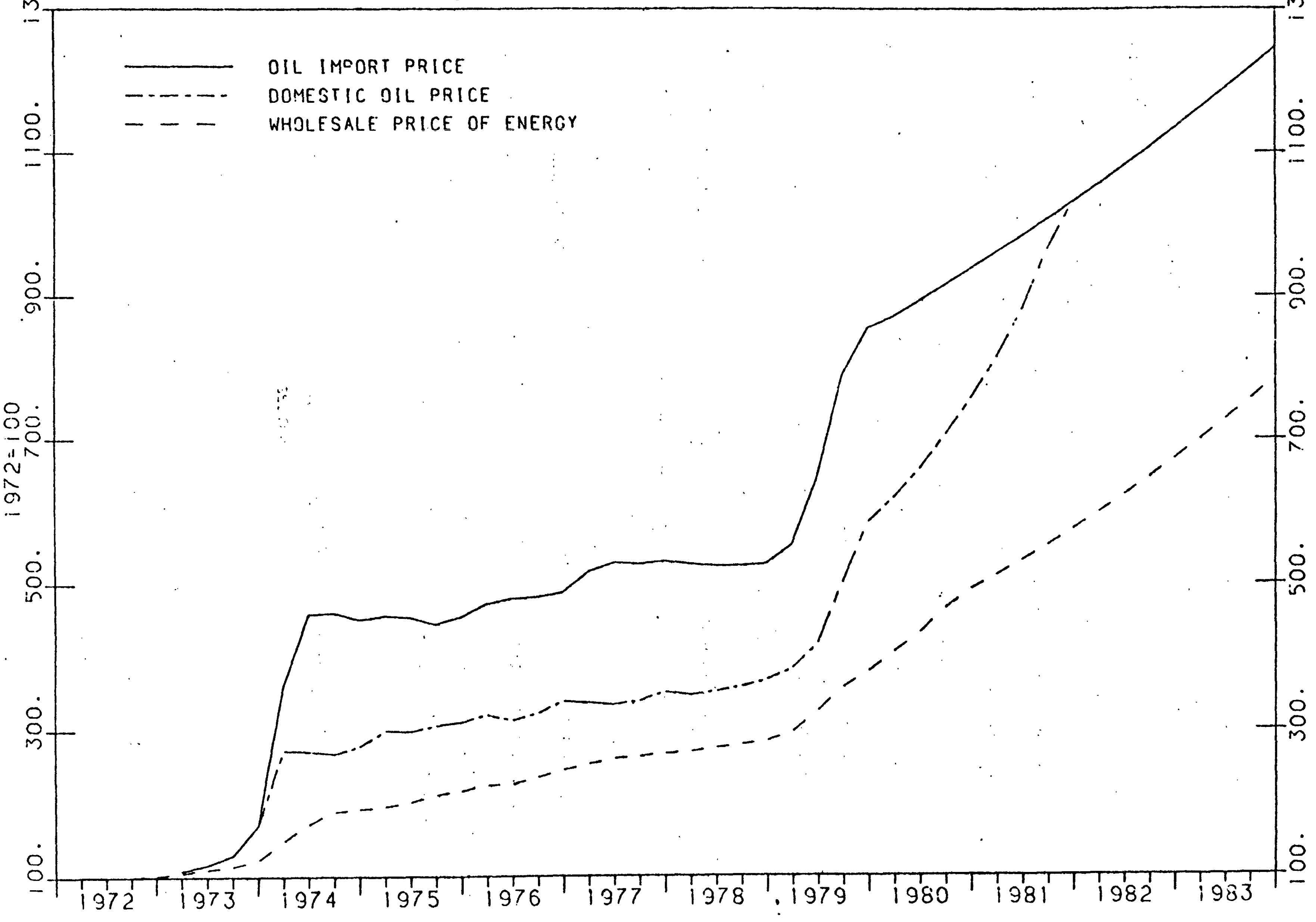
1/ The weights for average import prices are import share weights and for domestic oil prices production share weights, both from DOE Monthly Energy Review [18]. BTU equivalent output weights for the domestic wholesale energy price index from the SCB [17] also are calculated from this source.

GRAPH I

ENERGY PRICES IN THE UNITED STATES



wholesale energy price index, rise toward world oil prices at an increasing rate as oil price controls are removed.

We will analyze the macroeconomic effects of the announced June 1979 OPEC price increase, as well as two possible OPEC pricing alternatives. First, we look at the impact of denominating the dollar price of oil per barrel in terms of a basket of currencies rather than in dollars, and second, we analyze further discrete jumps in the OPEC price schedule beyond 1979. Both of these alternatives would significantly raise the OPEC price path and thus the path of domestic oil and competing energy prices as they rise to world levels by 1981.

The organization of the analysis is as follows. Section II discusses the features of an oil price shock that distinguish it from the analysis of the standard transmission channels of imported inflation. Section III will explain the methodology used to calculate the domestic energy price changes, as well as the way these energy price changes feed through the MPS model presented in Section IV. A concluding Section V discusses the importance of the simulation results for monetary and fiscal policy.

II. Transmission Channels of an Oil Price Shock

The effects of any increase in import prices is transmitted to domestic prices through three standard channels.
First, the increase in import prices is passed through to the price of final sales, both directly and indirectly, since imports are both

final and intermediate goods. Second, the price of import-competing goods—in this case, coal and natural gas — rise, and these price increases are passed on similarily to final sales prices. Finally, the first two effects on consumption prices result in higher wage demands, which result in higher prices, and so on.

In addition to these standard transmission channels, the analysis of oil price increases differs from the textbook exposition of the effects of import price increases in several ways.[1/]

(i) Demand and Supply Elasticities

While produced domestically, oil appears to be inelastically supplied with respect to price, at least in the short run. As an intermediate input or final product, it is inelastically demanded in the short run. The OPEC Cartel, acting in its own best interest as a quasi-monopolist, has the political and economic power to keep prices high as long as the cartel retains cohesion. Finally, many of the OPEC countries do not want to or cannot exchange anything but a small fraction of their receipts from the sale of oil for exports from the oil-importing countries.

Since oil demand is relatively insensitive to prices in the short run, a rise in oil prices means that total dollar expenditures on imported oil will increase. If there is no change in savings, the higher oil import prices will result in a decline in expenditures on domestic goods and services relative to what would have occurred in

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[1/] Cf. Berner, Clark, Enzler, Lowrey [3].

the absence of the price rise. Oil price increases have been likened to the imposition of a sales tax, the proceeds of which are not spent immediately (either by OPEC countries or American oil companies) resulting in a net contractionary effect on the economy because of a decline in aggregate demand. The loss in real domestic income is a real income transfer to OPEC.

Energy, labor and capital are all inputs used in production. As the price of energy rises relative to other factor prices, producers will tend to substitute away from energy towards the other factors. Since factor proportions are relatively fixed once capital is installed, most factor substitution will take place only when the capital is fully depreciated. Additionally, if capital and energy are complementary inputs, a rise in energy prices will tend to make producers substitute away from both factors towards labor. More labor-intensive production by definition involves lower productivity and less demand for new investment. In any case the aggregate supply of output is reduced.

(ii) World Prices and Activity

An increase in world oil prices increases inflation in other oil-importing countries.[1/] Consequently U.S. trading partner prices will also rise and their activity levels fall as a result of the oil price increase. World trade as a whole will shift from non-energy related products and services to imported oil from oil exporting countries. The net effect of this shift in the terms of trade of oil importing countries will be that trade volume will be lower among oil importing countries and at higher prices.

1/ The unique characteristics of world oil price increases as they affect worldwide inflation are discussed in Salant [12].

Ordinarily, large changes in relative prices between countries would be offset by changes in exchange rates if the world operated under a freely flexible exchange rate system. The exchange rate outcomes of an oil price increase are complicated by the fact that they depend on the share of unspent oil revenues which OPEC countries wish to hold in the form of dollar denominated financial claims. A very small percentage of OPEC revenues are used for purchases of goods and services from oil importing countries; the remainder must be invested. If OPEC decided to shift part of their assets from dollars to a foreign currency or a basket of foreign currencies (the SDR, for example), the resultant exchange rate impacts on U.S. inflation could be large. It is impossible to predict exchange rate changes following an oil price increase without knowing the distribution of the increase in OPEC wealth. A further complication is that the problem involves simultaneity: the willingness of OPEC to continue to hold their assets in dollars probably depends on their expectations of the dollar exchange rate, which in turn are related to U.S. inflation relative to that of other countries, and to U.S. monetary policy.

(iii) Inflationary Expectations

The discrete nature of oil price shocks affects inflationary expectations differently from other sources of inflation. The timing of OPEC price hikes has been generally impossible to predict. Hence, the variance of inflationary expectations will be larger in a world of unpredictable oil price rises.

Domestic output and expenditure patterns are difficult to plan when petroleum product supply sources are erratic in behavior, as was the case with the interruption in world oil production during the Iranian revolution.

(iv) Energy Regulation and Control

Domestic petroleum supply and prices are subject to administered stockpiling and a complicated set of price regulations. These price controls, and the recently announced plans for phasing them out, introduce further complexity to the analysis of OPEC price shocks. Under the price control regulations which existed up until April of 1979, an increase in the world price of oil widened the gap between imported and domestic oil price levels. The result of artificially low domestic prices was a fall in domestic production and an increase in oil imports.

The domestic oil price controls are gradually being phased out through 1981 when all domestic oil prices will be allowed to attain world levels.[1/] An analysis of the impacts of higher imported oil prices involves not only the increasing effects on the level of domestically produced oil, but also consideration of competing energy product prices and the probable domestic energy supply response.

[1/] The proposed domestic production oil price decontrol plan is described in "The White House Fact Sheet" [19].

(v) Policy Responses

The magnitude of the impacts of any price increase on the domestic economy will depend substantially on the policy actions taken by the monetary and fiscal authorities. If policymakers do not understand that oil price increases involve an income transfer to foreigners that ultimately cannot be avoided, the policy response to such price increases may be inappropriate. We will discuss this problem in further detail in Section V.

III. Model Methodology

Domestic Energy Price Calculations

Table 1 presents alternative energy price paths in levels and year over year rates of change for average oil import prices, domestic oil production prices and domestic wholesale energy prices, all of which are exogenous to the model. The control set of price schedules include the increase in average OPEC oil prices announced at the December 1978 OPEC meeting of 14% (annual rate) over 1979 and 1980 with the majority of the increase occurring in 1979. Beyond 1980, imported oil prices are assumed to grow at an annual rate of 7%. This corresponds closely with the inflation rate for that period which was arbitrarily built into the model control simulation, yielding constant real imported oil prices.

The three alternative oil price scenarios in this table represent calculations for world and domestic energy prices which result from 1) the announced June 1979 OPEC price schedule, 2) denominating the June 1979 schedule of prices in SDRs instead of dollars, and 3) the oil price schedule under assumptions of an additional 1980 increase in OPEC prices. The methodology used to calculate these price schedules is the same as that used in calculating the control schedule, but with different assumptions regarding oil import prices.

Average domestic oil prices in the control scenario follow the schedule for decontrol of domestic oil production prices announced in April 1979. This schedule allows those prices to attain world levels by 1981 Q4. Under the decontrol plan there are four different categories of domestic oil, each with its own decontrol schedule:

1. <u>Upper Tier Oil</u>, which accounts for over 30% of domestic production. The price will increase in equal monthly increments to adjust to the existing world oil price level beginning in January 1980 and attaining world levels in 1981 Q4.

2. <u>Lower Tier Oil</u>, which currently amounts to approximately 30% of domestic oil production, will be decontrolled toward the upper tier price through a "decline rate"[1] schedule of decontrolled quantities where the rates of decontrol are 1.5% per month through December 1979 and 3% per month between January 1980 and October 1981.

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[1] By "decline rate" is meant that each month, a fraction of production will be allowed to sell at the upper tier price.

Table 1

Alternative Domestic Energy Prices
(1972 = 100.)

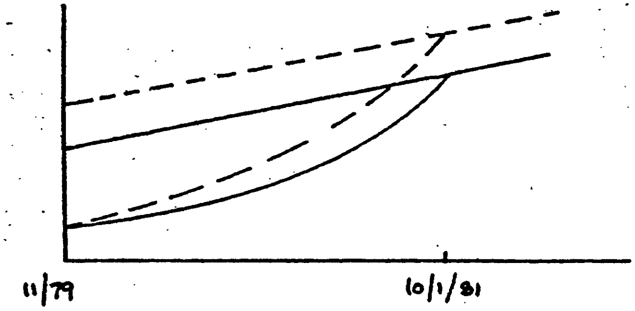
	Control Schedule			June 1979 OPEC Price Increase			June 1979 OPEC Prices in SDR's			Additional 1980 OPEC Price Increase		
YEAR	Average Oil Import Prices	Domestic Oil Prices	WPI Energy	Average Oil Import Prices	Domestic Oil Prices	WPI Energy	Average Oil Import Prices	Domestic Oil Prices	WPI Energy	Average Oil Import Prices	Domestic Oil Prices	WPI Energy
1978 Q4	527.2	416.3	284.2	527.2	416.3	284.2	527.2	416.3	284.2	527.3	416.3	284.2
1979 Q4 (Q4/Q4)	666.7 (26.5)	510.6 (22.7)	333.8 (17.5)	854.8 (62.1)	583.9 (40.3)	378.5 (33.2)	878.2 (66.6)	600.1 (44.1)	390.8 (37.5)	887.0 (68.2)	596.1 (43.2)	386.8 (36.1)
1980 Q4 (Q4/Q4)	684.9 (2.7)	593.8 (16.3)	373.4 (11.9)	935.6 (9.5)	753.8 (29.1)	490.6 (29.6)	972.1 (10.7)	783.1 (30.6)	509.7 (30.4)	1138.2 (28.3)	884.5 (48.4)	575.7 (48.0)
1981 Q4 (Q4/Q4)	732.8 (7.0)	732.8 (23.4)	425.5 (14.0)	1029.1 (10.0)	1029.1 (36.5)	588.7 (20.0)	1069.1 (10.0)	1069.1 (36.5)	611.6 (20.0)	1256.2 (10.4)	1256.2 (42.0)	718.6 (24.8)
1982 Q4 (Q4/Q4)	784.3 (7.0)	784.3 (7.0)	455.3 (7.0)	1132.1 (10.0)	1132.1 (10.0)	647.6 (10.0)	1176.1 (10.0)	1176.1 (10.0)	672.8 (10.0)	1381.9 (10.0)	1381.9 (10.0)	790.5 (10.0)
1983 Q4 (Q4/Q4)	839.8 (7.0)	839.8 (7.0)	487.2 (7.0)	1245.4 (10.0)	1245.4 (10.0)	712.4 (10.0)	1293.7 (10.0)	1293.7 (10.0)	740.0 (10.0)	1520.1 (10.0)	1520.1 (10.0)	869.5 (10.0)

3. Marginal Oil, comprised mainly of Alaskan North Slope and Naval Petroleum reserve oil with a domestic production weight of less than 15%, 80% of which was raised to the upper tier price in June of 1979, with the remainder decontrolled to upper tier prices in June of 1980.

4. Noncontrolled Oil, the remaining domestic category which already sells at about the world oil price level.

With the prices of all categories of domestic oil rising in monthly increments toward existing world oil price levels in that month, increasing imported oil prices generate an an accelerating path of domestic oil prices. Both are represented in Graph II by the solid lines:

GRAPH II



An upward shift in the imported oil price path as represented by the dotted lines leads to a domestic price path that accelerates still more rapidly than previously since all controls are removed by October 1, 1981. In either case, the impact on domestic oil prices is small in the early phases of decontrol and larger as price controls near expiration.

The assumptions concerning domestic wholesale energy prices take into account the direct and competing goods price effects of higher world oil prices on domestic refined petroleum products, coal, and natural gas. To calculate the impact, we begin by converting quantities of domestic oil, coal, and natural gas produced to BTU equvalents. The BTU equivalent output shares in the three energy categories in 1972 are used to weight the impacts on the domestic wholesale energy price. The impacts are expressed in terms of percentage changes in prices in each of the three energy categories. These percentage changes are calculated in two steps. First, the incremental revenue (change in price times BTU equivalent quantity) to the seller that would result from a $1/barrel increase in OPEC prices is divided by the projected values of expenditures for each of the three categories. Next, these unadjusted incremental revenues are adjusted by an assumed domestic energy catergory price response to OPEC prices.

Table 2 outlines the calculations for the impact of a $1 increase in the OPEC price per barrel on each category of domestically produced energy:

Table 2

Calculations for the Impact of a $1 Increase in OPEC Prices on Prices of Domestic Energy Products

Category	(1) Unadjusted Incremental Revenue	(2) Elasticity with respect to OPEC Prices	(3) Adjusted Incremental Revenue (1x2)	(4) Percentage Change	(5) Weight in BTU Equivalent	(6) Effect on Domestic Wholesale Energy Prices (percent increase) (4x5)
Refined Petroleum Products	$ .4 B	1.0[1]	$.4 B	0.56	.625	.35 %
Coal	1.2 B	.2	.24 B	1.92	.238	.46
Natural Gas	1.7 B	.2	.34 B	1.07	.137	.15 B
Total					1.000	.96 %

The incremental revenues that would result from a $1/barrel increase in OPEC prices, under the assumption that the prices of products in all three energy categories rise by the same amount, are displayed in Column 1. These must be adjusted by the elasticity

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[1] By 1981 Q4. Prior to 81 Q4, the impact is smaller. Elasticites for prior quarters are calculated from the decontrol assumptions in each of the four categories of oil, above.

of each category's price with respect to OPEC prices (Column 2); the adjusted incremental revenues are in Column 3.[1] These in turn are divided by a projected control level of nominal expenditures in each category to give the assumed percentage change in prices (since quantities are assumed to be unchanged); they are given in Column 4. Column 5 gives the BTU equivalent weights, and Column 6 gives the percentage impacts on domestic wholesale energy prices. We adjust the whlesale energy price by the amount in the "total" row for each $1/barrel increase in OPEC prices.

Oil Price Shocks in the MPS Model

The standard channels of transmitting the oil price shock through the MPS model structure were discussed in detail in the MPS model studies referred to above. The structure of the model has been modified since the publication of these studies, in part to facilitate this type of analysis. In this section, we will outline these modifications.

The version of the MPS model used in the earlier studies were not structurally rich enough to capture all the effects of external price shocks. Consequently, in those studies such effects

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[1] The elasticity for domestic refined petroleum product prices rises to 1.0 by 81-Q4 when controls are gone. For prior quarters, the elasticity is a weighted average of the response in each of the four petroleum categories described above and depends on the decontrol assumptions.

were modeled by judgmentally adusting relevant model equations. The current version of the model has a disaggregated foreign sector, incuding current and capital accounts and an exchange rate determination mechanism. It also has equations for all expenditure component price deflators that are constructed to be homogenous in the aggregate with respect to the aggregate price of output. Much of the structural detail necessary to simulate external price shocks is thus currently in the model.

Within the current account of the foreign sector,[1] the direct impact of higher world oil prces on demand is captured by the domestic petroleum demand equation. Domestic petroleum consumption (DQFL) is a function of real income (XGNP) and the exogenous wholesale price index for energy (PWIFE) relative to the implicit GNP deflator (PGNP):

$$\text{(1)} \qquad \ln DQFL = -3.8 + .944 \ln - .13 \ln (PWIFE/PGNP).$$

Imports of petroleum products (EMP) are then detemined by the identity

$$\text{(2)} \qquad EMP = (EQFL = SQFL) * PUVFL * k \, ,$$

where SQFL is exogenous domestic production and PUVFL is the average import price of oil per barrel.[2]

The MPS price sector determines a value added fixed weight nonfarm business deflator (P_{fw}) with an average markup over minimized long-run average cost specification:

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[1] See Thurman, "The International Sector," [14].

[2] In expression (2), k represents a consant factor of adjustment to obtain oil imports in billions of dollars at an annual rate.

$$(3)\qquad \ln P_{fw} = .2991 + .3039 \ln PL - .30406\ L(7) \ln OMH + .0830 \frac{1}{U} - .0679\ L(4)\ \ln P_{rm} + .0400\ L(5) \ln P_f + .6962 \ln P_{fw-1}$$

where L(N) is a distributed lag of N+1 quarters (including the current quarter), and where long run minimized average cost is proxied by unit labor costs—wages (PL) divided by output per manhour (OMH)—with a steady-state coefficient of unity. Arguments in the markup function include the inverse of the unemployment rate (U) and a foreign exchange rate adjusted foreign price index relative to domestic prices (P_f^*). Raw material prices (P_{rm}) enter the equation in differenced log form. The negative coefficients reflect the fact that increases in import prices reduce a value-added deflator until the increases are fully passed through to the price of final sales.

Final demand sector prices P_j, for j=1,2,...n expenditure categories are estimated within a system of relative prices where the properties of the system consistently allocate the changes in value added production prices throughout the system. The determinants of a typical relative price equation include those of P_{fw}, with effects that add to zero to preserve homogeneity in P_{fw}. In addition, arguments are included to adjust the coverage from nonfarm business (that of P_{fw}) to all sectors (i.e., including farm, rest of world, and households and institutions).1/

1/ The relative price system for final expenditure prices is explained in Thurman [13], [15].

Additional Exogenous Assumptions

Most indirect effects of an oil price shock — wage-price interaction, contraction of real aggregate demand, the income transfer loss — are captured in the MPS model. A few of the indirect impacts (particularly on foreign incomes and prices) are exogenous to the model.

Competing energy product prices should have an indirect effect on the model's main price equation. The wholesale energy price is not included in that equation, however. Thus, we have calculated estimates of this effect such that a ten percent increase in imported energy costs raises the nonfarm business markup function by 0.7%. [1/] This elasticity is used to apply an adjustment to the equation for P_{fw} which in turn is automatically distributed to expenditure deflators.

Foreign as well as domestic prices and activity levels enter into the model's trade and capital sector equations. We assume that the effects of higher world oil prices on U.S. trading partners will be similar to the effects on the U.S. Based on other simulation experiments, [2/] we assume that the elasticity of a weighted average of foreign consumption prices with respect to oil prices is 0.3.

The impact of oil price increases on foreign real activity is likely to be similar to that in the U.S. However, while we can be

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[1/] This calculation is derived as the sum of adjusted incremental revenues in Column 3 of Table 2 divided by a projected base path for nominal nonfarm business output. The actual adjustment varies with the decontrol assumptions. The assumption is again made that quantities are unchanged.

[2/] These experiments include those simulated with the Federal Reserve Board's Multi-country model [2], a modified version of the MPS model [13], and an EEC trade model [1].

reasonably sure of the sign, we are less sure about the magnitude of such real impacts, particularly for relatively energy independent countries like Canada and the U.K. Consequently we have ignored these real output effects. Thus, a probable reduction in foreign demand for U.S. exports is not captured in these simulation exercises. The weighted average exchange rate index (taken as exogenous in this exercise) is also left unchanged since, in our opinion, the impact of oil price changes on the exchange rate is indeterminate.

We have experimented with several alternative methods of calculating the government tax revenue and expenditure consequences of the administration's windfall profits tax proposal. The net result of the proposals seemed to be a modest redistribution of nominal income from domestic oil refiners to consumers without significantly altering the multiplier results. Given the current uncertainty of the final form of the windfall tax scheme as it will emerge from Congress, we did not incorporate it into the simulations below.

Estimates of the supply elasticity of domestically produced oil vary widely and have become more difficult to ascertain with the onset of the decontrol program. Combined with the recent and anticipated further increases in world oil prices, there exist substantial incentives in the domestic oil production industry to delay further new discovery until after 1981 when controls are completely gone. Additionally it can be assumed that discovery capacity is limited within the five-year horizon of our experiments. Under assumptions of some type of windfall profits tax, industry incentives and hence domestic oil supply would be reduced. In view of this uncertainty, we assume no domestic supply response to increased world oil prices.

There is a variety of monetary policy assumptions that can be simulated in the MPS model structure. However the results of the simulations are virtually invariant to the specification of monetary policy because the domestic price and output effects of the oil price increase offset each other. The demand for money is therefore little changed by the shock. Consequently it makes almost no difference whether monetary aggregates, interest rates, or bank reserves is used as the exogenous policy variable in simulation.[1/] Unless otherwise specified, we have held unborrowed member bank reserves exogenous.

The fiscal policy assumptions in the simulations are that most nominal Federal government expenditures are exogenous (so that real expenditures are endogenous), and all tax rates are similarly fixed. Federal Unemployment transfers and all receipts are endogenous.

Mork and Hall [8] allow substitution between energy and other factor inputs in the production function which is part of their model and hence are able to analyze the likely effects of such substitution. The MPS model uses a two-factor production function that does not include energy and, thus, has no way of capturing the effect of changed energy prices on output per unit of capital and labor input. Any such effect would have to be added by assumption, and our simulations include no such adjustments. We recognize this as an area for future model development.

[1/] For this reason the correction to the money demand function made by Pierce and Enzler in their study is not made here.

IV. Model Simulation Results

The methodology of this exercise is standard multiplier analysis: disturbed simulations are compared to a control simulation. First, a simulation was run which replicates the projected impacts of the OPEC June 1979 announcement of oil prices. The purpose of the second and third simulations is to highlight the continuing vulnerability of the U.S. economy to not unlikely further adverse oil price shocks. These come in the form of denominating OPEC oil prices in SDRs rather than dollars (under assumptions of a ten percent average depreciation of the dollar against major currencies) in the second simulation, and yet another OPEC price shock occurring in 1980 in the third simulation.[1]

The Impacts of the June 1979 Oil Price Increase

From Table 1 in the preceding section we interpret the effect of the June 1979 OPEC oil price schedule to increase average imported oil prices in the U.S. by 28% over what they would have been by the end of 1979 and increase both imported and domestic oil prices by 48% of what they would have been by 1983. This implies an extension of the announced OPEC schedule that grows at 10% per annum. This is higher than in the control scenario (7%), taking into account higher U.S. inflation rates. The domestic wholesale price index for energy is

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[1] We contrast these second two simulations with the OPEC June 1979 scenario such that the multipliers represent the additional impacts which could result over and above those presently anticipated.

calculated to be 34.8% above control levels by 1983. Using the methodology presented in the section above, the MPS model multiplier results are summarized in Table 3.

The simulated effects of the oil price rise are quite large. Real domestic economic activity, as measured by GNP in constant 1972 dollars, is off $12.4 B by the end of 1980 and is $48.6 B lower by 1983 as a result of the oil price increase. This represents roughly a 3.0% decline in the level of real economic output from base projections.

The impact of the higher oil prices on domestic consumption prices (part of the relative price system summarized above) is to add 1.3% to the price level by 1979 Q4 and 2.2% by the end of 1983. The effects on unemployment build up gradually with the unemployment rate increased by 0.4 percentage points higher by the end of the simulation as the depressing effects of the oil price shock continue to drive domestic activity lower.

Given the large domestic price increase, it may seem surprising at first that nominal GNP is lowered. If the price increase were confined to domestically produced oil, nominal GNP would indeed be higher and real GNP lower. However, through 1981 the price increases are mostly confined to imported oil due to the slow phasing out of domestic oil price controls. Both nominal and real GNP are consequently lower as a result of the income transfer to foreigners and the fact that the dollar increase in imports (as indicated by nominal NIA Net Exports) offsets the dollar increase in final sales. Hence the early part of this exercise is dominated by the income transfer effects of higher world oil prices.

Table 3

Effect of Increased Oil Price Projections
(Difference from Control)

	1979		1980				1981				1982	1983
	3	4	1	2	3	4	1	2	3	4	4	4
GNP$ (billions)	-3.5	-6.4	-4.5	-3.0	-2.5	-2.6	-3.0	-3.4	-3.6	-6.2	-24.5	-53.8
GNP (1972$)	-3.0	-5.8	-6.1	-8.1	-10.1	-12.4	-15.0	-18.1	-21.4	-24.9	-37.8	-48.6
Deflator (percent)	0.1	0.1	0.3	0.5	0.6	0.8	1.0	1.2	1.4	1.5	1.8	1.5
PCON (percent)	0.4	0.6	0.7	0.9	1.1	1.3	1.4	1.7	1.9	2.1	2.4	2.2
Unemployment rate	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.4	1.8
Bill rate	-0.0	-0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	-0.1
NIA Net Exports (billions)	-8.8	-12.1	-9.4	-9.1	-8.9	-9.1	-8.3	-7.5	-6.8	-7.1	-8.8	-10.7
Corporate Profits	-3.5	-5.6	-3.3	-1.7	-1.0	-0.8	-0.0	0.9	2.6	2.4	0.1	-1.6

The fall in nominal GNP explains two other results. Treasury bill rates initially fall, and then rise only as the proportion of prices rises in (the roughly constant) nominal GNP.[1] Also corporate profits fall in absolute terms although their share in GNP grows over time as reduced output more than offsets the effect of increased domestic energy prices.

The OPEC SDR Based Pricing Scenario

The inability of the U.S. to cope with the rising oil import bill often has been cited as a continuing source of weakness in the value of the U.S. dollar. This weakness in foreign currency markets would be larger still if OPEC decided to denominate world oil prices not in dollars but in terms of a basket of currencies — say the SDR.

We arbitrarily assume in this exercise that the result of such a shift would cause the dollar to depreciate by 10 percent (on a multilateral trade-weighted basis). We approximate such a scenario by shocking the model's endogenous exchange rate determining process sufficiently to cause a gradual 10% depreciation of the exchange rate index. Feedbacks from the rest of the model on the exchange rate attenuate the depreciation as the trade balance improves.[2]

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[1] The elasticity of money demand in the MPS model is one with respect to prices but less than one with respect to real output, so that with respect to nominal GNP, the elasticity depends on the mix of output and price changes.

[2] For a theoretical description of the MPS model exchange rate determination, see Urdang [19]. The importance of feedback effects is discussed in Hooper and Lowrey [6].

The U.S. dollar represents approximately a third of a multilateral trade weighted SDR exchange rate index. Hence an weighted average dollar depreciation of ten percent will roughly increase the average value of the SDR index by 6 2/3 percent. If there is no additional change in SDR-based OPEC prices, this would eventually add an additional $1.00 per average imported oil barrel cost to U.S. residents over the June 1979 OPEC dollar-based price. We contrast the additional macroeconomic effects of this assumption with those incorporated in the June 1979 OPEC price increase scenario in Table 4.

By the end of the simulation period, real GNP is down $10 B, the consumption price level is up 2 percent, and the unemployment rate is .4 percentage points higher than in the June 1979 scenario, as a result of the combined oil price increase and exchange rate depreciation. Exchange rate impact simulations we have done with the MPS model [6] indicate that of the combined exchange rate - OPEC SDR based simulation effects in this scenario, the oil price increase effects represent a $12 B decline in real GNP, a 0.5 percent increase in the level of consumption prices and most of the rise in thes unemployment rate.

The multiplier difference between these two experiments involves the usual effects of a decline in the value of the dollar together with the induced exchange rate increase in the dollar price per barrel of imported oil. The exchange rate impact on the economy has a longer lag than does that of an oil price increase. This is due in part to the price lags in the non-oil trade equations, and in part to the lags in transmitting exchange rate changes into prices. Thus, a depreciation of the dollar alone would <u>increase</u> real GNP as the

Table 4

Effect of OPEC Petroleum Prices Linked to SDR "Basket" of Currencies

(Difference from June 1979 OPEC Simulation)

	1979		1980				1981				1982	1983
	3	4	1	2	3	4	1	2	3	4	4	4
GNP$ (billions)	5.3	7.5	12.7	18.5	24.0	27.5	28.5	27.8	28.2	31.1	35.0	38.0
GNP (1972$)	-.9	-1.4	-1.1	-.9	-.8	-1.2	-2.3	-3.8	-4.7	-4.7	-7.0	-10.0
Deflator (percent)	-0.0	0.2	0.3	0.5	0.7	0.8	1.0	1.0	1.1	1.2	1.5	1.8
Consumption Deflator (percent)	.4	.5	.6	.8	.9	1.0	1.1	1.2	1.3	1.4	1.8	2.0
Unemployment rate	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.2	.2	.3	.4
Bill rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NIA Net Exports (billions)	.2	.6	3.1	5.8	8.1	8.9	7.9	6.5	6.0	7.2	7.1	7.2
Corporate Profits	4.6	6.3	9.7	12.9	15.6	16.7	16.1	14.9	15.1	17.3	20.0	23.0
Exchange Rate (%)	-3.8	-8.5	-9.1	-9.2	-9.3	-8.8	-7.7	-6.3	-7.7	-9.0	-9.5	-9.4
Import Oil Price ($/barrel)	0.18	0.59	0.85	0.88	0.90	0.92	0.94	1.00	1.00	1.00	1.00	1.00

trade balance improved (although eventually these effects would be offset by the increase in the price level), whereas in the present case, GNP is reduced. A depreciation of the dollar increases both output and the price level, unlike an oil price increase alone, so that this scenario is not insensitive to the monetary policy instrument. In particular, holding the bill rate fixed (as this scenario does) gives an extreme impression of the inflationary and output effects, since the Federal Reserve accomodates all of the rise in income and prices.

Additional OPEC Price Increase Scenario

In the first scenario, world oil price levels beyond the schedule announced by OPEC in June 1979 were projected to grow at a nominal 10% annual rate. This extension is based on an assumed desire by OPEC to keep real prices roughly constant after the large 1979 increase as was the case after 1974. It may well be, however, that this assumption is optimistic. Recent events suggest that such is the case.

Hence, we postulate further discrete OPEC price increases and we assume the worst case; that they come quickly. In this experiment we add an additional world oil price increase beginning in 1979 H2 which raises imported oil prices 21.7% by 1980 Q4 above those assumed in the June 1979 scenario. Domestic oil production prices, under the phased decontrol scheme, are 17.3% higher than the June 1979 scenario levels by 1980 Q4 and more rapidly catch up to world price levels, both of which attain levels 22.1% higher than the June 1979 scenario prices by 1983 Q4. Domestic wholesale energy prices, which include competing energy prices of coal and natural gas, are 20.% higher by 1983 Q4 than those assumed in the June 1979 OPEC scenario.

Here again we contrast the simulated effects of this experiment with those of the June 1979 scenario. The multiplier results are summarized in Table 5. These results indicate that in addition to the oil price shocks absorbed within the June 1979 experiment a further $32.6 billion reduction in real GNP, a 1.8% increase in consumption price levels, and a further 1.4 increase in the unemployment rate would result by the end of the simulation period as a result of the further oil price increase.

V. Policy Responses to the Oil Price Increase

It is unlikely that policy authorities would not attempt to offset recessionary and inflationary impacts of oil price increases such as those reported above. In this section we briefly outline some of the anticipated problems with policy responses to the effects of oil price shocks.

Fiscal policy can do much in the short-run to offset the income tranfer to OPEC countries, provided that monetary policy is accomodating, and provided the OPEC countries are willing to hold U.S. government debt. Suppose that OPEC buys no U.S. goods with the incremental revenue it

Table 5

Effect of Additional OPEC Price Increases in 1980
(Difference from OPEC June 1979 Scenario)

	1979		1980				1981				1982	1983
	3	4	1	2	3	4	1	2	3	4	4	4
GNP$ (billions)	-0.6	-1.0	-1.9	-2.4	-0.9	0.5	1.3	1.6	1.7	-0.3	-12.0	-26.0
GNP (1972$)	-0.5	-0.9	-3.5	-5.9	-7.0	-8.3	-9.9	-11.9	-14.3	-17.0	-26.1	-32.6
Deflator (percent)	0.0	0.0	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.2	1.4	1.4
Consumption Deflator (percent)	0.1	0.1	0.5	0.7	0.8	1.0	1.2	1.3	1.5	1.6	1.8	1.8
Unemployment rate	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	1.0	1.3
Bill rate	-0.0	-0.0	-0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	-0.0
NIA Net Exports (billions)	-1.4	-1.9	-7.6	-9.4	-7.7	-6.6	-5.8	-5.0	-4.3	-4.2	-4.5	-5.3
Corporate Profits	-0.6	-0.9	-2.0	-2.1	-0.5	1.0	2.0	2.6	3.4	2.9	1.1	1.6

obtains by raising oil prices. Instead, it is willing to hold financial claims on the U.S. Suppose further that the fiscal authorities cut taxes so as to exactly restore the income lost through the oil price induced transfer. The increased government deficit must be financed, say by issuing securities. If, even indirectly, OPEC buys all the government securities issued, the fiscal authorities have passed the income effects of the oil price increase on to future generations— the current costs being interest on the debt.[1/]

However, the price level is still increased so that the stance of monetary policy is crucially important to the effects of the fiscal offset. Even though foreign residents are holding the increase in public debt, so that it is not competing with and crowding out private debt in capital markets, non-accomodating monetary policy would result in higher interest rates and eventually no real effect of the fiscal action — complete crowding out. If, however, the Federal Reserve is willing to tolerate the increase in the price level, the fiscal action will effectively pass on to future generations the costs of the oil price increase. Hence, the choice for policymakers is whether to pay now or later.

Suppose, however, that OPEC does buy goods and services from the U.S. with the revenues generated by the oil price increase. In this case, there is no way — even in the short-run — of avoiding the part of the real income transfer associated with the decline in U.S. terms of trade. That is, the U.S. must give up more real resources to

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1/ Assuming it is short-term debt that is rolled over or long-term coupon debt.

import a barrel of oil. It is true that the aggregate demand loss will be partially offset by the increase in U.S. exports. This demand offset does not reduce the loss in real income, however.

Tax policy can have microeconomic effects by changing relative prices, perhaps to offset the effects of an oil price rise. If energy, capital and labor are all gross substitute inputs to production, an oil price increase, like a tax on energy, lowers the prices of capital and labor relative to energy, and producers will shift towards more labor and capital-intensive technologies.

Unfortunately, energy is likely complementary to the capital equipment it powers, so that an increase in energy prices lowers the factor demand for both capital and energy. Tax policy designed to stimulate investment as a response to an oil price rise will lower the cost of capital. In the short run, investment embodying new technology which is more energy-saving will likely be made, resulting in increases in both actual and potential output. However, the revenue loss to the Treasury from the tax cuts must be financed somehow. If it is financed by raising other taxes, the short-run increases in output will likely be offset by reductions in aggregate demand. It is financed by borrowing, the increased investment will eventually be crowded out by the reduction in government saving, unless OPEC is again willing to do the increase in saving required to finance the increase in investment.

In both the short and longer runs, there can be no increase in aggregate investment without an increase in aggregate saving. This fundamental principle of economics is frequently overlooked in discussions of the effects of tax policy on investment. It may be that a cut in personal taxes, particularly capital gains taxes, and elimination of the double taxation of dividends, would elicit more saving. The empirical and theoretical evidence on this is mixed, however. 1/

There is no one "correct" monetary policy response to the effects of the increased world oil prices. The monetary authorities can respond in two opposite directions: either they accomodate the inflationary impulse or they attempt to offset the resulting increase in prices. In the Pierce-Enzler analysis of external sources of domestic inflation, the monetary response to such a shock was dubbed a "slippery" concept at best. 2/ The direction of monetary policy response rests on the specification of the policy maker's objective function which must include, inter alia, paths of both expected inflation and unemployment over time. The nature of the short term external inflationary impulse is such that no choice of monetary policy can lead to the unambiguously better situation of lower paths for both inflation and unemployment. The policy dilemma is even more unattractive due to the current situation of both high inflation and slow real growth. The important fact is that as with fiscal policy, monetary policy faces a pay now or later situation — in the long run it cannot offset the income transfer to OPEC.

1/ For a thorough discussion of this issue, see von Furstenberg and Malkiel [5].

2/ [11], p.15.

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Thurman/Berner paper Errata:

p. 13 Table 2, column 6, last entry is .15 not .15 B
p. 14 1st paragraph, wholesale energy price...
p. 15 eq. 1: $.944 \ln XGNP$...
p. 16 eq. 3: $L(4)\Delta \ln P_{rm}$

MACROECONOMIC POLICY RESPONSES TO ENERGY PRICE SHOCKS

Paper presented at the Conference on Energy Prices,
Inflation and Economic Activity

Sponsored by

The Center for Energy Policy Research, Energy Laboratory,
Massachusetts Institute of Technology
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by

Otto Eckstein, President, Data Resources, Inc., and
Paul M. Warburg Professor of Economics, Harvard University

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The core inflation analysis discussed in the previous paper[1] can be used to explore the policy terrain open to macro policy in an era of energy price shocks. If we assume as a policy imperative that core inflation must flatten out over the next few years and begin to turn downwards, then the model can be used to identify the degree of demand restraint and the resulting level of unemployment that is necessary to offset the effects of the shock inflation. Of course, there are other ways to deal with the core inflation rate. They include various measures designed to stimulate productivity, including a resumption of an improving capital-labor ratio through tax incentive measures. But these are subjects beyond the scope of this conference and I shall limit this paper to the question of overall demand management.

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[1] "Macroeconomic Analysis of Price Shocks," by Otto Eckstein, presented at the Conference on Energy Prices, Inflation and Economic Activity, November 9, 1979.

There is one other critical model analysis that must be performed as a background to policy. Energy is not only a problem of price, but also of quantity. While world oil supplies may be very ample as a geological matter, OPEC has discovered the secret of a well functioning cartel, and is holding down production to keep the world oil market near the optimal monopoly price.

It has become evident that the strong phase of the business cycle of the industrial countries creates a level of oil demand which is highly inflationary for world oil prices, given OPEC's perception of the world oil market and its attitude toward the development of the industrial countries. Indeed, if one accepts the more pessimistic estimates of Saudi Arabian oil potential, the world need for oil in periods of rapid industrial growth approaches the limits of supplies and would lead to turbulent world oil markets even in the absence of cartel or political considerations.

To explore this range of issues, the DRI macro model, with its energy sector for estimating demands, has been simulated in a series of exercises in order to identify the energy supply constraint on macroeconomic growth. The President's 8½ million-barrel-a-day oil limit was taken as the effective constraint for our growth, assuming that neither an effective quota system nor gasoline rationing was used to dramatically shift the GNP-energy relationships. Model simulations reported elsewhere[2] suggest that a growth rate of 2½% is the maximum feasible path within that energy constraint.

Energy Shocks, Demand Management and Core Inflation

In the DRI intermediate term forecast, the average rate of shock inflation for the years 1980-85 is 1.2%. The shock rate is composed of a 0.9% energy component, where the forecast assumes a real rate of increase in OPEC prices of 4% a year, or a nominal rate of 13.2%, and where the current domestic price controls policies for oil and gas are assumed to be allowed to become effective. Other elements in the predicted shock inflation include sizeable payroll tax increases

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[2] "Supply Constraints and the 1980-1981 Recovery," by Stephen Brooks, September 1979 DRI Review.

scheduled for 1980 and 1981 and further increases in these rates assumed in the first quarter of each year through 1985. Food price increases are assumed to average out to a no-net shock contribution. The exchange rate is assumed to drop at 0.5% a year, given the United States' policies of rising outlays for oil imports and the disparity between our core inflation rate and those of the strong currency countries, Japan and West Germany.

Of course, the shock rate could be substantially worse, or even somewhat better. There is the possibility of a change in the world energy market for much the better or much the worse. The average experience on agricultural prices could be worse, and the government's ability to create other kinds of cost-raising shocks always remains considerable. Sic!

For the sake of illustration, we assume that the projected shock rate is a reasonable estimate, and then proceed to analyze the level of aggregate demand which would be required to produce the negative demand inflation effects required to offset the projected positive shock inflation. This exercise has to be conducted over a time span of at least five or six years because the persistence in core inflation derived from the inflation expectations of workers and investors will dominate the results in the near term.

Tables 1 through 6 show the results of this demand-management exercise. The demand levers used were nonborrowed bank reserves, the principal tool of monetary policy, Federal government defense and nondefense purchases, and Federal government grants-in-aid to state and local governments. It can be seen that to hold the core inflation at a plateau level of 8% in the years 1982-85, unemployment must reach as high as 9.2% and the utilization rate of the materials industries must average below 79%. To bring the core inflation rate down to 5.4% by 1985, the unemployment rate must reach as high as 13.4% and the corresponding utilization rate of the materials industries as low as 65%. Should the shock inflation rate be even worse, then the requisite demand management policies needed to hold the core inflation rate from steadily rising become truly prohibitive. An OPEC price increase of 10% a year in real terms would produce a shock inflation rate that would average 1.5% for the years 1980-85, sharply lifting the base from which any demand management policy must begin. The core inflation rate would accelerate to 9.7% by 1985, 0.5% higher than the already high DRI projection.

Table I
Summary of DRI Six-Year Forecast of the U.S. Economy
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.3	8.4	8.3	8.5	9.0	9.3	9.2
Shock Inflation Rate	2.2	1.8	1.5	1.2	1.0	1.0	1.0
Demand Inflation Rate	-0.2	-0.7	-0.9	-0.5	-0.5	-0.3	0.2
Real GNP (1972 Dollars)	2.0	-1.3	3.3	4.6	4.3	2.8	2.4
Total Consumption	2.3	0.0	3.0	3.8	3.9	3.1	3.1
Nonres. Fixed Invest.	5.1	-4.4	1.1	8.4	8.3	3.3	0.3
Invest. in Res. Structures	-6.1	-13.6	8.2	17.1	10.9	3.3	-2.1
Net Exports ($bil)	17.4	22.3	22.6	21.8	20.8	22.2	25.0
Government Purchases	0.1	0.9	1.5	2.0	2.3	2.4	2.3
Imported Fuel Price	36.6	35.9	13.0	12.7	14.6	13.8	8.6
Personal Consumption Deflator	8.9	9.1	8.6	8.1	7.8	7.8	7.4
Output per Hour	-0.8	-1.5	1.6	2.4	2.3	1.5	1.6
Potential GNP	2.7	2.8	2.8	2.8	2.8	2.8	2.8
Unemployment Rate (rate)	5.8	7.3	7.7	7.1	6.5	6.3	6.4
Capacity Utilization (level)	0.869	0.789	0.811	0.857	0.881	0.859	0.822

Table 2
Summary of Reduced Demand Scenario Producing 8% Core Inflation
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.3	8.4	8.1	8.0	8.0	8.0	8.0
Shock Inflation Rate	2.2	1.8	1.4	1.1	0.8	0.8	0.8
Demand Inflation Rate	-0.2	-0.9	-1.5	-1.7	-2.1	-2.0	-1.3
Real GNP (1972 Dollars)	2.0	-3.5	1.2	3.2	4.0	2.8	2.7
Total Consumption	2.2	-1.7	0.8	2.1	3.2	2.9	3.3
Nonres. Fixed Invest.	5.1	-5.9	-2.7	8.1	9.7	4.2	1.3
Invest. in Res. Structures	-6.4	-22.5	0.1	30.1	15.2	1.3	0.3
Net Exports ($bil)	17.4	24.5	29.3	32.8	35.2	37.3	38.0
Government Purchases	0.1	-2.2	0.0	-2.7	0.3	2.3	2.7
Imported Fuel Price	36.6	35.8	12.7	12.3	13.7	12.6	7.4
Personal Consumption Deflator	8.9	9.2	8.5	7.7	7.1	6.8	6.3
Output per Hour	-0.8	-2.5	0.9	2.2	2.5	1.7	1.8
Potential GNP	2.9	2.8	2.7	2.5	2.5	2.5	2.7
Unemployment Rate (rate)	5.8	7.8	9.2	9.1	8.7	8.3	8.3
Capacity Utilization (level)	0.869	0.752	0.744	0.792	0.830	0.818	0.793

Table 3
Economic Impact of Lowering Core Inflation to 8% Through Demand Management: Reduced Demand Scenario Compared to DRI Six-Year Forecast

	1979	1980	1981	1982	1983	1984	1985
			Difference in rate of change				
Core Inflation Rate	0.0	0.1	-0.2	-0.5	-1.0	-1.3	-1.2
Shock Inflation Rate	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.2
Demand Inflation Rate	0.0	-0.1	-0.7	-1.2	-1.5	-1.7	-1.5
			Percent Difference				
Real GNP (1972 Dollars)	0.0	-2.2	-4.3	-5.6	-5.8	-5.8	-5.6
Total Consumption	0.0	-1.7	-3.7	-5.3	-6.0	-6.2	-6.1
Nonres. Fixed Invest.	0.0	-1.7	-5.4	-5.7	-4.5	-3.6	-2.6
Invest. in Res. Structures	-0.2	-10.5	-17.2	-7.9	-4.4	-6.3	-4.0
Net Exports	-0.1	9.6	29.7	50.4	68.9	67.7	51.9
Government Purchases	0.0	-3.1	-4.6	-8.9	-10.7	-10.7	-10.3
Imported Fuel Price	0.0	-0.1	-0.3	-0.7	-1.4	-2.5	-3.6
Personal Consumption Deflator	0.0	0.0	-0.1	-0.4	-1.0	-2.0	-3.0
Output per Hour	0.0	-1.0	-1.6	-1.8	-1.7	-1.5	-1.3
Potential GNP	0.0	0.0	-0.1	-0.4	-0.8	-1.0	-1.1
Unemployment Rate*	0.0	0.5	1.5	2.0	2.1	2.0	1.9
Capacity Utilization*	0.00	-0.04	-0.07	-0.07	-0.05	-0.04	-0.03

*Differrence in level

Table 4
Summary of Reduced Demand Scenario Producing 5.4% Core Inflation
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.3	8.4	8.0	7.3	6.6	6.2	5.4
Shock Inflation Rate	2.2	1.8	1.4	1.0	0.6	0.4	0.4
Demand Inflation Rate	-0.2	-0.9	-2.0	-2.9	-3.6	-3.7	-3.4
Real GNP (1972 Dollars)	2.0	-4.7	-3.3	1.2	4.1	0.3	-1.0
Total Consumption	2.2	-2.8	-2.8	0.1	2.3	0.2	-0.5
Nonres. Fixed Invest.	5.1	-6.5	-7.5	4.4	14.4	5.5	-2.1
Invest. in Res. Structures	-6.4	-25.1	-19.6	33.5	32.3	-5.5	-3.6
Net Exports ($bil)	17.4	25.4	36.4	44.8	50.0	58.0	63.4
Government Purchases	0.1	-4.0	-5.7	-5.7	-4.6	-3.0	-2.6
Imported Fuel Price	36.6	35.7	12.2	11.3	12.0	10.2	4.6
Personal Consumption Deflator	8.9	9.2	8.3	7.0	5.6	5.0	3.9
Output per Hour	-0.8	-2.9	-0.6	2.1	3.1	1.0	1.0
Potential GNP	2.9	2.8	2.6	2.3	2.1	2.3	2.5
Unemployment Rate (rate)	5.8	8.0	10.9	12.2	11.8	11.9	13.4
Capacity Utilization (level)	0.869	0.736	0.659	0.692	0.770	0.733	0.654

Table 5
Economic Impact of Lowering Core Inflation to 5.4% Through Demand Management: Reduced Demand Scenario Compared to DRI Six-Year Forecast

	1979	1980	1981	1982	1983	1984	1985
			Difference in rate of change				
Core Inflation Rate	0.0	0.1	-0.2	-1.2	-2.3	-3.1	-3.8
Shock Inflation Rate	0.0	0.0	-0.1	-0.2	-0.4	-0.5	-0.7
Demand Inflation Rate	0.0	-0.2	-1.2	-2.4	-3.1	-3.4	-3.6
			Percent Difference				
Real GNP (1972 Dollars)	0.0	-3.4	-9.6	-12.5	-12.7	-14.8	-17.7
Total Consumption	0.0	-2.8	-8.2	-11.5	-12.9	-15.4	-18.3
Nonres. Fixed Invest.	0.0	-2.3	-10.6	-13.9	-9.1	-7.2	-9.4
Invest. in Res. Structures	-0.2	-13.5	-35.7	-26.6	-12.5	-19.9	-21.1
Net Exports	-0.1	13.9	61.2	105.2	139.7	160.7	153.4
Government Purchases	0.0	-4.8	-11.6	-18.2	-23.8	-27.8	-31.2
Imported Fuel Price	0.0	-0.1	-0.8	-2.0	-4.2	-7.3	-10.7
Personal Consumption Deflator	0.0	0.0	-0.2	-1.2	-3.2	-5.8	-8.8
Output per Hour	0.0	-1.4	-3.6	-3.9	-3.2	-3.6	-4.2
Potential GNP	0.0	0.0	-0.2	-0.6	-1.3	-1.7	-2.0
Unemployment Rate*	0.0	0.7	3.2	5.1	5.2	5.6	7.0
Capacity Utilization*	0.00	-0.05	-0.15	-0.17	-0.11	-0.13	-0.17

Table 6
Impact of 10% Real Energy Price Inflation
(Percent change)

	1979	1980	1981	1982	1983	1984	1985
Core Inflation Rate	8.3	8.4	8.3	8.7	9.2	9.6	9.7
Shock Inflation Rate	2.2	1.8	1.7	1.5	1.2	1.2	1.4
Demand Inflation Rate	-0.2	-0.7	-0.9	-0.7	-0.8	-0.7	-0.1
Real GNP (1972 Dollars)	2.0	-1.4	3.1	4.1	3.9	2.9	2.3
Total Consumption	2.3	0.0	2.9	3.5	3.6	3.1	3.0
Nonres. Fixed Invest.	5.1	-4.4	0.8	7.3	7.4	3.5	0.2
Invest. in Res. Structures	-6.1	-13.7	6.6	14.0	10.0	5.1	-3.6
Net Exports ($bil)	17.4	22.3	22.6	22.1	21.9	24.0	27.1
Government Purchases	0.1	0.9	1.4	1.7	1.9	2.0	1.9
Imported Fuel Price	36.6	39.1	20.0	20.0	20.0	20.0	20.0
Personal Consumption Deflator	8.9	9.2	9.1	8.8	8.5	8.4	8.4
Output per Hour	-0.8	-1.6	1.3	2.0	2.2	1.7	1.3
Potential GNP	2.9	2.8	2.8	2.8	2.7	2.6	2.7
Unemployment Rate (rate)	5.8	7.3	7.8	7.3	6.9	6.6	6.7
Capacity Utilization (level)	0.869	0.788	0.806	0.841	0.860	0.845	0.807

These results show that the core inflation problem cannot be solved by aggregate demand policies. The unemployment paths that are required are both politically unlikely and economically very dangerous. The unemployment rates of disadvantaged groups and of disadvantaged regions (including our central cities) would be dramatically higher. The economy would cease to be an engine of opportunity and progress and the political process would probably opt for worsening inflation rather than for its cure.

Policy must turn to other techniques to lower the core inflation rate. DRI is conducting various studies to explore the other possibilities, particularly various forms of tax incentives to investment for acceleration of capital formation and for restoration of a more normal productivity advance. Even with good, strong policies, the road ahead will not be easy.

Macroeconomic Policy Responses
to the 1979 Energy Price Shock

by

Knut Anton Mork
M.I.T. Energy Laboratory

and

Robert E. Hall
Stanford University

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Introduction

Most analysts agree that large and unanticipated increases in the price of energy are likely to cause severe dislocations in the economy.[1] The problem of selecting the best policy response to this kind of shocks seems yet unresolved. A whole range of measures have been discussed in the public debate, including policies as different as synthetic fuel programs and monetary contraction. The present paper reviews macroeconomic policy responses to the oil price shock. Policies operating directly on energy supply or demand, important as they are, will not be discussed in this paper.

Our analysis is done within a model constructed by the authors for the specific purpose of studying the macroeconomic effects of energy price shocks.[1] This model permits computation of numerical estimates of the effects of policy measures on key macroeconomic variables, including inflation, real economic growth, and employment. The policies studied are monetary expansion and contraction, fiscal expenditure policy, investment stimulus via changes in the corporate income tax, and a payroll tax cut. Personal income tax cuts are discussed as well, although some fundamental difficulties are involved in studying this policy. The policies are discussed in the context of the current economic situation, but the analysis applies to energy price shocks in general.

The analysis suggests that attempts to offset the energy-induced inflation by contractionary monetary policy may have severe consequences for employment and economic growth. Monetary expansion is preferred to

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[1] See Hall and Mork, "Macroeconomic Analysis Energy Policy Shocks: The M.I.T. Energy Lab Energy-Macro Model" and their survey of the literature.

increases in public spending because of the negative side effects of the latter on inflation and capital formation. As a pro-investment policy, an increase in the investment tax credit seems attractive and is not found to be very inflationary. A payroll tax cut seems a possiblity for cutting inflation in the short run and aiding employment and economic growth at the same time.

Monetary and Fiscal Expenditure Policy

Macroeconomic policies to offset energy price shocks face two important conflicts. The first is the dilemma of inflation against employment. The recent history of severe inflation in the U.S. has made national economic policy as concerned about offsetting the inflationary impact of an energy price shock as in shoring up employment and output. A policy to limit inflation--specifically, through monetary contraction--could worsen the adverse effects of the energy shock on real economic activity. Fiscal expansion to maintain employment and output might push inflation even beyond the current high levels attributable to the direct effects of the energy shock. Our analysis does suggest a way out of this dilemma, though, at it traces the indirect effects of alternative policies through capital formation. Policies with favorable effects on investment have a significant advantage in cushioning the real shock without too high a price in added inflation. A limited monetary accommodation of the energy shock is attractive for this reason. The opposite response--monetary contraction--is the only effective instrument for restraining inflation in the long run, but it works with a long lag and is unsuitable as a response to an energy shock because of its depressing effect on investment in the short run. Similarly, we find that fiscal stimulus, through income tax cuts or increases in government expenditures, is even less suitable because of its unfavorable effect on investment. Furthermore, we find that a sufficiently expansionary fiscal policy to offset the employment effects of the new energy shock would bring about unacceptable rates of inflation.

The other problem is the issue of timing. For accommodative monetary policy, we find it essential that the monetary authority acts quickly to expand money supply immediately after the shock. Usually this means that monetary action is needed several months before the economy reaches the bottom of the recession. A belated monetary response will have to be so much stronger and runs a larger risk of overheating the economy.

For fiscal policy, the main timing problem comes from the long decision process. We find fiscal action to be much more powerful when the government makes swift, surprising moves. Thus, although a public policy debate is necessary in a democratic system, a dragged out discussion about details of a policy package is likely to weaken its impact substantially. We consider this a major weakness of fiscal policy.

Table 1 shows a summary of the estimated effects of alternative monetary and fiscal policies as they would have been if introduced immediately after the 1979 energy price shock. For the sake of comparision, the two policies are assumed to operate at levels sufficient to stabilize unemployment at around 6 percent. The monetary expansion is assumed to take the form of increasing money growth from 5 to 6 percent in 1979, from 6 to 8 percent in 1980, and from 6 to 7 percent thereafter. For fiscal expenditure policy we study the effect of an exogenous increase in spending of 17 billion 1972 dollars in 1979, 69 billion in 1980, and 94 billion in 1981. Obviously these are far in excess of any likely fiscal response, but they are the magnitudes required to stabilize employment.

Fiscal expenditure policy would have been by far the more inflationary alternative, increasing the inflation rate by one percentage point this year and two percentage points next year. Furthermore, although it stabilizes employment, it has a severe negative impact on economic growth. Of course, our projections overstate the likely inflationary and anti-growth effects of expenditure policy because we study an expenditure response that is far larger than any remotely likely to be entertained by national economic policy-makers.

Our results are much more favorable for a monetary response to the employment effects of the energy shock. The magnitude of the necessary response is quite small if done in time--one percent extra monetary growth in 1979, two percent extra in 1980, and one percent extra in later years. Monetary stimulus achieves most of its effects by raising investment; the resulting additional capital formation enlarges the productive capacity of the economy and moderates the effect on inflation. Ultimately, higher money growth means higher inflation, but in the first few years after the energy shock and monetary offset, the favorable effect on capital formation and the unresponsiveness of wages assumed in our analysis combine to hold total inflation to a reasonable level.

The actual conduct of monetary and fiscal policy have not followed any of these paths in 1979. Rather, monetary policy was accommodative earlier in the year, and has recently turned toward lower money growth. No commitment has been made for fiscal policy, although a tax cut for

Table 1

Estimates of what the Effects of Monetary and Fiscal Policies to Stabilize Employment would have been if Introduced in early 1979.

	Year		
	1979	1980	1981
Monetary response			
Extra Inflation (per cent per year)	-0.7	-0.2	0.4
Extra real GNP growth (per cent per year)	1.6	2.3	1.1
Extra money growth (per cent per year)	1.0	2.0	1.0
Fiscal response			
Extra inflation (per cent per year)	0.9	2.0	1.7
Extra real GNP growth (per cent per year)	1.7	1.1	-2.7
Extra government expenditure required (billions of 1972 dollars)	17	69	100

1980 is discussed seriously. We have serious misgivings about the Federal Reserve Board's recent tightening. Though moderation of monetary growth is a necessity over the next several years to slow down inflation, a sudden sharply contractionary move at this time is unwise. It suggests a neglect of the central goals of maintaining capital formation and real growth.

Estimated effects of fiscal and monetary policy alternatives for 1980 are listed in Table 2. The necessary increase in money growth to stabilize employment in 1980 is much larger than what would have been needed if action were taken immediately. Again, the favorable effect on capital formation holds inflation to a reasonable level in the first few years. We anticipate, however, that the jump in money growth needed in 1980 will create expectations of increased future growth rates of the money supply, so that this policy may increase inflation by a couple of percentage points in the long run.

The effects of a fiscal expenditure policy depends crucially on whether or not the economy already expects such a program. If it does, the necessary outlay for stabilizing employment is almost twice as large in 1980 and fifty percent higher in 1981. The effects on inflation and economic growth are also much less favorable in this case. And even if the fiscal stimulus comes as a surprise, it is more inflationary than monetary policy and is much more harmful to capital formation and economic growth.

Rather than rely entirely on raising government expenditures, policy is likely to try to stimulate private consumption expenditures by cutting personal income taxes temporarily. The economic impacts of a successful policy to raise consumption would be very similar to those of an increase

Table 2

Estimates of the likely Effects of Monetary and Fiscal Policies to Stabilize Employment if Introduced in 1980.

	Year		
	1980	1981	1982
Monetary response			
Extra inflation (per cent per year)	-1.2	-0.6	0.8
Extra real GNP growth (per cent per year)	1.4	3.5	2.4
Extra money growth (per cent per year)	3.0	2.0	2.0
Unanticipated fiscal response			
Extra inflation (per cent per year)	0.9	1.0	-0.0
Extra real GNP growth (per cent per year)	4.4	-1.8	-2.1
Extra government expenditure required (billions of 1972 dollars)	63	70	0
Anticipated fiscal response			
Extra inflation (per cent per year)	2.3	1.7	-0.0
Extra real GNP growth (per cent per year)	-1.7	-3.0	-2.0
Extra government expenditure required (billions of 1972 dollars)	106	100	0

in government expenditure--in particular, part of the increase would come at the expense of capital formation and subsequent real growth. However, we do not pursue the analysis of a personal tax cut because we, like many other economists, are skeptical of the ability of a temporary tax cut to stimulate consumption in any substantial way. If fiscal policy is to offset the adverse effects of the energy shock on real output, it will have to rely mainly on very large increases in government expenditures, with highly unfavorable side-effects on growth and inflation, in our analysis.

Concern about inflation is certain to limit the magnitude of the response of both fiscal and monetary policy compared to the figures of Table 2. National economic policy will probably let a recession occur, in spite of the availability of tools that could prevent the recession. In fact, we seem to see a repeat of the experience of 1973-75, when monetary policy was slightly contractionary in response to the energy shock and succeeding recession, and fiscal policy slightly expansionary, through both tax cuts and expenditure increases, but by no means enough to offset the decline in employment caused by the energy shock. Policy seems to be biased toward a moderate anti-capital-formation response to the shock.

Tax Cuts for Inputs to Production

Fiscal expenditure and income tax cuts are only two of many possible options for the makers of fiscal policy. Two other types of response to the energy shock are now under consideration, namely, stimulating investment by changing the rules of corporate taxation, and stimulating employment by cutting payroll taxes. Our results for such policies are quite favorable. Both policies stimulate investment, like monetary expansion, but have less adverse effects on inflation in the longer run. Also, when administrated properly, they contribute less to the federal deficit than would a fiscal expenditure policy.

The estimated effects of change in the investment tax credit for 1980 and 1981 is summarized in Table 3. The tax credit is taken at a level sufficient to stabilize employment at around 6 percent in 1980 and 1981, so that the results are comparable to those of monetary and fiscal expenditure policy. The policy is assumed to be announced and take effect as well at the beginning of 1980. The moderate increase in inflation for the first two years contrasts sharply with fiscal expenditure policy. The reduction in inflation in the third year accompanies the decline in real growth as policy returns to normal in 1982. This decline in growth can be avoided by making the increased credit permanent or by a smoother return to normal. The effect on long run growth (after ten years in the model) is, however, positive, whereas fiscal expenditure policy lowers the long term growth path of the economy. The revenue loss for the investment tax credit seems well within the limits of realistic policy making.

Table 4 shows the estimated outcome of a cut in payroll taxes. Our model hypothesizes that much of the economic dislocation of an energy price increase is attributable to the unresponsiveness of wages. When energy prices rise, either the overall price level must rise or wage costs must fall. A cut in payroll taxes makes it possible for employers' wage costs to fall without a corresponding decline in wages received by workers. We find that a cut of 4.5 percentage points in payroll taxes

Table 3

Estimated Effects of a Fiscal Policy Aimed Specifically at Stimulating Investment: Temporary Increase in the Investment Tax Credit

	Year		
	1980	1981	1982
Extra inflation (per cent per year)	0.2	0.1	-2.5
Extra real GNP growth (per cent per year)	3.8	-0.0	-4.5
Increase in investment tax credit (percentage points)	6.9	4.9	0.0
Revenue loss (billions of 1972 dollars)	18.5	14.0	0.4

Table 4

Estimated Effects of Payroll Tax Cut

	Year		
	1980	1981	1982
Extra inflation (per cent per year)	-6.0	1.4	2.1
Extra real GNP growth (per cent per year)	3.9	-0.1	-4.2
Reduction in payroll tax rate (percentage points)	4.5	3.2	0.0
Revenue loss (billions of 1972 dollars)	44.3	26.0	2.0

in 1980 and 3.2 percentage points in 1981 would largely eliminate the impact of the energy price shock on employment. Inflation in 1980 would be as much as 6 percentage points lower with this cut than in the base case of Table 1 with no policy response. Because the policy would concentrate all of its effect of lowering costs in 1980, it would increase inflation somewhat in 1981, and, in 1982 when payroll taxes returned to their original level, inflation would be about two percentage points worse than in the base case. The net effect on the price level through 1982 would be favorable because the policy would stimulate capital formation.[1] The extremely favorable effect on inflation in 1980 depends on a direct linkage between prices and labor cost, which is assumed in our analysis and in most other macroeconomic models. This point may be worth further investigation, but the results so far seem very promising for this kind of policy. It is somewhat more expensive than a direct investment stimulus, but is substantially cheaper than fiscal expenditure policy, and promises a far more favorable effect on inflation than either of the latter two. Perhaps this is the right time to try an experiment along these lines.

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[1] In a previous paper (Mork and Hall, "Energy Prices and the U.S.Economy in 1979-81," M.I.T. Energy Laboratory Working Paper No. MIT-EL 79-043WP, August 1979) we reported somewhat different results for a payroll tax cut. The discrepancy is due to a difference in perspective: the policy studied in that paper was assumed to be announced in 1979 and take effect in 1980. Similar differences can be found for the investment tax credit. Also note an error in that paper. The revenue loss of 55 and 52 billion should be current dollars, corresponding to 30 and 25 billion 1972 dollars in 1980 and 1981, respectively.

Concluding comments

Our review of the options open to policy makers to deal with an energy price increase has called attention to the role of capital formation in the alternative effects of different policies. Some policies may be classified as pro-investment: monetary accommodation, investment credit, and payroll tax credit. Because they favor capital formation, they help offset inflation. Other policies are anti-investment: monetary tightness and increases in federal spending. Unfortunately, the present movements of macroeconomic policy seem to be in exactly this second direction. We favor as an alternative the following combination: Monetary policy aiming to achieve growth rates of monetary aggregates at approximately their averages over the past 5 years, without any sudden reduction in growth but with a committment to gradual reductions in money growth over the forthcoming five years. Second, temporary increase in the investment tax credit of 2 or 3 percentage points. Third, a permanent reduction in payroll taxes of several percentage points (with the necessary revenue for financing social security benefits coming from general federal revenues). This package would help put the U.S. back on the path of higher capital accumulation and growth from which it was deflected by the first energy shock in 1974 and from which a further deflection is threatening.

Preliminary - Not for quotation.

ENERGY PRICE INCREASES AND MACROECONOMIC POLICY*

Robert S. Pindyck
Massachusetts Institute of Technology

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1. Introduction

A rising world price of energy imposes a macroeconomic cost on the United Sates in two different ways. First, to the extent that energy is an important production input and consumption good with limited substitution elasticities, as it becomes more scarce the economy's production and consumption possibilities are necessarily reduced. Thus, even if an expansionary monetary and fiscal policy were successful in pushing the economy close to its full capacity level, the resulting GNP would be lower than if energy prices had not increased. The cost corresponding to this reduction in potential GNP might be thought of as a "direct" cost of higher energy prices.

Second, rising energy prices contribute directly to general inflation, and, by increasing the marginal cost of production may, if wages are rigid, further reduce GNP and employment. Depending on the macroeconomic policy response to this added inflation and unemployment - i.e. whether we accommodate the inflation and try to move back to full employment quickly, or accept the additional unemployment for some time - and depending on the effectiveness of that policy response, there will be an added cost, namely the cost of the increased inflation and/or the still further reduction in GNP. This might be thought of as an "indirect" cost of higher energy prices.

When I first began thinking about this paper I thought I would try to estimate these two costs for, say, a 10% increase in world oil prices. Intuitively it seemed to me that the "indirect" cost of an energy price shock, i.e. the cost of inflation and the re-establishment of full-capacity output and employment, would be quite large and might even outweigh the direct cost. In any case it seemed worthwhile to try to get an idea of just how large these costs are.

Furthermore as I first thought about it the task seemed fairly straightforward, and would involve the following steps:

1. First I would try to roughly estimate the loss in the productive capacity of the economy resulting from a given increase in the world price of oil. This would require certain assumptions about the impact of higher oil prices on the overall aggregate price of energy in the United States. However a story about this already exists in the form of the MIT World Oil Model, a large simulation model that translates Persian Gulf prices into, among other things, product prices for various fuels. Assumptions are also needed about the elasticity of substitution between energy and other factors of production for the industrial sector, and demand elasticities for the residential and transportation sectors. Here I could draw from my own recent econometric estimates (1979). I could also try to say something about the sensitivity of the estimated potential GNP loss to these assumptions.

2. My first inclination was that the proper macro policy response to an energy price shock would be one of full <u>accommodation</u>, i.e. the immediate inflationary impact would be accepted, and the nominal money supply increased proportionally - or perhaps more than proportionally to compensate for the depressing effect on investment resulting from short-run capital-energy complementarity. I found initial support for this intuitive feeling by reading Gramlich (1979), and it is also constant with the story told by Mork and Hall (1979).

3. I could then go on and use Gramlich's statistical results on the relative perceived costs of inflation and unemployment to attach a dollar cost to the policy of accommodation. In other words a dollar measure could be attached to the added inflation (based on an estimated perceived equivalence with some amount of unemployment and thus implicit GNP loss) under the assumption of full and instantaneous accommodation.

While this is a neat plan, I soon realized that the choice of the correct policy response to an energy price shock is not so clearcut, and that it may not necessarily be desirable after all to quickly accommodate the shock by expanding demand. It is not that I believe in Fellner's view of an implicit social contract with the government that would be overturned once firms and labor unions began to doubt the commitment to fighting inflation. Rather the issue seems to be whether prices and real wages will adjust (quickly enough) for demand stimulation to be effective, and even if they do adjust, whether the original Phillip's curve is re-established quickly enough after a price shock to warrant a rapid accommodation.

There are essentially three possible reasons why it might not be desirable to accommodate an energy price increase, at least quickly:

1. Suppose price and real wages adjust quickly enough sothat the goods market always clears, but money wages are rigid downwards so that a higher price of energy reduces the supply of output (at any particular price). This is basically the story told by the neoclassical models of the sort developed by Phelps (1978) and Gordon (1975). Gramlich (1979) uses such a model to argue that immediate accommodation is the optimal policy, but seems to brush over the issue of adjustment lags in the re-establishment of the long-run Phillip's curve. Would accounting for these lags, or the use of an objective function different from the linear one Gramlich uses, lead us to conclude that any accommodation should be gradual?

2. One might believe that there is rigidity in the real wage rate. (Sachs (1979) argues that this has indeed been the case in Europe.) This would mean modifying the neoclassical model so that the supply of output is perfectly inelastic, and implies that accommodation will not change employment, but will only increase inflation. The only policies that can reduce unemployment are those that stimulate supply.

3. If one believes that prices are rigid or that real wages are fixed given any particular level of output, one is led to a model or the sort developed by Solow and Stiglitz (1968), Malinvaud (1977), and Solow (1978). Here the goods market need not clear, and might be characterized by excess supply (and Keynesian unemployment) or excess demand (and "classical" unemployment). If an energy price increase leads to a situation of excess demand and "classical" unemployment (or occurs when the economy is already in that state), accommodation is of no use and once again will only increase the rate of inflation.

There are thus three alternative frameworks that can be used to analyze macro policy response, each of which might (and for different reasons) lead to the conclusion that full and rapid accommodation is not desirable. I will begin by briefly reviewing these alternative frameworks and trying to reconcile their differences. It seems to me that the differences boil down to assertions about how long rigid real wages, money wages, or prices remain rigid, so that the comparative statics of one model can be made to dynamically shift to that of another model by allowing one or more key parameters (that define a particular rigidity) to adjust (perhaps slowly) over time.

We next turn to the problem of optimal policy response. By letting certain parameters adjust slowly over time we can force any of the alternative models to lead us to the conclusion that macro policy should eventually accommodate price shocks. However, "eventually" might be a rather long time, and is not very useful as a guide for monetary policy over the next several months. Unfortunately the empirical evidence for the United States in 1979 is mixed and ambiguous, and the policy implications are likewise ambiguous. However the limited evidence seems to favor a neoclassical model where the goods market clears and real wages can adjust. I will use such a model to examine the optimal policy response.

2. Alternative Frameworks for Analyzing Macro Policy Response

If both prices and the real wage rate can adjust, we can look at the problem in the context of a neoclassical model of the sort used by Gordon, Phelps, and Gramlich. The story is illustrated in Figure 1, where aggregate demand for output is a decreasing function of price, aggregate supply is an increasing function (essentially the marginal cost curve), and the intersection (just before the energy price shock) is at full employment output, y_f. An increase in the price of energy raises the marginal cost of production (as well as the cost of imported fuels consumed directly) and shifts the aggregate supply curve to the left, so that output falls below the (new) full employment level, and there is a one-shot increase in the price level. The economy will remain in this position as long as the money wage is rigid downwards. A possible policy response is to accommodate the energy price increase through monetary or fiscal expansion, shifting the demand curve to the right, causing a further increase in the price level but also a movement to the new full employment output level. (Note that full employment output has dropped from y_f to y_f'.)

At issue, however, is how quickly the expansion should take place. Gramlich argues that it should occur very quickly, and supports the argument by specifying a simple model of price-wage inflation, and then choosing a set of unemployment rates to minimize a weighted sum of present and future discounted rates of inflation and unemployment. However, we will come back to this issue later and see that the result depends on the linearity of the objective function. If the objective function is convex, the rate of accommodation should be gradual.

The use of accommodation, even if it is gradual, is ruled out in the neoclassical model if the real wage rate is fixed. If we write the supply (marginal cost) curve as $P = w\phi(p_e, y)$, where w is the money wage rate and p_e the nominal price of energy, if the real wage $v = w/P$ is fixed, $\phi^{-1}(p_e, y) = v_0$, and y is fixed given p_e. As can be seen in Figure 2, increasing demand will

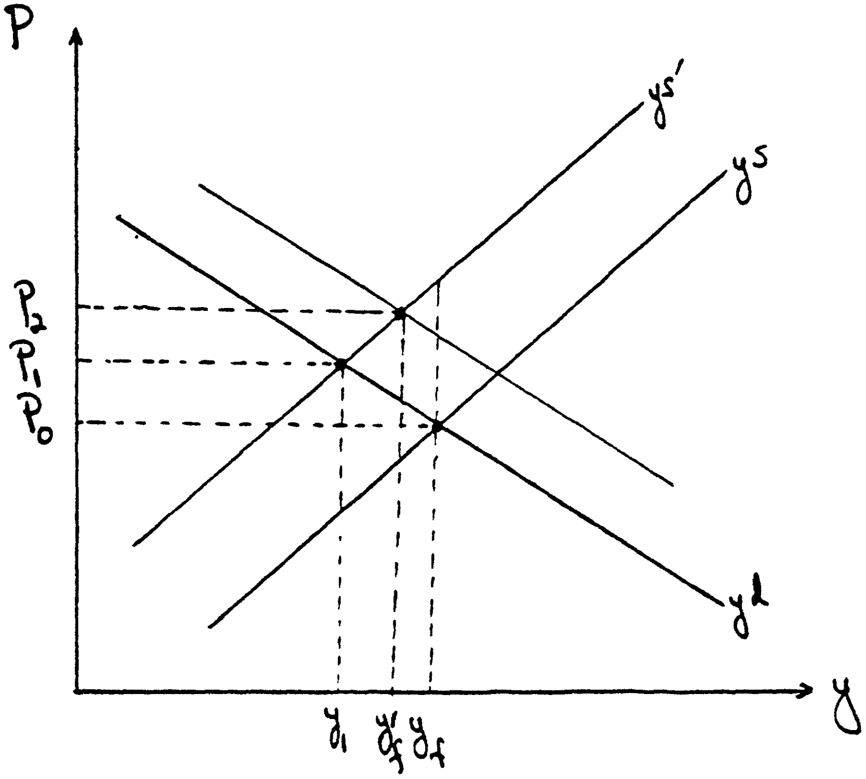

Figure 1

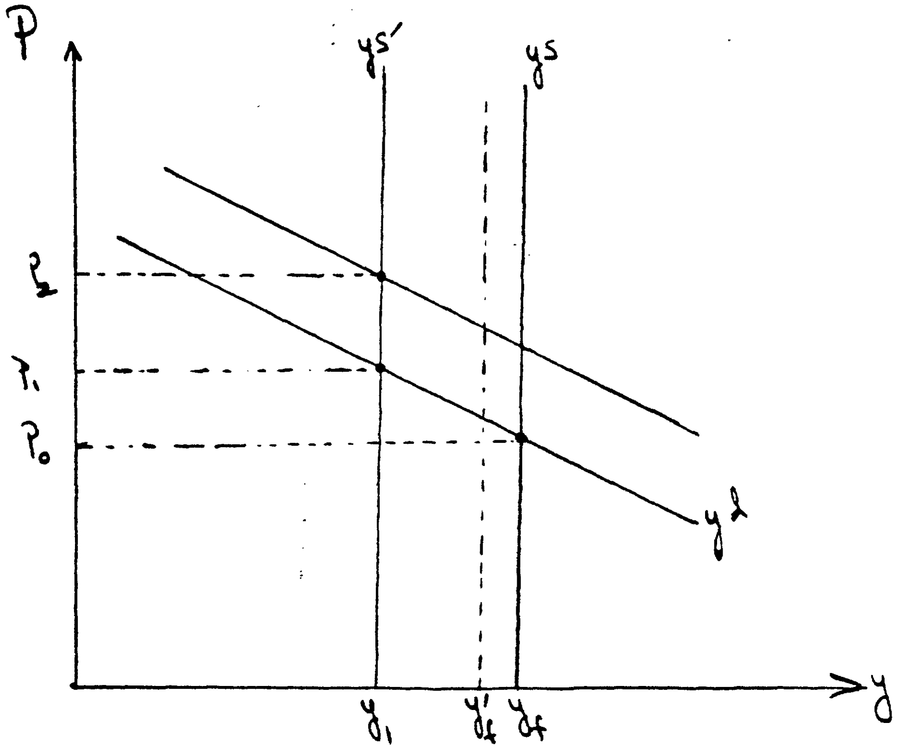

Figure 2

only increase the price level, and will do nothing to increase output and employment. One could argue that this picture might apply to Europe and Japan, where, as Sachs (1979) points out, real wage rates have increased rapidly over the past several years, and where there is a high degree of price indexation in the setting of wage contracts. We will discuss its applicability to the United States later.

One can also reach the conclusion that accommodation will be ineffective using a model of the sort developed by Solow and Stiglitz (1968) and Malinvaud (1977), and applied recently by Solow (1978) to the analysis of macro policy response to energy price shocks. Here the supply of output is a declining function of real factor prices, i.e. the real wage v and the real price of energy $z = p_e/P$. The demand for output is an increasing function of the real wage, but a decreasing function of the real price of energy. Potential output y_f is determined by the supply of labor and thus independent of v, but will fall if the real price of energy rises. Finally, actual output will be the smallest of demand, supply, and potential output, so that given a particular real wage (see Figure 3), there could exist excess supply and Keynesian unemployment ($v < v_1$), or excess demand and "classical" unemployment, i.e. stagflation ($v > v_2$).

To determine the equilibrium real wage a model of price-wage inflation is needed. Solow uses the following:

$$\dot{p}/p = g(y^d/y^s) + j\,\dot{w}/w\,, \qquad g' > 0, \quad 0 < j < 1 \tag{1}$$

$$\dot{w}/w = h(n/n^s) + k\,\dot{p}/p\,, \qquad h' > 0, \quad 0 < k < 1 \tag{2}$$

so that price inflation is determined (in part) by excess demand and wage inflation by unemployment. We can thus get the rate of change of the real wage from the reduced form of (1) and (2):

$$\dot{v}/v = \dot{w}/w - \dot{p}/p = -\gamma_1 g(y^d/y^s) + \gamma_2 h(n/n^s) = f(y,v) \tag{3}$$

where $\gamma_1 = (1 - k)/(1 - jk)$ and $\gamma_2 = (1 - j)/(1 - jk)$. This defines the locus of constant real wage $f(y,v) = 0$, and, as shown in Figure 3, determines the equilibrium value of v.

Four things occur as a result of an energy price increase. Full employment output y_f falls to y_f'. The demand curve shifts down and to the right. The supply curve shifts down and to the left. And finally, depending on the extent of the demand and supply shifts, the $f(y,v) = 0$ schedule will shift, since both y^d/y^s and n/n^s will now be different for any particular v. If the demand curve does most of the shifting so that for any v, y^d/y^s is now smaller (but, with the drop in y_f, n/n^s is about the same), the $f(y,v) = 0$ schedule will shift to the right, if the supply curve does most of the shifting the schedule will shift to the left.

Depending on the state of the economy before the energy price shock, and depending on the relative effects of the shock on demand and supply, the new equilibrium after the shock might be one of excess supply as in Figure 4a, or excess demand as in Figure 4b. Should it be excess demand and "classical" unemployment, accommodation through demand expansion would only increase the rate of inflation (by increasing excess demand) but would not reduce unemployment. Only a policy that expanded supply would help, and unfortunately the instruments available to effect such a policy are quite limited.

One might ask whether an equilibrium such as that in Figure 4b could actually be sustained for any significant length of time.[1] We might expect that after high unemployment persisted for any length of time, unions would soften their wage demands and be willing to accept a smaller degree of

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1 - We might also ask whether we could expect to see such an equilibrium at all. Its existence requires that the function $g(y^d/y^s)$ in eqn. (1) not be terribly elastic. If $g(y^d/y^s)$ is a highly elastic function (so that it doesn't take much excess demand to increase the rate of inflation or much excess supply to reduce it), the locus $f(y,v) = 0$ will always lie close to the intersection of y^d and y^s, and any shift in that intersection (from a shift in demand or supply) would shift the locus accordingly.

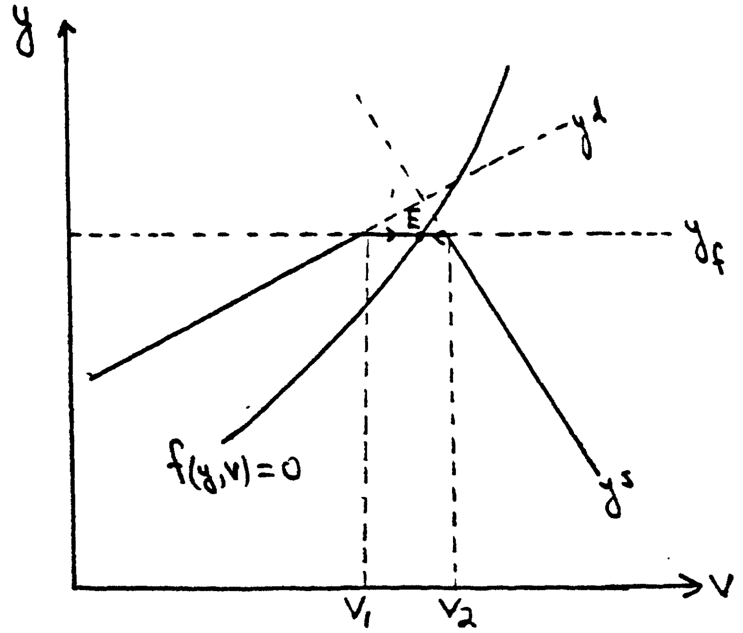

Figure 3

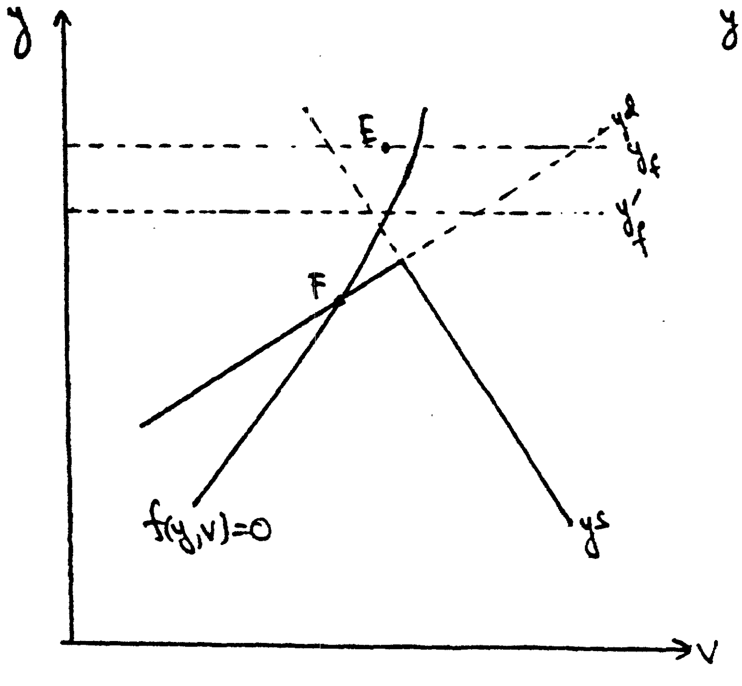

Figure 4a

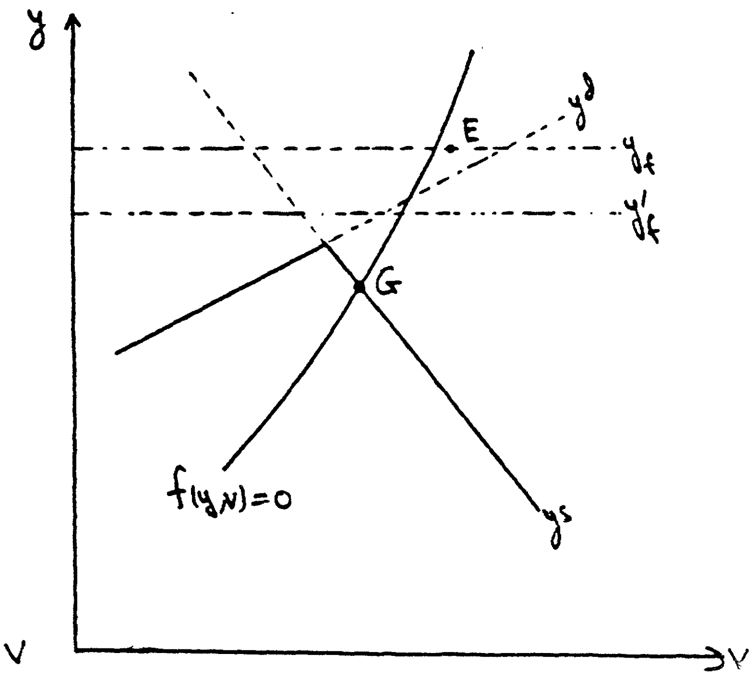

Figure 4b

indexation. This would mean a reduction in the parameter k in eqn. (2), so that the f(y,v) = 0 curve would shift to the left towards the intersection of y^d and y^s. Letting the parameter k be dynamic is thus one way of forcing this model to tell a neoclassical story in the long run. For example, we could write k as

$$k(t) = k_0 e^{\beta(n^s/n - 1)(t-t_0)} \qquad (4)$$

where t_0 is the time at which a price shock occurs, reducing supply. We could then argue about the size of β, i.e. how long it takes for markets to clear.[2]

Alternatively we could make the function $g(y^d/y^s)$ or the parameter j in eqn. (1) dynamic, adjusting over time according to the duration of excess demand (or excess supply). If j increased as excess demand persisted (so that wage increases were passed through more quickly), or $g(y^d/y^s)$ became more elastic, the f(y,v) = 0 locus would again shift toward the supply-demand intersection. As shown in Figure 5, demand stimulation would now be an effective policy, although it would take some time to work (leaving open the question, as in the neoclassical model, of whether accommodation should be rapid or gradual).

3. The Optimal Policy Responses for the United States

This brings us to the question of which view of the world seems most appropriate for the U.S. economy in 1979-80, and what are the policy implications

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[2] - The parameter k describes the degree of price indexation, while $h(n^s/n)$ describes the process of wage increase more broadly. We could also (or instead) let h be dynamic (falling with the duration of unemployment). For example, the function

$$h = \frac{An^s}{(n^s - n)} e^{\beta(n^s/n - 1)(t-t_0)}$$

would let markets clear in the long run.

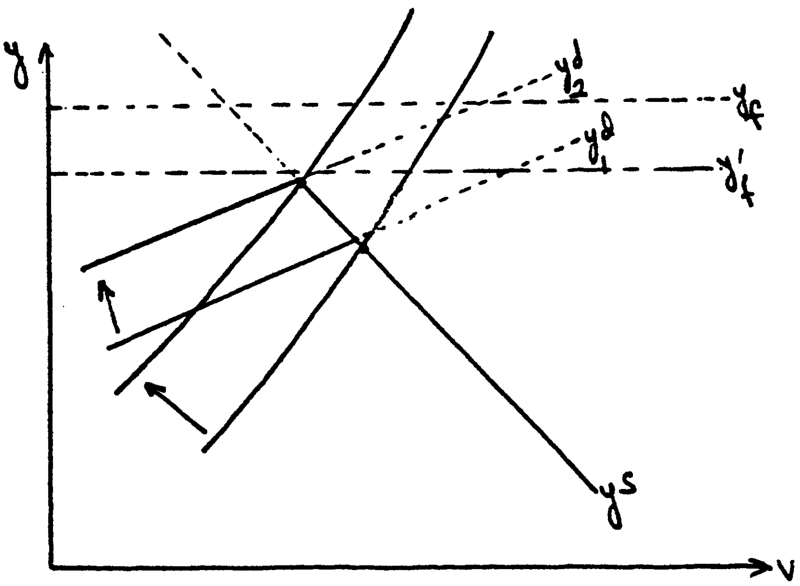

Figure 5

of that view. As I mentioned earlier, the evidence is limited and mixed, but I tend to doubt that the recession that is just beginning (or is about to begin shortly) can be charaterized by excess demand as in Figure 4b, or that real wages are perfectly rigid as in Figure 2. (Downward rigidity in real wages may indeed exist in some of the European countries, but we are talking now about the United States.) The following points support this view:

(1) First and perhaps most important is the fact that the real wage rate fell by about 4 percent over the past year, with most of the droo occurring after world oil prices started rising again in January 1979. This is even more than the 3 percent drop in the real wage rate that occurred while oil prices rose in 1974, and seems too large to be consistent with a rigid real wage model.

(2) Excess demand is costly to firms that have an incentive to keep servicing customers and maintain market shares. Thus even if real wages were rigid we would expect to see firms

maintain output at least over the short run, at the expense of lower profits. Indeed from 1978-IV to 1979-II profits (with the inventory valuation adjustment) fell by about 4 percent in nominal terms. (At the same time inventory investment in 1972 dollars rose from $12 Billion to $18 Billion in 1979-II.)

(3) As I mentioned before, if workers and their unions have a low tolerance for long-lasting unemployment, the parameters of the wage equation will change, with the degree of price indexation falling and the responsiveness of money wage growth to employment rising. As a result the constant real wage locus would shift so that the goods market cleared, and any "classical" unemployment would be temporary. It seems to me that this shift would occur relatively quickly in the United States. Unlike the Germans or the Swiss, we cannot send a significant fraction of our unemployed back to Turkey or Italy.

(4) Finally, there are a number of reasons why we might expect an energy price increase to shift aggregate demand significantly, perhaps even as much as it shifts aggregate supply. First, there is evidence (and it is reasonable to expect) that energy and capital are net complements in the short run, so that a higher price of energy will reduce the desired capital stock and, through the stock adjustment effect, cause a drop in investment demand.[3] Second, a growing fraction of our energy is imported from countries with a relatively low propensity to consume. Third, energy price increases in 1979 have resulted in more than proportional increases in the retail prices faced by consumers. (This

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3 - This was probably quite significant in 1974-75, but is likely to be less significant in 1979-80, since the capital stock is still adjusting to the energy price increases that occurred in 1974 and that have been expected to continue to occur over the next decade. Also, in the long run energy and capital are probably net substitutes, and this would reverse the stock adjustment effect and raise investment demand.

is due in large part to regulatory change.) And fourth, price increases in 1979 were accompanied by real and threatened shortages (notably gasoline), which reduced the demand for such things as autos, travel, etc. more than the price increase alone would have.

It therefore seems that the impact of energy price increases on the U.S. economy in 1979-80 can be best represented by Figure 2 or Figure 4a. In either case, the prescription calls for expansionary monetary and fiscal policy, i.e. accommodate the energy price increase and eliminate its impact on employment by increasing demand to the extent necessary.

However, as I mentioned at the beginning of this paper, there is still the question of how quickly to accommodate. This problem is interesting only if there is some kind of dynamic adjustment in the wage-price inflation model, so that after a disturbance the Phillip's curve returns to its original position only slowly. Referring to Figure 6 where the Phillip's curve is shifted vertically upwards by a price shock, and where point A is the pre-shock (socially optimal) trade-off, we can ask whether the old unemployment rate should be maintained so that the return to equilibrium is via path BA, or whether some increased unemployment should be tolerated for a while, with a return to equilibrium through gradual accommodation via path CA.

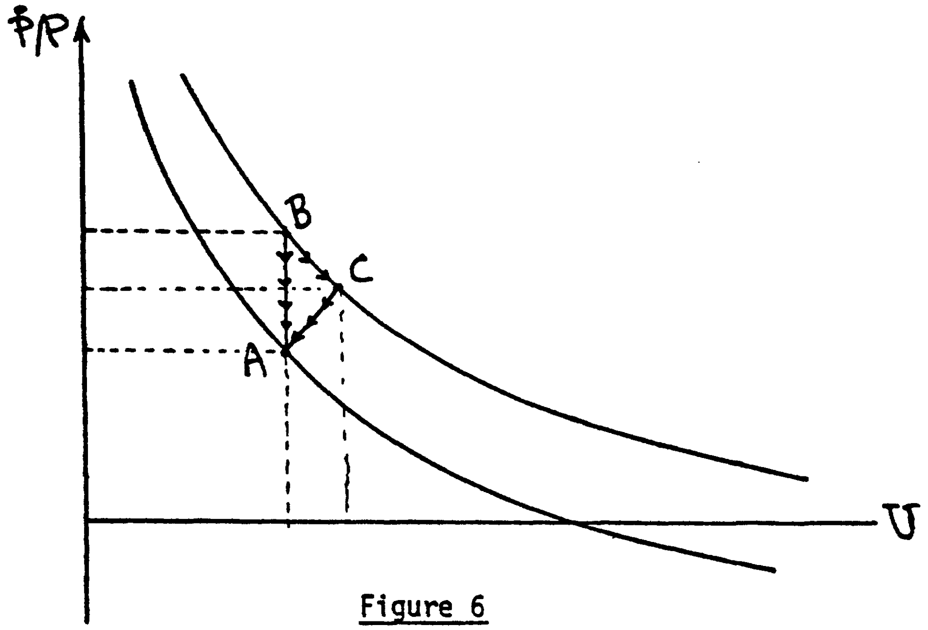

Figure 6

In the Appendix I modify equations (1) and (2) for the Phillip's curve by adding a lag adjustment, and by assuming that the goods market always clears so that $g(y^d/y^s)$ can be replaced by a constant. I then solve the optimal control problem for two different objective functions, and find the optimal unemployment rate path for each.

As one might expect, if the objective function is linear in the rates of inflation and unemployment, path BA in Figure 6 is optimal and accommodation should be complete and instantaneous (since the locus of tangencies with the Phillip's curve in each period must be a vertical line, i.e. constant unemployment). On the other hand, if we minimize a convex function of the rates of inflation and unemployment (I used a quadratic function), accommodation should be gradual (since the locus of tangencies is upwards sloping). In summary, and assuming that the inflation-unemployment trade-off was optimal just before the price shock:

(1) If the objective of policy is to minimize a linear function of inflation and unemployment, then accommodation should be instantaneous and complete. That is, increase aggregate demand to bring the unemployment rate immediately back to its pre-shock value, and keep it there while inflation slowly subsides to its pre-shock rate.

(2) If the objective of policy is to minimize a convex function of inflation and unemployment, then the optimal policy calls for an immediate partial accommodation, but only a gradual full accommodation. In particular, the unemployment rate should be brought part of the way down towards its pre-shock value immediately, but then brought the rest of the way down only gradually as the rate of inflation subsides. The extent of the initial partial accommodation, and the rate of full accommodation will depend on the particular objective function and the speed of recovery for the Phillip's curve.

I should stress again that this result assumes that the goods market always clears. If there is excess supply in the goods market the optimal rate of accommodation is determined by re-inserting the function $g(y^d/y^s)$ in eqn. (1), and relating y to employment through a production function. If there is temporary excess demand it may still be optimal to begin accommodating immediately (even before the market clears), since that will speed up the rate at which the constant real wage locus will shift. In any case, these are problems that still need to be solved.

As far as current economic policy is concerned, I think we can assume (for reasons given earlier) that the goods market clears. Unfortunately I do not know what kind of objective function is most in favor in Washington these days. Based on recent monetary policy, however, I can only surmise that it is not a linear one.

4. Postscript: The Macroeconomic Cost of an Energy Price Increase

I began this paper by saying that my original intention had been to to estimate the direct and indirect macroeconomic costs of an OPEC oil price increase. I therefore feel duty-bound to provide at least a quick and dirty back of the envelope calculation of those costs. I make the calculation for a 10% increase in the average Persion Gulf price of crude oil, I assume no substitution possibilities, but that energy-saving technological change limits the impact on potential GNP to an average of 5 years, and I assume a linear social cost function so that accommodation is complete and instantaneous (and therefore optimal). Finally I assume a value of 0.7 for α_2, the parameter that determines the speed of response of the Phillip's curve. The steps are as follows:

(1) I use the MIT World Oil Model to translate the 10% increase in the Persian Gulf price into corresponding increases in sectoral energy price indices, under the assumption that prices of non-liquid fuels increase by 50% as much as liquid fuels. I find that the aggregate energy price index rises 4.0% in the residential sector, 4.8% in the industrial sector,

5.3% in the transportation sector, and 8.0% in the "remaining use" sector. To aggregate across sectors I weight these figures by consumption shares (23%, 43%, 30%, and 4% respectively), and obtain a 4.9% increase in the overall price of energy.

(2) Energy as a share of GNP is approximately 5%. Assuming no substitution possibilities, we therefore get a 0.25% drop in potential GNP, or about a $6 Billion loss, as a result of the 15% increase in the Persian Gulf price. I carry this over 5 years, discounting at 10%, to get a direct cost of $25 Billion.

(3) In 1974 the price of energy in the U.S. increased by 30% in real terms, and this resulted in about 2½% of added inflation. We might thus expect the 4.9% increase in the real price of energy to add about 0.4% to the rate of inflation in the first year. But this will also result in added inflation in future years. In the Appendix, we show that (with a linear social cost function) an extra 1% of inflation in the first year would imply - in discounted cost terms - an accumulated total of $(1 + \delta)/(1 - \alpha_2 + \delta) = 2.75\%$ of added inflation. For our first-year increases of 0.49% in the rate of inflation, this means the equivalent of 1.1% of total added inflation.

(3) I use Gramlich's survey results for the perceived relative costs of inflation and unemployment. These results indicate that the public perceives 1 extra percentage point of unemployment to be equivalent to between 2 and 4 extra percentage points of inflation. Using the middle of this range, I translate the 1.1% of added inflation into a perceived equivalent cost of 0.37% of added unemployment. Using Okun's Law I get an equivalent loss of 1% of potential GNP, or an indirect cost of $22 Billion. The direct and indirect costs of an energy price increase thus seem to be roughly comparable in magnitude, and much larger than a cost estimate obtained by multiplying the increase in the cost of imported oil by the annual volume of imports.

Appendix - The Optimal Rate of Accommodation

In this Appendix we calculate the optimal unemployment rate trajectories corresponding to two different objective functions, and thereby determine the optimal rate of accommodation to an energy price shock. We base this on the neoclassical model in which the goods market clears and the real wage rate can shift, and on a Phillip's curve that returns to its pre-shock position only slowly.

Since $y^d/y^s = 1$ always, we can re-write eqns. (1) and (2) for the rates of price and wage inflation as:

$$\overline{w}_t = a_o + a_1 U_{t-1}^{-1} + a_2 \overline{P}_{t-1} \qquad \text{(A.1)}$$

$$\overline{P}_t = a_3 + a_4 \overline{w}_t + a_5 \overline{p}_{e,t} \qquad \text{(A.2)}$$

where a bar indicates a percentage rate of change, U is the unemployment rate, and a_2, a_4, and a_5 are all less than 1. Now combine these two to obtain the Phillip's curve equation, which we write in differenced form:

$$\overline{P}_{t+1} - \overline{P}_t = (\alpha_2 - 1)\, \overline{P}_t + \alpha_o + \alpha_1 U_t^{-1} + \alpha_3 P_{e,t+1} \qquad \text{(A.3)}$$

where $\alpha_o = a_3 + a_o a_4$, $\alpha_1 = a_1\, a_4$, $\alpha_2 = a_2\, a_4$, and $\alpha_3 = a_5$.

We now minimize two social cost functions subject to eqn. (A.3), the first of which is linear:

$$\underset{U_t}{\text{Min}}\ C_1 = \sum_{t=0}^{\infty} \frac{1}{(1+\delta)^t} [\overline{P}_t + bU_t], \qquad \text{(A.4)}$$

and the second is quadratic:

$$\underset{U_t}{\text{Min}}\ C_2 = \sum_{t=0}^{\infty} \frac{1}{(1+\delta)^t} [\overline{P}_t^2 + bU_t^2] \qquad \text{(A.5)}$$

In the first case the Hamiltonian is

$$H = \frac{1}{(1 + \delta)^t} [\overline{P}_t + bU_t] + \lambda_{t+1} [(\alpha_2 - 1)\overline{P}_t + \alpha_o + \alpha_1 U_t^{-1} + \alpha_3 p_{e,t+1}] \tag{A.6}$$

Minimizing H with respect to U_t gives:

$$U_t^* = [(\alpha_1/b)(1 + \delta)^t \lambda_{t+1}]^{1/2} , \tag{A.7}$$

and the dynamics of the co-state variable is given by

$$\lambda_{t+1} - \lambda_t = -\partial H/\partial \overline{P}_t = (1 - \alpha_2)\lambda_{t+1} - \frac{1}{(1 + \delta)^t} \tag{A.8}$$

It is convenient to introduce $\mu_t = (1 + \delta)^t \lambda_t$, i.e. μ_t is the undiscounted increase in the cost-to-go from an extra 1 percent of inflation lasting 1 period. Then

$$\lambda_{t+1} - \lambda_t = \Delta\lambda = \frac{\Delta\mu}{(1 + \delta)^t} - \frac{\delta\mu_{t+1}}{(1 + \delta)^{t+1}} , \tag{A.9}$$

and eqns. (A.7) and (A.8) can be replaced by:

$$U_t^* = \left[\frac{\alpha_1 \mu_{t+1}}{b(1 + \delta)}\right]^{1/2} \tag{A.10}$$

and

$$\Delta\mu = \frac{1 - \alpha_2 + \delta}{\alpha_2} \mu_t - (1 + \delta)/\alpha_2 \tag{A.11}$$

We can determine the optimal trajectories for $\overline{P}_t$ and μ_t from eqns. (A.3) and (A.11). As can be seen from the phase diagram in Figure A1, the optimal μ_t is constant (and as expected larger whan α_2 is larger so that the speed of adjustment of the Phillip's curve is slower). Thus from (A.10) we know that the optimal

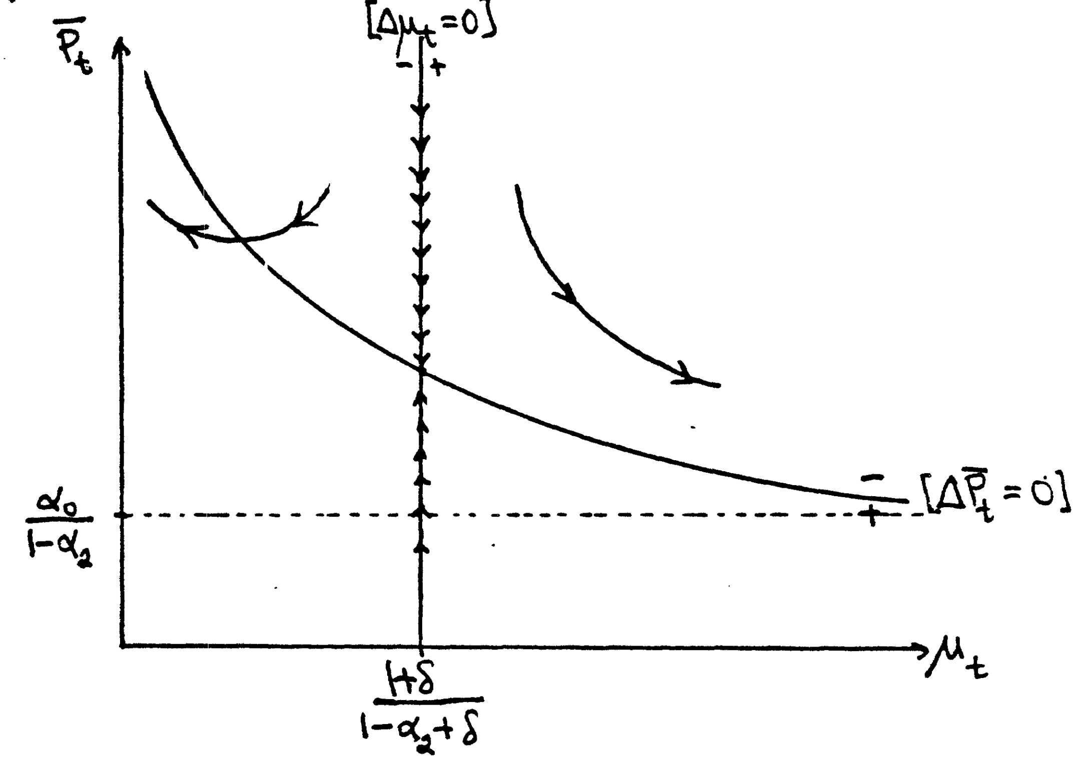

Figure A1 - Linear Cost Function

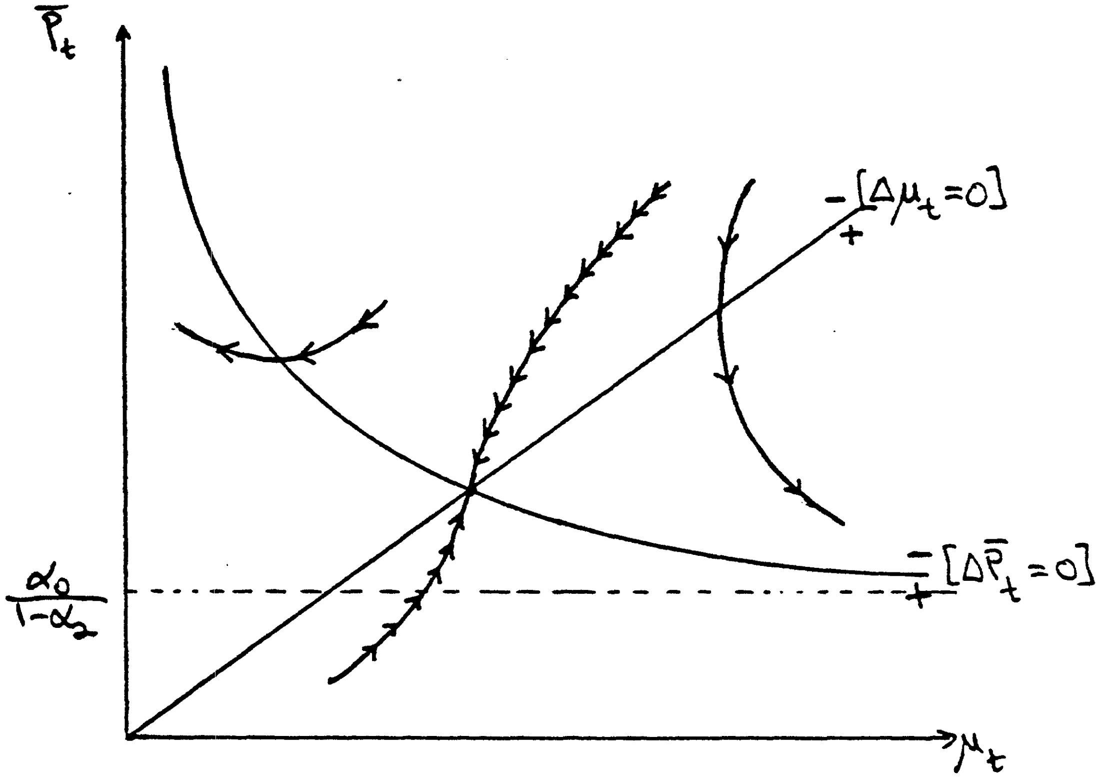

Figure A2 - Quadratic Cost Function

unemployment rate is constant, so that the optimal policy is to immediately bring the unemployment rate back to its pre-shock value and keep it at that value.

If the social cost function is instead quadratic as in (A.5), then the solution of the optimal control problem yields the following for U_t^* and μ_t:

$$U_t^* = \left[\frac{\alpha_1 \mu_{t+1}}{2b(1 + \delta)}\right]^{1/3} \tag{A.12}$$

and $$\Delta\mu = \frac{1 - \alpha_2 + \delta}{\alpha_2} \mu_t - 2(1 + \delta)\overline{P}_t/\alpha_2 \tag{A.13}$$

as can be seen from the phase diagram in Figure A2, the optimal μ_t is now falling over time, so that U_t^* is also falling. Furthermore the slope of the $[\Delta\mu = 0]$ isocline is $(1 - \alpha_2 + \delta)/2(1 + \delta)$, so that if α_2 is larger (and the rate of recovery of the Phillip's curve slower), U_t^* will fall from a larger initial value, and, as can be seen from (A.13), will fall more slowly. The optimal policy is therefore an immediate partial accommodation (since the optimal $\overline{P}_t$ is falling, so that some additional inflation is acceptable in return for an initially lower unemployment rate), and then a gradual reduction in unemployment to its pre-shock value as the rate of inflation subsides to its pre-shock rate.

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Economic Performance and Energy Policy Strategy:
Cornerstones and Corner Solutions

Richard J. Goettle IV
Dale W. Jorgenson Associates
P.O. Box 276
Cambridge, Massachusetts 02138

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I. INTRODUCTION

Recent developments affecting the price, availability, and safety of conventional energy supplies have provided anew the motivation for a strategic review of domestic energy policy and the opportunity to define and clarify the future direction of that policy. By design and formulation, the Strategic Cost-Benefit Analysis of Energy Policies is intended to serve informationally this process of evaluation. Specifically, the study defines available directions for future energy policy and compares and evaluates each in terms of its energy, economic, and environmental consequences.

Three major strategies are considered as possible directions for future energy policy. The first is to introduce no new policies beyond those presently in effect. Operationally, this strategy is represented by a policy that presumes the implementation of only those policies currently enacted or currently announced and under direct control of the Executive Branch. The second strategy involves a redirection of policy toward demand reduction, i.e., energy conservation. The policy equivalent of this strategy is provided by a set of conservation initiatives, constructed by the Office of Assistant Secretary of Conservation and Solar Applications (CSA), that are proposed for introduction beginning in FY 1981. The third strategic option is to promote increased domestic supply, primarily through an accelerated commercial development of the so-called synthetic and unconventional fuels. This policy direction is analyzed in terms of the development program that was proposed by President Carter on 15 July 1979.

The consequences of these policy alternatives are examined for the period 1980 to 2000 using the combined Brookhaven National Laboratory/Dale W. Jorgenson Associates (BNL/DJA) energy-economy model system (TESOM-LITM). The DJA economic model (LITM) depicts production and spending throughout the economy within a flexible interindustry framework. The model provides for substitutions in the final spending on the goods and services that comprise the Gross National Product. Further, it permits substitutions among the capital, labor, energy, and materials inputs into the production of these goods and services. The BNL component of the system (TESOM) is a technological model of energy extraction, conversion, and end use. It represents the economic, technical, and environmental characteristics of the future substitution possibilities among new and conventional energy technologies and energy sources. The combined models give a comprehensive long-run representation of the nation's energy and economic systems, energy-economy interactions, and the environmental consequences of these. Using this integrated system, the method of analysis is, first, to project developments under the no new policy strategy and, then, to perform alternate projections corresponding to each of the more active policies. The three cases then are compared to estimate:

- the relative merits of the strategies as measured by national energy security objectives;
- the costs imposed on (or, benefits realized by) the U.S. economy for each strategy;
- the environmental consequences arising from the energy system under each strategy.

Focusing on the economic results, the purpose of this paper is to report the major findings of this comparison and, from these, develop implications for the future direction of national energy policy.

II. ASSUMPTIONS AND METHODOLOGY

A. The Reference Projection

The LITM economic model requires input assumptions on future population, government expenditure and revenue policies, and the unemployment rate. The Census Bureau's Series II population projections (fertility rate of 2.1) were used to derive figures on the future population. Labor force participation rates are endogenous to the model and are not specified as assumptions. The unemployment rate is assumed to follow a cyclical rate from 6.0% in 1978 to 5.6% in 1985 and then to decline slightly over the rest of the forecast period. Government purchases increase slightly relative to the rest of the economy (from 19.4% of real GNP in 1980 to 19.9% by 2000) reflecting current trends of government programs including new developments in the health, services, energy, and defense areas. Government transfers and tax revenues rise approximately in line with the economy as a whole. Most of the productivity effects in the model are endogenous and are not specified as assumptions, while the energy supply and productivity information is obtained from the TESOM model.

The reference projection incorporates a variety of energy system assumptions: prices and availabilities of energy resources; capital and operating costs for electricity generation, synthetic fuel production, and end-use devices; market penetration rates for new energy technologies; and changes in efficiencies of fuel conversion over the 1980 to 2000 time horizon. The energy assumptions include the impacts of policy initiatives or actions already legislated or already announced and under control of the Executive Branch. In particular, the oil import quotas announced by President Carter in his energy initiatives speech of 15 July 1979 are incorporated. These quotas require that future, annual levels of oil imports never exceed the 1977 level, and that they be reduced to one-half the 1977 level by the year 1990.

Domestic pricing assumptions are based on the phased decontrol of domestic oil prices by the year 1981. A windfall profits tax (proposed, but not enacted) is not included. The NEP II High Price Trajectory (U.S. Department of Energy. National Energy Plan II. Washington, D.C.: May 1979) is assumed for world oil prices. This has the world oil price rising at an average annual rate of 3.3 percent, from $20 per barrel in 1980 to $38 by the year 2000 (in constant 1978 dollars). Domestic natural gas prices are assumed to be deregulated by 1985 and then to increase rapidly, approaching the crude oil price; this takes the price of $0.99 per million Btu in 1980 to $5.50 by the year 2000.

Domestic oil and gas production possibilities are determined by applying a Hubbert Curve analysis to the U.S.G.S. mean geology estimates of 1 January 1978. Nuclear electric generating capacity is assumed to reach 155 gigawatts during the 1985 to 1990 period, and increase to a range of 225 to 240 gigawatts by the year 2000.

A set of measures of environmental effects is generated from each TESOM solution using emission and conversion factors associated with each activity. The impacts measured include air contaminants, water contaminants, solid waste materials, and items such as radiation exposure levels, and occupational injuries. The emission and conversion factors assume that best available control technologies are used in each process in the system, and that the effectiveness of these control technologies does not change over time.

The BNL/TESOM and DJA/LITM models are coupled so that in each year there is a consistency between the energy and economic information obtainable from each model. This coupling is achieved through an iterative process in which the principal points of interaction are:

- the economic activities of each sector and the aggregate energy inputs to the producing sectors, household sectors, and other final demands;
- The relationship between the aggregate energy inputs to the producing and consuming sectors and the levels of the nonsubstitutable, functional energy services;
- The details of energy prices, technology production functions, quantities, imports, and the levels of new and conventional energy technologies;
- The relationship among the energy sector details, aggregate energy and nonenergy input substitutions, product substitutions and compositional changes in final demand and the growth of the economy from both demand and supply points of view.

The two models interface at the point of energy demand, with LITM linking aggregate energy demand to the general economy and with TESOM linking primary resources to energy demand. The linked system extends the coverage and applicability of each model and provides a framework for the consistent analysis of the role of energy technologies, energy supply and conversion and their environmental consequences, energy-economy interactions, and economic effects.

The model coupling operates through several stages. Initially, average supply price indices are projected using, as weights, the energy quantities from a previous BNL/DJA reference projection. The price changes from the reference projection are related to price-quantity elasticities of demand to yield initial estimates of primary energy consumption and, through average system efficiencies, the corresponding levels of energy service demands. These elasticities summarize the equilibrated degree of responsiveness of energy quantity changes to energy price changes from previous solutions of the combined system. TESOM is then solved, constrained by the supply, import, and conversion limitations and subject to the satisfaction of these initially determined levels of energy services.

The solution values of energy prices, and quantities technology production functions, energy imports, and the levels of new energy technologies from TESOM are entered into the LITM model which is solved to yield estimates of the level and composition of production and spending throughout the economy. Economic sector outputs and the energy input per unit of output are transformed into a restructured set of demands for energy services in physical units. This mapping occurs through a "reduced form" version of the BNL/University of Illinois Input-Output Model. Mathematically, these adjustments to the level and structure of energy service demands are determined by accounting for changes in service levels due to changes in the level and structure of economic activity and changes in the energy requirements per dollar of output or consumption for each sector. These account for the substitution of nonenergy inputs in production and consumption.

The final adjustment in the mapping process accounts for changes in demand levels resulting from efficiency improvements for each service category. The resultant vector of energy service demands changes in energy prices, the level and composition of economic activity, energy and nonenergy inputs in production, and energy system efficiencies. These energy demands are inserted into TESOM and produce a new simulation of the configuration of the energy system. This iterative procedure continues until consistency between the energy and economic systems in the two models is attained.

B. The Conservation Projection

Beginning with Fiscal Year 1981, the conservation policy represents the programmatic and induced, i.e., private sector, expenditures and the associated energy savings of the combined Minimum and Current programs of the Office of Assistant Secretary for Conservation and Solar Applications (CSA). The expenditure and energy information is provided by the Consolidated Ranking of FY 1980 Decision Packages and supporting materials that were prepared by CSA personnel. The incremental energy savings reported for these programs are solely attributable to the post-FY 1980 levels of effort, irrespective of their continuing nature. Thus, the introduction of this policy into the reference projection affords the direct determination of the energy, economic, and environmental consequences of the demand reduction strategy.

The conservation policy, as described in the CSA materials, incorporates subprograms into major program areas as follows:

- Buildings and Community Systems
- Transportation
- Industrial
- State and Local Programs
- Appropriate Technology

The supporting documentation for the conservation policy contains information for each subprogram as to the direct benefits and costs of the particular initiative. The direct policy benefits are represented by the levels of annual energy savings (1985, 1990, and 2000); the direct costs are reflected in the cumulative public and private expenditures, discounted to the present (FY 1981), that are required to achieve the ultimate levels of energy savings.

The energy displacements induced by the CSA programs are introduced directly into the reference projection. These energy reductions permit the annual release of those resources associated with the production and/or importation of petroleum, natural gas, and electricity. However, these benefits are not costless. They result from a temporally phased diversion of productive resources, public and private alike, into those activities implied for each of the conservation initiatives. The annual benefits from conservation policy are measured against the annual claims on the inputs available to the economy. These claims are implicit in the CSA discounted expenditure information and are represented by a reallocation of capital and labor services from other productive uses to energy conservation activities.

The total cost information for each subprogram, shown in Table 1, results from the discounting of an annual series of expenditures. In order to determine the capital and labor services claims due to this policy, it is necessary to:

- develop the annual expenditures series for each subprogram;
- allocate annual expenditures between investment purchases and labor services expenditures;
- convert the investment expenditures series into a capital services series.

Rules that are specific to each subprogram are required for converting the total discounted costs into an undiscounted expenditure stream. Three types of distribution mechanisms are used to annualize and undiscount the total cost. These are denoted the uniform, constant rate of growth, and trapezoidal distribution patterns. They are depicted graphically with their parameter requirements in Figure 1.

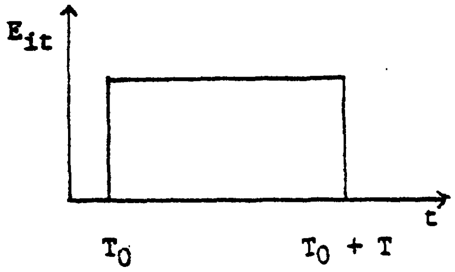
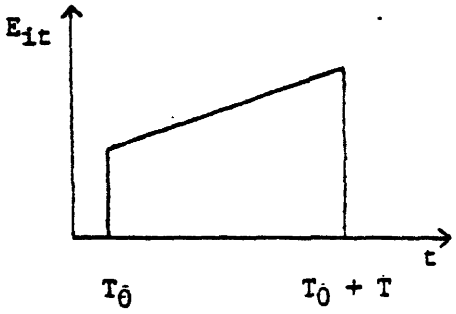
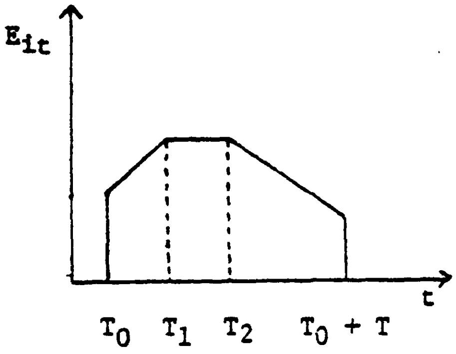
TABLE 1

Total Discounted Costs: Conservation Policy

Program	Discounted Public and Private Cost (Millions of 1972 Dollars)	
Buildings/Community Systems		55857
Buildings Systems	20271	
Appliance Standards	5619	
Community Systems	5152	
Urban Waste	6264	
Technology and Consumer Products	4401	
Analysis and Technology Transfer	6343	
Residential Conservation Service	2711	
FEMP	4453	
Small Business	643	
Transportation		40074
Vehicle Propulsion RD&D	13681	
Electric Vehicle RD&D	3940	
Transportation System Utilization	4495	
Alternative Fuels Utilization	17958	
Industrial		14798
Waste Energy Reduction	5299	
Industrial Cogeneration	6243	
Industrial Process Efficiency	3253	
Implementation and Deployment	3	
State and Local		471
Schools and Hospitals	6	
Local Government Buildings	0.1	
Weatherization Assistance	409	
EMPA	56	
Appropriate Technology		4554
Small Scale Technology	4554	

FIGURE 1

Types of Distribution Mechanisms for Determining Annual Undiscounted Expenditures (E_{it}) from Total Discounted Costs

Distribution Type	Shape	Parameters
Uniform		T_0 = Initial Year of Expenditures, usually 1981 $T_0 + T$ = Terminal Year of Expenditures T = Duration of Subprogram
Constant Rate of Growth		g = Annual Rate of Growth of Expenditures T_0, $T_0 + T$, and T as above
Trapezoidal		g = Annual Rate of Growth of Expenditures, Year T_0 to Year T_1 d = Annual Rate of Decline of Expenditures, Year T_2 to Year $T_0 + T$ T_1 = Terminal Year of Expenditure Growth T_2 = Terminal Year of Constant Annual Expenditure T_0, $T_0 + T$, and T as above

The uniform distribution is chosen for subprograms in which all costs are incurred in the first year, e.g., EMPA, and those that require a series of constant annual expenditures for some number of years, e.g., Weatherization Assistance. The costs for these subprograms have virtually no private sector content and, hence, the uniform distribution conforms closely to the public outlay patterns reported in the CSA documentation.

In subprograms where initial R, D, and D costs are followed by costs that grow in proportion to annual energy savings, a constant rate of growth distribution is the appropriate rule. These subprograms are characterized by initial outlays that lead, relatively quickly, to commercially successful end-use technologies promoting energy efficiency or fuel switching. From this, additional energy savings are obtained only by increasing the penetrations and, consequently, the purchases of these products. Examples of these subprograms include Appliance Standards, Technology and Consumer Products, and Alternative Fuels Utilization. The growth parameters for these distributions are determined from the growth of energy savings over the period 1980-2000 with an allowance for economies of scale, i.e., the diminution of cost per million Btu, resulting from increased market penetrations.

The trapezoidal distribution is selected for subprograms that initially require increasing R, D, and D expenditures which level off for some length of time as the product or service provided by the program increases its penetration or effectiveness, or nears commercialization. These periods are followed by a period of decreasing unit costs resulting from the influences of increased market penetration and information diffusion. In essence, this distribution mechanism is applicable to subprograms for which the most likely expenditures pattern is concentrated toward the earlier years. Thus, the realization of the direct net benefits that accompany increased market penetration in the longer run is conditional on the incurrence of direct net costs for the nearer term.

The annual expenditures associated with each subprogram next are divided into investment and labor services purchases in accordance with the type of expenditure implied by the success of that subprogram. For example, the commercial successes of the Vehicle Propulsion R, D, and D and Alternative Fuels Utilization subprograms imply that incremental conservation expenditures are directed toward purchases from industries not unlike motor vehicles and petroleum refining, respectively. Similarly, efficiency improvements induced by the Appliance Standards and Technology and Consumer Products subprograms result in incremental purchases, in part, from the household appliances industry. Thus, the allocation between investment and labor is determined from the corresponding expenditure shares of the total sectoral output most closely resembling the purchases implied for a successful CSA program. The information for this allocation is provided by "The Input-Output Structure of the U.S. Economy, 1972" as reported in the February, 1979 Survey of Current Business.

Finally, the stream of annual investment expenditures for each subprogram is converted into a capital services series that reflects the permanency of the services available from the undepreciated capital stock.

The resulting series for capital and labor services represent the annual resource claims, i.e., the direct policy costs, associated with the annual energy savings provided by each of the CSA initiatives. For the years 1990 and 2000, summaries of the costs and energy savings are provided, by major program area, in Table 2.

The introduction of the conservation policy into the reference projection from the BNL/DJA model system is accomplished in two stages. The first establishes the initial conditions for the projection by accounting for reductions in energy use, releases of real resources originally devoted to energy production in absence of conservation, and claims on total available resources associated with conservation activities. In the second stage, the model system is iterated as usual.

In the BNL energy model, conservation is represented as a new source of the delivered energy required to satisfy particular end uses, e.g., space heat, process heat, motive power, etc. Conservation in the CSA documentation is specified as primary energy savings in the residential, commercial, industrial, and transportation sectors. The primary energy savings in each program area are allocated to specific end uses in accordance with the relative importance of the end use in the consuming sector to which the conservation subprograms are directed. Then, for each end use, the delivered energy inputs in the reference projection are converted to their primary energy equivalents and an average conversion efficiency (delivered Btu per Btu of primary energy) is determined. This, when multiplied by the primary energy savings in each end-use category, determines the delivered energy savings resulting from conservation activities. For each end-use demand, a constraint is introduced into the energy model. These restrict total delivered

TABLE 2

Annual Costs and Energy Savings: Conservation Policy

		Annual Resource Claims (Costs) (Millions of 1972 Dollars)			Energy Savings (Quadrillion Btu)
Year	Major Program	Capital	Labor	Total	
1990	Buildings/Community Systems	2506	5078	7584	5.600
	Transportation	971	3001	3972	1.894
	Industrial	645	1319	1964	2.520
	State and Local	12	0	12	0.005
	Appropriate Technology	247	392	639	0.250
	TOTAL	4381	9790	14171	10.269
2000	Buildings/Community Systems	3216	2884	6100	10.000
	Transportation	4457	12074	16531	7.372
	Industrial	634	460	1094	4.250
	State and Local	5	0	5	0.005
	Appropriate Technology	283	152	435	0.630
	TOTAL	8595	15570	24165	22.257

energy inputs to a particular end use to be no greater than the total from the reference projection less the delivered energy savings as determined above. The energy model then is solved. In the solution, the excess of end-use demand over the sum of delivered energy inputs times their respective end-use device efficiencies is the amount of conservation expressed as delivered energy equivalent. In subsequent iterations of the energy model the conservation amounts determined by this procedure are fixed and the constraints on total delivered energy to each end-use are removed. In this manner, the energy benefits from conservation policy are maintained in the solution in isolation from other energy changes.

A comparison of the reference projection with the initial solution from above provides information on the amounts of refined petroleum, natural gas, and electricity that are displaced as a result of conservation policy. When valued at their respective prices, these displacements represent the direct economic benefits of energy conservation against which the direct policy costs are measured. The new energy solution is incorporated into the DJA economic model sequentially with the net direct claims on capital and labor services. The net direct claims are determined as the differences between capital and labor claims induced by the conservation policy and those resources released through energy displacements.

From this point, the usual solution process for the combined model system is followed. The economic solution contains information on the new level and pattern of production and spending throughout the economy. Adjustments to the level and structure of energy service demands are determined by accounting for energy changes due to changes in the level and structure of economic activity and the substitution of nonenergy inputs into production and consumption. The resultant vector of end-use demands is inserted into the energy model producing a new configuration of the energy system. The solution values of energy prices and quantities, energy imports, and the output levels and input structures for new energy technologies are entered into the economic model. This iterative procedure continues until consistency between the energy and economic systems in the two models is achieved.

C. The Synfuels Projection

The synfuels policy is represented by the program that was proposed by President Carter on 15 July 1979. This program provides for the accelerated commercial development of synthetic and unconventional fuels. The policy objective is stated as an incremental production target of 2.5 million barrels (crude oil equivalent) daily from these technologies by the year 1990. The allocation of this increment, in millions of barrels per day (mmbd), is: coal liquefaction and coal methanol, 1.25 mmbd; high-Btu coal gas, 0.25 mmbd; shale oil, 0.40 mmbd; biomass, 0.10 mmbd; unconventional gas, 0.50 mmbd. Reflecting this acceleration, growth in the output of these fuels is projected to continue over the post-1990 period. This growth occurs at a more moderate rate than that in the reference projection, though it originates from a significantly higher 1990 base. The annual, incremental costs and production amounts for the synfuels policy are presented in Table 3.

The synfuels policy is introduced into the reference projection in the following manner. Constraints, establishing minimum production levels for the outputs of the synfuels technologies, are incorporated into the TESOM model. In effect, these override the competitive behavior of synfuels as evidenced in the market penetrations of the reference projection and determined by the TESOM solution algorithm. From here, the combined model system is iterated as usual. The solution values of energy prices and quantities, energy imports, and the output levels and input structures for new energy technologies are introduced into the economic model. LITM, then, is solved to yield information on the new level and pattern of production and spending throughout the economy. Adjustments to the level and structure of energy service demands are determined by accounting for energy

TABLE 3

Annual, Incremental Costs and Energy Production: Synfuels Policy

Year	Technology	Annual, Incremental Cost (Billions of 1972 Dollars)	Incremental Production (Quadrillion Btu)
1990	Coal Liquids/Methanol	7.4	2.3
	High-Btu Coal Gas	1.3	0.5
	Shale Oil	3.2	0.8
	Biomass	0.6	0.2
	Unconventional Gas	4.2	1.1
	TOTAL	16.7	4.9
2000	Coal Liquids/Methanol	16.6	4.5
	High-Btu Coal Gas	2.7	0.9
	Shale Oil	11.1	2.1
	Biomass	0.8	0.2
	Unconventional Gas	5.8	1.1
	TOTAL	37.0	8.8

changes due to changes in the input and output compositions of production and consumption, i.e., the level and structure of economic activity. The adjusted vector of end-use energy demands is inserted into TESOM which, when solved, provides another reconfiguration of the energy system under the synfuels policy. This iterative process continues until the sequence of energy-economy interactions indicates that consistency between the systems is attained.

III. THE ECONOMIC EFFECTS OF ALTERNATIVE ENERGY POLICIES

Introducing policies to encourage the curtailment of the growth in energy demand or to promote the accelerated expansion of domestic energy supply has a significant effect on the growth and structure of the nation's economy. In general, the conservation policy is economically superior to the synfuels policy in achieving energy reductions consistent with national objectives. However, from the perspective of the reference projection, there is an economic cost that results from the introduction of either of the more active policies.

Comparative final output and productivity measures for the policy alternatives are shown in Table 4. Through 1990, real GNP is lower than that for the reference projection under both the conservation and the synfuels policies. In the case of conservation, the \$(1972) 2.2 bn reduction in economic activity is the net consequence of equilibrated supply and demand responses to changes in spending and production patterns throughout the economy. The conservation programs, to be successful, require significant commitments of the capital and labor resources available within the economy. These additional claims are measured against the release of resources permitted by conservation, i.e., reductions in the required levels of energy production. To the extent that resource claims exceed releases, additional resources must be diverted from other productive uses because of their strictly limited availabilities. This reallocation is not costless in terms of economic efficiency. Thus, in 1990, the small net diversion of available resources to conservation activities leads to a 0.1 percent decline in real GNP.

For the synfuels policy, the causes of the \$(1972) 12.4 bn reduction in the 1990 level of real GNP are similar. Expanding domestic supply by means of synthetic and unconventional fuels requires the deployment of tech-

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TABLE 4

Output and Productivity

	Reference	Conservation	Synfuels
1990			
Real GNP	1901.3	1899.1	1888.9
Real GNP Per Capita	7.808	7.799	7.757
Gross Labor Productivity	16.885	16.881	16.805
2000			
Real GNP	2469.3	2473.7	2413.3
Real GNP Per Capita	9.483	9.500	9.268
Gross Labor Productivity	19.834	19.869	19.462

Average Annual Growth Rates

	Reference	Conservation	Synfuels
1980-1990			
Real GNP	2.98	2.97	2.92
Real GNP Per Capita	2.04	2.03	1.98
Gross Labor Productivity	1.54	1.54	1.49
1990-2000			
Real GNP	2.65	2.68	2.48
Real GNP Per Capita	1.96	1.99	1.80
Gross Labor Productivity	1.62	1.64	1.48

Units: Real GNP in $(1972) billion;
Real GNP Per Capita in $(1972) thousand/person
Gross Labor Productivity in $(1972) thousand/person

nologies that provide energy at a cost not yet competitive with the energy from the conventional sources they displace. As there is a substantial drain on the resources available for other productive activities, the synfuels policy imposes a significant cost in terms of income and production foregone. This cost is greater than that caused by the conservation policy and, consequently, has a more permanent effect on future economic performance.

By the year 2000, the synfuels policy has resulted in additional penalties to economic growth. Even though the synfuels technologies have become increasingly more competitive with conventional energy supplies, their accelerated commercial application has had a cumulative, adverse impact of sufficient magnitude to preclude economic recovery. In 2000, the level of real GNP under the synfuels policy is 2.3 percent or $(1972) 56.0 bn below that in the reference projection.

However, the conservation policy provides net economic benefits in this period. Here, the total resource claims of the conservation activities are more than equally compensated by the benefits of energy displacements and reduced energy production. The gains in economic efficiency from providing lower cost energy through conservation permit an increase in net output. That is, real GNP is increased to $(1972) 2473.7 bn, 0.2 percent above the reference case level.

With annual rates of labor force expansion approximately equal for the three cases, the macroeconomic impacts of the alternative policies translate directly into productivity effects. For the period 1980 to 1990, the rates of advance in gross labor productivity for the reference and conservation projections are almost identical. Moreover, they lie above the rate determined for the economy under the synfuels policy. To the end of the century, the productivity advance associated with conservation dominates those of the other cases.

The implications for the aggregate economic efficiency of energy use under these policies are of sufficient clarity to warrant little elaboration. The energy-GNP ratio and its components are shown in Table 5. Conservation provides a dramatic acceleration of the gains realized for this measure over the projection horizon. Conversely, the synfuels policy slows the rate of improvement relative to the reference case. For conservation, the annual rate of decline in the energy-GNP ratio is 2.4 percent for the period 1980 to 1990 and 2.5 percent to the year 2000. These are slightly more and less than double the rates of improvement observed for the synfuels and reference projections, respectively.

The changes in the pattern of economic growth are illustrated further by the division of total final output into consumption and investment purchases. These are presented in Table 6. In 1990, consumption absorbs 89.0 percent of the decline in real GNP under the synfuels policy. Investment accounts for the remaining 11.0 percent of the GNP decline. In 2000 under this policy, the fractions of the total decline in real economic activity attributable to consumption and investment are 85.0 and 15.0 percent, respectively. In these situations, the losses in overall economic efficiency due to the synfuels policy reduce the net output and corresponding incomes that are achievable within the economy. In the static sense, investment, as a component of aggregate demand, is reduced because of the reduction in real income and the associated decline in saving. In each year that investment falls, there is a corresponding reduction in the available stock. Over time, the slower growth of capital stock slows the growth of the productive potential of the economy and, so, reduces the incentive for saving and investment, i.e., the prospective rate of return to capital. In the earlier years, the expenditure reductions are concentrated

TABLE 5

ENERGY AND ECONOMIC GROWTH

Year	Policy	Real GNP (Billions of 1972 Dollars)	Primary Energy (Quadrillion Btu)	Energy-GNP Ratio (Thousand Btu per 1972 Dollar)
1990	Reference	1901.3	96.9	51.0
	Conservation	1899.1	86.6	45.6
	Synfuels	1888.9	98.9	52.4
2000	Reference	2469.3	109.5	44.3
	Conservation	2473.7	87.2	35.3
	Synfuels	2813.3	112.4	46.6

TABLE 6

Economic Output and Expenditure

		Reference	Conservation	Synfuels
Real GNP Components (Billions of 1972 Dollars)				
1990	Consumption	1235.2	1233.1	1224.2
	Investment	283.7	283.6	282.3
	GNP	1901.3	1899.1	1888.9
2000	Consumption	1605.6	1607.7	1557.8
	Investment	368.0	370.3	359.8
	GNP	2469.3	2473.7	2413.3
Composition of Real GNP (Percent)				
1990	Consumption	65.0	64.9	64.8
	Investment	14.9	14.9	14.9
	GNP	100.0	100.0	100.0
2000	Consumption	65.0	65.0	64.6
	Investment	14.9	15.0	14.9
	GNP	100.0	100.0	100.0

on consumption rather than investment, since the price impacts of the synfuels policy primarily affect consumption and as there is a partially offsetting boost to investment due to the capital requirements of these technologies. Later, however, the situation is altered. The proportionate decline in investment increases under the dynamic influences of the saving and rate of return effects. The consequent slowing of capital growth accentuates the reductions in real GNP due to the efficiency effects.

For the conservation case, there is again evidence that the burden of economic losses falls relatively more heavily on consumption. Under the conservation policy in 1990, consumption absorbs 95.0 percent of the decline in real GNP with investment accounting for the remainder. However, in the nineties, the economy realizes efficiency gains from this policy, so that economic growth over the final decade of the century is slightly higher than that in the reference case. The recovery, relative to 1990 and the reference projection, results from the excess of direct policy benefits over the policy costs. This excess permits the increase in net output and, since capital formation is one of the main stimulants promoting the increase, investment necessarily grows in a manner consistent with the expansion in real GNP.

In comparing macroeconomic performance among the alternative projections, two of the three possible policy comparisons are straightforward. Over the entire projection horizon, real GNP is higher under the conservation and reference case policies than it is with the implementation of the synfuels programs. The synfuels policy clearly imposes an economic cost in terms of income and production foregone. Not so obvious, however, is whether the conservation policy shows overall net economic costs or benefits in comparison to the reference projection. Therefore, it becomes useful to develop a measure that represents the policy costs or benefits throughout the entire period 1980 to 2000.

For any two policy cases, a common measure for such representations is provided by the present value of the differences between indicators of economic performance. Computationally, this value accumulates annual differences in economic variables where these are discounted to a near-term reference period through weights that reflect a social rate of time preference. At a zero social rate of discount, the present value simply measures the total cumulative differences. For positive discount rates, the differences occurring in earlier periods are weighted more heavily than those in later ones. Thus, at selected discount rates, the present value formulation permits the determination of overall net policy benefits or costs.

Applying the present value formulation to differences in real GNP yields the results shown in Table 7. These figures support the conclusion that the policies underlying the reference and conservation cases are more beneficial economically than those for the synfuels projection. However, at reasonable social rates of discount, the conservation policy also involves an economic cost when viewed from the perspective of the reference projection. Only at extremely low discount rates does the conservation policy produce net economic benefits.

The national income accounts give another basis for measuring economic performance that is, perhaps, a better indicator of economic welfare than is real GNP. This measure is the sum of real personal consumption and government purchases or real private and public consumption. This indicator reflects the volume of goods and services that society extracts from the economy for its current use. As the benefit from investment is future consumption and since this is included in the measure of economic performance, investment is excluded. Its purpose is to provide output in the future, rather than to sustain current use. On the other hand, real personal consumption is a direct

TABLE 7

The Discounted Net Benefits of Alternative Energy Policies: GNP Effects*

(Billions of 1972 Dollars)

Cases	Social Discount Rate		
	0%	5%	10%
Reference vs. Conservation	0.4	-3.7	-4.3
Reference vs. Synfuels	-410.0	-200.7	-106.7
Synfuels vs. Conservation	410.4	197.0	102.4

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* Determined as changes between cases in the present value of real GNP.

use of output for the satisfaction of individual preferences. Government purchases are a similar use of output except that preferences are revealed through the political process and are satisfied collectively.

The information in Table 8 was determined by applying the present value formulation to the differences in real public and private consumption between the policy cases. The results here are more decisive; neither of the more active policies is costless when compared to the reference projection. Under this criterion alone, the conservation policy again is preferred to the synfuels programs, but the policies of the reference projection are preferable to both.

The policies also differ in their impact on the sectoral patterns of final spending and, hence, the output mix of the economy. Table 9 summarizes the sectoral composition of aggregate demand expenditures for the policy alternatives. The most noticeable feature of this is energy's share of final spending. Conservation both promotes and permits traditional energy expenditures to be redirected toward spending on nonenergy goods and services. These are concentrated, for the most part, on additional purchases from the manufacturing and trade and services sectors. Thus, relative to the structures of final demand for the other projections, energy's share is the smallest and the shares of manufacturing and trade and services are the largest under the conservation policy. The synfuels policy, however, substitutes energy from high cost technologies for that available from lower cost, conventional sources. The absolute and relative importance of energy in final demand spending is, therefore, larger for this projection. The imposition of more expensive energy requires a redirection of expenditures on nonenergy goods and services toward energy purchases; this is diametric to the impact of the conservation policy.

The mix of inputs into production provides the final basis for comparing

TABLE 8

The Discounted Net Benefits of Alternative Energy Policies: Consumption Effects*

(Billions of 1972 Dollars)

Cases	Social Discount Rate		
	0%	5%	10%
Reference vs. Conservation	-10.3	-8.2	-6.2
Reference vs. Synfuels	-353.7	-173.6	-92.5
Synfuels vs. Conservation	343.4	165.4	86.3

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* Determined as changes between cases in the present value of real consumption plus government expenditures.

TABLE 9

Aggregate Final Demand Expenditures

		Reference	Conservation	Synfuels
Purchases (Billions of 1972 Dollars)				
1990	Agriculture, Non-fuel Mining, Construction	173.0	172.5	171.6
	Manufacturing	522.0	522.4	517.0
	Transportation	66.1	66.0	65.0
	Services	1157.2	1167.0	1146.8
	Energy	77.8	59.6	83.0
2000	Agriculture, Non-Fuel Mining, Construction	213.6	212.6	208.8
	Manufacturing	704.1	706.4	687.8
	Transportation	102.1	99.6	99.6
	Services	1540.7	1559.0	1509.7
	Energy	81.9	63.0	83.0
Composition of Purchases (Percent)				
1990	Agriculture, Non-Fuel Mining, Construction	8.67	8.68	8.65
	Manufacturing	26.15	26.28	26.07
	Transportation	3.31	3.32	3.28
	Services	57.97	58.72	57.82
	Energy	3.90	3.00	4.18
2000	Agriculture, Non-Fuel Mining, Construction	8.08	8.05	8.07
	Manufacturing	26.65	26.75	26.57
	Transportation	3.86	3.77	3.85
	Services	58.31	59.04	58.31
	Energy	3.10	2.39	3.21

the three cases. The input-output coefficients for capital, labor, energy, and intermediate materials are presented and compared in Tables 10 through 12. In all cases, the general trend is for the economy to grow continually more capital intensive and less intensive in the use of labor and energy. However, the magnitude of the changes differs significantly, depending on the policy being considered. According to these results, the common perception that conservation stimulates employment is contradicted. By the end of the century, the conservation case is the least labor intensive, whereas it is the synfuels policy that leads to the greatest labor intensity of aggregate output. Also, the rate of increase in the amount of capital per worker is largest in the conservation case, followed next by the reference projection. Since this is an important factor contributing to the advance of gross labor productivity, it follows that the greatest benefits in this area arise from the conservation policy. The synfuels policy, given this measure, is the least favorable to the rate of advance of gross labor productivity. Finally, the rate of improvement in the energy efficiency of capital is largest for the conservation case and smallest for the synfuels policy.

These influences of the policies on the input structure of the economy result from several considerations. First, the policies require a withdrawal of productive resources from other activities within the economy. Simultaneously, they promote the substitution of new energy production techniques so that resources originally dedicated to producing conventional supplies are released. As indicated, the net withdrawals under the synfuels policy are substantially larger than those associated with the conservation policy. Finally, the new levels and structures of final spending under the policies are consistent only with reconfigured input patterns. With equilibrium a requirement in each factor market, these changes influence the relative price structure and, so, further

TABLE 10

Input-Output Coefficients for Aggregate Output

Year	Factor	Reference Case	Conservation Case	Percent Change
1990	Capital, K	.1789	.1794	0.28
	Labor, L	.2077	.2072	-0.24
	Energy, E	.0289	.0272	-5.88
	Materials, M.	.5844	.5862	0.31
Percent Change (1980-1990)	Capital, K	18.87	19.20	
	Labor, L	-8.62	-8.84	
	Energy, E	-7.96	-13.38	
	Materials, M	-1.08	-0.78	
2000	Capital, K	.2044	.2041	-0.15
	Labor, L	.1829	.1815	-0.77
	Energy, E	.0279	.0267	-4.30
	Materials, M	.5848	.5876	0.48
Percent Change (1990-2000)	Capital, K	14.25	13.77	
	Labor, L	-11.94	-12.40	
	Energy, E	-3.46	-1.84	
	Materials, M	0.07	0.24	

TABLE 11

Input-Output Coefficients for Aggregate Output

Year	Factor	Reference Case	Synfuels Case	Percent Case
1990	Capitla, K	.1789	.1793	0.22
	Labor, L	.2077	.2080	0.14
	Energy, E	.0289	.0298	3.11
	Materials, M	.5844	.5829	-0.26
Percent Change (1980-1990)	Capital, K	18.87	19.14	
	Labor, L	-8.62	-8.49	
	Energy, E	-7.96	-5.10	
	Materials, M	-1.08	-1.34	
2000	Capital, K	.2044	.2052	0.39
	Labor, L	.1829	.1845	0.87
	Energy, E	.0279	.0283	1.43
	Materials, M	.5848	.5819	-0.50
Percent Change (1990-2000)	Capital, K	14.25	14.45	
	Labor, L	-11.94	-11.30	
	Energy, E	-3.46	-5.03	
	Materials, M	0.07	-0.17	

TABLE 12

Input-Output Coefficients for Aggregate Output

Year	Factor	Synfuels Case	Conservation Case	Percent Change
1990	Capital, K	.1793	.1794	0.06
	Labor, L	.2080	.2072	-0.38
	Energy, E	.0298	.0272	-8.72
	Materials, M	.5829	.5862	0.57
Percent Change (1980-1990)	Capital, K	19.14	19.20	
	Labor, L	-8.49	-8.84	
	Energy, E	-5.10	-13.38	
	Materials, M	-1.34	-0.78	
2000	Capital, K	.2052	.2041	-0.54
	Labor, L.	.1845	.1815	-1.63
	Energy, E	.0283	.0267	-5.65
	Materials, M	.5819	.5876	0.98
Percent Change (1990-2000)	Capital, K	14.45	13.77	
	Labor, L	-11.30	-12.40	
	Energy, E	-5.03	-1.84	
	Materials, M	-0.17	0.24	

affect input decisions. The interactions, however, continue from these adjustments, insofar as the pattern of input choices has an impact on macroeconomic performance.

The reciprocals of the input-output coefficients, i.e., total output per unit of input, represent measures of net productivity. Over the entire projection horizon, the productivities of labor and energy rise the most in the conservation case and the least in the synfuels case. Also, the conservation policy causes the slowest rate of decline in capital productivity, while the synfuels policy imposes the largest decrease. These differences in factor productivities contribute materially to the macroeconomic impacts that result from the introduction of these policies.

For the alternative energy policies, the principal comparative conclusions regarding the growth and structure of the U.S. economy are summarized as follows:

- the policies have a significant effect on the output and input structures of the economy with energy changes being both the motivating force and the dominant impact;
- positive economic growth at steadily declining rates continues under either the synfuels or the conservation policies;
- both policies when compared to the reference projection are seen to impose an economic cost in terms of income and production foregone. However, conservation's impact on macroeconomic performance is neither large nor permanent and is significantly less than that imposed by the synfuels policy;
- over the long run, the conservation policy has a favorable effect on both gross labor and net factor productivities, whereas the reverse is true for the synfuels policy.

IV. THE INFLUENCE OF ENERGY POLICY REPRESENTATIONS ON ECONOMIC PERFORMANCE: A SENSITIVITY ANALYSIS

The measured economic impacts from the synfuels and conservation policies are conditional on the specific policy representations introduced into the reference projection. The importance of this dependency is bidirectional. First, for policies of this scale, the interdependencies of the energy, economic, and environmental systems are such that factors affecting one system lead to reciprocating interactions among all systems. Second, variations in the economic effects associated with alternative policy representations and their repercussions alter the comparative advantages of policies with respect to their success in attaining national energy, economic, and environmental objectives. Thus, it is important to examine the sensitivity of the impacts on economic performance to variations in the policy representations.

The macroeconomic results in the subsequent assessments are determined from the application of only the DJA economic model to alternative policy specifications. In performing these analyses, energy-economy interactions were not considered. The results are indicative of only the direction of change (partial equilibrium) rather than the absolute magnitude of change (general equilibrium), since the fully integrated BNL/DJA model system was not employed. The information determined in this manner is sufficient for approximating the sensitivity of the economic effects to policy variations. But, for the design and evaluation of energy policy, the completeness of detail (energy, economy, and environmental) afforded by the integrated BNL/DJA methodology is necessary.

The economic effects of conservation depend on the timing of conservation expenditures, the pattern of energy savings by fuel type, and the effectiveness of conservation policy.

The first of these refers to the annualization schemes applied to the cost information from the CSA program documentation. The annualized policy costs for conservation were developed from the total discounted public and private expenditures associated with each subprogram. This process involved three steps. First, the undiscounted conservation expenditures were determined for each subprogram in each of the years, 1981-2000. These then were allocated between investment goods purchases and labor services expenditures. Finally, the stream of annual investment purchases was converted into a capital services series to reflect the permanency of services available from undepreciated capital. The annual expenditures for capital and labor services constitute the direct policy costs of energy conservation. These claims are measured against the release of those productive inputs that formerly were required for energy production. For the conservation analysis just presented, resource claims exceeded releases through the early nineties whereas the converse was true thereafter. The effects of this were to lower and raise the level of real economic activity (relative to the reference case) in the years 1990 and 2000, respectively.

The step most critical to the above determination is the annualization of the total discounted cost information. Given the nature of discounting, a greater concentration of annual expenditures in the earlier years implies a smaller cumulative cost, i.e., the sum of the annual, undiscounted costs over the life of the policy. Conversely, the cumulative policy cost of conservation increases the more the annual costs are deferred into the future. There are additional implications associated with the timing of the energy savings. If annual expenditures are concentrated in the nearer term, then the direct policy costs substantially exceed the direct benefits, i.e., the valuation of energy savings, in those years. However, in later periods, this situation is reversed because of lower cumulative and annual policy costs. If the annual expenditures are deferred, then there is relatively more congruence between the incidence of cost and the realization of benefits. There even exists the possibility of positive net direct benefits in the earlier years, though this is at the expense of potentially significant net costs in the future. Thus, with no modifications to either the discounted policy costs or the energy savings, changes in the time pattern and, hence, the magnitude of conservation expenditures affect whether the policy imposes a net economic cost or leads to a net economic benefit. These variations also affect the time horizon over which net costs are incurred or net benefits are realized. That is, they affect the timing of benefits and costs as measured by increases and decreases from the reference case levels of real GNP in 1990 and 2000.

For each subprogram, one of three distributional rules or patterns was selected to annualize the total expenditure data: the uniform, the constant rate of growth, and the trapezoidal. Of these, only the latter two are important to the sensitivity analyses. The programs to which the uniform distribution was applied have virtually no private sector content. Consequently, a reliable time pattern of expenditure is provided in the CSA program materials.

The pattern characterizing the constant rate of growth subprograms is one in which expenditures grow approximately in proportion to energy savings. In applying this rule, an allowance is made for unit cost reductions from increased market penetrations and economies of scale in consumption. Table 13 shows the effects on the total annual resource claims of doubling

TABLE 13

Effects on Total Annual Policy Costs of Varying the Expenditure Growth Rates for the Constant Rate of Growth Subprograms

Case Number	Policy Variation	Total Resource Claims Due to Conservation Policy (Billions of 1972 Dollars)	
		1990	2000
	Original Specification	14.2	24.2
I	Double Growth Rates	12.7	40.6
II	Halve Growth Rates	14.7	16.6

and halving the expenditure growth rates for these conservation subprograms. A doubling of the growth rates implies that the unit costs of energy from these conservation activities rises over time. Thus, total annual conservation expenditures are moved forward in time and increased with the result that the levels of real GNP would be higher in 1990 and lower in 2000 than those obtained for the original specification. It is possible that, at reasonable social discount rates, policy variations of this type lead to net economic benefits when compared to the reference projection. A halving of the growth rates has the opposite effect. Here, annual conservation expenditures are lowered and biased toward the nearer term, thereby further lowering real GNP in 1990 and raising it in 2000. The effect of this type of policy variation could be to exacerbate the net economic cost originally observed.

The trapezoidal distribution is selected for subprograms that initially require increasing R, D, and D expenditures which level off for some length of time as the product or service provided by the program increases its penetration or effectiveness, or nears commercialization. These intervals are followed by a period of decreasing unit costs resulting from productivity advances in the provision of energy services from conservation. This distribution mechanism is applicable to subprograms for which the most likely expenditure pattern is concentrated toward the earlier years.

There are several parameters for the trapezoidal distributions that can be varied to affect the time pattern and levels of conservation outlays. These include the lengths of the growth, uniform, and decline intervals and the rates of expenditure growth and decline occurring in the first and last of these periods.

Table 14 shows the impacts on the total annual conservation expendi-

TABLE 14

Effects on Total Annual Policy Costs of Varying the Time Intervals for the Trapezoidal Subprograms

Policy Variation	Total Resource Claims Due to Conservation Policy (Billions of 1972 Dollars) 1990	2000
Original Specification	14.2	24.2
Shorten Growth Period, Lengthen Decline Period	12.4	22.6
Shorten Uniform Period, Lengthen Growth Period	16.1	25.8
Shorten Decline Period, Lengthen Growth Period	15.5	26.8

tures that result from varying the lengths of the periods. In the first of these variants, the growth and decline periods were shortened and lengthened, respectively. The effect of this is to spread a reduced level of total expenditures more evenly over time. As the total annual policy costs for 1990 and 2000 are lower than those for the original specification the resultant levels of GNP would be higher. For the second of these cases, the period of increasing expenditures was lengthened at the expense of the uniform period. This enlarges the original level and fraction of total conservation expenditures that occur over the decline period and, so, leads to higher unit costs in the future. Expenditures are, therefore, higher in both 1990 and 2000 and these increased annual claims would serve to increase the net economic costs of conservation policy. In the final variation of this type, the growth period was lengthened and the decline period was shortened. This has the same impact as the previous case, though to lesser and greater degrees in 1990 and 2000, respectively.

In Table 15 , the effects of changes in the growth and decline parameters of the trapezoidal distributions are illustrated. Here four cases are considered: doubling the growth and decline rates; halving the growth and decline rates; doubling the growth rates and halving the decline rates; halving the growth rates and doubling the decline rates. Doubling or halving both the growth and decline rates has the effect of biasing the expenditures toward the nearer or longer term, respectively. In addition, the respective cumulative costs for these policy cases are smaller and larger. Compared to the original analysis, the doubling case could worsen the macroeconomic cost of conservation whereas the reverse could be true in the case of halving the rates. Doubling the growth rates and halving the decline rates moves more of the increased total expenditures into the future with the effect of

TABLE 15

Effects on Total Annual Policy Costs of Varying the Expenditure Growth and Decline Rates for the Trapezoidal Subprograms

Policy Variation	Total Resource Claims Due to Conservation Policy (Billions of 1972 Dollars)	
	1990	2000
Original Specification	14.2	24.2
Double Growth and Decline Rates	15.8	22.4
Halve Growth and Decline Rates	13.2	25.4
Double Growth Rates, Halve Decline Rates	14.7	27.0
Halve Growth Rates, Double Decline Rates	13.9	21.7

increasing the claims of conservation in 1990 and 2000. In this instance, real GNP would be lower than originally determined and the net economic cost of the policy would be higher. Finally, halving the growth rate and doubling the decline rate has precisely the opposite effect.

However, for the trapezoidal distributions, it is combinations of these variations that are of interest. In comparing the cost implications of the possible combinations of cases, three variations are identified as capable of providing relatively larger deviations from the pattern of economic growth in the original conservation projection. Two of these variations are extreme points in that they produce the largest changes in the original policy costs for both 1990 and 2000. Other combinations of interest are those for which the policy variation exerts a strong influence on the cost in one period without producing offsetting effects in the other period. Of these, only one provides more extreme policy cost effects in any period than those for the other two specifications. The annual policy cost information for these three variations is summarized in Table 16. For the first and last of these cases, the net economic cost of conservation would be lower and higher, respectively, than that for the original projection. In the instance of the second policy variation, the adverse macroeconomic impact would be larger as the annual policy cost for 1990 is significantly higher and that for 2000 is virtually unchanged. It is interesting to note that, for the year 2000, none of these variations lead to more significant changes in policy costs than do the parametric modifications to the constant rate of growth subprograms.

The previous assessments established the sensitivity of the total annual costs of conservation policy to sequential changes in the annualization parameters of the constant rate of growth and trapezoidal distributions. In

TABLE 16

Effects on Total Annual Policy Costs of Combined Variations for the Trapezoidal Subprograms

Case Number	Policy Variation	Total Resource Claims Due to Conservation Policy (Billions of 1972 Dollars)	
		1990	2000
	Original Specification	14.2	24.2
III	Halve Growth Rate, Double Decline Rate, Shorten Growth Period, Lengthen Decline Period	11.6	20.7
IV	Double Growth and Decline Rates, Shorten Uniform Period, Lenghten Growth Period	20.1	24.1
V	Double Growth Rate, Halve Decline Rate, Shorten Decline Period, Lengthen Growth Period	16.8	30.8

addition, indications were given as to the directional influence of these isolated changes on economic performance. As the logical final step of this analysis, therefore, it is important again to combine policy cases and to examine more explicitly the economic effects associated with these reconfigurations. Table 17 shows the effects on real GNP and the total resource claims of conservation from alternative policy representations. These reflect the simultaneous introduction of changes to the parameters of both distributional schemes. It can be seen that, with no modifications to either the total discounted policy costs or the energy savings, there are wide variations in the pattern of economic growth. Equally significant are the cumulative economic effects of temporal variations in the expenditure levels and patterns. The discounted net benefits of conservation policy are presented in Table 18. From this, the policy can be seen to impose a macroeconomic cost as large as $(1972) 193 bn or lead to an overall net economic benefit of $(1972) 114 bn. Again, these are conditional only on variations in the timing and annual levels of the policy costs.

The purpose of the preceding analysis was to investigate the sensitivity of the economic consequences of conservation policy to the assumptions that most influence the representation of that policy. Variations in the annualization parameters for the conservation subprograms affected the timing and annual levels of conservation outlays and the cumulative policy cost incurred over the entire projection horizon. These changes, in turn, were seen to have a significant impact on the pattern of economic growth and, hence, on the relative economic merits of the conservation strategy. However, even the case least advantageous to conservation is significantly less damaging to the economy in view of the $(1972) 410 bn cumulative net cost determined for the synfuels policy.

TABLE 17

Effects on Total Annual Policy Costs and Economic Performance of Combined Variations in the Annualization Schemes for Conservation Subprograms

Case Number	Policy Variation*	Total Resource Claims Due to Conservation Policy (Billions of 1972 Dollars)		GNP (Billions of 1972 Dollars)	
		1990	2000	1990	2000
	Reference Projection	--	--	1901.3	2469.3
	Original Conservation Specification	14.2	24.2	1899.1	2473.7
VI	I and III	10.1	37.1	1904.0	2456.3
VII	I and IV	18.6	40.5	1893.9	2447.5
VIII	I and V	15.4	47.2	1898.0	2438.0
IX	II and III	12.1	13.1	1901.3	2491.6
X	II and IV	20.7	16.5	1891.4	2482.9
XI	II and V	17.4	23.2	1895.4	2473.6

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* Numbers refer to policy variations on Tables and

TABLE 18

The Discounted Net Benefits of Conservation Policy*

(Billions of 1972 Dollars)

Case Number**	Social Discount Rate		
	0%	5%	10%
Original Conservation Specification	0.4	-3.7	-4.3
VI	-39.3	-12.4	-2.5
VII	-185.2	-93.8	-51.7
VIII	-192.8	-89.9	-45.2
IX	113.5	49.5	22.7
X	-30.1	-30.6	-25.6
XI	-37.2	-26.6	-19.1

---

* Determined as changes in the present value of real GNP measured from the reference projection.

**Numbers refer to policy variations on Table

The second major area of sensitivity for the conservation policy concerns the division of energy savings among petroleum, natural gas, and electricity. Variations in the pattern of these savings can affect significantly the timing and magnitude of net benefits or costs. In terms of their real input claims on the economy, electricity, petroleum, and natural gas are the most, second most, and least expensive, respectively. Consequently, the more electricity that is displaced through conservation, the larger (smaller) are the net economic benefits (costs) from conservation policy. To illustrate this, three alternatives to the original conservation projection were specified. The total amount of primary energy savings is the same for all cases. Further, the displacement of petroleum and, hence, the value of this displacement is the same for the three alternatives. The differences among them center on the allocation of nonpetroleum savings to crude natural gas and electricity inputs. These differences lead to differences in the total quantity and mix of the delivered energy that is conserved. More importantly, the configurations are different with respect to the total value and input composition of the resources released from energy production. In the first of these cases, the nonpetroleum energy savings are biased toward the conservation of inputs to electricity. In the second case, the nonpetroleum primary energy savings are divided equally between natural gas and electricity. In the third alternative, the gas-electricity split of the first case was reversed so that most of the conservation was allocated to the savings of utility gas. The macroeconomic impacts and net policy benefits for these alternatives are shown in Table 19 . The policy implication of these results is clear. In designing conservation policies that promote jointly national energy, economic, and environmental objectives, the net economic benefits are greatest (or, the costs are least) for

TABLE 19

Impacts on Economic Performance and Benefits of Varying the Mix of Energy Savings from Conservation

Policy Variation	GNP (Billions of 1972 Dollars)		Discounted Net Benefits at Selected Social Discount Rates (Billions of 1972 Dollars)		
	1990	2000	0%	5%	10%
Reference Projection	1901.3	2469.3	--	--	--
Original Conservation Projection	1899.1	2473.7	0.4	-3.7	-4.3
Electricity Bias*	1902.1	2486.5	95.6	43.1	20.7
Equal Division*	1900.0	2478.4	33.3	12.2	4.1
Natural Gas Bias*	1898.1	2470.2	-27.5	-17.6	-11.8

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*Refers to division of primary, nonpetroleum energy savings between inputs to electricity and crude natural gas.

strategies that place relative emphasis on substitutions away from petroleum _and_ electricity.

Finally, for conservation, there is the issue of policy effectiveness. The controllable instrument for this policy is represented by the government outlays associated with each conservation subprogram. The desired effect of the public expenditure and programs is to motivate the private sector to redirect its purchases toward conservation activities. This ultimately provides the energy savings and, hence, the direct and indirect economic benefits (or, costs) from conservation policy. However, the levels of private expenditure and the resultant energy savings that are realized from the government incentives are the outputs of the policy. As such, they are, to some extent, uncontrollable. For the given levels of public and private expenditure, the energy savings could be significantly less than anticipated; conversely, the anticipated energy savings might be attained only at a substantially higher cost. To examine the economic consequences of these, two cases are considered. In the first, the energy savings achieved for the given levels of total expenditure were taken to be half those obtained in the original assessment. The mix of these savings, however, was unaffected. For the second case, the original levels and mix of energy savings were presumed to be attained at double the original cost. Both of these cases have the effect of increasing by twofold the unit cost of energy from conservation. But, their economic impacts will differ as each case implies a different structural mix and level of resource claims and releases due to conservation policy. The effects on real GNP and the discounted net benefits of these variations are presented in Table 20. Doubling the policy cost has approximately twice the impact as does halving the energy savings. As indicated, this difference is attributable to the level and compositional implications of these changes. More important, however, is the comparison of the effects

TABLE 20

Impacts on Economic Performance and Benefits of Varying the Effectiveness of the Conservation Policy

Policy Variation	GNP (Billions of 1972 Dollars)		Discounted Net Benefits at Selected Social Discount Rates (Billions of 1972 Dollars)		
	1990	2000	0%	5%	10%
Reference Projection	1901.3	2469.3	--	--	--
Original Conservation Projection	1899.1	2473.7	0.4	-3.7	-4.3
Double Policy Costs	1881.9	2431.4	-387.5	-203.3	-116.0
Halve Energy Savings	1891.2	2450.6	-196.4	-103.5	-59.3

of these variations to the results for the synfuels policy. For the net economic costs of the two policies to be equal requires either a doubling of the unit cost of energy from conservation or the virtual elimination of any energy savings for the given levels of effort.

However, this issue of effectiveness also extends to the synfuels policy. In developing the synfuels projection, the input requirements for each technology were time invariant. No consideration was given to cost reductions due to learning effects, technical improvements, economies of scale, or other types of productivity advance. Changes in the costs of fuels from the synthetic and unconventional sources can affect significantly the net economic cost associated with this policy. Three variations are considered: a doubling of the synfuels costs, a halving of these costs, and the situation in which synfuels are competitive with the energy from conservation. Table 21 presents the impacts on economic performance and net policy benefits resulting from these changes. These results clearly demonstrate the benefit potential of directing the synfuel programs toward the promotion of accelerated cost reduction rather than accelerated commercial deployment. Reducing the costs of these fuels to the point at which they are competitive with the energy from conservation more than halves the adverse macroeconomic impact of the synfuels policy.

That there still is a significant economic cost, as compared to conservation, results from two considerations. First, the mix of energy displacements and its valuation are substantially different between the two policies. The synfuels policy is not directed toward the displacement of energy, in general, or electricity, in particular. Rather, its focus is the production of petroleum and gas products by means other than importation. The effect of this can be inferred from the analysis of the pattern of energy savings, by fuel type, from conservation. As little electricity is displaced,

TABLE 21

Impacts on Economic Performance and Benefits of Varying the Effectiveness of the Synfuels Policy

Policy Variation	GNP (Billions of 1972 Dollars)		Discounted Net Benefits at Selected Social Discount Rates (Billions of 1972 Dollars)		
	1990	2000	0%	5%	10%
Reference Projection	1901.3	2469.3	--	--	--
Original Synfuels Projection	1888.9	2413.3	-410.0	-200.7	-106.7
Double Technology Costs	1880.7	2373.1	-698.0	-340.8	-180.7
Halve Technology Costs	1895.0	2433.4	-246.2	-118.5	-61.8
Synfuel Costs Competitive with Energy from Conservation	1896.9	2441.4	-186.4	-89.0	-46.0

the synfuels policy imposes a net cost on the economy that is directionally the same as was observed for conservation with a natural gas bias (Table 19). Second, and more important, there are large differences in the composition of the resource claims, i.e., policy costs, between the two policies. For the same unit cost of energy, the synfuels policy is relatively more capital and less labor intensive than the conservation policy. The process of capital formation is crucial to economic growth and, thus, factors that affect relatively more have a relatively larger impact on economic performance. Since the synfuels policy involves a relatively larger diversion of capital service inputs from other productive uses, its economic consequence is larger than that for conservation, even though the unit costs of energy are the same.

These assessments show that there are reasonable circumstances under which the comparative economic advantage of the conservation policy over the synfuels policy begins to erode. However, for the synfuels policy to be judged economically superior to conservation requires relatively extreme combinations of policy assumptions biased against demand reduction and in favor of supply expansion. Overall, there is strong analytical evidence that supports active programs for energy conservation and continued R, D, and D efforts for synthetic and unconventional fuels.

V. POLICY IMPLICATIONS

The results from this analysis yield important implications for the focus and direction of U.S. energy policy. Each strategy succeeds in reducing the nation's import dependence and slowing the growth in energy demand. In the reference projection, the influences of import quotas and domestic oil and gas price decontrol result in a halving of oil imports relative to the current levels of approximately 8 million barrels per day. These influences also serve to slow the rate of growth of primary energy consumption to well under 2.0 percent per annum and promote a shift in energy use patterns toward a greater utilization of coal. The introduction of the conservation or the synfuels policy reduces further U.S. import requirements with the conservation policy being slightly more effective. Under the conservation policy, oil imports are reduced from the reference case levels by 3.5 and 8.4 quads for the years 1990 and 2000, respectively. The corresponding reductions for the synfuels policy are 3.2 and 7.0 quads. Either of these policies permit the almost total elimination of imports by the year 2000. From conservation, there is the additional benefit that the growth in aggregate primary energy demand is virtually halted. For the years 1990 and 2000, total primary energy savings from conservation are 10.3 and 22.3 quads, respectively. However, even the large-scale introduction of synthetic fuels results in only marginally higher primary energy consumption than in the reference case, being only 2.0 and 2.9 quads higher in the respective years. Thus, to different degrees, energy conservation is evident under all three of the strategies.

It is in the environmental and economic areas that the strategies most differ. For the environment, an ordering of the strategies indicates that substantial environmental benefits are obtainable from energy conservation. In addition to the emissions reductions associated with the decreased use of petroleum and natural gas, there are significant improvements in environmental quality attributable to the slower growth of total coal consumption and nuclear inputs into electric generation. Relative to the reference projection, future nuclear power requirements are decreased by 30.0 to 40.0 percent due to the successes of the conservation programs. Also, by 2000, conservation has led to a 9.1 quad reduction in annual coal use, down almost 20.0 percent from the reference case amount. The energy reductions from conservation provide important benefits in the forms of less damage to land, improvements in air and water quality, and increased public health and safety. However, these benefits are increasingly lost in moving to the policies that characterize the reference and synfuels projections, respectively.

For the economy, the introduction of the synfuels policy imposes a significant net economic cost. Real GNP is projected to be \$(1972) 1888.9 bn and \$(1972) 2413.3 bn for the years 1990 and 2000, respectively. The growth in real GNP is lower for this case than for either the reference or or the conservation projections. Relative to the former, the synfuels policy results in a cumulative macroeconomic cost between \$(1972) 410.0 bn and 107.0, depending on the choice of discount rate.

The conservation results are mixed. Relative to the reference projection, the conservation policy leads to lower [\$(1972) 1899.1 bn versus 1901.3] and higher [\$(1972) 2473.7 bn versus 2469.3] levels of economic activity in the years 1990 and 2000, respectively. When discounting these annual real GNP differences, the conservation policy provides cumulative net economic benefits only at extremely low social rates of discount, e.g.,

$(1972) 0.4 bn at a zero discount rate. At more reasonable discount rates, e.g., 5.0 or 10.0 percent, conservation results in a cumulative net economic cost of less than $(1972) 5.0 bn.

From these comparisons, it is clear that conservation, even in isolation from other policies, can play a major role in alleviating the liquids problem and slowing the growth of energy demand. These are achieved at only a small macroeconomic cost and with substantial environmental benefits. Further, conservation compares favorably to the synfuels policy. It is slightly more successful in reducing imports and provides the only mechanism for reducing demand growth. Relative to the reference projection, there are environmental costs from the synfuels policy whereas, with conservation, there are significant improvements in environmental quality. Finally, the relative impacts on economic performance are much less severe from conservation policy than from the synfuels program.

These conclusions do not deny a benefit potential from current synfuels policies. Nor should they be interpreted as advocating a de-escalation of supply expansion programs. The favorable economic results for conservation policy as compared to synfuels are directly attributable to the policy costs of each program. In terms of only the program costs, the conservation policy provides energy at a lower cost than that of the fuels it displaces. The converse is true for the synfuels policy. For example, the 1990 cost of energy from conservation is $(1978) 2.10 per million Btu while the cost of energy from synfuels is $(1978) 5.25 per million Btu. This suggests that synfuels programs directed toward cost reduction and the resolution of environmental issues are more appropriate than those that promote the accelerated commercial deployment of current technologies.

The measured impacts on economic performance that were determined for the policy cases are sensitive to, inter alia, the actual policy representations introduced into the reference projection. The economic effects of conservation depend on the timing of conservation expenditures, the pattern of energy savings by fuel type, and the effectiveness of conservation policy.

The first of these refers to the annualization schemes applied to the cost information from the CSA program documentation. Changes in the time pattern and, hence, the cumulative and annual magnitudes of conservation expenditures affect whether the policy imposes a net economic cost or leads to a net economic benefit. These variations also affect the time horizons over which net costs are incurred or net benefits are realized, i.e., the timing of benefits and costs as measured by increases and decreases from the reference case levels of real GNP in 1990 and 2000. However, in varying the annualization parameters, even the case that is least advantageous to the conservation policy imposes a significantly more moderate cost on the economy than does the synfuels policy. In fact for this case, the cumulative macroeconomic cost is less than half of that for the synfuels policy [$(1972) 193.0 bn versus 410.0].

The second area of sensitivity for the conservation policy concerns the division of energy savings among petroleum, natural gas, and electricity. Variations in the pattern of these savings can affect the timing and magnitude of net economic benefits or costs. As electricity is relatively more expensive in terms of its input claims on the economy, the more electricity that is displaced through conservation, the greater the net economic benefits from conservation policy. Cumulative economic benefits were determined to be as high as $(1972) 96.0 bn when the nonpetroleum energy savings were directed toward the conservation of electricity inputs. Alternatively, an economic cost of $(1972) 28.0 bn was observed for the situation in which natural gas dominated the nonpetroleum energy savings. Thus, in designing conservation policies that promote jointly national energy, economic, and environmental objectives, the net economic benefits are greatest (or, the costs are least) from strategies that place relative emphasis on substitutions away from petroleum <u>and</u> electricity.

Finally, there is the issue of the effectiveness of conservation policy. The controllable instrument for conservation policy is represented by the programmed expenditure of public funds. The public expenditures and programs, in turn, motivate the private sector to redirect expenditure patterns toward conservation activities. These ultimately provide the energy savings from conservation. However, the levels of private expenditure and the resultant energy savings are outputs of the policy and, to some extent, are uncontrollable. For the given expenditures, the energy savings could be significantly less than anticipated; conversely, the anticipated energy savings might be attained only at a substantially higher cost. An analysis of this suggests that only extreme increases in conservation costs or reductions in anticipated energy savings lead to a macroeconomic cost of similar magnitude to that incurred with the synfuels program. More specifically, for the economic damages from conservation policy to equal those from the synfuels policy requires either a doubling of the costs of conservation programs or the virtual elimination of any energy savings.

However, the issue of policy effectiveness also extends to the synfuels policy. In developing this projection, the capital and labor costs for each synfuels technology were assumed to be invariant over time. No consideration was given to cost reductions due to learning effects, technical improvement, economies of scale, or other types of productivity advance. Cost reductions for the synthetic and unconventional fuels technologies can reduce dramatically the net economic cost associated with this policy. In fact, reducing the costs of these fuels to the point at which they are competitive with the energy provided from conservation more than halves the adverse macroeconomic impact from the synfuels policy. In this situation, the remaining differences in the economic consequences of the two policies are attributable to the different mixes of energy displacements and structural differences in the capital and labor composition of policy costs.

Thus, there are reasonable circumstances under which the conservation and synfuels policies become less and more favorable, respectively. In these cases and in terms of macroeconomic effects, the decisive comparative advantage of conservation over synfuels begins to erode. However, for synfuels to be judged economically superior to conservation requires relatively extreme combinations of policy assumptions biased against demand reduction and for supply expansion.

As the principal implication evidenced by these analytical results, active programs for energy conservation and continued R, D, and D support for synthetic and unconventional fuels belong as integral components of future U.S. energy policy.

A MACROECONOMIC ANALYSIS OF THE CARTER ENERGY PLAN

by

George R. Schink

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Introduction

President Carter has proposed an ambitious plan to reduce our dependence on imported oil by 4.5 million barrels per day by 1990. Assuming that the price of imported crude oil is $50 per barrel in 1990, which is a conservative estimate, this oil import reduction would reduce our import bill by $82 billion. This large a potential swing in our nominal trade balance would reverse the downward pressure on the dollar and could return the international value of the dollar to its 1973 levels.

To accomplish the 4.5 million barrel per day (MMBD) reduction in U.S. dependence on foreign oil by 1990, the President has proposed spending $117 billion dollars of government funds over the next decade. Since the proposed windfall profit tax on deregulated U.S. oil production is expected to yield in excess of $140 billion during the same period, this spending can be financed without other tax increases. Although energy experts are uncertain that the President's objectives can be attained by 1990, they have indicated that the objectives are at least feasible.

The major issue, however, is not whether the President's objectives can be accomplished, but whether we should pursue these objectives. The arguments in favor of subsidizing new energy supplies and/or energy conservation and conversion stress economic security and international balance of payments improvement while the arguments against stress losses in economic efficiency if these subsidies are employed.

Given the potential for political instability in the Persian Gulf states over the next decade, the likelihood of oil supply disruptions even worse than our 1974 and 1979 experiences is quite high. The current situation in Iran could produce such a disruption and, over the next decade, political upheaval in even Saudi Arabia is not implausible. We have recently completed a study for Department of Energy in which we examined the effects of supply disruptions on the U.S. economy under the polar assumptions the Carter energy plan was implemented and successful versus no energy plan (a net difference in oil demand of 4.5 MMBD). While the study is still incomplete, the percentage reduction in real GNP as a result of a given interruption is signicantly less under the Carter energy plan scenario.

Most of this paper is devoted to a consideration of the implementation of the Carter energy plan and the implications for the U.S. balance of payments is a major result. A marked improvement in the U.S. balance of payments position removes the current constraints on monetary policy (permits an easier money policy) ~~and~~ results in appreciation of the dollar which, in turn, contributes significantly to bringing the inflation rate down.

The efficiency arguments against subsidizing the production of synthetic fuels imply that such a program would lead to a misallocation of resources, lower growth, and higher inflation. This argument usually starts with the assumption of efficient allocation of resources in the absence of subsidies. Given that crude oil supplies and prices are determined by a monopoly (OPEC) and that the conclusion that resources will be efficiently allocated by the market requires the assumption of a perfectly competitive market, the extent of the negative effect of subsidies or efficiency is uncertain.

In the remainder of this paper, I address the macroeconomic impacts of implementing the Carter energy plan. The Wharton Annual Model is used to perform this analysis. The results are contrasted to a baseline (Control Solution) which incorporates domestic oil price decontrol (by October 1981) and natural gas price decontrol (by the end of 1985).

Energy Plan Details and Implied Scenario Assumptions

By 1990, the new energy plan calls for an increase in domestic oil and natural gas production (from conventional and synthetic sources) of the equivalent of 3.0 million barrels per day (MMBD) and a reduction in oil consumption (through conservation and conversion to coal and natural gas) of 1.5 million barrels per day (MMBD).

The composition of the incremental supply is as follows:

1) 2.0 to 3.0 MMBD resulting from subsidies, loan guarantees, product price guarantees, etc. of the Energy Security Corporation.
    - a) Natural gas from tight sands, shale, and coal seams: 0.5 to 1.0 MMBD
    - b) Natural gas from biomass: 0.1 MMBD
    - c) Shale oil: 0.4 MMBD
    - d) Synthetic crude oil, natural gas, and methane from coal and/or alcohol from grains: 1.0 to 1.5 MMBD
2) Eliminate price controls on hard-to-get crude oil (heavy oil) with no windfall profits tax: 0.5 MMBD
3) Tax credit of 50 cents per thousand cubic feet of natural gas produced from tight sands and other hard-to-get sources (excluding that produced with a subsidy from the Energy Security Corporation): no estimate given for potential supply response; assumed to be 0.5 MMBD.

Our interpretation of the total potential supply increase by 1990 by type of fuel (in MMBD equivalents) is as follows:

	Low	High
1) Natural Gas	1.0	1.5
2) Heavy Oil (California)	0.5	0.5
3) Shale Oil	0.4	0.4
4) Biomass (Natural Gas)	0.1	0.1
5) Synthetic Fuels	1.0	1.5
	3.0	4.0

In the analysis below, we have taken the low estimates for all energy supplies. Further, we have assumed all synthetic fuels are produced from coal and are liquid fuels. Introducing alcohol from grains would complicate the scenario substantially but assuming that natural gas (methanol) is produced from coal, in addition to liquids, would not alter the results.

The oil demand reduction of 1.5 MMBD is to be accomplished as follows:

1) 0.5 MMBD resulting from residential and commercial conservation and conversion to natural gas heating. This is to be aided by a direct federal subsidy and by loans from utilities to customers.

2) 0.25 MMBD resulting from greater use of mass transit and more efficient automobile engines. This is to be aided by direct federal aid for local transit systems and subsidized auto engine research.

3) 0.75 MMBD resulting from electric utility conversion from oil to coal and/or nuclear. We have assumed conversion to coal only. This is to be aided by loan subsidies and/or guarantees by the federal government.

The President proposed spending $142.1 billion dollars allocated as follows:

1) $88 billion by the Energy Security Corporation
2) $10 billion for mass transit
3) $6.5 billion for improved auto efficiency
4) $5.0 billion for utility loans
5) $3.5 billion for the Solar Bank (solar energy research)
6) $2.0 billion tax credit for hard-to-get natural gas
7) $2.0 billion for residential/commercial conservation and conversion to natural gas
8) $24 billion for aid to the poor
9) $1.2 billion for administrative expenses

Other Scenario Assumptions

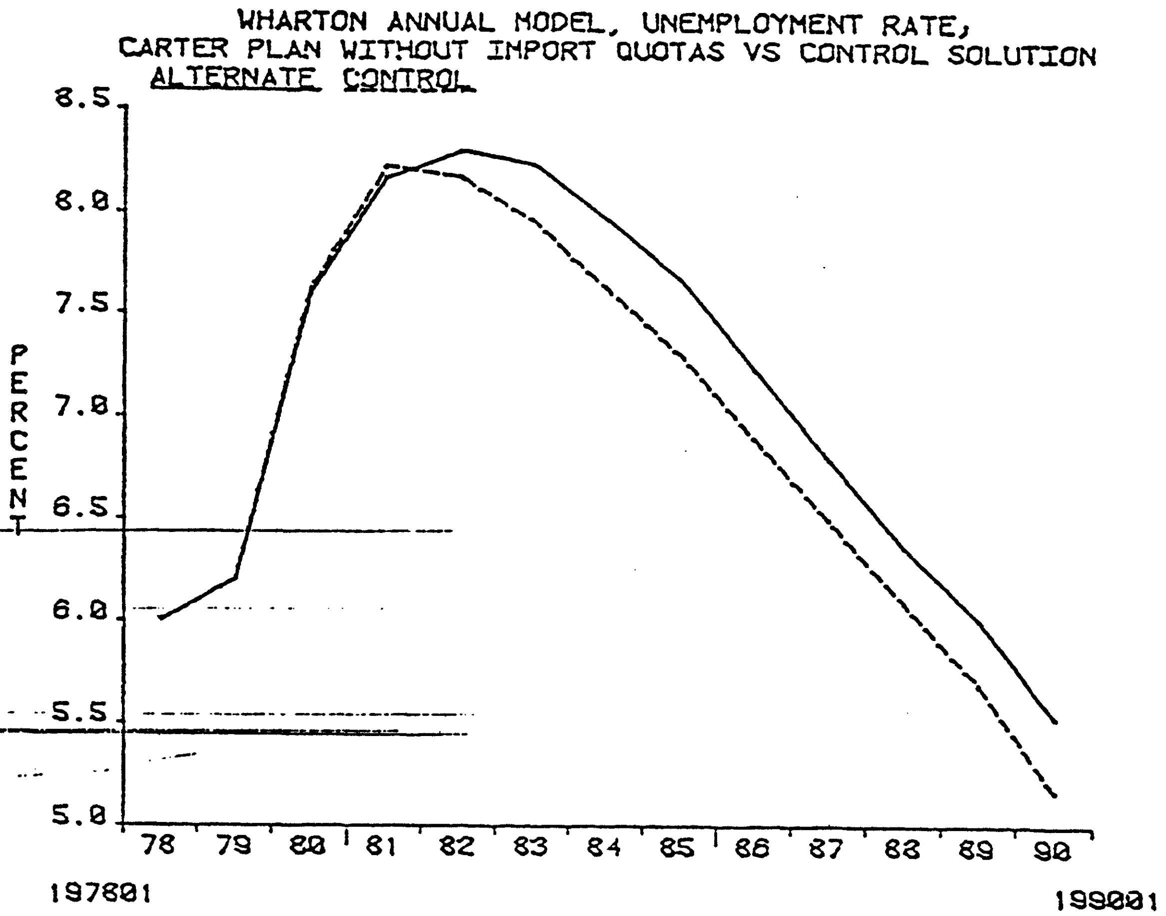
The new domestic supply assumptions, energy conservation/conversion assumptions and dollar spending changes are discussed above. We have assumed that the Energy Security Corporation dispenses all of its funds in the form of subsidies to the private sector (either as direct sudsidies or as price guarantees). The subsidies for research on auto engine efficiency are assumed to result in more rapid increases in MPG during the second half of the 1980 decade. Since the windfall profit tax was included in the Control Solution and was rebated to persons, personal taxes were increased to reflect the elimination of this form of rebate (transfers to persons were left unchanged since aid to the poor remains in the new energy plan).

The above changes resulted in a reduction of net oil imports by 1990 of 4.5 MMBD. Given that the OPEC countries would face a loss of revenues as a result, we have assumed that the OPEC cartel would accelerate world oil price increases in an attempt to recapture part of these lost revenues (the annual rate of increase in world oil prices is assumed to increase from 7 percent in 1981 to 10 percent in 1990). Despite this more rapid increase in world oil prices, the U.S. positive trade balance would be very large by 1990. As a result, we have assumed a steady appreciation of the dollar from 1982 to 1990 (by 1990, the German Mark is worth 35 cents - versus 55 cents today - while the Japanese Yen is worth .34 cents - versus .46 cents today). Given the assumed more rapid increase in world oil prices and the strong appreciation of the dollar, the U.S. trade balance returns to a value of about zero (from a large positive value) by 1990.

Analysis of the Scenario Results

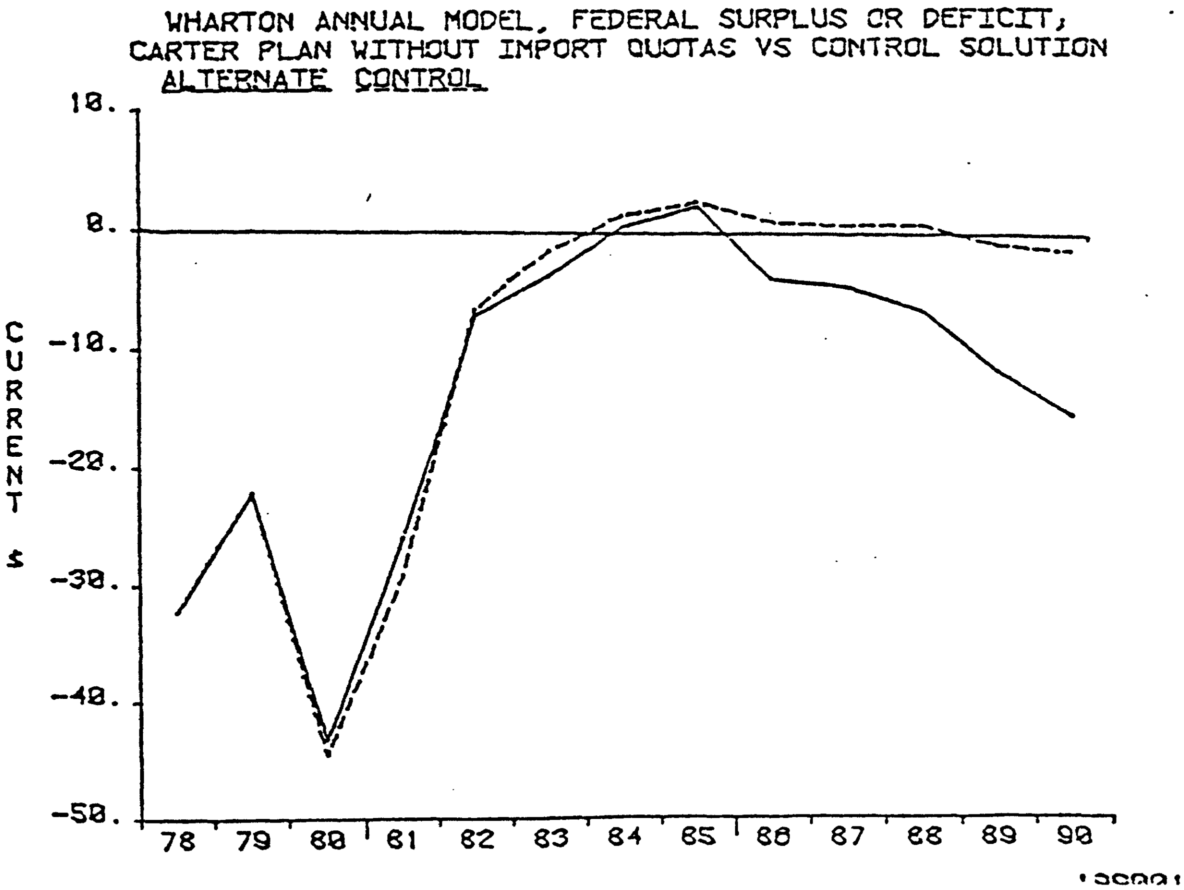
Implemenation of the energy plan results in a slight reduction in the level of economic activity during the 1980's decade. By 1990, real GNP is $16.2 billion dollars less than in the Control Solution. The difference in activity levels is illustrated by the comparison of the unemployment rate projections shown in Figure 1. To attain the desired reduction in oil imports and to sustain a growth rate near that in the Control Solution, the federal government budget is in deficit from 1986 to 1990 (see Figure 2). The trade balance, however, is more strongly positive than in the Control

FIGURE 1



WHARTON ANNUAL MODEL, UNEMPLOYMENT RATE, CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION

FIGURE 2



WHARTON ANNUAL MODEL, FEDERAL SURPLUS OR DEFICIT, CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION

Solution from 1984 through 1989 (see Figure 3).

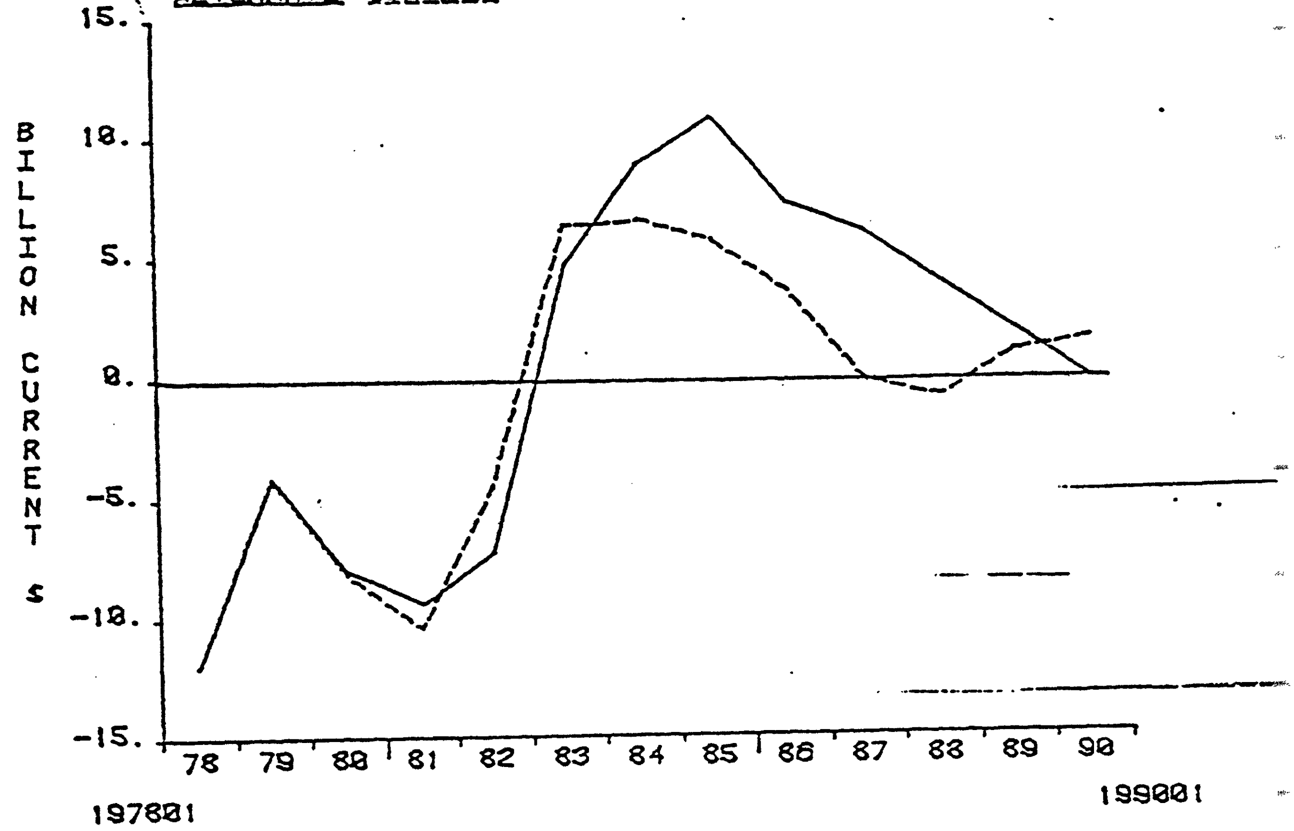
Net imports of oil in millions of barrels per day (MMBD) under the Control Solution and Energy Plan Alternative are as follows (see also Figure 4).

Year	Control Solution	Energy Plan Alternative	Reduction
1979	8.176	8.176	--
1980	8.540	8.509	0.031
1981	9.381	9.265	0.116
1982	9.353	9.068	0.285
1983	9.168	8.441	0.727
1984	9.118	7.963	1.155
1985	9.271	7.668	1.603
1986	9.531	7.550	1.981
1987	9.996	7.435	2.561
1988	10.417	7.335	3.082
1989	10.995	7.129	3.866
1990	11.495	6.741	4.754

The overachievement of the net oil import reduction target in 1990 results primarily from the assumption of higher world oil price growth. Net oil imports decline from 1981 through 1984 under the Control Solution in response to the sharp world oil price increases during 1979-80 and the decontrol of domestic oil prices during the 1979-81 period. After 1984, however, net oil imports in the Control Solution increase steadily to 11.5 MMBD in 1990. Under the Energy Plan Alternative, net oil imports decline steadily after 1981 falling to 6.7 MMBD in 1990.

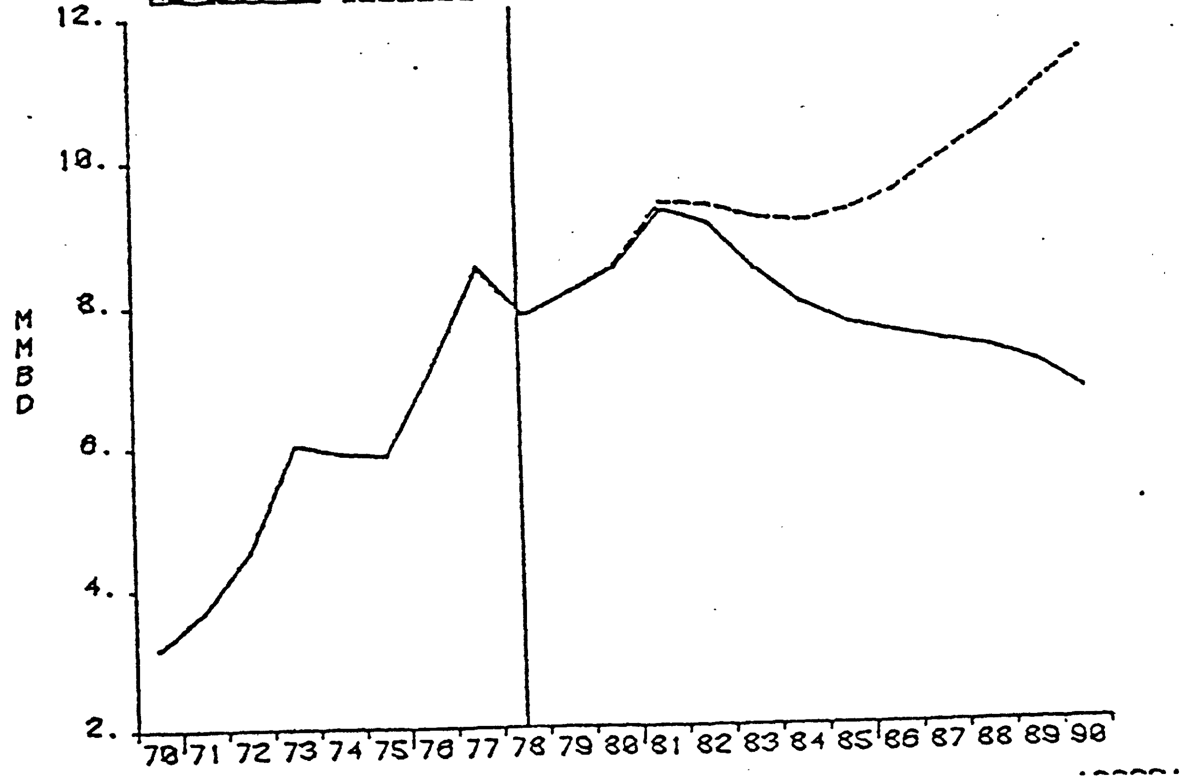
A large share of the reduction in net oil imports is due to the substitution of alternative fuels. The share of petroleum in

FIGURE 3



WHARTON ANNUAL MODEL, NET EXPORTS OF GOODS AND SERVICES;
CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION
ALTERNATE CONTROL

FIGURE 4



WHARTON ANNUAL MODEL, NET IMPORTS OF PETROLEUM;
CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION
ALTERNATE CONTROL

total U.S. energy supply declined steadily under the Control Solution after 1981, but the decline is substantially more rapid under the Energy Plan Alternative (see Figure 5). Natural gas provides some of the offset to the reduction in petroleum's share of total energy supply, but the natural gas share of total energy supply declines after 1981 in both the Control and Energy Alternative solutions (see Figure 6). The coal share of total energy supply increases substantially due to the utility conversion to coal and to the production of 1.0 MMBD of synthetic crude from coal by 1990 (see Figure 7). While the share of coal in total energy supply increased under the Control Solution, the increase in the coal share is significantly greater under the Energy Plan Alternative. The non-fossil fuel electricity share (nuclear, hydro, geothermal, and other) increases by only a modest amount under the Energy Plan Alternative vis-a-vis the Control Solution (see Figure 8). However, the non-fossil fuel electricity share increased substantially under the Control Solution. The percentage shares of energy supply under the Control and Energy Plan Alternative solutions in 1981 and 1990 are as follows:

	Control Solution		Energy Plan Alternative	
	1981	1990	1981	1990
Petroleum	48.6%	42.2%	48.4%	34.5%
Natural Gas	24.3%	18.1%	24.5%	20.8%
Coal	20.9%	26.4%	20.9%	29.5%
Non-fossil electricity	8.4%	13.2%	8.4%	13.5%

Note: Percentage shares do not sum to 100% due to the omission of net exports of electricity and coke, energy inventory changes, and statistical discrepancy.

FIGURE 5

WHARTON ANNUAL MODEL. CRUDE PETRO. AS % OF TOTAL ENERGY SUPPLY, CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION

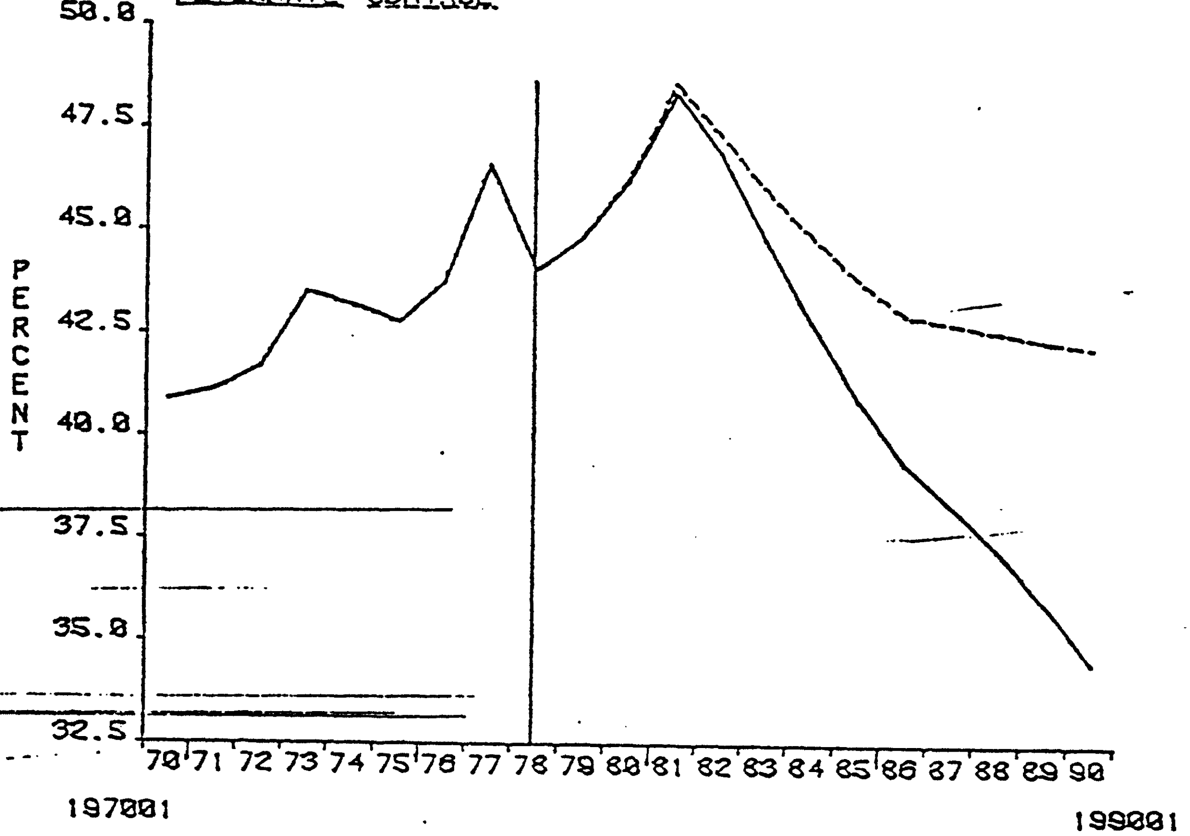


FIGURE 6

WHARTON ANNUAL MODEL. NAT GAS AS % OF TOTAL ENERGY SUPPLY, CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION

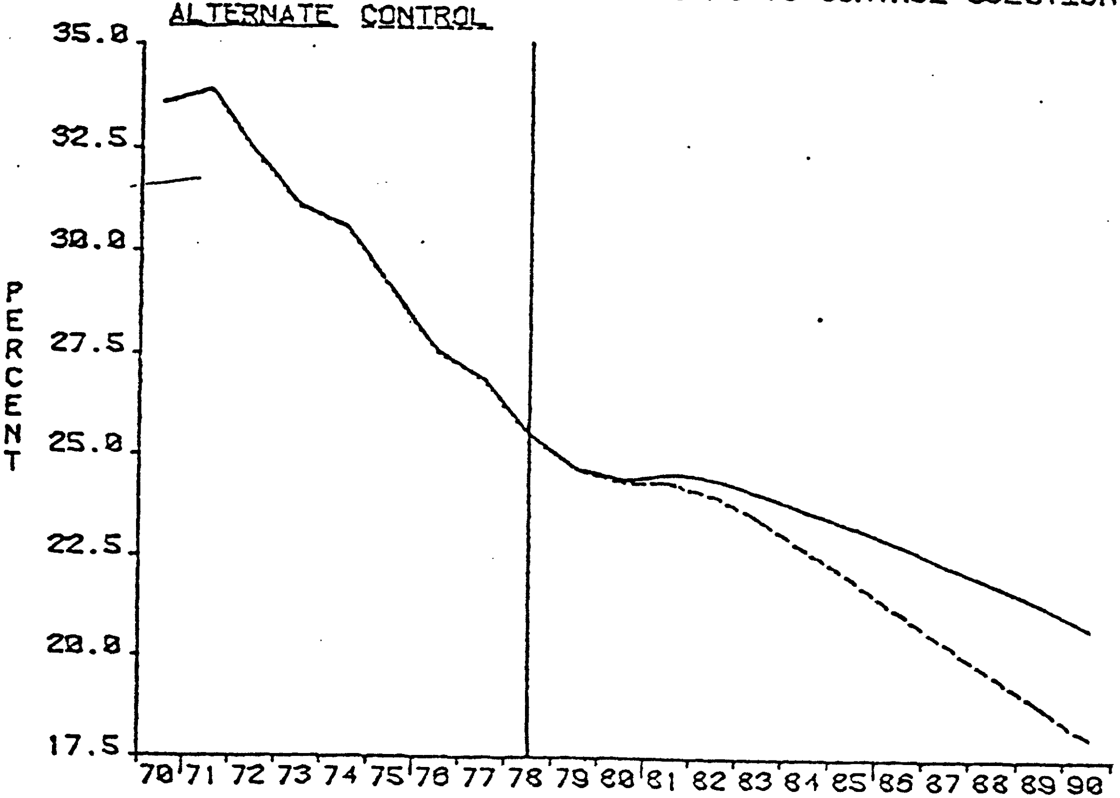


FIGURE 7

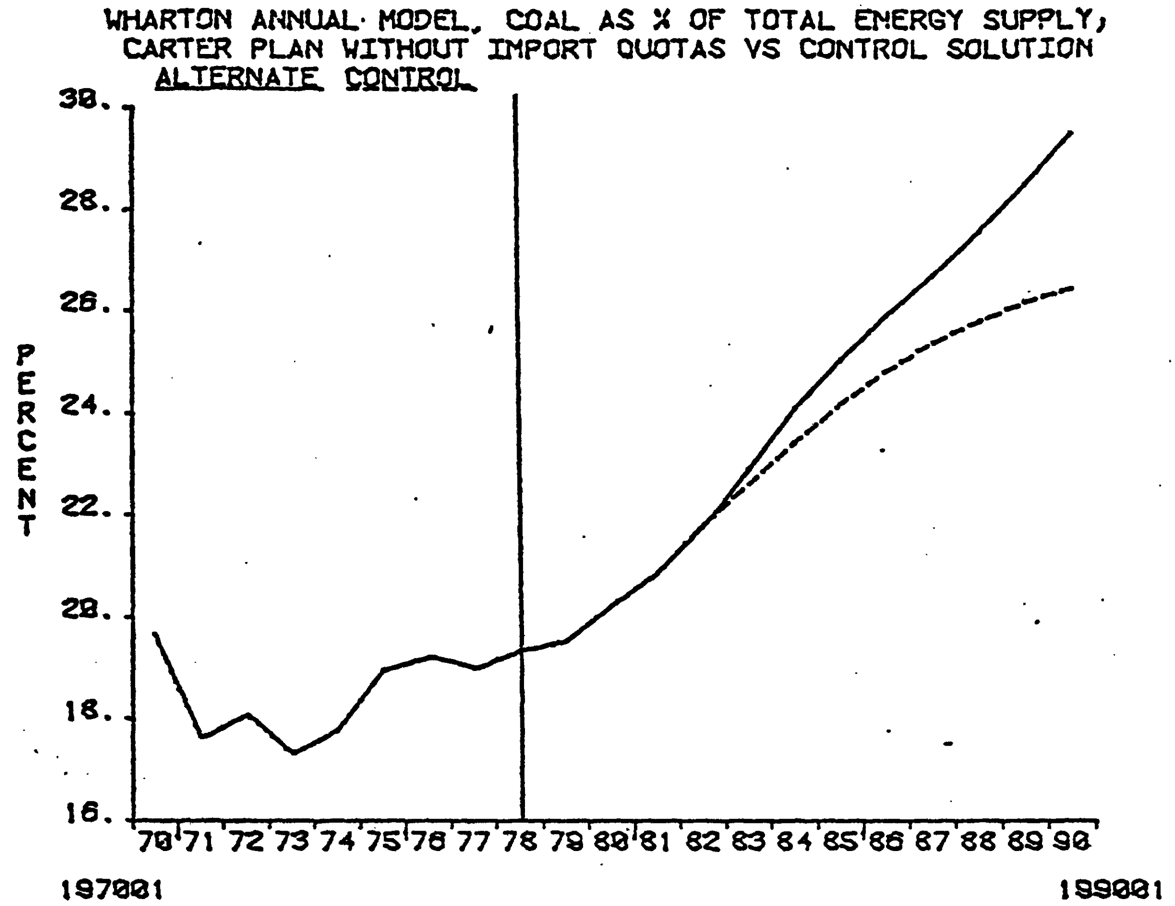
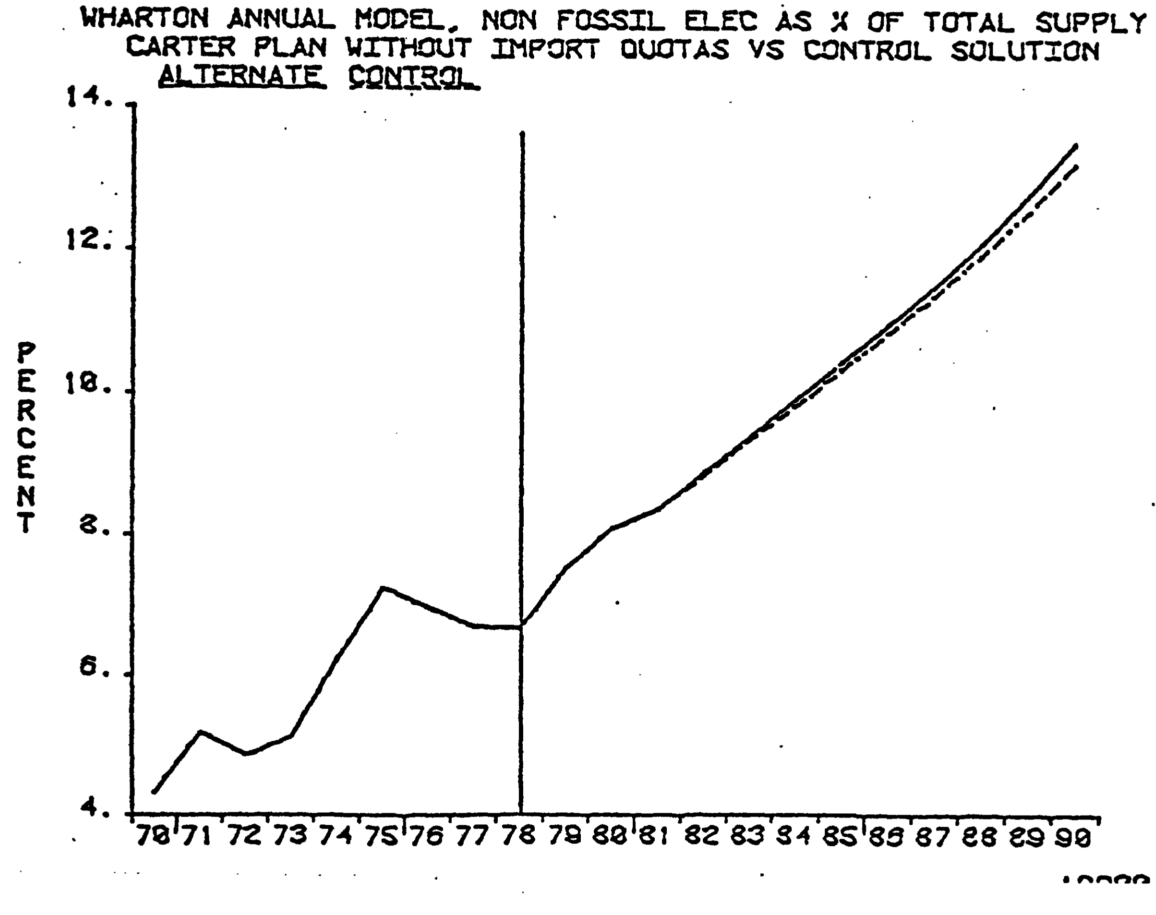


FIGURE 8



The ratio of energy consumption to real GNP declines significantly in both the Control and Energy Plan Alternative Solutions (see Figure 9). The energy/GNP ratio is 1.4 percent lower in 1990 under the Energy Plan Alternative due to the energy conservation assumptions and to the assumed higher world oil prices. The higher annual world oil price growth is reflected in the composite crude oil price deflator growth (see Figure 10).

The new energy plan, if successful, as assumed in this analysis, would substantially strengthen the U.S. dollar at a very minor cost in terms of slower growth and higher prices. Further, the U.S. would be in a position to rapidly increase the production of synthetic fuels during the 1990's if world oil prices dictated such a move. If synthetic fuel costs were still significantly above world crude oil prices, expansion of synthetic capacity could be delayed. However, unless the U.S. develops the capacity to commercially produce synthetic fuels, the U.S. economic growth potential for the 1990's could be determined by OPEC pricing and supply decisions.

FIGURE 9

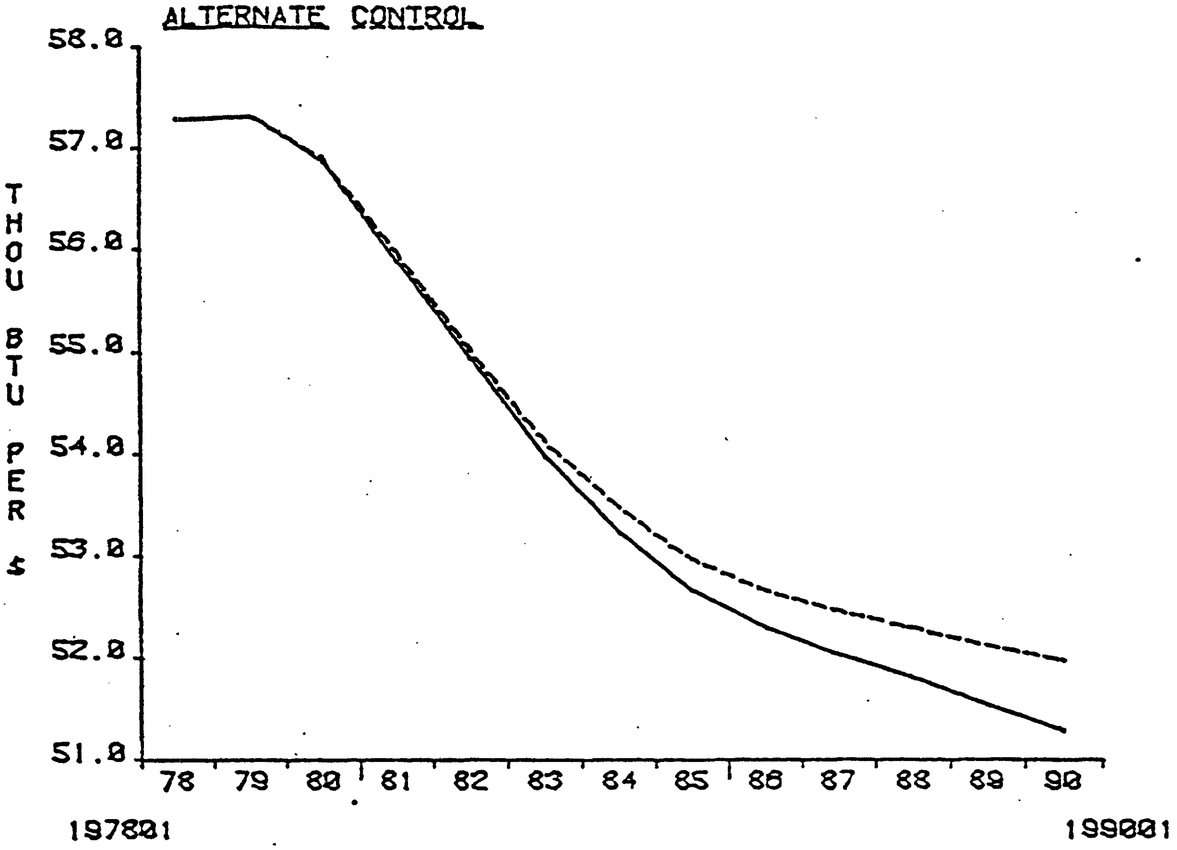
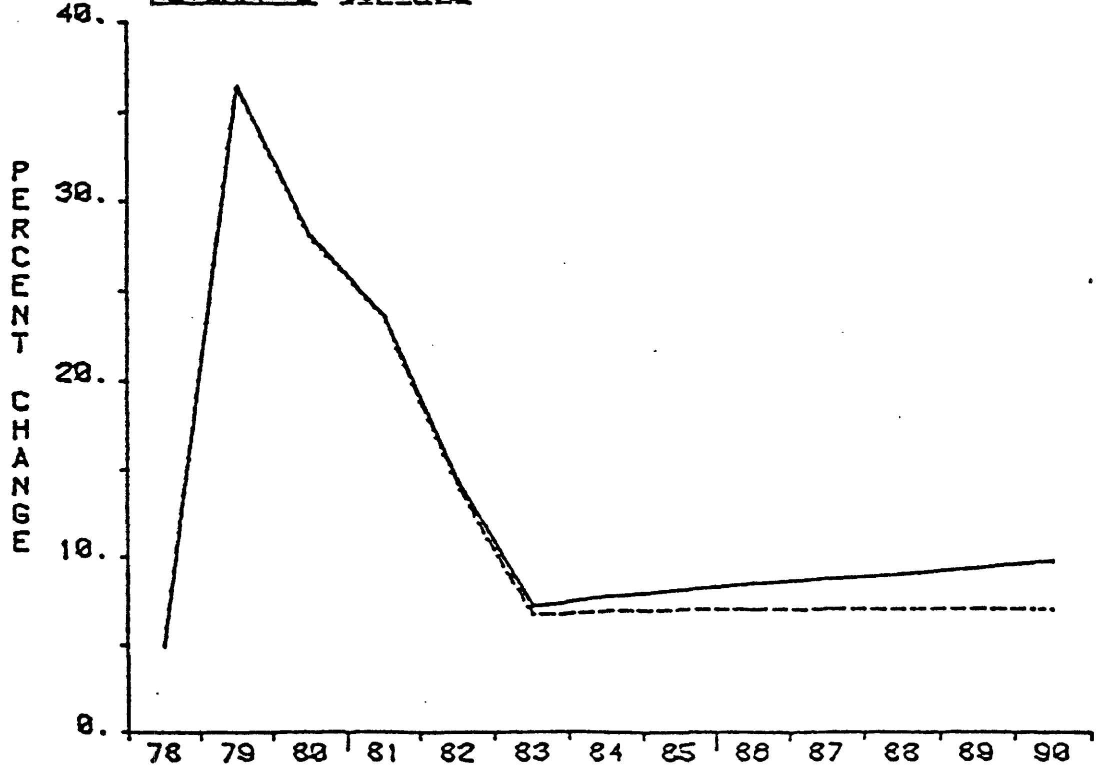

WHARTON ANNUAL MODEL, RATIO OF ENERGY CONSUMPTION TO GNP;
CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION
ALTERNATE CONTROL

FIGURE 10


WHARTON ANNUAL MODEL, COMPOSITE CRUDE PETROLEUM DEFLATOR;
CARTER PLAN WITHOUT IMPORT QUOTAS VS CONTROL SOLUTION
ALTERNATE CONTROL

ENERGY PRICES, ECONOMIC ACTIVITY AND INFLATION:

A SURVEY OF ISSUES

Robert S. Dohner
Fletcher School of Law and Diplomacy
Tufts University
October 1979

The views expressed here are those of the author's and do not necessarily reflect those of the Fletcher School, Tufts or the M.I.T. Energy Laboratory. I would like to thank Richard Mancke and Knut Mork for helpful discussions. Nicholas Ronalds provided research assistance. Financial support from the M.I.T. Center for Energy Policy Research is gratefully acknowledged.

With the considerable momentum of modern economies, and the "long and variable lags," macroeconomic analysis is seldom identified with an event. This month (October) is the fiftieth anniversary of one, and the sixth of another, the Yom Kippur War and the associated oil embargo. As a result of American support for Israel in the war and the decision to supply arms,[1] the oil producers, with Saudi Arabian leadership, declared an embargo on oil exports to the United States, and a 10% reduction in oil production with further monthly reductions to follow. A few days later the Netherlands was also placed under embargo. A second conference in Kuwait refined the boycott; November production was to be reduced to 75% of the September level. In December production was raised to 85% of the September level, and in March the oil ministers agreed to end the embargo of shipments to the United States and restore production to pre-October levels.

The reduction in Arab oil production was offset only slightly by increases in other producing areas, and world crude oil availability has been estimated to have been reduced by about 14% in December 1973 from October 1973[2]. Despite the direction of the embargo against the United States, the U.S. fared reasonably well during the October to March period. At first there was little effect on the volume of imports as tankers at sea continued to land at U.S. ports. Later, the oil companies were able to redirect supplies from non-Arab producing countries to the United States. A reduction in crude oil imports began to be felt in December, and the volume of crude oil imports reached a low in February of 60% of its October level. U.S. imports of petroleum products (mainly heavy fuel oil) were of roughly the same magnitude as crude oil imports and were scarcely affected by the embargo.[3]

About 75% of U.S. crude oil requirements were met by U.S. oil production in the first three quarters of 1973, and this cushioned the effect on supply in the U.S. Petroleum consumption in the first quarter of 1974 was down 7% from a year earlier, a considerably smaller decline than in most European countries.[4] Actions by the Federal Energy Office shifted the brunt of the shortfall to gasoline consumption, although the distribution of the hardship, as measured by the length of gasoline lines, varied considerably by state. An exceptionally warm winter helped. The consumption decline perhaps exaggerated the extent of the supply shortfall; by April the stocks of almost every petroleum product had increased considerably.[5]

The 1978-79 Oil Crisis[6]

Events in Iran in late 1978 confronted the consuming countries with the prospect of a second shortfall of oil production. Perceptions of the vulnerability of the Shah began to grow in the latter half of the year among oil companies,that began adding to their stocks of oil in anticipation of a possible reduction in supply. During the turmoil which eventually forced the Shah's departure, Iranian oil production dropped, and oil exports were suspended entirely in January and February of 1979. The fear of a prolonged shortage sparked considerable pressure on spot markets, where prices soared. Iranian oil production was eventually resumed in the second quarter, but at a level roughly 30% below that of the first nine months of 1978.

In 1978 Iran was the world's second largest exporter of crude oil, and responsible for about 15% of the world oil trade. The effect of the cessation of Iranian exports on the world oil market was of course considerable, but production increases in other countries (especially Saudi Arabia, Iraq, the United Kingdom and Nigeria) moderated the effect on world oil supplies. Data from the Oil and Gas Journal show that total production in non-communist countries fell by about 4½% from the fourth quarter of 1978 to the first quarter of 1979, and regained its previous level in the second quarter. A relatively minor effect on the available supply of oil was worsened by speculative buying and stockpiling to assure supplies; and, in the United States, by regulations which precluded access to more expensive supplies.[7] The visible effects of the reduction in Iranian oil production was much smaller than the effects of the 1973-74 oil embargo, but lengthy lines for gasoline developed in some sections of the country, and particularly in New York City.

Oil Prices

While the production cutbacks during the oil embargo exposed the vulnerability of the consuming countries to a more protracted reduction of oil supplies, and the behavior of spot prices during 1973-74 and 1978-79 are an indication of the seriousness with which a potential supply shortfall is taken, in reality the supply reductions had little effect upon the output or the employment of the industrial countries, just as the coal strike and the severe weather of 1977-78 apparently had little effect on U.S. output. Economies show surprising resilience to supply interruptions in the short run, and perhaps over longer periods, as the largely unsuccessful attempts at international boycotts seem to show. While the two past supply interruptions or a future interruption could have been or could be much worse, the 1973 oil embargo did not usher in an age of scarcity of oil supplies. The supply interruptions quickly subsided, spot market prices receded, and consumers could purchase all the oil they wished at the going prices. Indeed, the 1974-75 recession in the industrial countries weakened demand for petroleum, and produced some concern among the producing countries of an oil supply glut. Production was adjusted, and prices weakened at times in the 1974-78 interval.

This is not to say that the events of five years ago were unimportant — in fact they had a profound effect upon the industrial economies, and changes in energy markets have had a great deal to do with poor economic performance of late. But the effects have stemmed from the price of oil and other energy substitutes, rather than from its lack of availability. It is the dramatic rise in the price of oil (and, for reasons which will be stressed below, the rise of the price of oil relative to the price of output of the consuming countries) which has forced difficult adjustments upon the rest of the world. This paper will review the effects of the oil price rise from a number of standpoints: the effects upon aggregate demand, aggregate supply, potential (full employment) output, and the effects upon the inflationary process. Before examining these issues, it will be useful to present a chronology of price movements.

From the mid 1950's to 1970 the price of crude petroleum trended downward slightly, and fell somewhat more in real terms (relative to output prices in the consuming countries). Dividing the posted price of Saudi Arabian crude oil by the unit value of industrial country exports (as a rough measure of the relative price of crude oil imports) gives an average 1966-1970 value 31% below that of 1956-60.[8] This may overstate the actual fall in the relative price of energy in the consuming countries since posted prices did not always reflect transactions prices, and since industrial countries gave tariff and quota protection to their domestic fuel industries. In the United States the wholesale price of fuels, power, and related products relative to the GNP deflator was 17% lower in 1966-70 than in 1956-60.

Although the most dramatic increase in world oil prices occurred in the first quarter of 1974, the price of oil had already risen substantially by 1974. From December 1970 to October 1973, the posted price of Saudi

Arabian light crude oil increased from $1.80 to $5.12, while the Saudi Arabian government take on crude oil production is estimated to have jumped from 88¢ per barrel to $3.05/bbl.[9] The explanation of this price rise and the shift in the balance of power away from the companies and toward OPEC has been analyzed elsewhere. Suffice it to say here that the exhaustion of U.S. spare productive capacity, and the United States' consequent turn to world markets for 100% of its marginal requirements (rather than 12% under the Oil Import Program) was an important factor.

In December 1973, during the embargo, the OPEC ministers met in Tehran and announced that the posted price for Saudi Arabian light crude for January 1974 would be raised to $11.65 a barrel, yielding a government take of $7 per barrel. Changes in sales prices and in participation further boosted the government take on crude oil productions to $10.12 a barrel by the December 1974 price revisions.

Subsequent revisions raised posted prices to $13.34 in early 1979. After Iranian oil production had resumed, OPEC ministers met in Geneva and announced that, effective July 1, oil prices would be raised to between $18.00 and $23.50 a barrel, depending upon various surcharges. The dispersion of crude oil prices has been substantial, with Saudi Arabian oil selling at $18.00, Kuwait's at about $19.50, Iran's at $22.20 and the African light crudes at about $23.50.[10]

Using the posted price of Saudi Arabian light crude as a rough indicator of world oil prices, and export unit values of industrial countries as an index of the prices of their products, Figure 1 shows the movement of the relative price of oil from 1972 to July 1979. The index rises at the end of 1973 and then reaches a peak in the first quarter of 1974. During the next five years the index of the relative price of oil falls, due both to infla-

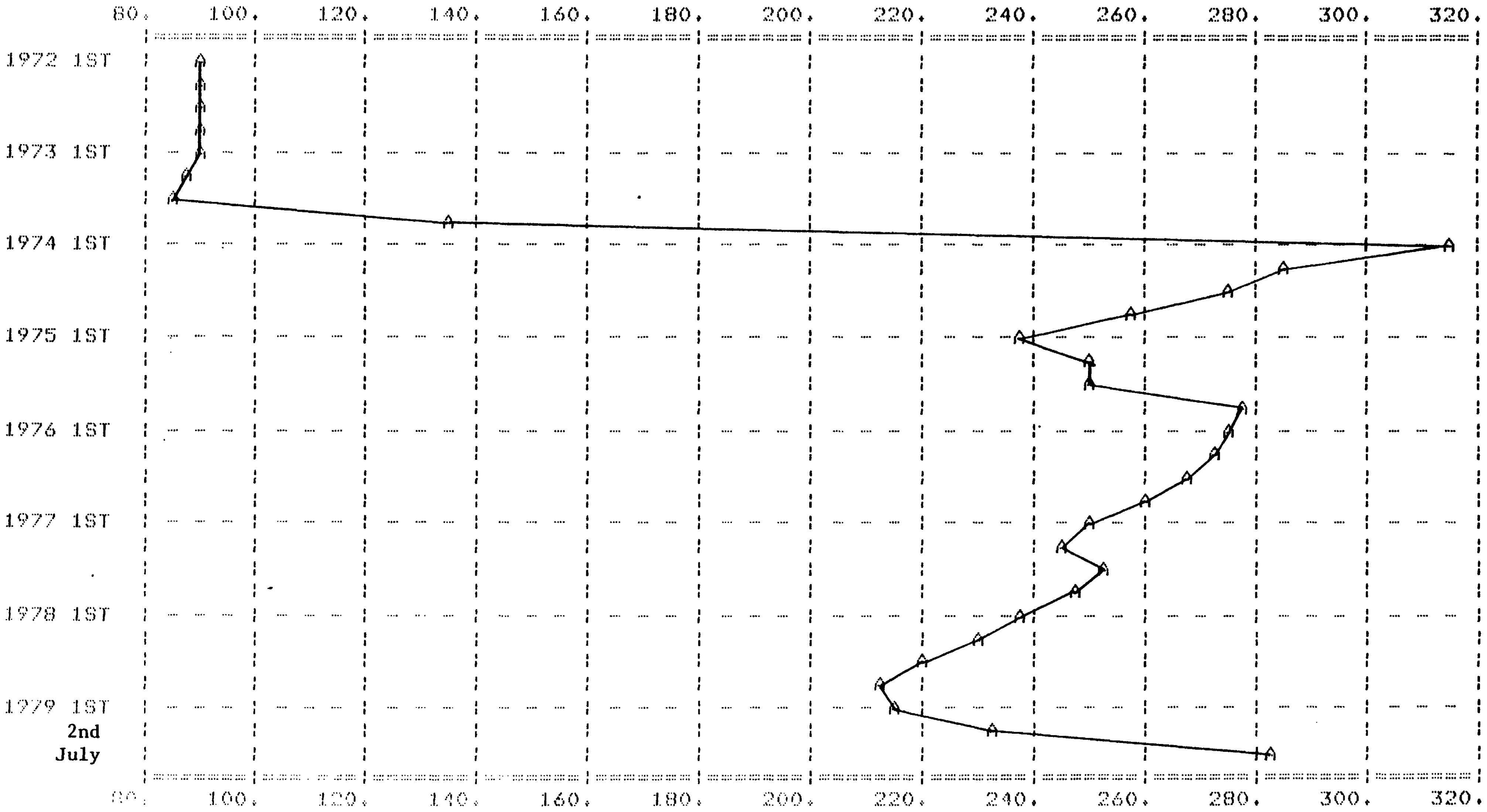


FIGURE 1

Posted Price of Saudi Arabian Crude Oil Relative to
Industrial Country Export Unit Value Index
in U.S. dollars 1973 = 100

Source: IMF, <u>International Financial Statistics Yearbook</u>, 1979 tion in the industrial countries and the depreciation of the dollar, although the 1975 appreciation of the dollar relative to other industrial country currencies reversed, for a time, the decline in the relative price of oil. In 1979, the deterioration of the relative price of oil was reversed by price increases early in the year and by those announced in Geneva at the end of June.

As I shall argue at some length below, it is the increase in the price of oil relative to the output prices of the industrial countries that is the crucial feature of the macroeconomic adjustment problems of the 1970's, and the feature that distinguishes "supply shocks" from a general inflation of world traded goods prices. It is also the appropriate focal point from the point of view of OPEC price-setting behavior, since the price of oil relative to the price of manufactured goods appears to be the central concern of OPEC pricing policy. This concern is not new, but goes back to price negotiations in January 1972, when an agreement was reached for an increase in posted prices of 8.59% to compensate for the 1971 devaluation of the dollar, with a second revision in June 1973 after the second devaluation of the dollar.[11] In the period since the 1974 price rise, the OPEC ministers have repeatedly warned the industrial countries that failure to control their rates of inflation would lead to further increases in the price of oil. As the oil minister from Kuwait told a western audience before the 1979 Geneva meetings, "It is not to your benefit or to ours to see the real price of oil fall".[12]

The 1974-1975 Recession

Revised data show that real gross national product fell in each quarter of 1974, slowly in the first three quarters and then dramatically in the fourth quarter of 1974 and the first quarter of 1975. The depth of the decline came as a surprise to most forecasters. Although consumer demand had weakened, business demand remained strong in 1974, and forecasters in September predicted little change in the coming quarters.[13] Real GNP fell by 6.6% from the fourth quarter of 1973 to the first quarter of 1975 and the unemployment rate peaked at 9.0% in May, 1975. It was the worst postwar recession the United States had experienced.

Although the fall in business activity was sharpest in the United States, the recession was concurrent among the OECD countries. Between July 1974 and April 1975, OECD industrial production fell by 10% and GNP by 3½%.[14] Unemployment increased from a low of 8 million workers to a high of 15 million workers, with migrant laborers in Europe being particularly hard hit. Inflation, already high from the co-ordinated expansion of 1973, accelerated in the OECD countries. Both the recession and the working through of the oil price increases brought some moderation, but rates of price increase have nevertheless remained high in several of the OECD countries.

Recent analyses (Mork and Hall (1978), Hudson and Jorgenson (1978) and Okun (1975)) have attributed a major role to the rise in energy prices in explaining the 1974-75 recession. Eckstein (1978) reviews the rise in energy prices and concludes:

> The energy crisis was the single largest cause of the Great Recession. Without it, the economy would have suffered no worse than a year of small GNP decline in 1974, and would have seen 1975 as the first year of recovery. But when the energy crisis was superimposed upon an already highly vulnerable economic situation, it was sufficient to turn the beginnings of recovery into the sharpest decline of the postwar period.[15]

In what follows I shall outline the effects of energy price increases on the United States economy. One issue, which was the subject of considerable concern and debate in 1974 and which is not covered here, is that of financing oil deficits, or "recycling". In the wake of the 1974 oil price increases, it was feared that, given the inability of the producing countries to spend their increased revenues and their preference for highly liquid and secure investments, capital markets would not be able to finance the required deficits in the balances of payments of the consuming countries.[16] This worry was not borne out in the ensuing years. Interest rate differentials moved funds among financial centers, and international banks successfully intermediated the supply of funds to longer maturities. The balance of payments difficulties of less-developed oil consuming countries were resolved by direct aid, IMF facilities, and increased recourse to private capital markets, while industrial balances of payments were guaranteed by the "Safety Net". The allocation of balance of payments deficits among the industrial countries was an important issue,[17] but the financing of those deficits turned out not to be a critical problem.

Energy Prices, Aggregate Demand and Aggregate Supply

When the oil price increases were announced at the beginning of 1974, the initial reaction of policy makers, at least in this country, was to consider the price changes as an external, inflationary impulse, and to advocate restrictive policies. Thus monetary growth slowed considerably in the United States in 1974. As an introduction to the discussion, it is useful to examine the question: what made the rise in the price of imported oil in 1974 different from an external inflation (a rise in the general world price level for traded goods)? To answer this, we develop a simple aggregate demand and supply model and investigate the effects of changes in world prices, and changes in oil prices.[18]

FIGURE 2

Aggregate Supply and Demand, and

The Effects of General Foreign Inflation

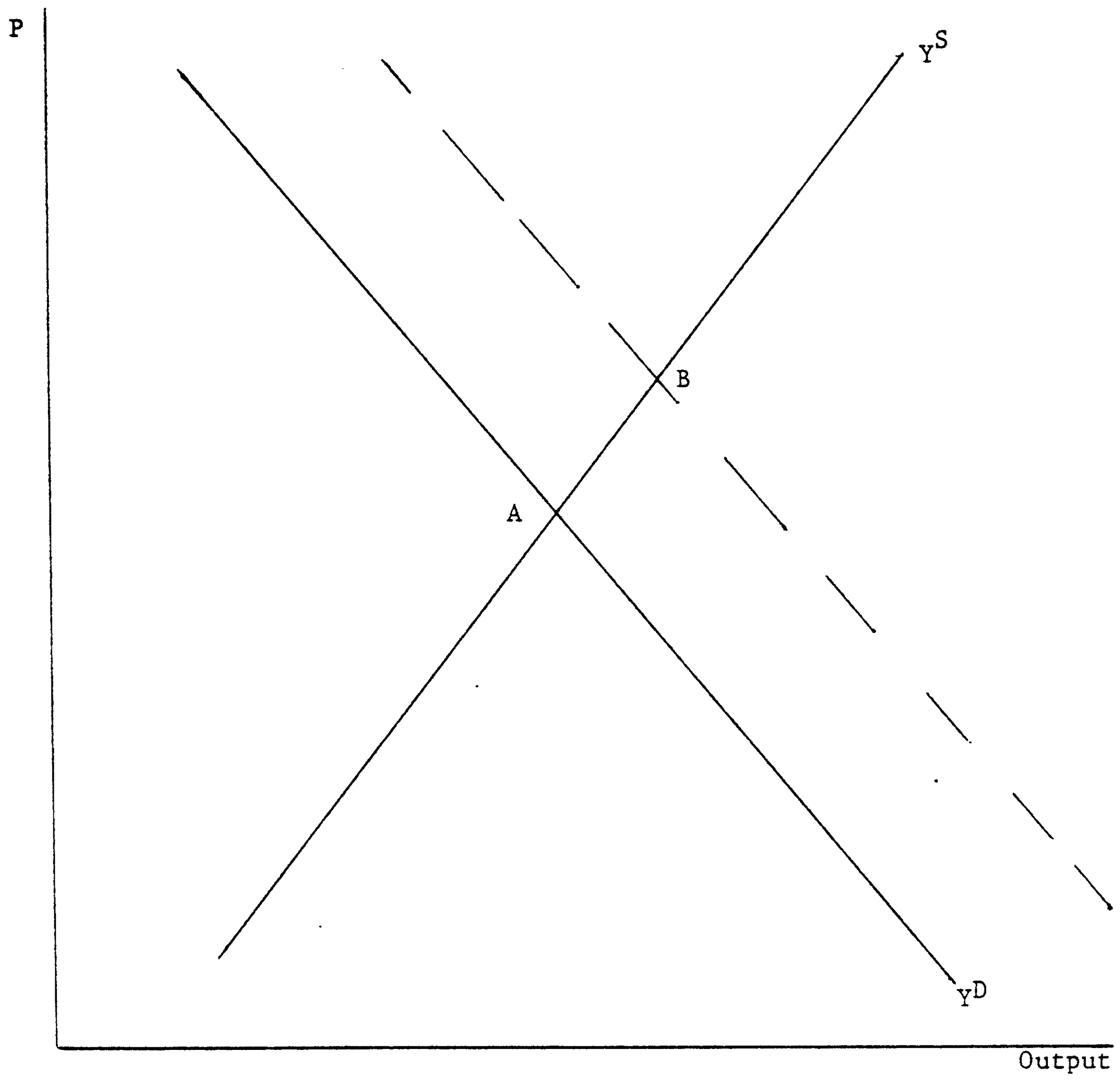


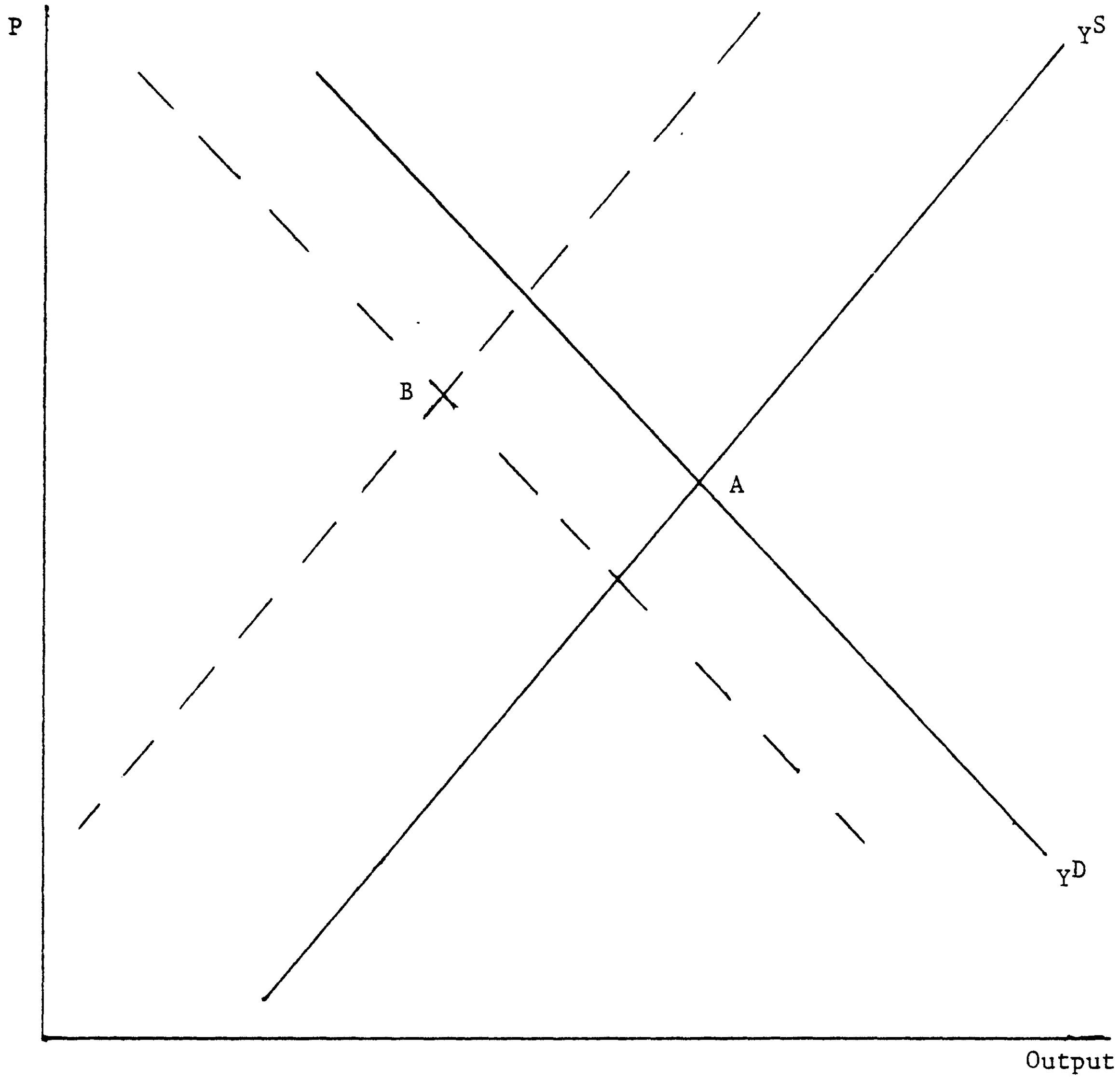
Figure 2 graphs aggregate demand and supply (volume of domestic output) against the price of domestic output, P . The aggregate demand curve is drawn with the assumption of a given quantity of money, government fiscal policy, and level of foreign prices. It slopes down and to the right for the following reasons. An increase in the price of domestic output lowers the real value of the money stock, and raises interest rates. This causes demand (particularly investment demand) to fall. The fall in the real value of money holdings may also discourage domestic demand through its adverse wealth effect. Finally, a rise in the price of domestic goods, given foreign prices, makes foreign goods cheaper, shifting demand away from domestic goods.

The aggregate supply curve in Figure 2 is drawn on the assumption that wages are fixed (at least in the short run).[19] Aggregate supply slopes up and to the right because an increase in price leads firms to operate at a higher marginal cost and therefore higher output.

A general rise in the price of traded goods (a general external inflation) is illustrated in Figure 2. The aggregate supply curve is unaffected by the rise in external prices, but the aggregate demand curve shifts to the right for the following reason. An increase in foreign prices relative to domestic prices raises foreign demand for domestic goods. The foreign price increase also shifts domestic demand away from foreign, and toward domestic goods. The increase in output at B implies reduced unemployment and upward pressure on wages. Rising wages cause the aggregate supply schedule to shift up, reducing output and further increasing prices, unless a contractionary policy reduces domestic demand. Thus a general rise in foreign prices leads to an eventual rise in domestic prices, and perhaps only a temporary increase in output.

FIGURE 3

A Rise in the Relative Price of Imported Oil



An increase in the price of oil relative to the prices of other traded goods has quite different effects in this framework, and these are illustrated in Figure 3. Since oil (or more generally, energy) is an input to the productive process, at a given wage and level of output costs of production increase and therefore the supply price must rise. The aggregate supply curve shifts up in Figure 3.

The effects upon aggregate demand are not completely clearcut, but there are strong reasons for thinking that the aggregate demand curve will shift to the left instead of to the right. First, there is no longer a reason for assuming a substitution effect toward domestic goods, since the price of oil, and not the price of foreign goods with which domestic output competes, has gone up. Second, if expenditure on energy can't be reduced very much when its price goes up, total spending on energy must rise, leaving less expenditures on domestic goods. Finally, as was the case with the 1974 price increases, if the oil producers cannot spend their increased revenues and instead save a large fraction of them, then world demand for the kind of goods the home country produces will fall. The resulting reduction in aggregate demand (leftward shift of the curve) reduces total output and employment, although moderating (perhaps) the rise in prices.

It is the rise of the relative price of oil that is crucial in this context. If the oil price rise is accompanied by an equal rise in the world price of the goods the country produces then the analysis of Figure 2 applies. It is the effect of the relative price change which will show up throughout the analysis, altering the conclusions of conventional macroeconomic models with a single commodity price.

Effects Upon Demand

We shall now consider in some detail the effect of oil price increases upon aggregate demand in Figure 3. The argument will proceed from a discussion of the effects upon income to effects upon expenditure, with a brief discussion of the effects upon wealth and its expenditure effects. Finally we consider the effects upon investment demand.

In the textbook development of macroeconomics, the circular income-expenditure process is introduced to show that each product sale results in an equal amount of income, divided among the factors of production. In an economy that imports some inputs (intermediate goods, or primary factors such as oil) not all of the income generated goes to domestic factors, since a part goes to foreigners. If relative prices and input proportions do not change, then an increase in output leads to a proportionate increase in domestic income, and no harm is done by referring to domestic output as domestic income, as most models do.

However, when the price of the imported input rises relative to that of domestic output, then domestic income changes occur. These income changes are most severe in the case of fixed input proportions, when the amount of imports needed to produce our unit of output cannot be reduced. To illustrate this point, suppose that imports make up 10% of total costs, and the price of imports rises by 50% relative to the price of domestic output. If there are fixed proportions, then the share of imports in total factor income rises from 10 to 15 percent, and the domestic income from one unit of production falls by 5/90 = 5.56%. The domestic income generated by any level of domestic production falls as a result of the relative price change.[20]

If there are possibilities for substitution in production, then the use of imports in production can be reduced, and the effect upon domestic income moderated. The extent to which domestic income is maintained depends upon the extent of substitution, which is captured by a parameter called the own-price-elasticity of substitution. If this elasticity is 1 , as in a

Cobb-Douglas production function, then imported inputs are reduced by the same proportion as their price increases, and domestic income per unit of product does not change.

George Perry (1978) has assembled a series on business inputs of energy. He finds that the ratio of energy to output declines by 10.2% between 1973 and 1976, a period in which the relative price of energy rose by 57%. Perry attributes most of the 10.2% fall to causes other than the rise in energy prices (a point which will be discussed below), but if we take the entire figure as representing price substitution, payments to energy per unit of output rise by 41.0%. If we take the share of energy in inputs to be 5%, the finding of several recent estimates,[21] non-energy factor income per unit of output falls by 2.16%. Econometric estimates of the own-price-elasticity of energy demand have been somewhat larger. Berndt and Wood (1975) find an elasticity of -.47 which would imply a fall in domestic factor income of 0.79% per unit of output.

If the country produces some of its energy and imports the rest, then part of the increased payments for energy inputs provide additional income to domestic factors in the energy industries. However in the United States, prices for domestically produced fuels were largely controlled, so that most if not all of the additional payment for energy in production went to foreign producers. This was an unfortunate aspect of the price controls policy - it was that action which would minimize substitution away from energy and maximize the payment to foreign factors.

The effect of the rise in the price of imported oil in 1974 was therefore to lower domestic income for any level of output. Here domestic income is measured in units of (command over) domestic goods, since it is the production and sale of domestic goods which generates domestic income. But a given level of income in units of domestic goods now represents a lower real income when measured in terms of a basket which includes domestic goods and imported oil. (The appropriate measure, since a significant proportion of consumer expenditures go to direct energy purchases for transport, heating and lighting - 9.16% in the last CPI revision.[22])

A rise in the relative price of oil at a given level of domestic income (measured in units of domestic goods) produces an income effect (which reduces expenditure on all goods) and a substitution effect away from oil and other energy. If the substitution effect is small (precisely: if the short-run price elasticity of energy demand is less than one) then the income offset dominates, and expenditure on domestic output at a given level of income falls.

However, expenditure on domestic goods and expenditure on foreign goods are not the only alternatives for disposal of income. Part of income is saved, and savings may absorb some of the effects of the relative price change. If the proportion of income saved increases with real income, as most simple Keynesian models assume, then a rise in the price of imported oil would lower real income and lower the proportion of income saved. This effect, associated with Laursen and Metzler (1950) might increase expenditure on both foreign oil and domestic goods from reduced savings, moderating the decline in aggregate demand above.

These are the main effects that occur through the income-expenditure channel. Several macroeconomic models emphasize the effects of changes in real wealth upon consumption. If other prices (and in particular, wages) are not sufficiently flexible to fall, then the rise in oil prices forces the general price level up through its own rise and through its effect upon prices of domestic output. This causes asset holdings to fall in real value, lowering the wealth and therefore the expenditure of domestic consumers.

The rise in prices may also severely affect the liquidity of consumers, causing a further retrenchment of expenditure. The "consumer balance sheet" as a determinant of expenditure is examined by Mishkin (1977) who finds that it explains a significant proportion of the decline in expenditure, particularly for consumer durables, during the 1974-75 recession.

Two additional, policy-determined factors which played a role in the 1974-75 recession deserve mention. The first is the behavior of the money stock, and the second is the effect of the price rises on the stance of fiscal policy through the progressive tax system. To combat what was seen as an inflationary shock to the economy, monetary growth slowed in 1974. As a result the real value (in terms of the consumer price index) of the broadly defined money stock (M2) fell by 4.0% from the fourth quarter of 1973 to the fourth quarter of 1974. Interest rates rose to record levels in mid-1974, and the demand for investment goods, particularly housing, was severely affected. Inflation rates hit 11% (year to year changes) in 1974, raising money but not real incomes. This forced many taxpayers into higher tax brackets and, due to the progressivity of the income tax system, raised the proportion of income taken in taxes. Federal receipts rose 12.6% from calendar 1973 to 1974, compared to an 8.1% increase in nominal GNP and a 1.4% fall in real GNP. Personal income tax receipts rose by 15%, although personal income minus transfer payments (roughly: taxable income) rose by 8%.[23] This increase in the proportion of income taxed was inflation's effect, and exerted a substantial drag on aggregate demand.

So far we have mainly discussed determinants of consumption expenditure. Investment demand is reduced by higher interest rates, but a complete story requires a word about the marginal productivity of capital. Since a rise in energy prices lowers non-energy factor incomes, the average rate of return on the existing capital stock would fall, presumably lowering the demand for additional investment. Other effects depend upon the characteristics of the production process. If capital can be substituted for energy in production (capital-energy substitutability) then the demand for capital services would increase with a rise in energy prices. If capital use is associated with energy use so that additional capital requires additional energy (capital-energy complementarity), then the demand for capital services falls with an increase in the price of energy.

Capital-energy substitutability or complementarity is an area of considerable controversy, and a problem which has important implications for the level of investment and medium-term economic growth. Econometric analyses seem to indicate that capital and energy are complements, while engineering, or process, studies conclude that they are substitutable. (For a careful discussion of the evidence, see Berndt and Wood (1979).) We shall not examine this question in detail, other than to mention that certain industries (viz. energy producing industries) are obvious candidates for additional investment, and to raise the conjecture that energy is complementary to existing capital and substitutable with capital in prospective investment. Thus the energy usage, or energy efficiency of a given type of capital good is nearly fixed, and energy to capital usage cannot be altered once one type of capital good (for example, one type of refrigerator) is installed. But if types of capital goods (e.g. types of refrigerators) vary as to their initial cost and energy efficiency, as engineering studies suggest, or if the energy usage of the existing capital stock can be reduced by additional investment (for example, additional insulation) then investment demand may be increased by the energy price rise.

Effects on Supply and Productivity

The empirical evidence that has been accumulated suggests strongly that prices are determined, at least in the short run, by a markup over unit costs.[24] If energy prices rise and other input prices do not fall, then domestic product prices will rise, on a first approximation by the proportion of energy in total costs. This causes the upward shift in the aggregate supply curve in Figure 2. If wages rise (due to indexing, or for other reasons described below) then the upward shift of the aggregate supply curve will be magnified.

If energy prices rise relative to the price of domestic output (if the OPEC producers pursue a policy of maintaining a higher real price of oil), then other factor returns must fall relative to the price of output and relative to the price of oil as well. This change in relative factor prices alters the desired input proportions, factor productivity, and even desired output as a simple example will show.

After the 1974 rise in oil prices it was reported that oil tankers were running at slower speeds to conserve fuel oil. In this case, tankers were substituting capital services (ship days) and labor (crew days) for energy, and at the same time reducing their flow rate of output (ton-miles per day). As a result of the change in input proportions the average productivity of labor (ton-miles per crew day) and capital (ton-miles per ship day) both fell, and these are the effects to be expected in general from changes in input proportions.

If production processes do allow some substitution of other inputs when energy becomes more expensive, then in general the productivity of those inputs which are substituted must fall. We will concentrate on labor, because the capital stock is largely fixed and therefore always employed, and because the possibilities for substituting capital for energy appear to be limited in the short run. At a given level of output, with a rise in energy prices, the firm will substitute labor for energy inputs if possible. This will lower the average productivity of labor, since more labor is now being used to produce the same volume of output. The substitution will also lower the marginal product of labor, since the supply of other inputs is now spread more thinly across the labor employed, and each new laborer has less other inputs to work with. For this reason, one would expect the equilibrium (full employment) real wage to fall in terms of the price of the domestic product.

The extent of substitution possibilities and the effect of the rise in energy prices on labor demand and labor productivity have been the area of some recent controversy. Robert Rasche and John Tatom (1977b) have made a case for considerable substitutability of labor and energy in production, and therefore for a considerable impact on labor demand and average labor productivity. Rasche and Tatom estimate a Cobb-Douglas production function for the output of the U.S. private business sector in terms of inputs of capital, labor and energy.

$$Y = Ae^{rt} \; K^{1-\alpha-\beta} \; L^{\alpha} \; E^{\beta}$$

The estimates that they find are $\alpha = .65$ and $\beta = .12$, which, if the Cobb-Douglas form is correct, should also be the shares of labor and energy in total costs. The Cobb-Douglas form imposes considerable substitutability between energy and labor, and the change in labor demand in production would be $\frac{\beta}{\alpha+\beta}$ times the change in the relative price of labor. From 1972 to 1977 the price of energy relative to labor rose by 78%;[25] this would indicate an increase in labor demand at a constant level of output of about 12%, and a corresponding fall in the average productivity of labor.

The conclusions of Rasche and Tatom of considerable substitution possibilities for energy and the substantial effect of a rise in energy prices on productivity have been challenged by Perry (1978) and Denison (1979). The challenges have been on two grounds. Rasche and Tatom did not have information on energy inputs, and instead used an equilibrium energy demand relationship involving relative prices. The 12% estimate of energy's share in total costs is much higher than the 4 to 5% which others have found. This would overstate the effect on labor demand considerably. (Substitution for $\beta = .05$ and $\alpha = .70$ would reduce the increase in labor demand at constant output to 5.2%.) Perry and Denison also argue that the Cobb-Douglas function overstates the degree of substitutability between labor and energy.

Perry (1978) builds a time series of business fuel consumption per unit of output and estimates that it falls by 10.2% between 1973 and 1976, while the price of energy rises relative to output by 57% over the same period. He then estimates the trend of energy use per unit of output from 1949 to 1973, and attributes one-half to two thirds of the 10.2% reduction to trend changes. Much of the rest he attributes to elimination of non-productive energy use, and concludes that possibilities for substitution away from energy toward labor (and therefore possiblities of a fall in the average product of labor) are quite limited.

The calculation of energy input is an important step in the right direction, but Perry probably errs in his calculation of the trend effect. Energy use per unit of Gross National Product can be easily calculated, and this ratio did fall steadily in the postwar period, until about 1965. But then a sharp reversal occurred. Energy consumption rose by 5% annually from 1965 to 1970 while GNP grew by 3.2% per year. The reasons for this reversal are not completely understood, but much of the change can be attributed to the failure of electricity generation to improve its energy conversion ratio after 1965.[26] Therefore it is not clear what, if anything, should be subtracted from (or added to) the 10.2% decline in business energy use per unit of output, but it appears much more likely that possibilities for substitution of labor for energy exist in the short run.

Other econometric estimates indicate some possibilities for substitution, but lower than those of a Cobb-Douglas function. Berndt and Wood (1975) estimate a partial elasticity of substitution between labor and energy of .65 which, if energy's share in costs were 5%, would indicate an increase in labor demand per unit of output of (.78)·(.05)·(.65) = 2.54%. Hudson and Jorgenson(1978), using a sectoral model which emphasizes energy, find that real GNP falls by 3.2% from 1972 to 1976 due to the increase in energy prices, while labor demand declined by only 0.6% (or 0.5 million jobs), and "as a consequence, productivity growth fell substantially over the period 1972-76."[27] The increase in labor demand per unit of output comes from two sources in their model, the substitution of labor for energy in each sector, and the shift in final demand away from energy intensive and toward labor intensive industries.

The substitution of labor for energy may be the key to the recent changes in productivity growth, the topic examined by Denison (1979).

> The growth rate of National Income Per Person Employed (NIPPE) fell from 2.43 percent in 1948-73 to -.54 percent in 1973-76...
>
> According to my estimates there is no unexplained retardation in the rate of growth of productivity until 1974, and the drop in the rate that started at that time was abrupt and large. I consider this timing an important clue in any attempt to unravel the mystery surrounding the productivity slowdown. 28

Denison rejects the rise in energy prices as the explanation for the productivity bread, based largely on Perry (1978). As I have said above, I find Perry's estimates inconclusive, and I consider the question still open.

One may be tempted to conclude that since greater substitutability of labor for energy in production involves a greater fall in labor productivity, the more substitutability one has, the worse off one becomes. This conclusion is incorrect. The discussion above on demand effects stressed the distinction between output and income that goes to domestic factors. The smaller the substitution possibilities, the greater the fall in income received by non-energy factors of production when energy prices rise. It is the desire to produce at lower cost that leads to substitution in production, and substitution leads to a reduction in payments to (largely foreign) energy.

The substitution of labor for energy would also play an important social role, by cushioning the unemployment affects of the fall in output. Because substitution possibilities exist, the effects of the rise in energy prices and reduction in output can be spread across the labor force. More people can continue to work, but each is paid a bit less in real terms because of the fall in productivity, just as one could share unemployment by reducing hours and sharing the available work.

Rasche and Tatom (1977a) and others have noted that employment has recovered much faster from the recent recession in comparison to its behavior during previous recessions. This is an indication that labor substitution (taking place with some lag) alleviated the unemployment effects of the recession.

Effects on Potential Output and Growth

If firms use less energy to produce their output, then when all other inputs (capital, labor) are fully employed, the level of total output will be reduced, just as conservation of fuel in our tanker example lowered the transportation output of the ship. If one defines potential output as the output of cost minimizing firms when all domestic resources are fully employed, then potential output falls as a result of the increase in the relative price of imported energy. (The reader is reminded once more, however, of the distinction between output and income when energy prices change.)

Calculations of potential, or "high employment" output have conventionally been made using an empirical relationship between employment and the rate of growth of output known as Okun's law. Substitution in production would alter the relationship between labor and output, and thus affect the calculation of potential output. This would have important implications for analyzing fiscal policy, since the stance of fiscal policy is determined by government expenditures and receipts at potential output, rather than at current output. It would also have important implications for determining how close the economy is to full utilization, and therefore to inflation (although in this case the rate of unemployment is an alternative, and preferable, measure).

Rasche and Tatom (1977a) and Perry (1978) examine the issue of potential output and reach opposing conclusions. Rasche and Tatom find potential output increases by only 6.0% from 1973 to 1976, while the Council of Economic Advisers' measure indicates potential output rose by 11.0%[29] during this period. Perry (1978) finds essentially no change in the estimate of potential output due to the rise in energy prices, since, for the reasons reviewed above, he finds essentially no substitution away from energy.

The extent to which potential output dropped due to the rise in the relative price of energy is one issue. An equally important issue is what will happen to the path, or growth rate, of potential output. An increase in energy's relative price leads to a fall in the real return on capital, and therefore a lower demand for investment. In addition, if capital and energy are complements, then the rise in energy prices lowers the demand for capital services in production and further depresses the rate of return on the existing capital stock. As the labor force grows, the labor intensity of production will increase. This will raise the marginal product of capital, and raise investment demand. Thus investment will recover from a rise in energy prices but only after a period of slow growth in output and productivity. If there is no future change in the relative price of energy, then the previous rate of output growth will be restored. Models which assume a rising real price of energy (e.g. Hudson and Jorgenson (1978b)) produce a permanently lowered output growth rate.

Effects on Inflation

If wages and other factor returns were fully flexible, then there would be no necessity for a rise in the general price level with a change in the nominal price of energy. Other factor returns could fall sufficiently to allow product prices to fall, maintaining the same level of a composite price index. If other prices don't fall, then a rise in the price of energy relative to other prices can only be accomplished through a rise in the general price level. Much of the extraordinarily high rate of inflation in 1974 can be described in this fashion, as an adjustment to the rise in oil prices in the first quarter.

One can draw a logical distinction between the impact effect of the rise in energy prices on the prices of other goods, and any inflationary process which may or may not arise from the relative price change. In practice it is difficult to maintain this distinction, for the cost increases caused by the rise in energy prices may take some time to completely pass through in the prices of other goods. Prices of direct energy use (e.g. gasoline) and goods with a very high energy or petroleum content (petrochemicals, fertilizers) would rise quickly. Prices of other goods might respond to increases in costs from direct energy use in production, but the response would be slower to the increased energy costs of intermediate good inputs. Increases in costs in the production of capital goods would be the slowest to pass through into costs of finished consumer goods.

The adjustment time would depend to a greater extent on how quickly energy prices facing energy users rose. For the industrial countries as a whole, from Figure 1, the relative price of energy rises very quickly and reaches its highest point in the first quarter of 1974. From then until 1979, inflation and the depreciation of the dollar lower the relative price of energy for Europe and Japan, easing the adjustment to the 1974 rise.

In the United States prices paid for energy did not rise by the full extent of the OPEC price increase, because price controls on domestic oil and gas production kept prices down, and because rate hearing processes delayed the increase in electricity prices. Over time, average prices for energy increased as cost pass-throughs in electric generation were allowed, as price controls on natural gas production were relaxed, as more of United States oil production passed into uncontrolled categories, and as the United States imported a higher fraction of its total energy use, for which it paid the higher world price.

The wholesale price index for fuels, power and related products relative to the Gross National Product deflator (a general index of goods and services prices) is plotted in Figure 4. In contrast to the relative price of oil for the industrial countries shown in Figure 1, the relative price of energy in the United States rises continuously through the period. Because this kind of adjustment in energy prices took place in the United States, the impact of the OPEC price increases in 1974 was translated into a higher rate of inflation in the United States in the latter half of the 1970's. (The determination of what is adjustment and what is the "underlying rate of inflation" is a difficult question.)

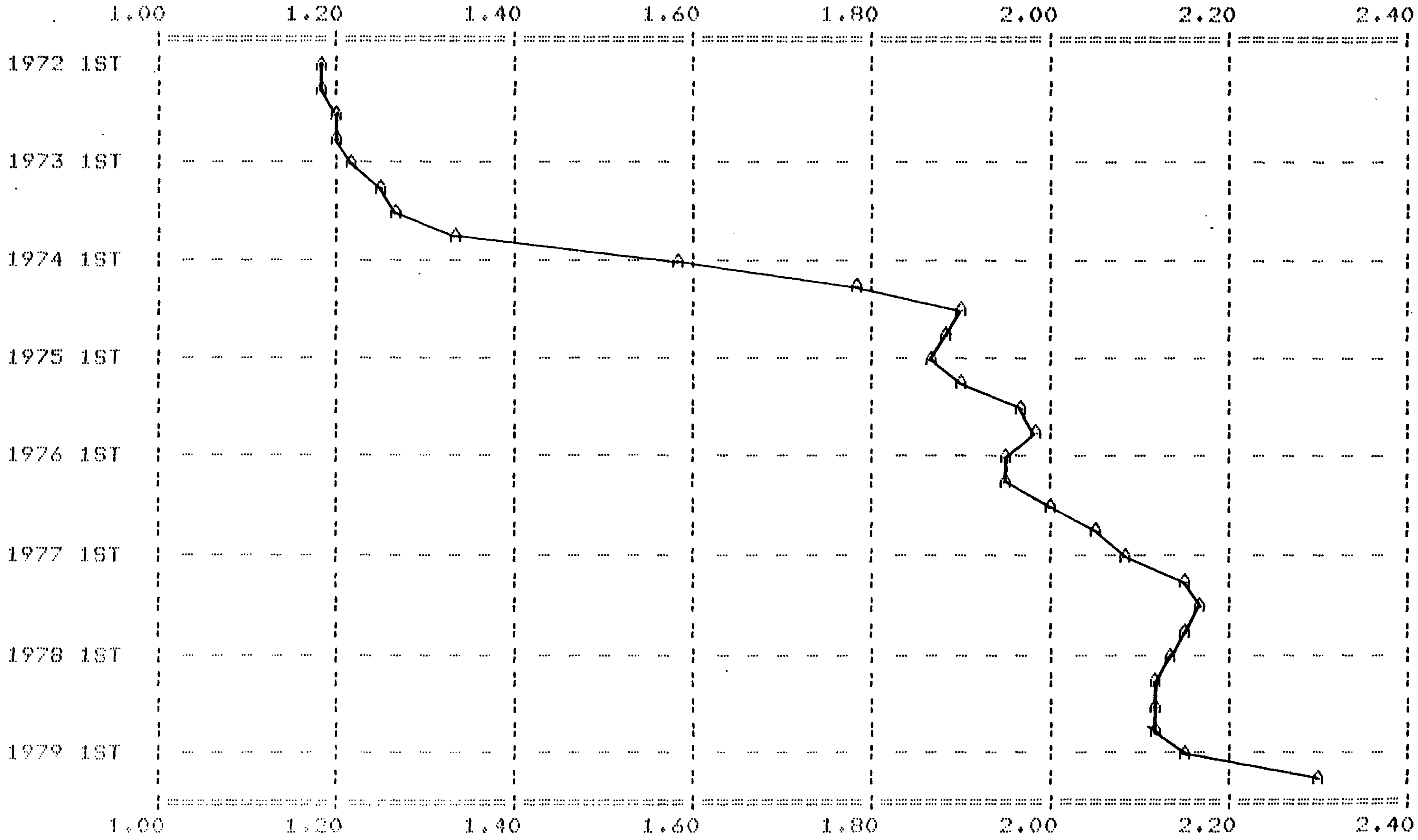


FIGURE 4
United States Wholesale Price Index, Fuels and Power
Relative to the GNP Deflator

Source: Citibank Database

The empirical evidence on what determines prices suggests strongly that prices, even in the short run, are determined largely by unit costs of production. Since roughly two-thirds of costs are labor costs, an inquiry into the effects of the oil price rise in initiating an inflationary process must center on the labor market.

The macroeconomic theory of wage determination goes back to A.W. Phillips, who found a relation between the unemployment rate and wage increase in England over long periods of time. The theoretical foundations of the Phillips curve were refined by E.S. Phelps and Milton Friedman, who argued that real, and not nominal, wages were at issue in the bargaining and wage determination process. Unemployment might affect the path of wages, but inflation which was expected by all parties in the bargaining process would result in equivalent wage increase.

In a simple macroeconomic model with a single commodity price there is no difficulty in defining "the real wage." A rise in energy prices complicates the definition, for the energy price increase is a change in relative prices, or a terms-of-trade change, which introduces at least two goods into the real wage definition.

The domestic producer is interested in his cost of labor relative to the price of his product, and defines the real wage in this fashion. We argued above that a rise in the price of energy relative to the price of the product would require a fall in the wage relative to the product price. For the producer the real wage, in terms of current wages and prices, is now too high.

The wage earner is concerned with his wage in terms of the goods he buys, including energy. For the wage earner, with the rise in energy prices, the current real wage is too low.

To illustrate this point, consider the price changes which occurred in the United States. Between 1973 and 1974, the implicit deflator for personal consumption expenditures (a consumption basket index) rose by 10.81% while the Gross National Products deflator (a domestic product price index) rose by only 9.66%-a difference of 1.15 percentage points. If no substitution away from energy in production is assumed, it is possible to net out the increased production expenditure for energy as Robert Gordon (1975b) does. His gross national product price index net of food and energy rises by 7.1% from 1973 to 1974, or 3.7 percentage points less then that of the personal consumption deflator.[30]

The question of which real wage definition is controlling in the wage setting process is therefore crucial for whether a rise in the relative price of energy initiates a round of wage-price inflation.[31] There are reasons for believing that changes in the real wage defined in terms of a consumption price index determines at least a part of wage change, and therefore that an increase in the relative price of energy leads to a round of inflation.

The most straightforward reason for thinking that the consumption real wage determines wage change is wage contract indexation, almost all of which is done on the basis of a consumption price index. Of the 9.7 million workers the Labor Department estimates are covered by major collective bargaining agreements, some 5.8 million (60%) have contracts with escalator clauses.[32] Most cost-of-living adjustments are based on changes in the Consumer Price Index, the most common of which is a 1 cent per hour increase for each 0.3 or 0.4 percentage point change in the CPI.[33] Indexation is much more widespread in Europe (with the exceptions of France and Germany) than in the United States or Japan,[34] and would therefore make adjustment to a rise in the relative price of energy more difficult.[35] There is also reason for believing that wage changes respond to the consumption price index even in those cases without explicit indexation clauses, either because wage setting follows the pattern of major agreements, or because consumption price changes are issues in the bargaining process.

If wages rise because of the rise in energy prices, then the aggregate supply curve would shift up further in Figure 3, since increasing wage costs increase the supply price at any level of output. Prices would rise, lowering the real wage, and output would fall, raising unemployment. This wage-price spiral would continue until unemployment and disappointed real wage expectations reconcile labor to a new, lower real wage. The policy authorities would be faced with a difficult choice, since a policy of increasing demand might prolong the inflation process.

The empirical evidence on this kind of wage adjustment process is mixed. Klein (1978) attributes wage increases in Britain and Scandinavia after 1973 to the rise in oil prices.[36] In contrast, Gordon (1977), using lagged changes in a price index net of food and energy, and lagged change in a consumer price index, finds that the consumer price index changes do not help to explain U.S. wage inflation. Gordon concludes: "<u>none</u> of the 1973-74 inflation in food and energy prices 'got into' wages, and all pre-1971 wage equations that allow any influences of food and energy prices drastically over-predict the cumulative 1971-76 wage increase."[37]

Dohner (1979) investigates an alternative model where rates of wage change are determined by previous values of the real wage. The real wage defined in terms of a consumption price index does affect wage determination in the United States and the United Kingdom, and equations with lagged real wage terms better explain (in out-of-sample prediction) the behavior of wages in 1974 and 1975. Sachs (1979), in reviewing the trend of real wages after the oil price rise, finds that real wage growth slows in the United States, providing some scope for demand policies, but wage growth squeezes profits in Europe and Japan, limiting the scope for increasing output. The effect of the oil price rise in spurring wage inflation is an important and unsettled issue, but the preliminary results, I think, indicate some effect of energy price rises in increasing inflation beyond that required for the energy price adjustment. A more careful modeling of the effects of energy price increases on the wage process, would require a more explicit attention to the institutional arrangements which govern wage change than macroeconomics has traditionally had.[38]

Conclusion

If the implications of the analysis are gloomy, it is because the effects of a rise in the relative price of oil are rather gloomy, and impose difficult adjustments upon the consuming countries. The rise in the relative price of oil lowers the real income of the consuming countries since more of their output is needed to pay for the now more expensive oil. This fall in real income must be distributed among domestic factors of production, and if the factors are unwilling to accept a reduction in their real income, then inflation occurs to reconcile the inconsistent claims on (now lower) national income. The fact that energy use is more expensive affects production decisions, lowering output and lowering productivity.

If the relative price of oil rises to a higher level and stays there, then the adjustment is eventually completed. Prices no longer rise due to the rise in the relative price of energy, and incomes begin to grow through investment and technological advance. If the relative price of energy falls, through inflation in the consuming countries, then the adjustment is eased or reversed, until the next round of energy price increases. If the relative importance of energy falls, because of substitution over time away from energy use in production or consumption, then the effects of the rise in energy's relative price can be permanently moderated.

I will close with a few remarks about economic analysis. The oil price change is a difficult analytical problem because it involves a substantial relative price shift. Traditional macroeconomic models do not describe these effects because the aggregation in those models assumes that relative price shifts do not take place. Recent theoretical models by Gordon (1975a), Phelps (1978) and Solow (1979), and by Bruno and Sachs (1979) and Dohner (1978) for open economies have been developed for this purpose, with the substantial impetus of hindsight. Distinctions between output and income, and income and real income; and the precise definition of real magnitudes (for instance, the real wage) are all extremely important.

There is also reason to distrust the implications of econometric models, which have been estimated for periods of near constancy in relative prices. One example might be the econometric finding of capital energy complementarity. With labor a large share of costs, and energy a small and perhaps declining share of costs over much of the postwar period, techniques may have developed to substitute labor for capital, with little regard for energy use.[39] Thus it is not surprising that additional capital use was associated with additional energy use, or that capital and energy would appear as complements in the postwar period. Higher energy prices may well encourage future techniques which substitute capital for energy.

Experience with higher relative prices for energy will improve econometric models, as well as theory. But higher energy prices are so new that econometrics should not substitute for good judgement in analyzing the economic affects of higher energy prices.

FOOTNOTES

[1] Lenczowski, G. "The Oil Producing Countries" Daedalus Fall 1975 pp 64-5.

[2] Stobaugh, R. "The Oil Companies in the Crisis" Daedalus Fall 1975 pp 180-81.

[3] Perry, G. "The United States" in Fried, E. and Schultze, C. eds. Higher Oil Prices and the World Economy (Washington; Brookings Institution, 1975) Table 2-1 page 75.

[4] Stobaugh, op. cit. p 192.

[5] Mancke, R. Performance of the Federal Energy Office American Enterprise Institute, National Energy Study #6. (Washington, AEI, 1975) p 4.

[6] The material in this section is drawn largely from Mancke, R. "The American Response to the 1978-1979 Oil Crisis" Orbis (forthcoming) which the author graciously supplied.

[7] This point is stressed by Mancke. Ibid.

[8] International Monetary Fund, International Financial Statistic Yearbook 1979. The posted price of Saudi Arabian crude oil in US$/bbl is divided by the Industrial Country export unit value index (pages 70-1, line 110) which is also defined in terms of U.S. dollars. Posted prices are for tax reference purposes, and do not precisely measure the actual realizations of the producing states or the oil companies. However the posted price trend gives an indication of relative price movements. A calculation by Adelman for Venezualan crude oil realizations show that they drop by 5% from 1956-60 to 1966-70, while Saudi Arabian posted prices fall by about 25% over this period. Thus the measure in the text probably overstates the fall in the real price of oil. Adelman, M. The World Oil Market (Baltimore; Johns Hopkins, 1972) Table V-A-4. page 342.

[9] Darmstadter, J. and Landsberg, H. "The Economic Background" Daedalus Fall 1975, p 26.

[10] Petroleum Economist October 1979, page 443.

[11] Penrose, Edith, "The Development of Crisis" Daedalus Fall 1975, pages 44, 46.

[12] The Economist June 30, 1979, page 71.

[13] U.S. Council of Economic Advisers, Economic Report of the President 1975 page 37.

[14] OECD, Towards Full Employment and Price Stability (McCracken Report) (Paris; OECD, 1977) page 72.

[15] Eckstein (1978) page 124.

[16] On the problems of financing, see Williamson, John, "The International Financial System" in Fried and Schultze, op. cit.

[17] This issue is discussed in Solomon, R. "The Allocation of Oil Deficits" Brookings Papers on Economic Activity 1:1975 pages 61-79.

[18] For a further discussion of the aggregate supply and demand model, see Dornbusch, R. and Fischer,S. Macroeconomics (New York: McGraw Hill, 1978) Chapters 11, 12, and pages 600-03. The effects of the oil price rise in this context are discussed by Dohner (1978) and Bruno and Sachs (1979).

[19] The derivation of the aggregate supply curve is discussed in Dornbusch and Fischer op. cit. Chapter 11. The positive slope depends upon wages and other input prices not being completely flexible in the short run. When full adjustment of wages takes place the supply curve is much steeper, if not vertical. In drawing the aggregate supply curve, I also assume that the ratio of other input prices to the output price (the real price of the other inputs) is constant.

[20] A note on measurement. GNP is measured net of imports, and so would move along with domestic income, so GNP and income would be reduced at any level of goods and services production. Figures 2 and 3 show the volume of goods production, and not GNP.

[21] C.f. Brinner, R. Technology, Labor, and Economic Potential (Lexington, Mass.; Data Resources, 1978) page 74. for an estimate of 5%, and Hogan, W. and Manne, A. "Energy-Economy Interactions: The Fable of the Elephant and the Rabbit?" in Hitch, C. ed. Modeling Energy-Economy Interactions (Resources for the Future, 1977).

[22] U.S. Bureau of Labor Statistics, Facts About the Revised Consumer Price Index (Washington, GPO, 1978) p 8. The 9.159 figure is for urban wage earners and clerical workers. The share of energy in the expenditure of all urban consumers is given a weight of 8.585.

[23] U.S. Council of Economic Advisers, op. cit. pages 61-2.

[24] See for instance, Nordhaus, W. "Recent Developments in Price Dynamics" in Eckstein, O. ed. The Econometrics of Price Determination (Federal Reserve Board, Washington, 1972) and Godley, W. and Nordhaus, W. "Pricing in the Trade Cycle" Economic Journal 82 (1972) pages 853-82. But see also Gordon (1975b) for a discussion of excess demand effects upon prices.

[25] Wholesale price index, fuels, power, and related products, divided by average hourly earnings in manufacturing adjusted for overtime and interindustry shifts. Council of Economic Advisers, Annual Report.. 1979.

[26] See Darmstadter, J. "Energy" in The Commission on Population Growth and the American Future, Population, Resources, and the Environment (Wash.; GPO,1972)

[27] Hudson and Jorgenson (1977b) pages 1, 29.

[28] Denison (1979) pages 4, 5.

[29] Rasche and Tatom (1977a) page 20.

[30] This series was graciously provided by the author for my work on a previous paper (Dohner(1979)).

[31] Of course the monetary authority must ultimately "validate" the price increase. The failure of the money stock to rise would lead to price increases and a fall in output. I think the view that monetary authorities have this much independence, and do not react to unemployment, is misplaced.

[32] LeRoy, D. "Scheduled Wage Increase and Escalator Provisions in 1978" Monthly Labor Review January 1978, Table 4.

[33] *Ibid*. page 7.

[34] Braun, Anne R. "Indexation of Wages and Salaries in the Developed Economies" IMF Staff Papers 23 (1976) Table 1, page 238.

[35] Braun argues that indexation schemes are designed to protect the lowest paid worker and therefore have a heavy weighting on foodstuffs and other commodities, making them respond more to commodity price changes. *Ibid.* page 246.

[36] Klein (1978) page 86

[37] Gordon (1977) page 268.

[38] Sachs (1979) is a step in this direction. See also Phelps-Brown, E.H. "A Non-Monetarist View of the Pay Explosion" Three Banks Review 1976, and Barkin, S. ed. Worker Militancy and its Consequences 1965-75 (New York; Praeger, 1975).

[39] See Bullard, Clark "Discussion" American Economic Review 68:2 (May 1978) page 125.

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