A COMPUTER SIMULATION MODEL FOR EVALUATING THE DEPENDENCY AND BARGAINING POWER OF THE OIL PRODUCING COUNTRIES VERSUS THE INTERNATIONAL OIL COMPANIES

AN ECONOMETRIC APPROACH

BY

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The Participants in the World Crude Oil Market

During the current century, all countries have become increasingly dependent on oil. Oil has satisfied greatly expanded energy requirements since World War II, and future expansion is likely to be met by oil at least until the commercial development of atomic energy. Because oil plays such an important role in both developed and underdeveloped countries, it is frequently subject to national and international policy decisions.

Certain essential forces interact in the world crude oil market, enabling the market to function continuously and effectively. The analysis of the interaction of these forces in the oil economy is the subject of this study.

The world crude oil market is essentially controlled by the following participants: (1) the oil-producing countries, (2) the international oil companies, (3) the oil-importing countries, and finally (4) the parent countries of the international oil companies. The power of these participants is unequal, and, of course, their relative power varies from one situation to another.

In order to have an uninterrupted supply of oil to the consuming countries and a resulting flow of earnings to the international oil companies and the oil-producing countries, continuous cooperation of all the participants in the market is required. Basically, this cooperation is determined

by the amount of benefit that each participant obtains for its contribution.[1] If the actual reward does not match the desired return, conflict will arise: This conflict might be resolved through a bargaining process. In order to remove conflict, a balance must be achieved of many essential variables such as political, social, legal and commercial policies and practices.

The Sources of Conflict Among the Participants

Naturally, each participant tries to maximize its benefits; as a result, conflict of interest occurs between the participants.

The oil-producing countries' governments have increasingly thought it desirable to negotiate directly with the international oil companies over the terms on which they are allowed to operate. In general, the demands of these countries have centered on the financial returns accruing to the government. They seek higher returns through higher royalties, increased production and exports, and price raises. The oil-producing countries also wish to increase the degree of domestic control exercised over the oil operation. They prefer to receive their revenues in hard currencies in order to adjust their balance of payments, and to have their oil refined locally in order to increase revenue and provide additional employment.

In almost all matters, the governments of the oil-producing countries have made steady and spectacular gains in their negotiations.[2] Initial terms of the exploration and production concessions have been repeatedly

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[1] Walter J. Levy, "Interdependence as the Foundation for World Oil Operations," Proceedings of the Fourth World Petroleum Congress, Section IX.

[2] Edith T. Penrose, The Large International Firm in Developing Countries: The International Petroleum Industry, (London: George Allen and Unwin Ltd., 1968), pp. 200-202, 210.

renegotiated, invariably in favor of the producing countries: Where the concessions covered a large portion of a country's area, they have been reduced in size; different regulations covering drilling requirements, reservoir maintenance and similar matters have been introduced; and financial arrangements of all kinds have improved in favor of the countries. Some of these developments have been the direct result of the rapid increase in the quantity of oil produced, but most of them have been obtained by the governments of the oil-producing countries using a steadily increasing bargaining power to maintain heavy pressure on the international oil companies. It seems highly probable that increasingly greater shares of profit will be demanded by the oil-producing countries.[3] By establishing the Organization of Petroleum Exporting Countries (OPEC), the oil-producing countries expect to strengthen their bargaining position.

Although Middle East oil has the lowest cost, the consuming countries' fear of political instability or extreme dependence on the action of Middle Eastern governments has intensified their search for new sources of oil and also for oil substitutes. The consuming and importing countries seek access to uninterrupted oil supplies with the lowest possible price. These countries would prefer to build refineries in their countries and import crude oil rather than refined products, in order to expand employment, improve the balance of payments, produce more revenue and increase industrial growth. They prefer to diversify the sources of oil supplies due to security considerations. In some cases, the importing countries have discriminated against

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[3] M. A. Adelman, "The World Oil Outlook" in Natural Resources and International Development (Marion Clawson, ed.), (Baltimore, Md.: Johns Hopkins Press, 1964), pp. 104, 109.

oil imports from some sources and established severe trade restriction in the form of quotas or other trade barriers, attempting through political manipulation to ensure diversity of sources.

The international oil companies have great economic power. They have the ability to influence the use of oil resources, the distribution of products, the prices of products, the development of new technology and the distribution of income. International oil companies, like other private enterprises, are trying to maximize their profit, and at the same time to secure their competitive position in the world oil market. In order to achieve these goals, they seek to maintain freedom of control over all their worldwide operations.

Finally, the parent countries of the international oil companies are interested in the continued operation and growth of these companies and in the safety of their foreign investments.

These various and divergent interests of the various participants in the world crude oil market create serious potential conflict.

Conflict Resolution, Process of Adjustment and Equilibrium Point

The interdependence and conflict of interest of the four participants in the world crude oil market have already been described. It has also been stated that the economic survival of these groups depends upon a secure and uninterrupted supply of oil, which will result from good relations and coexistence among the participants. Good relations would be established when all the participants receive a reward they believe to be adequate for their contributions. But since the participants have unequal power, the reward to each participant can be increased or decreased through the

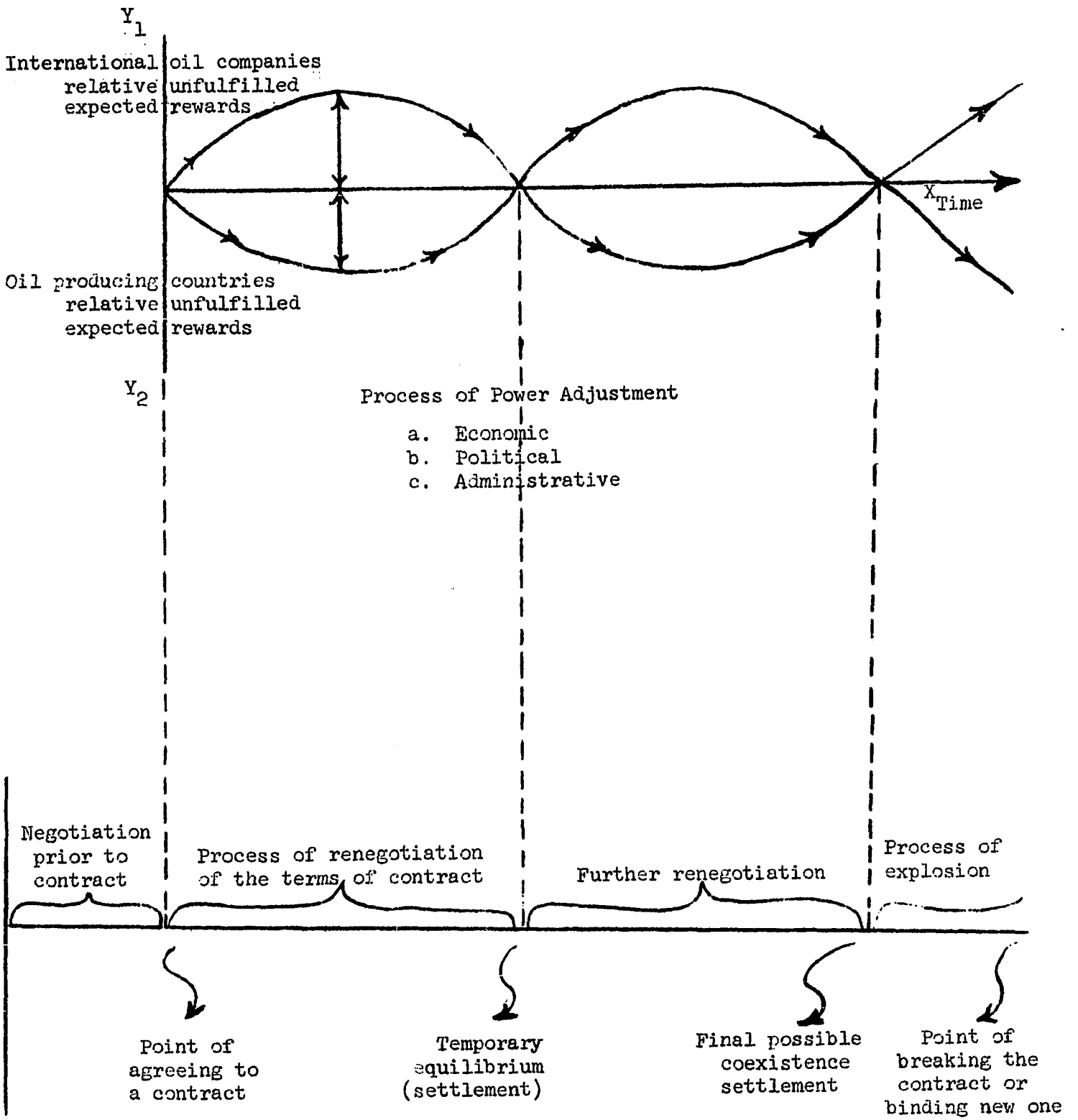
bargaining process. It is postulated that the process of power adjustment through bargaining will continue until it reaches some equilibrium point, where there is balance of power. This point will remain stable as long as the participants think that they have gotten the reward they regard as essential.

A general conceptual picture of bargaining processes is presented in Figure I. This is not a precise argument but rather it is a conceptual view of the bargaining horizon between the international oil companies and the oil-producing countries.

For the purpose of illustration two perpendicular axes have been considered with time variable measured on the axis OX, the relative unfulfilled expected (desired) rewards of the international oil companies measured on the axis OY_1, and the relative unfulfilled expected (desired) rewards of the oil-producing countries measured on the axis OY_2.

Conceptually, the bargaining horizon might be divided into several stages: (1) Period of negotiation prior to agreeing to a concession, (2) point of binding or rejecting the concession, (3) period of rising expectation and desire for more rewards, (4) process of renegotiation of the terms of contract, (5) temporary settlement (equilibrium point) through reallocation of rewards, (6) period of further increases in expectation and desire for more rewards, (7) period of further renegotiation, (8) final possible coexistence settlement, (9) process of explosion (rapid increase in the desired rewards), (10) point of breaking the contract or binding a new one. These processes might take place due to the advantages that one party might have obtained through improving its economic, political or administrative position.

FIGURE II.--Bargaining Horizon



In order to measure the dependency and relative bargaining power of the oil-producing countries and the international oil companies, several research techniques are introduced. Among these techniques, econometric analysis has been selected as most appropriate and unique for analysis of conflict resolution, evaluation of the relative bargaining power and determination of the equilibrium point. Using this technique, the interaction of the variables relevant to the bargaining strength and dependency of the participants in the market is measured.

A model with a system of twelve equations has been constructed. These equations are grouped into four blocks: United States, Western Europe, the oil-producing countries (OPEC), and a Dependency and Bargaining Power block. The first two blocks consist of demand, production and import equations. The oil-producing countries block consists of exports and revenue equations. The fourth block, the Dependency and Bargaining Power block, however, consists of equations that measure the bargaining power and dependency of each participant on the other participants in the world crude oil market. This model attempts to express the relationships of the relevant economic variables that affect the bargaining strength or weakness of each participant in the market. Indices are constructed to measure some of the variables and relationships such as dependency and bargaining power in the model.

In order to specify the parameters of these equations, the two-stage regression technique has been used. From the analysis, it is apparent that the hypothetical relationships in this model are not only theoretically valid but also statistically defensible.

In order to measure its predictability power, the model is simulated in two modes: One Period Change Model, and Process Model. The model has been run for the years 1950-1964 in order to determine how accurately it can duplicate the known historical performance of the real system. Finally, after showing the predictability power of the model in the past history, the behavior of these variables can be predicted in the future by using forecasting and simulation techniques.

CHAPTER I

THE IMPORTANCE OF OIL FOR THE PARTICIPANTS

The Growing Importance of Oil

After the rapid growth of over-all energy consumption that had characterized the period from the end of World War II until 1956, a two-year lull occurred. In 1957 and 1958, the rate of increase in general industrial activity levelled out and demand for energy showed little change. By 1959, however, the upward trend in both industrial activity and over-all energy consumption had resumed. Despite the temporary slack in the over-all demand for fuel, oil consumption between 1955 and 1959 in the countries of Europe participating in Organization for European Economic Cooperation (OEEC) increased by some 50 million tons. From 1960 to 1964, there was a further rise in oil consumption in the European area of the Organization for Economic Cooperation and Development (OECD)[1] of nearly 70 per cent, i.e., from 181 to 306 million tons.[2]

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[1]The Organization for Economic Cooperation and Development was set up under a Convention signed in 1960 by the member countries of the Organization for European Economic Cooperation and by Canada and the United States. The OECD supplanted OEEC, in effect, from September, 1961, when it became a legal entity. The Members of OECD are: Austria, Belgium, Canada, Denmark, France, The Federal Republic of Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

[2]Organization for European Cooperation and Development (OECD), Energy Policy: Problems and Objectives, (Paris: OECD, 1966), pp. 23-34.

In its 1964 report Oil Today,[3] the OECD Special Committee on Oil found that the greatest growth in oil consumption was in public electricity generation. As a result, oil's share of the over-all energy market increased further between 1959 and 1962 from 30 to 39 per cent and by 1965 to about 45 per cent. The main reason for this rapid increase in the use of oil was undoubtedly the greater convenience of liquid fuels and their lower market prices relative to other fuels.

Importance of the Oil-producing Countries' Crude Oil

It may be noted that the major part of the world's petroleum production is consumed in North America, Western Europe and the Soviet Union, followed by such countries as Japan, Argentina, Brazil and Australia. Furthermore, all the leading consuming countries, with the exception of the Soviet Union, are net importers of petroleum. The imports of these countries, as well as those of smaller importers in Latin America, Asia and Africa, are supplied mainly by two major sources: the Persian Gulf and the Caribbean areas. In addition, the Soviet Union, Indonesia, and Rumania export appreciable amounts of petroleum, and it is expected that North Africa, which started shipping oil in 1958, will become an important exporter in the near future.

The United States, the leading producing and consuming country, had an exportable surplus through 1948, but since then the rise in production has lagged behind the increase in consumption, due to the rationing of

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[3]Organization for Economic Cooperation and Development (OECD), Oil Today, 1964, As Viewed by the OECD Special Committee for Oil, (Paris: OECD, 1964), pp. 7-9, 15-21.

production to conserve local oil resources. The United States has now become the leading importer in the world. The Soviet Union, the second major consumer, has been able to expand its production at a higher rate than its consumption. Another major consuming area, Western Europe, has enormously expanded its petroleum demand in the postwar period, partly because of conversion from coal to oil. Owing to its negligible local production, however, it has relied on imports of petroleum from abroad. In the past, the bulk of Europe's petroleum needs was supplied by the Western Hemisphere (the United States and the Caribbean area), but in the postwar years the Middle East became the main supplier of oil to Europe. Recently, the Middle East has been joined by the Soviet Union and North Africa in exports from both these areas to Western Europe. The Far East, Oceania and Africa rely for their petroleum needs mainly on imports from the Middle East and Indonesia, while the oil-deficit countries of the Western Hemisphere depend largely on imports from the Caribbean area and to a smaller extent from the Middle East.

> Costs in the Middle East generally are extremely low, compared with both prevailing prices and costs in the Western Hemisphere. Moreover, they have fallen further in recent years. If Middle East crude prices had been set mainly with an eye toward these low production costs, Middle East oil would have displaced all but the lowest cost-production in other areas. Neither the interest of the International Oil Companies nor the policies of the governments concerned (yet to be considered) could allow this to happen.[4]

The United States produces about 26 per cent of the world's oil, but the Middle East is slightly ahead with 27 per cent when considered as a region. The Communist Bloc produces 18 per cent and Latin America 15 per cent.

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[4]Helmut J. Frank, Crude Oil Prices in the Middle East, (New York: F. A. Praeger, 1966), p. 155.

Africa produced only 7½ per cent in 1965, but its share is increasing rapidly because of activity in Libya and Nigeria.

The concentration of reserves has changed considerably since the early 1940's when the United States had 50 per cent of the world's crude oil reserves. Later discoveries in the Middle East caused a shift in proportion of reserves. In 1965, the United States had only 10 per cent of the world's crude oil reserves compared to 60 per cent in the Middle East.

Dependency of Oil-producing Countries on Oil Revenues

It is apparent that oil is of major and growing importance as the basis for future economic growth in the countries of OECD. It is of at least equal importance for the major oil-producing countries in the Caribbean and Middle East because their economies are vitally dependent on oil operations. Income of the oil industry constitutes a large part of national income, a major contribution to government revenues and the bulk of foreign exchange earnings. In common with most countries of the world today, these nations have plans for their own economic development. In due course, development may be expected to broaden their economic base, and hence reduce in some measure their present dependency on oil revenues. At the present, however, they turn to oil revenue for the capital investment necessary to finance their planned development. The oil-producing countries can be expected to continue to seek increases in their revenues from their oil resources.

Establishment of OPEC and Its Past Bargaining Achievements

After the great expansion of crude oil production following World War II and the accompanying increase in operating profits, the host governments began to exert pressure for a major revision of concessions, including financial provisions. The new profit sharing, led by Saudi Arabia late in 1950, appealed to all Middle Eastern oil-producing countries, and they persuaded their major concessionaires to submit to it. Since the level of prices at which oil is sold under these agreements affects the profit of the oil-producing countries, and thus the tax receipts of the host governments, these governments obviously have a direct interest in the price policy of the concessionaire companies.

A world oil surplus leading to Middle Eastern price reduction in the winter and the spring of 1959, generated a strong desire among the Middle Eastern oil-producing countries to control production and to stabilize prices in order to increase revenues. The reduction in posted crude oil prices in August, 1960, was the last one ventured by the international oil companies. It was followed, in September, by formation of the Organization of Petroleum Exporting Countries (OPEC). This organization was established by the representatives of Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. Later, Qatar, Indonesia, Libya and Abu-Dhabi joined the organization. These countries supply about 90 per cent of the world exports of crude oil.

One of the organization's key aims has been the stabilization of world oil prices. Its general objectives were stated as: agreement on common policies toward the companies, the restoration of the recent cuts in price of crude oil and the assurance of notification by the companies before

future price changes. The United Nations has recognized their rights to take such action in one of its resolutions:[5] To pursue policies designed to ensure to the developing countries an equitable share of earnings from the extraction and marketing of their natural resources by foreign capital in accordance with the generally accepted reasonable earnings on invested capital . . .

> It is widely expected that as concessions are revised to give governments more royalties (including also taxes and other payments), this increased 'cost' will also push up the price of crude oil. Revisions are generally expected, though I am not competent to say that they have or have not any basis in law.[6]

> More recently, the concessionaire's power of disposal has decreased because of independent refiner-marketers, excess capacity, and the possibility of other concerns doing exploration and development; and so the basic economics of petroleum production explains the paradox that new sources of supply, such as those of North Africa and the Soviet Union, far from weakening the bargaining power of the old host governments, actually strengthen it. The entry of new concessionaires strengthens it also.[7]

Two elements of strength or weakness in bargaining between the international oil companies and the oil-producing countries may be recognized. The first is the volume of the world's oil production controlled by the oil-producing countries, which would determine the volume of oil available to the international oil companies. The other is the ability of the oil-producing countries to sustain a cessation of royalty receipts

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[5] United Nation Assembly, Report of the Economic and Social Council, Economic Development of Under-Developed Countries. Questions Relating to International Trade and Commodities, (A/5056, December 18, 1961), pp. 20, 43, 56.

[6] M. A. Adelman, "The World Oil Outlook," in Natural Resources and International Development (Marion Clawson, ed.), (Baltimore, Md.: Johns Hopkins Press, 1964), p. 104.

[7] Ibid., p. 105.

compared with the ability of the international oil companies (or the consuming countries) to sustain a cessation of the flow of oil from the OPEC members.[8]

OPEC has already entered into the renegotiation of its members' concessions and has made some achievements. In July, 1962, the OPEC countries presented three major demands to the international oil companies operating within their respective borders. The international oil companies negotiated with OPEC, and in 1964 reached a settlement with the following results:

1. Posted Prices: OPEC demanded posted prices be restored to the pre-August 1960 levels (resolution IV. 32). The international oil companies refused this completely.

2. Royalties: OPEC demanded that royalties be fixed at uniform rates and increased for all OPEC countries (resolution IV. 33); a minimum of 20 per cent (of Posted Prices) for Middle Eastern countries was suggested. The international oil companies did not respond positively to this point.

OPEC demanded that royalties be "expensed," i.e., they should be included as part of the cost of production and no longer treated as credit against the oil companies' income tax liability. This demand would have increased the government's total income by 50 per cent of the royalty. The international oil companies agreed, provided a discount off posted prices of 8.5 per cent would be permitted in 1964, 7.5 per cent in 1965, and 6.5 per cent in 1966--with later years to be negotiated. This roughly

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[8]Harold Lubell, Middle East Oil Crises and Western Europe's Energy Supplies, (Baltimore: Johns Hopkins Press, 1963).

amounts to payments of about 3.5 cents per barrel in 1964, to be increased by a sum averaging about one cent per barrel by 1966, varying with the gravity of crude oil.[9]

3. Marketing Allowance: OPEC demanded elimination of the marketing allowance (resolution IV. 34).[10] This was the first settlement reached, since the volumes of crude sold had gone up so markedly the old allowance could be reduced (and was) to 0.5 cents per barrel.

Another condition of the settlements was that the international oil companies, by undertaking to make the higher payments to the OPEC governments, should not be placed thereby in a less favorable position than their competitors--actual or potential--in the same country.

The settlement reached gave OPEC member countries about a fifth of what they originally asked.[11]

In July, 1965, OPEC adopted a resolution calling for prorationing or limitation of production by its member countries in the hope of strengthening the price of crude oil.

Further negotiations were undertaken to seek the elimination of the remaining allowance (6.5 per cent off posted prices in 1966) granted to the oil companies in accordance with the Supplemental Agreement on the expensing of royalty concluded in 1964. A settlement on this issue was reached in 1968. The new arrangement provides for the gradual elimination

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[9] Zuhayr Mikdashi, A Financial Analysis of Middle Eastern Concessions: 1901-1965, (New York: F. A. Praeger, 1966), p. 250.

[10] OPEC, Explanatory Memorandum of the OPEC Resolutions, April-June, 1962, pp. 8, 14.

[11] Mikdashi, p. 250.

of the allowance over a period of seven years ending by 1974. In terms of net additional revenues to the member governments concerned, these range between 4.8 and 9.0 cents per barrel, depending on the gravity of the crude oil and its posted price.[12]

The governments of the oil-producing countries have continued to press for changes in profit-sharing arrangements. Recent developments in concessionary arrangements have tended toward increasing governments' participation in the exploitation of their indigenous oil resources. Where new concessions are granted, it is increasingly the practice of governments to participate in operations, usually subsequent to the exploration stage. The areas over which new concessions are granted are usually smaller than in the past; furthermore, where governments of oil-producing countries have in the past granted concessions over a very large area, it is increasingly their practice to demand that the concessionaires relinquish parts of these concessions. Recently, the governments of some producing countries have established oil companies within their boundaries. These companies are created not only to increase the state's income from the oil industry, but also to give nationals skills and experience in a business vital to their economies.

The major oil concession agreements of the Middle East have undergone extensive modification since they were originally signed. Their acreage has shrunk, and their financial provisions have been altered markedly. Furthermore, direct participation of host governments or their agencies in the equity ownership and management of oil production, and

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[12] OPEC Bulletin, No. 2, (February, 1968).

sometimes in the later production stage has been conceded. The newly acquired advantages are largely a function of a decline in the geological uncertainty of discovering commercial oil deposits and of an improvement in the relative bargaining position of the host governments.[13]

International Oil Companies in World Crude Oil Market

The outstanding feature of the world crude oil market has been the predominance of seven major international oil companies: British Petroleum Company (formerly Anglo-Iranian Oil Company), Gulf Oil Corporation, Royal Dutch-Shell Oil Company, Standard Oil Company of California, Standard Oil Company of New Jersey, Socony-Vacuum Oil Company, The Texas Oil Company. To these may be added an eighth, Compagnie Francaise des Petroles. These companies have extensive control over the reserves, production, refining and transport of oil in the world. In addition, and not of least importance, it would appear that the seven international oil companies are dominant forces in marketing in most countries.

The foremost reasons for this concentration are perhaps the huge capital investments and the extraordinary technical and managerial skills required in international operations. In order to minimize risk factor, the companies have had to diversify their interests by engaging in oil operations in several of the major areas of the world. Moreover, in order to assure themselves of access to markets and availability of supplies, they have had to build up a completely integrated chain of operations, from exploration and production to refining, distribution and marketing. Only

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[13]Penrose, pp. 73, 75, 214-15.

in this manner could the companies be reasonably certain that their vast investments would be continuously, and therefore profitably, employed at all times.

Throughout the period under study, international oil companies have commanded specialized and superior quality talents and skills in the areas of legal, economic, accounting, geological, engineering and other fields. Consequently, they have had access to better information than the host governments. This, together with other factors, has undoubtedly given the international oil companies an advantage over the oil-producing countries' governments in negotiating concessions and implementing them. As the governments of the oil-producing countries become more organized and unify their goals, the possibility of renegotiating of the concessions arises.

Importance of Crude Oil for the Consuming Countries

Oil is termed the lifeblood of modern industry, agriculture and transport. Without oil in its different forms, the economic life of countries, technical progress and indeed the promotion of prosperity of every country would be seriously retarded.

The following points may clarify the importance of oil. First for certain uses, such as the majority of road, sea and air transport, virtually no alternative is available. Consumption in these sectors has increased steadily as economy has expanded and has led, for example, to a rapid growth in the number of motor vehicles. Secondly, more and more consumers--with different requirements--have learned the advantages of using oil, and

it is now regarded as suitable for many uses that were once considered the preserve of other forms of energy. There is also a growing use of oil products as feed-stocks for the petrochemical industry.

Importance of Crude Oil in OECD Countries[14]

> Europe's oil requirements are certain to rise sharply over the next 15 years and indigenous resources will far from satisfy total needs. Not only is Europe short of oil in terms of reserves but, in the main, high production costs make indigenous oil uncompetitive with imports.[15]

The OECD area is not in a fortunate position in regard to oil. Two-thirds of the world total is consumed in the area, but about half of this amount is produced elsewhere.

Consumption of oil has greatly expanded everywhere, particularly in road transport. Since 1959, oil has been the largest single source of energy in the OECD area as a whole. Some explanation of the rapid growth of oil consumption is provided by the persistent shortage of coal and other forms of energy and the convenience of importing energy in this form. But a large part of the growth undoubtedly reflects the convenience and economy of liquid fuels in certain uses in comparison with coal. It is clear that for each of the OECD regions, the majority of energy imports will continue to be in forms of oil.

> If total European imports were covered by oil, the overall imports requirements of the OECD area could amount to 870 million tons in 1970 and 1485 million tons in 1980.[16]

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[14] OECD countries are considered here because they are the principal oil importers from the oil-producing countries and because they have energy data available.

[15] OECD, Energy Policy, p. 88.

[16] OECD, Energy Policy, p. 99.

Importance of Oil and OECD Energy Committee's Reports

The significance of energy in the economy of OECD countries makes energy policy an important subject for each member country.

In view of the continuing rapid growth in the demand for energy in West European countries and the consequent rise in prices and in imports, the Secretary-General of the Organization of European Economic Cooperation (OEEC) in December, 1953, submitted to the Council of Ministers of OEEC a memorandum designed to draw the attention of all member countries to the growing problems of the supply and cost of energy. As a direct result of this report, the Council of OEEC in June, 1955 passed two resolutions. The first called for the establishment of a Committee for Energy; the second concerned methods of cooperation in the peaceful use of nuclear power. The first of these resolutions led to the publication of the Hartley report, Europe's Growing Needs for Energy: How Can They Be Met.

Four years after the Hartley report, a second detailed study was prepared by the OEEC energy advisory committee, under the chairmanship of Professor Austin Robinson of Cambridge University. This report, known as the Robinson Report, is entitled Towards a New Energy Pattern in Europe. The report reassessed the prospective energy requirements and supplies for Western Europe in light of the developments that had taken place in the energy market since the Hartley report was written. The Robinson Commission began by reviewing the long-term forecast with respect to energy requirements in 1965 and 1975 made by Hartley Commission. The following table shows the comparison between the two forecasts:

TABLE I.--Comparison of Hartley and Robinson Estimates: Indigenous Production of All Forms of Energy in the OEEC Area 1955-75 (in million tons of coal equivalent)

	Hartley			Robinson		
	1955	1960	1975	1955	1965	1975
Coal	478	500	520	477	460	465
Lignite	31	35	35	30	40	60
Hydro-power	57	75	130	56	95	140
Crude Oil	13	25	50	13	30	50
Natural Gas	5	10	20	7	25	55
Total	584	645	755	583	650	770

Sources: Organization of European Economic Cooperation (OEEC), Europe's Growing Needs of Energy: How Can They be Met? (Paris: OEEC, 1956).

OEEC, Towards a New Energy Pattern in Europe (Paris: OEEC, 1960).

The Robinson Commission's estimates showed an anticipated rise in oil imports from 146 million tons in 1955 to between 260-310 million tons by 1965 and between 380-500 million tons by 1975. No difficulty was foreseen in obtaining import requirements of this magnitude. They also concluded that the choice between coal, lignite, natural gas and oil or nuclear fuels for the generation of electricity is by no means rigid, and consumers will be attracted by relative prices and the relative convenience and security of using them.

Six years after the Robinson Report, in 1965, the Energy Committee of the OECD decided to undertake a further general study of the energy

situation in the whole of the OECD area. This report, which was published in 1966, was entitled Energy Policy: Problems and Objectives. This report emphasized the rapid rate at which the European OECD area is becoming dependent on imports for its energy supplies. It indicated that in 1950 energy imports were equivalent to less than one-seventh of total requirements, while by 1960, they had risen about one-third, and by 1964 to about one-half. By 1970, they predicted that over 55 per cent and by 1980 over 64 per cent of total requirements will have to be imported. The problems posed by such a degree of dependence on outside suppliers and, more particularly, on the oil-producing countries of the Middle East, are evident in this report.[17]

The main conclusion of the report was that, confronted with Europe's rapidly growing energy import requirements, it was imperative to develop as rapidly as possible any indigenous source of supply that might be available and competitive.

Dependency of OECD Countries on the Oil-producing Countries

In contrast to the oil-producing areas, consuming countries are very numerous. In addition to the industrialized countries of Western Europe, substantial and growing oil import requirements exist in virtually all countries of Latin America, Africa, Asia and Oceania. The United States, even though it is the world's foremost oil-producer, is also an importer of very large quantities.

Forecasts of crude oil production in Western Europe are very difficult to make since not only are the reserves uncertain but

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[17]OECD, Energy Policy, pp. 109, 121, 135-37.

> also their exploitation is likely to form a relatively small part of the worldwide activities of the international oil companies.[18]

For many years, the Middle East will continue to be the main source of Europe's oil supplies. Its production, which is highly competitive in cost, is capable of expansion without undue difficulty. A considerable proportion of the refining and marketing facilities in Europe is owned by the international oil companies with shares in, or access to, production in the Middle East. These factors, along with the ready availability of super tankers for transporting the oil, indicate that the Middle East should continue to be a major and competitive source of supply for Europe.

> The dependence of Europe on imports, already very substantial, is likely to increase in the years ahead; many economic difficulties face the European coal industry for which no short-term solution can be expected; the prospects for the indigenous oil industry do not give grounds for supposing there will be any large increase in its capacity; and the contribution of nuclear power and natural gas, in spite of recent encouraging developments in both fields, is likely for some years to come to be relatively small.[19]

The increasing dependence of Europe on imported oil supplies raises two important questions: (1) What steps have to be taken to reduce the risk and the effects of possible denial of supplies? (2) How can Europe pay for the imports?

Alternatives for Secure Sources of Energy

Indigenous Sources of Energy.--Is it possible for West European countries to achieve a measure of security through indigenous sources of energy for the foreseeable future? It has been argued that some form of

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[18] Organization for European Economic Cooperation (OEEC), Towards A New Energy Pattern in Europe, (Paris: OEEC, 1960), p. 44.

[19] OECD, Oil Today, (Paris: OECD, 1964), p. 32.

protection should be given to indigenous supplies of energy. However, it is difficult to prove or disprove this argument; some facts are presented in order to clarify the situation. In the first place, it is most unlikely that indigenous sources could supply Europe's growing needs unaided. Second, the cost of increasing indigenous production would soon become prohibitive, and European fuel users, particularly European industry, would suffer through increased costs. Third, oil has many uses for which there is virtually no substitute. To achieve even a relatively limited increase in security, therefore, by concentrating on indigenous rather than imported fuels, could radically upset the present pattern of oil supply and have serious effects on Europe's economy as a whole. Given that, for technical and economic reasons, Europe will have to draw increasingly on fuel supplies from overseas, the most effective way of achieving greater security seems to be to diversify sources from which such supplies are drawn.

Nuclear Energy as an Alternative.--There is a wide range of uncertainty over the contribution of nuclear energy by 1975. It is quite unlikely that nuclear energy will be fully competitive with other forms of energy during the next decade, except under very unusual conditions. Both costs of construction and fuel costs in nuclear plants are expected to decline more rapidly than those of conventional thermal stations and, on present evidence, nuclear energy might be expected to become more fully competitive by about 1975.[20] Attention should be drawn to the fact that in the present circumstances an active policy of developing nuclear energy

[20] OEEC, Towards A New Energy Pattern in Europe, pp. 49-57.

secures a relatively small immediate saving of foreign exchange at the cost of a large investment of indigenous European sources.

Diversification of Sources of Imported Energy.--Over the past years, international trade in oil (the main energy import for OECD countries) has been regular, and prices have generally remained stable or fallen. Nevertheless, because of risks both of interruption of supply and artificial price increases, governments of the OECD countries usually seek to avoid undue reliance on a few sources of supply, even if the actual price level rises somewhat. Diversification of supplies, therefore, is a common aim in order to maintain secure supplies in sufficient quantity. Diversification in oil supply can aim at increasing both the number of sources of supply (countries of origin) and the number of competing suppliers (oil companies). In countries of the OECD area where oil supplies are mostly assured by private companies, market considerations have been mainly responsible for geographical diversification, which has essentially been handled by private industry.

In some cases, however, governments of the consuming countries in the OECD area have taken steps to add to the number of suppliers by helping to create publicly owned or mixed national companies to find and produce oil abroad. Japan is one example. Mainly through low interest loans, the Japanese government has helped to create two oil companies, which now operate in Saudi Arabia, Kuwait, Indonesia and Malaysia, with the resulting production finding increasing outlets in Japan. In other countries of the OECD, governments have helped negotiate oil import contracts or helped to ensure that the national market is shared among different

international, private national and government-owned companies. Imports from Soviet Bloc countries to OECD countries are made under bilateral trade agreements and are subject to close government supervision. Although these agreements are usually concluded for other reasons, a certain diversification has been an incidental result.

At the present time, Europe's apparent lack of concern about the safety of its oil supply stems from two assumptions: that group political action of the oil-producing countries is quite unlikely since these countries do not want to lose oil revenues by stopping production; and that as in past emergencies, other countries outside the Middle East (e.g., Venezuela, the United States, etc.) will supply them. Both assumptions entail greater risks than appear at first sight, since Venezuela now is a member of Organization of Petroleum Exporting Countries (OPEC) and future Venezuelan governments might be reluctant to permit the use of Venezuelan oil in an emergency. The United States could not meet European demand in an emergency and still maintain its reserve at desirable levels because it lacks adequate supplies.

A more reasonable way to improve security is by investigating the sources of conflicts of interest between the participants in the world crude oil market. The shutdown of the oil-producing countries' oil could come about in two ways: directly as the result of a breakdown of bargaining between oil-producing countries and the international oil companies, the subject of this paper, or as the result of a disturbance in the oil-producing areas not necessarily connected with the control or marketing of oil.

Oil Imports and the Balance of Payments Problem

The problem of security has already been discussed. The balance of payments situation of the consuming and importing countries should be evaluated. From the point of view of balance of payments, payments for oil do not follow a direct route to the oil-producing countries. Because most of the capital and technical knowledge required in oil production originates in the importing countries, only a part of foreign exchange is in fact transferred across the borders. The amount paid to the oil-producing countries usually covers only the royalties and taxes due to them plus the net foreign exchange cost of local expenditures incurred in production, refining and shipping of oil. The balance is retained by the oil companies, which make expenditures in the oil-importing countries for equipment, taxes and refining and marketing facilities. Imports of oil by the Sterling and Franc countries cause some drain on their dollar earnings and reserves, but these drains have been minimized through arrangements with the various American companies.

Foreign exchange outlays of the importing countries, therefore, tend to be smaller than the data for trade alone would indicate. For the United States, Great Britain and Holland, where most of the great international oil companies are based, actual foreign payments for oil imports comprise only royalties, taxes, and some local expenditures paid out in the oil-producing countries. Moreover, a substantial portion of these payments, although constituting a foreign exchange liability, involves no immediate foreign exchange transfer as it is credited to New York and London bank accounts of oil-producing countries. Furthermore, importing countries

with balance of payments problems benefit from the reciprocal arrangements under which oil-supplying concerns strive to use foreign currency earnings as much as possible for local purchases. In short, therefore, oil payments are seldom made in hard currency. Rather, the currency of payment tends to be determined first by the nationality of the oil company, and second by the currency area of the consuming country.

In the OECD area, the cost in terms of foreign currency of imports of oil is offset in various ways. First, there is the net receipt of foreign currency from oil sales outside the area by oil companies resident in it. Second, nonresident companies use some of their currency earnings in the OECD area for investment in the area in new refining, transport and distribution facilities. Third, both resident and nonresident companies purchase such equipment as tankers in the area for use in oil operations outside it, thus giving rise to a substantial export trade.

The Parent Countries of the International Oil Companies

For a variety of historical, political and economic reasons, the international oil companies are mostly based in the United States, Britain, Holland, or France. The main reason for the concentration is that these countries dominate world industry and trade in oil. Their leading role has been accompanied by extensive capital formation, the development of economic, technical and managerial skills, and, in the case of the United States, the early establishment of large-scale oil operations at home. On the basis of such a strong foundation, the companies of these countries were willing and able to risk the large sum of capital and to supply the specialized

technical and managerial skill required for successful international development.[21]

In case of serious conflict between the oil-producing countries and the international oil companies, the attitude of the governments of the West would depend in part on the political attitude of the former. If the conflict were a political one, the Western governments would be more likely to back the international oil companies, but this stand would be less likely if the matter were couched in commercial terms of profits and marketability.

> However, a breakdown of negotiations could hardly be reached without political unrest in the producer countries, bringing riots to the cities and strikes to the oil installations, so that political hostility would quickly become a part of the bargaining picture.[22]

In the United States, despite the presence of a large number of competing oil producers, petroleum prices have been sustained since the 1930's at an artificial level by restrictions on domestic output and on imports. Under a conservation policy, the system of proration practiced in almost all oil-producing states has kept domestic output well below the level it would otherwise have attained. As for imports into the United States, in addition to a small duty levied since 1932, a mandatory quota system has been in effect since 1955.

In addition to the United States, various other countries have adopted measures that influence the pattern of imports. The reasons for these measures are varied and include, among others, the desires of

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[21] Levy, Section IX.

[22] Lubell, p. 30.

governments to manage balance of payments problems, to promote the sale of crude oil and products developed in foreign areas by national petroleum industries, and to enhance international security by regulating the total energy supply among competing fuel industries.

> In addition to encouraging the development of competitive indigenous energy supplies, most of the energy producing countries of OECD area have found it desirable in recent years to protect indigenous industries which have found it difficult to compete with imports.[23]

The considerations that must be taken into account in import policies of the OECD countries are: (1) the security provided by her indigenous supplies, weighed against their higher relative cost; (2) the pace at which one kind or source of fuel can gain ground on another without undue social or economic difficulty; (3) the degree of control that can be exercised over it; and (4) the reliance that can be placed upon different sources of supply.

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[23]OECD, Energy Policy, p. 69.

CHAPTER II

POTENTIAL RESEARCH TECHNIQUES FOR THE ANALYSIS OF CONFLICT RESOLUTION AND EVALUATING BARGAINING POWER

Behavioral Theory Approach

The behavioral theory approach was used by Walton in his analysis of social interaction systems, particularly labor negotiations.[1] He has analyzed four sets of activities, which he believes account for almost all behavior in negotiations. The first set of activities, "distributive bargaining" comprises competitive behaviors that are intended to influence the division of limited resources. The second set, problem-solving and other activities that increase the joint gain available to the negotiating parties is called "integrative bargaining." The third set, activities that influence the attitudes of the parties toward each other and affect the basic relationship bonds between the social units involved, is referred to as "attitudinal structuring." The fourth set of activities comprises the behaviors of a negotiator that are meant to achieve consensus within his own organization. The fourth subprocess is called "inter-organizational bargaining."

In his behavioral theory, Walton has tried to close the gap between, on the one hand, empirical case studies and the insights they yield and, on the other hand, the literature on bilateral monopoly, decision theory,

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[1] R. E. Walton and R. E. McKersie, A Behavioral Theory of Labor Negotiations, (New York: McGraw-Hill, 1965).

experimental games, small-group problem solving, attitude change and role conflict.

International negotiations are most amenable to analysis as an instance of social negotiations. These negotiations are not confined to official verbal exchanges; they include other economic, social and sometimes military moves of many types. Clearly, all four types of bargaining activities presented above might occur in these types of negotiations.

Schelling[2] concludes that the speed with which a number of Middle Eastern oil-royalty arrangements converged on the fifty-fifty profit-sharing formula after World War II was the result of some dramatic and conspicuous political, social and behavioral factors involved in the bargaining of the oil-producing countries and the international oil companies. Perhaps more impressive, according to Schelling, is the remarkable frequency with which the ad hoc shares in some costs for benefits converge ultimately on something as crudely simple as equal shares, shares proportionate to some common magnitude, or the shares agreed on in some previous but logically irrelevant negotiation. Precedent seems to exercise an influence that greatly exceeds its logical importance or legal force.

Theory of Games Approach

The mathematical theory of games has been applied to market situations in which the outcome depends upon the actions of participants with conflicting interests. Situations of duopoly, oligopoly and bilateral

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[2]Thomas C. Schelling, The Strategy of Conflict, (Cambridge, Mass.: Harvard University Press, 1960), p. 68.

monopoly often fit into this category. The theory of games provides specific behavior assumptions that result in an equilibrium for such a market, though the equilibrium is quite different from those provided by the economic theory solutions.

Game theory assumes that the behavior of the participants is correctly described as the maximization of a utility function. For this purpose, participants should know the function, i.e., the numerical utilities, of the other negotiating parties. That is, each player is assumed to know the preference patterns of the other players. In most cases, it is further assumed that each participant has a finite number of strategies, though the number may be very large. This assumption rules out the possibility of continuous variation of the action variables; however, this assumption could be relaxed.

Games are classified on the basis of two criteria: (1) the number of participants and (2) the net outcome. The first merely involves counting the number of participants with conflicting interests. The second criterion allows a distinction between zero-sum and non-zero-sum games. A zero-sum game is one in which the algebraic sum of the outcomes (e.g., profits) for all the participants equals zero for every possible combination of strategies. If the net outcome of a game is different from zero sum for at least one strategy combination, it is classified as a non-zero-sum game. Most economic games are non-zero-sum games.

If the international oil companies as a whole are considered as a single buyer and the oil-producing countries as a single seller, the world crude oil market is a bilateral monopoly. Discussion, understanding and

bargaining are vital to bilateral trading. By the very nature of the situation, cooperation is called for: Without some degree of cooperation, either side can block trading and reduce individual gain to zero. Bilateral monopoly and bargaining are amenable to treatment as two-person, non-zero-sum games. Theoretical studies by Von Neumann and Morgenstern, and by the Nash solution with side payments are relevant to consideration of this type of market structure.[3] Jannaccone offers several division conventions for bargainers; Zeuthen has constructed a dynamic scheme to deal with wage problems; and Raiffa considers bargaining situations under many different assumptions concerning individual utilities, thus deriving several "fair" arbitration schemes.[4] If we assume with Nash that individual utilities are not comparable, then part of Raiffa's work leads to the same "fair" division as Nash. The Nash solution was normative in nature. Zeuthen and Raiffa assumed away such features as bargaining ability.

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[3] J. Von Neumann and O. Morgenstern, Theory of Games and Economic Behavior, (Princeton: Princeton University Press, 3rd ed. 1953.

J. F. Nash, "The Bargaining Problem," Econometrica, Vol. XVIII. 1950, pp. 155-62.

_____, "Two Person Cooperative Games," Econometrica, Vol. XXI. 1953, pp. 128-40.

[4] H. Raiffa and D. R. Luce, Games and Decision Making, (New York: McGraw-Hill Book Company, Inc.), 1958.

F. Zeuthen, Problems of Monopoly and Economic Warfare, (London: Routledge), 1930.

J. C. Harsanyi, "Approaches to the Bargaining Problem Before and After the Theory of Games: A Critical Discussion of Zeuthen's, Hicks', and Nash's Theories," Econometrica, Vol. XXIV. 1956, pp. 144-57.

One important point must be considered. The extensive writings on union-management negotiations, international agreements and legal arguments all deal with the dynamics of settlements, taking into account lack of knowledge, negotiation skills, psychological factors and other realistic complications. The theoretical approach to the bilateral monopoly situation of bargaining is more limited. The features of major interest have been the magnitude of threats and the role of side payments.

The bargaining situation presented in this paper is an N-person type of game; strategies are not finite; and it has a dynamic nature with many psychological, economical and political factors that can hardly be treated by the theoretical literature presently available on game theory. Moreover, restrictive assumptions such as utility measurement of an individual along with subjective probabilities required for constructing utility functions make a game approach impractical and unrealistic.

Given the current status of game theory, more research would be necessary in order to find solutions for such complex problems as the one at hand.

Theoretical vs. Simulated Laboratory Experiment Approach

Economic conflict involving a few principals, such as occurs in bilateral monopoly and oligopoly, has long attracted the interest of economists. There has been a recent revival of interest in bilateral monopoly, because the bare structure of the situation has the essential characteristics of many social conflict situations. In one sense, a situation of bilateral monopoly involves the mutual interests of the participants

and would seem to call for harmonious cooperation between them. In another sense, the interests of the participants are exactly in opposition, and severe competition would seem to be the behavior norm. Social scientists are particularly concerned with the system of decisions whereby such conflicts are resolved.

After long deductive reasoning, economists are left with several plausible but conflicting theories regarding behavior under conditions of bilateral monopoly. Several attempts have been made to collect appropriate experimental data to test alternative hypotheses drawn from these theories. One of the more extensive experimentations is by Siegel and Fouraker.[5]

Siegel and Fouraker were primarily interested in testing several hypotheses concerning bilateral monopoly and oligopoly to determine which ones fit the actual behavior of subjects in simulation of these market environments. They varied the amount of information available to subjects, and they randomized the selection of buyer-seller pairs and oligopoly sellers in order to reduce, if not eliminate, the effects of variables not relevant to their study. Social interaction between the participants was eliminated before, during and after the sessions, with communication carried out through research assistants and written bids. Communication extended only to prices and quantities in the case of bilateral monopoly, and to prices in the case of price adjuster oligopoly. The subjects received as compensation for participation in the experiments the actual profits they earned in the sessions.

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[5]S. Siegel and L. E. Fouraker, Bargaining and Group Decision Making, (New York: McGraw-Hill, 1960).

All the theories with any element of determinacy predict that contracts will be made at the quantity that maximizes joint payoff. This estimate is consistent with the economists' presumption of "rational" or maximizing behavior. Their initial test, then, is a test of whether or not bargainers negotiate contracts at the joint maximizing quantity, i.e., on the Paretian Optima. If the hypothesis of Paretian Optimality should fail, there would be little hope for weaker generalization regarding expected regularities. Therefore, the first hypothesis to be considered is that contracts negotiated under simulated bilateral monopoly conditions will tend to the quantity that maximizes the joint payoff.

The following conclusions have been reached by Siegel and Fouraker in different experiments under simulated bilateral monopoly conditions.

Bargainers have a clear tendency, under simulated bilateral monopoly situations, to negotiate contracts at the quantity that maximizes the joint payoff. Dispersion of negotiated quantities around the amount that maximizes joint payoff is reduced by increasing the amount of information possessed by the bargainers and by increasing the payoff increments associated with unit deviations around the Paretian Optima.

Negotiated prices, unlike negotiated quantities, are not predicted by economic considerations alone. Personal characteristics of the bargainers seem to be the main determinants of differential payoff and price in bilateral monopoly bargaining. On the average, negotiated prices do not vary significantly from the price associated with a fifty-fifty division of the maximum joint payoff. Dispersion of negotiated prices around the even division price is reduced as the amount of information is increased,

approaching the limit under complete fifty-fifty splits of the maximum joint payoff. The levels of aspiration of the subjects appeared to be a major determinant of the differential payoff and thus of price, especially in the contracts negotiated with incomplete information. Also, the traditional economic forces cannot be depended on to give an adequate explanation of the prices arrived at in bilateral monopoly bargaining.

This raises a very interesting question regarding the fifty-fifty profit-sharing principle introduced in early 1950's between almost all the oil-producing countries and the international oil companies as concessionaires. This principle has been the subject of great controversy. To many oilmen, it is an equitable arrangement. The oil-producing countries, however, want to renegotiate the terms of the concessions as their relative bargaining power increases. Many leaders of the oil-producing countries have expressed their desire to alter the fifty-fifty profit-sharing principle to the advantages of their governments.

Laboratory experimentation is an interesting and useful method for analyzing the bargaining power of groups with conflicts of interest. However, it is not appropriate in the case of bargaining between the international oil companies and the oil-producing countries, because this bargaining process is very complex, and many economic and environmental variables must be considered.

Econometric Approach

Analysis of several potential approaches to the study of conflict resolution has revealed a number of problems involved in the use of

nonquantitative techniques. First is the difficulty of explicitly treating the many important variables. The more complex the problem setting, the larger is the number of factors that require consideration and the more complex are their relationships. When an initial analysis can be structured, additional problems arise in the lack of verifiability, reliability and repeatability of such analysis.

Quantitative techniques may dispose of these difficulties. One such technique is econometrics, which has been widely used for predicting and measuring the interaction of economic variables over time, based on what has happened in the past. Econometrics is a scientific technique in which the tools of economic theory, mathematics and statistical inference are applied to the analysis of economic phenomena, utilizing numerical and institutional data. Any economic relationship that can be expressed in the form of a mathematical equation can be considered a potential object of econometric study.

A question might be raised as to whether econometrics includes relationships involving social and psychological variables. The answer to this question is a conditional yes; i.e., we should be able to express these relationships in mathematical form. This study will attempt to investigate a socioeconomic problem (conflict resolution through bargaining) with this powerful technique. It is hoped that this attempt will help other researchers in the social sciences deal with the treatment of qualitative problems.

CHAPTER III

THE RELATIVE DEPENDENCY AND BARGAINING POWER MODEL

It is appropriate to treat the economic relations between the oil companies and the oil-producing countries largely in terms of bargaining and balance of power, rather than in terms of ordinary trade and commercial competition, because the conditions under which trade takes place, as well as the nature of the fiscal and other financial arrangements, are to a large extent determined by negotiation between the international oil companies and the governments of the oil-producing countries. The terms of these agreements are frequently renegotiated when changes take place in external circumstances or in the effective bargaining positions of the governments of the oil-producing countries.

On the other hand, the nature of the bargaining process in this case differs from labor-management negotiations. The outcome of labor-management bargaining is largely determined by the power and the tactics used by the negotiators. In the case of bargaining between international oil companies and oil-producing countries, the strength of the parties involved in bargaining comes from several directions. The strength of each of the participants in the world crude oil market is determined by the degree of economic dependency of each participant on the other participants. For example, as the relative rate of crude oil reserves discoveries diminishes in the United States and Western Europe, the oil discoveries outside

this area will have extraordinary value in light of rapidly rising demand throughout the industrialized world and the rising costs of production in the West. Thus, the increased rate of crude oil reserves discoveries along with the lower cost of production of crude oil in the oil-producing areas increases the bargaining power of the oil-producing countries. On the other hand, increased oil revenues also increase the economic dependence of the oil-producing countries on the international oil companies. This factor will increase the bargaining power of the oil companies. These are just a few examples of the variables that influence the bargaining process between these two participants in the world crude oil market.

In summary, the balance of bargaining power between the international oil companies and the oil-producing countries is an economic phenomenon. Although other variables may have a bearing on the process--for example, international relations or bargaining ability of the negotiators--relative bargaining power is determined mostly by variations in economic factors.

Since the participants have unequal and varying power, rewards to the participants are also variable through the bargaining process. The process of power adjustment through bargaining will continue until it reaches conceptually to some equilibrium point, where a balance of power occurs. It is postulated that this equilibrium point and balance of power will remain stable as long as the participants are satisfied with the rewards they have obtained for their contributions and as long as they believe they have no advantage and that there is no opportunity to gain greater rewards. As time passes, the oil-producing countries might be able to improve their bargaining position. This is true for the international

oil companies as well. At this time, relative dependency and balance of power between the oil-producing countries and the international oil companies have changed; the equilibrium has been disturbed. Consequently, the participants that have obtained relatively more power will start to renegotiate the terms of the concessions under which they have been operating. Thus, the process of power adjustment will recommence and continue until a new equilibrium point is reached, which may or may not differ from the previous equilibrium point. This bargaining cycle will be repeated over and over until it is no longer possible for one party to continue to operate under the contract.

In order to evaluate the dependency and bargaining power between the international oil companies and the oil-producing countries, an econometric model with twelve simultaneous equations has been constructed. These equations are grouped into four blocks: United States, Western Europe, Oil-producing Countries (OPEC), and finally Dependency and Bargaining Power Block. In each equation and block, variables relevant to the bargaining strength of the participants in the world crude oil market are included. The interactions of these variables in the model are intended to reflect the pattern of dependency and bargaining power of the international oil companies versus oil-producing countries. This model enables analysis of the behavior pattern of the variables over a period of time. In short, we will be able to predict which one of the participants will gain more power and reward in several years to come.

The first three blocks of equations generally consist of demand, production and import equations. The Dependency and Bargaining Power block

consists of the equations that measure the power and dependency of each participant on the other participants in the world crude oil market. Following is the list of endogenous and exogenous variables in each block of the model.

LIST OF THE ENDOGENOUS AND EXOGENOUS VARIABLES

(1) United States Block

Endogenous Variables:

$DDoil_{(us)}$ = United States Domestic Demand for crude oil.

$DPoil_{(us)}$ = United States Domestic Production of crude oil.

$IMoil_{(us)}$ = United States Imports of crude oil.

Exogenous Variables:

$GNPca_{(us)}$ = United States GNP per capita in 1958 dollars.

$TMVH_{(us)}$ = United States Total number of Motor Vehicles.

$RDEX_{(us)}$ = United States Research and Development Expenditures in petroleum industry.

$IDIN_{(us)}$ = United States Industrial Index for manufacturing activities, 1958 = 100.

$RESoil_{(us)}$ = United States proved Reserves of crude oil.

$AVCoil_{(us)}$ = United States Average Cost per barrel of crude oil.

(2) Western Europe Block

Endogenous Variables:

$DDoil_{(we)}$ = Western Europe Domestic Demand for crude oil.

$DPoil_{(we)}$ = Western Europe Domestic Production of Crude oil.

$IMoil_{(we)}$ = Western Europe Imports of Crude Oil.

Exogenous Variables:

$TMVH_{(we)}$ = Western Europe Total number of Motor Vehicles.

$IDIN_{(we)}$ = Western Europe Industrial Index for manufacturing activities, 1958 = 100.

$DDsf_{(we)}$ = Western Europe Domestic Demand for solid fuels.

$DPsf_{(we)}$ = Western Europe Domestic Production of solid fuels.

(3) OPEC Block

Endogenous Variables:

$Exoil_{(op)}$ = OPEC total crude oil exports.

$GRoil_{(op)}$ = OPEC total Government Revenues from the oil.

$DEPop_{(co)}$ = Dependency of international oil companies on the OPEC (see the Dependency and Bargaining Power block).

$DDoil_{(us)}$ = United States Domestic Demand for crude oil.

$DDoil_{(we)}$ = Western Europe Domestic Demand for crude oil.

$IMoil_{(we)}$ = Western Europe Imports of crude oil.

$IMoil_{(us)}$ = United States imports of crude oil.

Exogenous Variables:

$REPoec_{(op)}$ = Relative Power position of the OPEC member countries to all the OECD member countries (see the Dependency and Bargaining Power block.)

(4) Dependency and Bargaining Power Block

Endogenous Variables:

$DEPop_{(us)}$ = Dependency of the United States on OPEC's oil, measured by the ratio of $(IMoil_{(us)} / DDoil_{(us)})$.

$DEPop_{(we)}$ = Dependency of Western Europe on OPEC's oil, measured by the ratio of $(IMoil_{(we)} / DDoil_{(we)})$.

$DEPop_{(co)}$ = Dependency of the international oil companies on OPEC's oil, measured by the ratio of $(Poilop_{(co)} / Poiltot_{(co)})$.**

$BPIN_{(opco)}$ = Relative Bargaining Power Index of OPEC member countries versus International oil companies, measured by the ratio of $(GRoil_{(op)} / NItot_{(co)})$.**

Exogenous Variables:

$OCR_{(us)}$ = Output Capital Ratio of oil production in the United States, measured by the ratio of $(DPoil_{(us)} / CEX_{(us)})$.**

$RCA_{(opus)}$ = Relative Cost Advantages in OPEC countries and the United States measured by the ratio of $(AVCoil_{(op)} / AVCoil_{(us)})$.**

$REPoec_{(op)}$ = Relative Power position of OPEC member countries to all the OECD member countries, measured by the ratio of $(EXoil_{(op)} / IMoil_{(oec)})$.**

$RSS_{(us)}$ = Relative self-sufficiency of the United States in emergency cases, measured by the ratio of $(DPoil_{(us)} / RESoil_{(us)})$.

$DRSW_{(us)}$ = Diminishing Rate of discovery of Successful Wells and new reserves of crude oil in the United States measured by ratio of $(IMoil_{(us)} / RESoil_{(us)})$.

$RRCopwe_{(co)}$ = Relative Risk Coverage for the international oil companies' investments in OPEC countries versus investments in West European countries, measured by the ratio of $(RRop_{(co)} / RRwe_{(co)})$.**

**NOTE: These variables are not directly included in the model and are listed below.

List of the Variables Used for Calculating Indices and Variables

$RRop_{(co)}$ = Rate of Return of the international oil companies on the oil investments made in the OPEC countries.

$RRwe_{(co)}$ = Rate of Return of the international oil companies on the oil investments made in the Western Europe.

$CEX_{(us)}$ = Capital Expenditure made for crude oil production in the United States.

$AVCoil_{(op)}$ = Average Cost per barrel of crude oil in the OPEC countries.

$IMoil_{(oec)}$ = Total imports of OECD member countries together, (OECD Europe, North America and Japan).

$Poilop_{(co)}$ = Production of oil by the international oil companies in the OPEC area.

$Poiltot_{(co)}$ = Production of oil by the international oil companies in their entire operations.

$NItot_{(co)}$ = Net Income of the international oil companies from their entire operations.

(1) United States Block

Demand Equation

In most economics literature, the demand for any commodity is explained as a function of price and the level of income. This generalization applies to competitive markets, but the world crude oil market is not

competitive, since the price of crude oil is under the control of the international oil companies.

> A further difficulty in making comparisons is that our knowledge of prices actually paid for fuels is very limited. We have little idea in many cases of the rebates granted on the posted prices of crude oil or on the prices paid by the consumers. Even though list prices are published in most countries, the prices actually applied are known only to the parties involved.[1]

There is a definite relationship between the rate of consumption of fuel and power and productivity, standard of living, gross national product and other technical and economic indices. The growth of economic activity reacts differently upon energy demand in different countries, and its influence depends on the stage of industrialization attained by each country and, to some extent, upon climate. Transportation is a function of the level of economic activity and the standard of living of a country, and the demand for fuel is directly related to the demand for transportation. Additional variables are the size of the country, commuting distance and habits, etc. In many parts of the OECD area, personal transport is one of the most dynamic elements of the changing structure of energy demand.

An attempt was made to express domestic demand for oil as a function of the price of oil, but statistical analysis failed to show a significant correlation between these two variables. Consequently, the demand for oil is expressed as a function of relevant variables other than prices of crude oil or petroleum products. The demand for crude oil is expressed as a function of: number of motor vehicles, GNP per capita and the relevant industrial activity index. As industrial activity increases, more fuel

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[1] OECD, Energy Policy, p. 52.

will be consumed; the same is true for an increased motor vehicle population. Also, as GNP per capita increases, more petroleum products will be consumed, and demand for crude oil consequently will rise. These variables have been frequently used for over-all projections of energy demand in the United States and Western Europe.

$$(1)\quad DDoil_{(us)} = a_o + a_1\, GNPca_{(us)} + a_2\, TMVH_{(us)} + a_3\, IDIN_{(us)} + e_1$$

Production Equation

The United States, the world's leading producer and consumer of oil, had an exportable surplus until 1948. Since then, production has lagged behind the increase in consumption, due to the rationing of production to conserve local oil resources. This country has now become the world's leading importer. The proportion of imports to total consumption in the United States is the reverse of that in Western Europe, where indigenous production accounts for only 6 per cent of total supplies; the remaining demand is met by imports. The United States, on the other hand, imports less than one-quarter of total requirements; indigenous production accounts for the remainder.

The variables hypothesized to explain the behavior of the domestic production of crude oil in the United States are given in the following relationship.

$$(2)\quad DPoil_{(us)} = b_o + b_1\, DDoil_{(us)} + b_2\, RESoil_{(us)} - b_3\, AVCoil_{(us)} + b_4\, RDEX_{(us)} + e_2$$

This relationship states that as domestic demand for and reserves of crude oil increase, domestic production increases. On the other hand, as the average cost of production increases in the United States, domestic production decreases. Finally, the amount of research and development expenditure is another determinant of the amount of crude oil produced.

Imports Equation

Even though many of the international oil companies are based in the United States, the U. S. government considers it necessary to maintain a strong and healthy domestic petroleum industry as a strategic reserve for emergencies. The ability to produce and refine oil has been developed well in excess of current requirements by the domestic industry. In order to maintain a surplus capacity, the United States has imposed import controls that tie increased imports of foreign oil to increases in domestic production. The protection thus gained provides continued incentive for exploration and development of new crude oil reserves within the United States.

Although current demand for petroleum in the United States can be met by indigenous sources, the price attractiveness of imported oil has led to supplementary imports for the last decade. In order to prevent imports from displacing domestic production of reducing it to a level inadequate for national security purposes, the federal government imposed mandatory import controls in 1959, attempting to maintain adequate domestic production.

The following equation shows the amount of oil imports from OPEC countries, which is virtually equivalent to total oil imports. Accordingly, it shows the demand for OPEC's oil. This variable shows the relative dependency of the United States on the OPEC member countries. The variables

that attempt to explain the behavior of the oil imports are: amount of domestic crude oil production, demand for crude oil and crude oil reserves. The greater the domestic production of crude oil, the lower the oil imports, and the greater the demand for oil in the United States, the greater will be the volume imported. As the crude oil reserves diminish in the United States, imported oil will receive more attention both for security reasons and because of price considerations.

$$(3)\quad IMoil_{(us)} = c_o - c_1\, DPoil_{(us)} + c_2\, DDoil_{(us)} - c_3\, RESoil_{(us)} + e_3$$

It has been argued that the import equation is a definitional relationship (identity) rather than a functional relationship. In that case, the amount of imports should be computed with the following definitional relationship without any need for a regression.

$$IMoil_{(us)} = DDoil_{(us)} - DPoil_{(us)} \pm \text{stock-changes} \pm \text{Measurement Error}$$

This argument is basically sound, but it warrants certain discussion. First, equation (3) has been intended to measure the amounts of imports by the United States from OPEC countries rather than total imports of oil by the United States.

Second, the presence of stock-change in the above relationship makes it difficult to make an accurate calculation of imports of oil in the above definitional relationship. This is due to the nature of stock changes as well as the variables that influence it. As has already been explained,

stock-piling has been considered one of the effective ways to provide secure sources of energy. At the same time, the amount of stock-piling is a function of many variables including the available discovered reserves of oil in the country.

(2) Western Europe Block

Demand Equation

The precise rate at which demand will grow depends on a number of factors--particularly the policies of the governments of consuming countries with regard to the use of indigenous resources of fuel and power; the policies of the oil-producing countries' governments; the industry's capacity to expand its resources; the degree of competition within the industry; and the competing attractiveness of other sources of energy.

The main use of oil is in transport, but it also finds markets in the domestic and industrial sectors. Apparently, most of the substitutable markets formerly held by coal have now been captured by oil, and the relative importance of coal is decreasing. Oil has been an important substitute for coal in Europe due to its competitive price and convenience in handling. Thus, the demand for crude oil is inversely related to the demand for coal and solid fuels.

Personal transport is one of the most dynamic elements of the changing structure of energy demand. Thus, the number of motor vehicles in Europe is an important explanatory variable in measuring the demand for oil, because of its direct relationship with the total consumption of petroleum products. Further, numbers of motor vehicles also represents--to some

degree--the current level of a country's industrialization. An attempt was made to express domestic demand for oil as a function of the price of oil, but statistical analysis failed to show a significant correlation between these two variables. According to this reasoning, the domestic demand for crude oil in Western Europe might be measured by the following relationship:

$$(4) \quad DDoil_{(we)} = a_o - a_1 DDsf_{(we)} + a_2 TMVH_{(we)} + e_4$$

Production Equation

The Western European countries lack adequate crude oil reserves and production facilities and depend almost completely upon oil imported from the OPEC member countries. Generally, European oil wells are of comparatively low output, and high production costs more than offset their cost advantage of proximity to the final market. Against these drawbacks, the domestic wells offer the advantage of a certain security of supply. Several European countries have therefore adopted measures to develop and encourage their indigenous oil production.

Because of the risks of both interruption of supply and artificial increases in prices, governments usually wish to avoid undue reliance on a few sources of supply. They commonly seek diversification of supplies and increased domestic production of energy materials. OECD countries have devised many policies to deal with the problems of contraction in their indigenous coal industries. Numerous measures have been adopted to make contraction an orderly process, to safeguard coal production that may ultimately be economically feasible, to ensure uninterrupted domestic supplies,

to moderate the balance of payments impact, and to ensure adequate employment for displaced miners by means of regional planning or other measures to provide alternative industry in the areas concerned.

Direct and indirect subsidies or other aids to European coal industries take varying forms. Wages or miners' pension schemes are subsidized, for example. Selective taxes on fuel oil are now levied in all major European coal-producing countries. A number of other government measures have the effect of increasing the amount of energy available from indigenous resources or facilitating the development of indigenous coal industries.

Although it is difficult to determine the variables that explain the behavior of domestic production of oil in Western Europe because of variations in government policies, the following relationship may explain the behavior of domestic production of crude oil in Western Europe.

$$(5)\quad DPoil_{(we)} = b_o + b_1\, DPsf_{(we)} + b_2\, IDIN_{(we)} + e_5$$

The difficulty of finding a functional relationship between the domestic production of oil in Western Europe and the other variables is mostly due to the Western European countries' relatively small crude oil reserves and high production costs. Further, in order to provide more security for the Western European countries in case of emergency, many measures have been adopted by the governments to increase the rate of discovery and production of oil and solid fuels in this area. Production of solid fuel has been protected by the governments against imported solid fuel and oil. The production of solid fuel is semi-complementary to the production of oil; it is not a perfect substitute.

It has been argued that in order to establish a better functional relationship for measuring the domestic production of oil in the West European countries the price of oil and the price of solid fuel should be considered as exogenous variables in place of the domestic production of solid fuel.

In order to evaluate this argument the domestic production of oil was regressed on the price of oil and the price of solid fuel in Western Europe, but no significant correlation with these two variables and domestic production of oil was obtained. This might have been due to administrative pricing of oil and of solid fuel in Western Europe or other measures adopted to promote production both of oil and solid fuel.

Since it is possible to argue that the domestic production of solid fuel in Western Europe has a positive or negative relationship with the domestic production of oil in that area, it is preferable not to give a definite sign to this variable but to let empirical analysis determine this sign ($\pm b_1 \, DPsf_{(we)}$).

Imports Equation

In the past, the bulk of Europe's petroleum needs was supplied by the Western Hemisphere--the United States and the Caribbean area--but in the postwar years the Middle East became the main supplier of oil to Europe. In recent years, exports from both North Africa and the Soviet Union have joined those from the Middle East.

The increase in oil use has meant a rise in the proportion of energy requirements met by imports to 15 per cent in 1950 and 46 per cent

in 1964. This change has affected fundamental policy issues, e.g. security of supply, social and regional problems, balance of payments questions, etc., and has involved the governments of the producing countries closely in the affairs of their coal industries. Although coal is supplying a decreasing proportion of Europe's energy needs, coal production is still of vital interest to Europe.

The amount of oil imported is a function of domestic demand for oil in Western Europe and domestic production of solid fuels in this area.

$$(6) \quad IMoil_{(we)} = c_o + c_1 DPsf_{(we)} + c_2 DDoil_{(we)} + e_6$$

The objection might be raised that imports of oil should be computed with a definitional relationship similar to the one presented for the imports of oil in the United States block, rather than by a functional relationship. The same argument presented for the United States holds true for Western Europe as well, especially in view of the fact that Western European authorities have considered stock-piling and indigenous energy sources of vital importance for obtaining secure sources of energy in case of emergency.

(3) OPEC Block

This block consists of two equations that differ from those of the other blocks. No demand equation is considered in this block, since the countries involved are not industrialized and their demand for oil does not have an important effect on world oil demand or production. Domestic demand is so low that almost all the crude oil produced will be exported; the supply equation, therefore, is the same as the export equation.

Exports Equation

OPEC's oil is exported to most of the world. The importance of the Middle East's oil resources is enhanced by the high yields per well in the area. Each well in the Middle East produces, on the average, about 5,000 barrels per day of crude oil. This compares with about 12 barrels per day in the United States, or 200 barrels per day in Venezuela. Middle East crude oil resources are large compared to other worldwide sources, and they can be expected to continue to be an important source of world supply in the future.

> Amongst other changes in the pattern of production may be noted an increase in the proportionate share of the Middle East in total world production. This trend of increase is likely to continue for some time to come.[2]

> Europe continues to draw a large part of its supplies from the Middle East, despite some decline in the latter's proportionate contribution to total European supplies. The possibilities of discovering new sources in the Middle East are not exhausted with the development of recent discoveries in the area. Imports from the Middle East have steadily increased in total volume, and there is scope for considerable further increase.[3]

The following hypothesized relationship may explain variations in amounts of exports of crude oil from the OPEC member countries.

$$(7) \quad EXoil_{(op)} = a_o + a_1 DDoil_{(us)} + a_2 DDoil_{(we)} + e_7$$

This relationship states that the quantity of oil exported by the OPEC countries is a function of the demand for oil in the United States and Western Europe.

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[2] Ibid., p. 25.

[3] Ibid., p. 46.

Exports of oil might be calculated by the following definitional relationship.

$$EXoil_{(op)} = IMoil_{(us)} + IMoil_{(we)}$$

Two objections must be noted. First of all, it is important to realize that OPEC's oil is exported to most of the world not only Western Europe and the United States. Secondly, to predict the amounts of oil that OPEC member countries will export in the future, a functional relationship is necessary. The variables that caused increased exports of oil by OPEC must be determined. These variables are the ones that influence the demand for oil in the United States and Western Europe. Considering demand in these two regions indirectly includes consideration of variables that will have an impact on future exports by OPEC.

Government Revenue Equation

In the OPEC countries, almost the entire domestic industry is in hands of affiliates of the international oil companies, which explore and produce under comprehensive concession agreements. The main benefits to the oil-producing countries arise from the net investment of the oil companies and the fees and taxes they pay. Among the most important questions for negotiation of tax arrangements are the prices to be attributed to crude oil for tax purposes, the expenditures to be allowed as costs for tax purposes and the rate and form of taxation.

Oil revenues constitute a large portion of these governments' revenues. In common with most countries of the world today, OPEC member

countries have plans for their own economic development: Oil revenues will finance a large portion of these plans.

> We have seen that oil is of major and growing importance as the basis for future economic growth in the countries of the OECD; it is of at least equal importance for the developing parts of the world, who need to develop their economic structure . . . Many of the oil exporting countries may also be classed as countries in the process of development, and must rely on their revenues to achieve their own economic development.[4]

The OPEC member countries seek to maximize the income obtained from their oil. They are therefore interested in the highest possible price as well as a high royalty, because a high price would increase the profit of the operating companies subject to taxation. For the same reason, they tend to press for maximum production and sales of their oil. They would further prefer to receive their income in hard currencies.

Since the largest part of the oil revenues of the OPEC governments comes from sales of crude oil to the West, the amount of oil imported by these countries is a relevant variable in explaining the behavior of oil revenue in the OPEC member countries. Along with the import variables, the degree of dependency of the international oil companies on OPEC oil plays a significant role in determining the amount of oil revenues. This variable is measured by the dependency index. Finally, the relative bargaining position of the OPEC countries influences oil revenues. This variable is measured by the relative power position index of the OPEC countries to all the OECD countries. The following relationship shows the relevant variables included in the measurement of the OPEC governments' revenues from the oil.

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[4] Ibid., p. 28.

$$(8)\quad GRoil_{(op)} = b_o + b_1\ IMoil_{(us)} + b_2\ IMoil_{(we)} + b_3\ REPoec_{(op)} + b_4\ DEPop_{(co)} + e_8$$

(4) Dependency and Bargaining Power Block

United States Dependency Equation

The petroleum resources of the United States would be relatively adequate to support total consumption for several years to come. But a real issue is whether they can be located and produced at a cost that allows them to compete with other sources.

> The United States, although capable of meeting the whole of its current petroleum demand from indigenous sources, has imported foreign oil over the past decade to supplement its domestic supply. The United States has been concerned to provide for emergency requirements by maintaining a comparatively large productive reserve, and in 1959 introduced mandatory control over oil imports, with the object of ensuring that as large a production potential as possible was maintained within its own borders.[5]

As for crude oil reserves, the distribution of reserves has changed since the early 1940's when the United States had 50 per cent of the world's total crude oil reserves. Later discoveries in the Middle East caused a shift in the percentage location of reserves. In 1965, the United States had only 10 per cent of the world's crude oil reserves, compared to 60 per cent in the Middle East. Finding and developing oil reserves is costly and, for purely economic reasons, no more is done than necessary. However, it must be pointed out that in the case of the United States, exploration is encouraged for national security reasons.

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[5] Ibid., p. 30.

Costs in the Middle East generally are extremely low compared with both prevailing prices and costs in the West and have declined in recent years. If Middle East crude prices had been set mainly with an eye toward these low production costs, Middle East oil would have displaced all but the lowest cost production in other areas. Neither the interests of the international oil companies nor the policies of the governments concerned could tolerate such a development, however, and prices of Middle Eastern oil have been set at artificial levels to protect more costly U. S. production.[6]

The following relationship is hypothesized to measure the degree of dependency of the United States on OPEC's oil.

$$(9)\quad DEPop_{(us)} = a_o - a_1 RSS_{(us)} + a_2 DRSW_{(us)} - a_3 OCR_{(us)} + e_9$$

This relationship states that as the Relative Self-Sufficiency variable of the United States decreases, the dependency of the United States on OPEC's oil increases, and this interpretation also holds for the Output Capital Ratio variable. On the other hand, as the Diminishing Rate of discovery of Successful Wells and new reserves variable in the United States increases, this country becomes more dependent on OPEC's oil. All of the above variables have been previously defined.

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[6] Frank, p. 155.

Western Europe Dependency Equation

The success of the European countries' attempt to maintain a high rate of economic development will depend, among other things, on a continuing increase in energy supplies. Indigenous resources will fail to satisfy total needs. Not only is Europe short of oil in terms of reserves, but, in the main, high production costs make indigenous oil uncompetitive with imports. Consequently, the necessary increase in energy supplies can come only from a growth in the rate of fuel importation.

> By far the majority of imports will continue to be in the form of oil, whether the level of indigenous production is at the top or bottom end of the forecast.[7]

In spite of protection, international trade in energy has continued to increase both in countries with indigenous resources and those without. Oil is the main commodity involved. Most oil imports come from a relatively small number of developing countries grouped in OPEC, which will continue to supply the bulk of world oil exports for many years to come.

> Energy import requirements will grow even faster than total consumption--possibly at a rate of between 6 per cent and 7 per cent per year. Certain parts of the indigenous energy resources in OECD countries are unlikely to improve significantly their competitive position vis-a-vis the world's major low-cost resources and may find themselves increasingly at a disadvantage.[8]

With the prospective increase in demand and dependence of European countries for oil supplies on the OPEC countries, the possible effects of the denial of oil supplies from these regions have been closely studied. Governments have been concerned with safeguarding their economies from such

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[7] OECD, Energy Policy, p. 89.

[8] Ibid., p. 133.

disruptive effects by means of stock-piling, planning alternative means of supply and the encouraging diversification of oil sources.

> The member nations of OECD are vitally concerned with the maintenance of good relations between oil producing countries and the oil companies. In their situation of large and growing dependence on imported oil there has been a growth in the interest of Member Governments of the OECD in the implications of this dependence for security and their internal economies.[9]

In order to measure the dependency of the Western European countries on OPEC's oil, the following relationship is hypothesized.

$$(10)\quad DEPop_{(we)} = b_o - b_1\, RSS_{(us)} - b_2\, OCR_{(us)} + b_3\, RRCopwe_{(co)} - b_4\, RCA_{(opus)} + e_{10}$$

This relationship states that as the Relative Self Sufficiency variable of the United States decreases, the dependence of the West European countries on OPEC's oil increases. Also, as the Relative Cost Advantages variable in the United States decreases, the dependence of this area on OPEC's oil will increase. This relationship also holds true for the Output Capital ratio variable. Finally, as the Relative Risk Coverage variable for the international oil companies' investments in OPEC countries versus the investment in the West European countries increases, the dependency of Western Europe on OPEC's oil will increase. All of the above variables have been previously defined.

Support for the relationship described above has been discussed in the first chapter and throughout this chapter as well. To summarize: The

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[9] OECD, Oil Today, p. 30.

world crude oil market is under control of the international oil companies. The companies are mostly based in the United States, and they have extensive operations in this country as well as abroad. Western Europe's supplies of oil come from the oil-producing countries via the international oil companies, as do those of the United States. The dependencies of these three participants are obviously interrelated.

International Oil Companies Dependency Equation

The international oil companies are highly dependent on OPEC's oil for a profitable operation. Ownership of a large proportion of the world's crude oil supplies outside the United States has not only been extremely profitable in itself, but it also has been a decisive factor in the struggle of the major oil companies to maintain and strengthen their position in the product markets. At the annual meeting of Standard Oil of New Jersey in 1960, the company's president revealed that about 28 per cent of the company's earnings came from the Eastern Hemisphere, and that a fairly substantial part of this per cent came from the Arab world, where the investment represented a much smaller proportion of the company's total investment.

The international oil companies gained rights to search for oil over very large areas, in some cases covering entire countries--and their rights were exclusive. Hence, the maintenance of concession rights in the oil-producing countries was of great importance to them, and they were prepared to go a long way to meet the demands of their host governments for changes in their original agreements and for more revenues.

> The creation of a producers' cartel controlling 27 per cent of the non-soviet world's oil-producing capacity would put the international oil companies in a much weaker bargaining position than

> they are in now, especially since the oil that would be controlled by such a cartel is the world's cheapest (and therefore most profitable) crude oil. The absolute limit to the oil companies' willingness to back down in bargaining would be approached when expected profits (after royalty payments) from producing the cartel's oil were no higher than from production elsewhere. Another limit would be the minimum degree of technical and commercial independence that the oil companies would be willing to accept.[10]

The crude oil industry of the oil-producing countries was indeed under foreign control. But because the international oil companies were dependent on the oil-producing countries and were also in competition with each other, the companies were not free to exercise control entirely in their own interest.

The international oil companies cannot pressure the oil-producing countries. They must submit to raised costs, reduced net revenues or impaired managerial independence in order to satisfy the demands of their host governments, losing some advantages of their investment in crude oil production. Because continued investment in their crude oil-producing affiliates is presumably undertaken because it is considered profitable, it is worthwhile to examine the consequences if this profitability is undermined.

The following relationship seeks to explain the degree of dependency of the international oil companies on OPEC's oil.

$$(11)\quad DEPop_{(co)} = c_o + c_1\, DRSW_{(us)} - c_2\, OCR_{(us)} + c_3\, RRCopwe_{(co)} + c_4\, REPoec_{(op)} + e_{11}$$

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[10] Lubell, p. 29.

This relationship states that as the Diminishing Rate of Successful Wells and discovery of new reserves variable in the United States increases, the dependency of the international oil companies on OPEC's oil will increase. Also, as the Output Capital Ratio of oil production variable in the United States decreases, the dependency of the international oil companies on OPEC's oil increases. The Relative Risk Coverage variable for the international oil companies on their investments in OPEC countries versus investment in West European countries is directly related to the dependency of the oil companies on OPEC's oil. Finally, as the Relative Power position of the OPEC member countries to all OECD member countries variable increases, the dependency of the international oil companies on OPEC's oil will increase. All of the above variables have been defined in the previous part of this chapter.

Bargaining Power Equation

As noted earlier, the bargaining power between international oil companies and the oil-producing countries is an economic phenomenon determined mostly by variation in economic factors over a period of time rather than merely by the power and tactics of the negotiators. The terms of agreements reached by the international oil companies and the oil-producing countries are frequently re-negotiated when changes take place in external circumstances or in the effective bargaining position of the governments of the oil-producing countries. A brief history of bargaining between the oil-producing countries and the international oil companies is presented in the first chapter.

For an uninterrupted supply of oil, an essential requirement is the preservation of mutually profitable arrangements between the oil-producing countries and the international oil companies. It is equally necessary for the stability of contracts that such relationships continue to be at some point where both parties think that they have obtained their necessary reward.

The power position of each party should be evaluated briefly. The international oil companies have great economic power and consequently a strong bargaining position. This means that they influence the use of resources, the product distribution, prices, the development of new technology and the distribution of income.

The OPEC countries are aware of the international oil companies' economic power, but have increasingly wished to negotiate directly with these companies over the terms on which they are allowed to operate. This view results from the oil-producing countries' knowledge of their increasing relative bargaining power. In addition, it has not always been possible in the past for a government to protect itself adequately by contractual agreements when the conditions under which they were originally negotiated change substantially. These points along with the other commercial practice of the international oil companies, have brought the oil-producing countries into conflict and continuous bargaining with the international oil companies.

Basically, the demands of the oil-producing countries have centered on the financial returns accruing to the governments, and on the degree of domestic control over the oil operation and participation in the activities of the industry. In almost all matters, the governments of the oil-producing

countries have made steady and spectacular gains. The oil concessions granted in the early days have been repeatedly re-negotiated, invariably in favor of the oil-producing countries. Some of these developments have been the direct result of the rapid increase in the quantity of oil produced, but most of them have been obtained by the governments' increasing bargaining strength and maintenance of heavy pressure on the international oil companies. The governments of the oil-producing countries feared that the companies' interests would conflict with their own, and they therefore imposed many constraints on the actions of the companies. These included a large variety of regulations with respect to the operations of the industry in the area of production, employment and pricing.

How has this bargaining strength developed? The low-cost oil of the OPEC countries has extraordinary value to the international oil companies in light of rapidly rising demand in the industrialized world and rising costs of production in the United States. On the other hand, oil is the major source of income for many of the oil-producing countries of the world, and they are financing economic development with oil revenues. These countries' awareness of the importance of the oil revenues has augmented their bargaining power. By offering oil concessions to new foreign firms, they obtain better terms and more control over their natural resources. In addition to the economic development that the oil companies' operations have brought to the OPEC areas, there has been an accompanying growth of political and administrative expertise, which has progressively decreased the inequality between the governments and the companies in the bargaining process. Finally, the formation of OPEC in 1960 enhanced the bargaining power of the oil-producing countries as a group.

Although the interdependence of the OPEC countries and the international oil companies will remain as long as the former produce a significant portion of the world's oil and the latter refine and sell it, many signs indicate that the present institutional framework in which this interdependence is expressed will not continue. The model developed in this study will help to measure the factors that may cause changes in this framework in either direction.

In order to measure the bargaining power of the international oil companies versus the oil-producing countries, the following relationship is hypothesized.

$$(12)\quad BPIN_{(opco)} = d_o + d_1\, DEPop_{(us)} + d_2\, DEPop_{(we)} + d_3\, REPoec_{(op)} + d_4\, DEPop_{(co)} + e_{12}$$

This relationship states that the bargaining power behavior of the oil-producing countries versus the international oil companies is a function of dependency of the United States, Western Europe and the international oil companies on OPEC's oil, as well as Relative Power position variable of the OPEC member countries to all OECD member countries. Each of the dependency variables has been endogenously determined in a separate equation in this model. Bargaining Power Index is measured by the ratio of the oil revenues for the governments of the oil-producing countries to the net income of the international oil companies from their entire operations.

The increased oil revenues to governments of the oil-producing countries is a function of several factors: increases in production and

exports of oil, additional revenue derived from past bargaining and royalties obtained from the concessions offered to new foreign oil companies. Based on what has already been discussed, these factors measure the relative bargaining power of the oil-producing countries. Net income of the international oil companies from their entire operation is a rough measure of their economic power and, because bargaining power is determined by economic factors, it approximately represents their bargaining power.

The characteristic of the present relative dependency and bargaining model is that it is a recursive model, i.e., the output of a unit in any period depends on prior inputs to the unit, so that there is no simultaneous interaction between units, and thus, there are no simultaneous equations involving more than one unit at a time to be solved. The equations can be ordered to form a triangular matrix and in this arrangement, every endogenous variable which is encountered in an equation has been calculated at an earlier point in the system. This does not mean that units are conceived to act independently from each other, since the prior outputs of other units may be inputs to the unit in question, but it does mean that all interaction among units in the model is sequential rather than simultaneous. Recursive systems are particularly associated with Wold, who has argued that this stepwise chain of causation is a valid representation of economic mechanisms.[11] In this study the hypothetical relationships have not been expressed in form of a difference equation, i.e., all the variables have been expressed at the time (t) and no lagged variables are involved.

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[11] H. Wold and L. Jureen, Demand Analysis, (New York: John Wiley & Sons, Inc., 1953.

CHAPTER IV

THE EMPIRICAL ANALYSIS

Estimation Procedure

Parameter Estimation Techniques

The model described here has twelve structural linear (not reduced form) equations. A completely specified econometric model contains only equations in which all the parameters have been given numerical values. Such models are the most concrete forms in which researchers try to describe the world. Each structural equation states the manner in which one endogenous variable is determined by the value of exogenous plus other endogenous variables and usually contains a random term.

In the past, most econometricians interested in estimating the values of the parameters would have applied least squares regression analysis to each equation separately. One of the major advances in econometric methodology has been the discovery that applying least squares procedures directly to the structural equations produces numerical estimates of the parameters that are biased and inefficient. Superior estimates of the parameters in a model can usually be made by procedures that explicitly take into account the simultaneous character of the relations incorporated in the model.

In order to estimate the coefficients of the structural parameters in a linear equation model, an econometric technique should be used that has the property of consistency. For estimating a single structural equation,

consistent estimators can be obtained by Two-Stage Least Squares, by Limited Information/Least Generalized Residual Variance Estimators, or by some other (k) class estimators.[1] The researcher's task would be simple if one of these techniques could be used. The problem is not limited to the complexity of the technique or the computer time; the further question of identification remains, which is purely theoretical. One of the above techniques may be used if and only if the system of equations is over-or just-identified, i.e., they cannot be used when the system is under-identified.[2] The developed model in this study is over-identified.

Serial Correlation and Multicollinearity Problems

It is well known that economic time series tend to be serially correlated. This property in the dependent variable tends to reduce the efficiency of regression estimates. In effect, serial correlation means that the number of degrees of freedom available is far less than the number of observations. Statistical tests are provided by Durbin-Watson and Von Neumann with regard to general randomness of the residuals, especially serial correlation.[3]

Multicollinearity or intercorrelation is a result of interdependence in time series of regressors. Multicollinearity may produce large standard errors of coefficients and consequently make it very difficult to accept or reject the hypotheses made concerning parameters. Multicollinearity is

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[1]Arthur S. Goldberger, Econometric Theory, (New York: John Wiley & Sons, 1964), pp. 329-46.

[2]Ibid., pp. 306-18.

[3]Ibid., pp. 243-44.

associated with most economic time series.[4] In order to avoid multicollinearity among the variables in this model, the actual variables that have lower interdependence have been selected. In this model, the created variables (i.e., created by stating two real-life variables as a ratio) have low interdependence with all other variables.

Results obtained from the statistical analysis performed on the variables created by setting two variables as a ratio show that the new variable has different statistical properties than either of the two variables used in the ratio. For example, if the variable in the numerator or the denominator is intercorrelated with other variables in an equation, it does not necessarily follow that the created variable will also be intercorrelated with these variables. The use of new, created variables thus avoids the problem of multicollinearity involved in the time series.

> If forecasting is a primary objective, then intercorrelation of explanatory variables may not be too serious, provided it may reasonably be expected to continue in the future.[5]

The rank and order conditions given for identification are met for this model, and the system is over-identified. Thus, use of one of the above techniques is permitted. Two-Stage Least Squares is used for estimating the parameters of this model.

In order to be sure that the relations hypothesized in this model are defensible, the empirical results should be put through logical and theoretical examinations such as validity tests, reliability tests and

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[4] J. Johnston, Econometric Methods, (New York: McGraw-Hill Book Company, 1963), pp. 201-207.

[5] Ibid., p. 207.

suitability tests. For this purpose, the following statistics are used: R^2, the coefficient of determination; R^2 corrected for the number of observations; T value, which is the number of times each estimated regression parameter exceeds its standard error; and, finally, the Durbin-Watson statistic, which measures the degree of serial correlation of the residuals, as well as the sign of the parameters estimated.

The Empirical Results

The empirical analysis has been carried out for the years 1950-1964. Using the estimation procedure described above, the following results were obtained. For each equation, R^2 (coefficient of determination) and R^2 corrected for the number of observations (R^2 corrected) are presented. For every variable in each equation, T value (the number of times each estimate exceeds it standard error) is shown in the parentheses below the regression coefficient. The Durbin-Watson statistic, the measure for serial correlation, is presented for each equation.

(1) United States Block

Demand Equation (1)

$$DDoil_{(us)} = -642.523 + \underset{(2.10)}{1.2396}\ GNPca_{(us)} + \underset{(3.94)}{0.0201}\ TMVH_{(us)} + \underset{(1.60)}{102.9766}\ IDIN_{(us)}$$

$R^2 = .94$

R^2 corrected = .92

D.W. statistic = 1.066

Production Equation (2)

$$DDPoil_{(us)} = -82.3245 + 0.7205\ DDoil_{(us)} + 0.0204\ RESoil_{(us)} - 0.916\ AVCoil_{(us)} + 152.1407\ RDEX_{(us)}$$

(23.51) (3.37) (2.26) (5.13)

$R^2 = .997$

R^2 corrected = .995

D.W. statistic = 2.35

Imports Equation (3)

$$IMoil_{(us)} = -81.6429 - 0.7120\ DPoil_{(us)} + 0.8049\ DDoil_{(us)} - 0.0030\ RESoil_{(us)}$$

(7.28) (11.02) (0.90)

$R^2 = .99$

R^2 corrected = .98

D.W. statistic = 2.24

(2) Western Europe Block

Demand Equation (4)

$$DDoil_{(we)} = 12.6176 - 0.1013\ DDsf_{(we)} + 0.0863\ TMVH_{(we)}$$

(1.10) (58.82)

$R^2 = .996$

R^2 corrected = .995

D.W. statistic = 1.785

Production Equation (5)

$$DPoil_{(we)} = -25.6258 + 0.0048\ DPsf_{(we)} + 0.2132\ IDIN_{(we)}$$
$$(3.87) \qquad (32.20)$$

$R^2 = .99$

R^2 corrected = .98

D.W. statistic = 1.37

Import Equation (6)

$$IMoil_{(we)} = -545.2407 + 0.1483\ DPsf_{(we)} + 8.7539\ DDoil_{(we)}$$
$$(0.97) \qquad (36.18)$$

$R^2 = .993$

R^2 corrected = .991

D.W. statistic = .876

(3) OPEC Block

Exports Equation (7)

$$EXoil_{(op)} = -2.9518 + 0.0067\ DDoil_{(us)} + 1.0078\ DDoil_{(we)}$$
$$(0.56) \qquad (23.46)$$

$R^2 = .995$

R^2 corrected = .994

D.W. statistic = 1.286

Government Revenue Equation (8)

$$GRoil_{(op)} = -2738.8007 + \underset{(7.03)}{2.081}\ IMoil_{(us)} + \underset{(18.60)}{0.4653}\ IMoil_{(we)} + \underset{(5.45)}{988.1806}\ REPoec_{(op)} + \underset{(6.21)}{18.8641}\ DEPop_{(co)}$$

$R^2 = .998$

R^2 corrected = .997

D.W. statistic = 2.40

(4) Dependency and Bargaining Power Block

United States Dependency Equation (9)

$$DEPop_{(us)} = 0.1249 - \underset{(12.91)}{1.3153}\ RSS_{(us)} + \underset{(63.43)}{9.56}\ DRSW_{(us)} - \underset{(2.59)}{0.0069}\ OCR_{(us)}$$

$R^2 = .99$

R^2 corrected = .99

D.W. statistic = 1.759

West Europe Dependency Equation (10)

$$DEPop_{(we)} = 19.5568 - \underset{(1.72)}{85.4421}\ RSS_{(us)} - \underset{(2.73)}{4.3075}\ OCR_{(us)} + \underset{(1.50)}{0.1652}\ RRCopwe_{(co)} - \underset{(2.51)}{17.6341}\ RCA_{(opus)}$$

R^2 = .68

R^2 corrected = .52

D.W. statistic = 1.51

International Oil Companies Dependency Equation (11)

$$DEPop_{(co)} = 72.3154 + \underset{(6.38)}{1143.1737}\ DRSW_{(us)} - \underset{(5.22)}{27.0895}\ OCR_{(us)} + \underset{(3.68)}{1.1882}\ RRCopwe_{(co)} + \underset{(2.19)}{25.8077}\ REPoec_{(op)}$$

R^2 = .93

R^2 corrected = .90

D.W. statistic = 1.56

Bargaining Power Equation (12)

$$BPIN_{(opco)} = -203.4298 + \underset{(7.18)}{639.3854}\ DEPop_{(us)} + \underset{(4.24)}{639.3854}\ DEPop_{(we)} + \underset{(3.88)}{102.4666}\ REPoec_{(op)} + \underset{(0.99)}{0.3778}\ DEPop_{(co)}$$

R^2 = .97

R^2 corrected = .96

D.W. statistic = 1.13

Analysis of the Empirical Results

The above coefficients and statistical results were obtained by using the estimation procedures discussed in the last section. In order to be sure that the relations assumed in this model are defensible, the empirical results should be subjected to logical and theoretical examination such as validity, reliability and suitability tests.

With large samples, and moderate or small correlations, the correlation obtained from a sample of N pairs of values is distributed normally about the true value S, with variance $(1 - S^2)^2 / N-1$; it is therefore usual to attach to the observed value (r), a standard error: $(1-r^2)/\sqrt{N-1}$ or $(1-r^2)/\sqrt{N}$. This procedure is only valid under the restrictions stated above. With a small sample, as in the present case, which has only 15 observations, the value of (r) is often very different from the true value S and the factor $(1-r^2)$ is correspondingly in error. In addition, the distribution of (r) is far from normal, so that tests of significance related to the large-sample formula are often very deceptive.

Furthermore, in time series analysis, R^2 cannot be the sole measure for testing significance; the R^2 test should be supplemented by the T test (ratio of estimated regression coefficient to standard error of estimate). In addition to these two relevant tests, the sign test is of great importance, since in order for the hypothetical relationships between the variable in the equations to be acceptable, the sign of the coefficients obtained through empirical analysis should correspond to the sign of hypothetical relationships between the variables in the equation.

All the R^2 values obtained for the equations in the model are significant. The R^2 values corrected for the number of observations are also significant. As far as the sign of coefficients is concerned, all of the signs obtained through empirical results correspond to the hypothetical signs given in the equations.

In this study the T test has not been used for screening out the variables. It has rather been applied to show the relative significance of one variable in respect to other variables in an equation. The T values are given in the parentheses below the regression coefficients. The following table presents the selected T values at different levels of significance and with different degrees of freedom.

TABLE II.--Selected T Values

Degrees of Freedom	Level of Significance		
	99%	97%	95%
15	2.60	2.13	1.75
14	2.62	2.14	1.76
13	2.65	2.16	1.77
12	2.68	2.18	1.78
11	2.72	2.20	1.80
10	2.76	2.23	1.81

The Durbin-Watson statistic (d statistic) measures the degree of serial correlation in residuals. In order to determine the magnitude of serial correlation an upper limit (d_u) and a lower limit (d_l) have been

introduced. The values of these limits are a function of degrees of freedom and vary with different levels of significance. The values of upper and lower limits for different degrees of freedom and significant levels are provided in the article footnoted below. If $d < d_l$ we reject the hypothesis of random disturbances in favor of positive serial correlation. If $d > d_u$ we do not reject the hypothesis and tentatively conclude that the disturbances are independent (random). If $d_l < d < d_u$ the test is inconclusive.[6]

In short, the model appears to be a good abstraction from reality, and the hypothetical relationships in the model are not only theoretically valid but also statistically defensible.

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[6] J. A. Durbin and G. S. Watson, "Testing for Serial Correlation in Least Squares Regressions," Part I and II Biometrika, Vol. XXXVII. 1950, pp. 409-28 and Vol. XXXVIII. 1951, pp. 159-78.

CHAPTER V

COMPUTER SIMULATION OF THE RELATIVE DEPENDENCY AND BARGAINING POWER

Role of Computer Simulation

The process of simulation involves constructing a theory or model of a system that describes the system's processes. These processes can refer to macro as well as micro-elements, and the descriptive detail reflects the researcher's knowledge of or interest in particular parts of the system. By carrying out the processes postulated in the theory, a hypothetical stream of behavior is generated that can be compared with the stream of behavior of the original system.

The central problem inherent in all simulation processes--and in all model building generally--is that of adequate reproduction of the real system. In simulation, the researcher is trying to learn about a real system by working with a model of it. If the researcher doesn't put into the model the necessary attributes of the real system, the results found in solving problems in the simulated environment cannot successfully indicate the behavior of the real system.

Simulation can be considered as a general approach to the study and the use of models. As such, it furnishes an alternative approach to that offered by conventional mathematical techniques. In using conventional mathematical techniques to solve a model, the objective is to determine the

way in which the model implicitly relates uniquely endogenous variables to initial conditions, parameters and time paths of exogenous variables.[1]

Simulation techniques are also used to solve models, but in any single simulation run the solution is highly specific. Given complete initial conditions, parameters and exogenous variables, a single simulation run yields only a single set of time paths of the endogenous variables. To determine how the behavior of the endogenous variables is more generally dependent on initial conditions, parameters and exogenous variables may require a large number of simulation runs, and even then, induction from specific results to general solutions will be required.[2]

Simulation as employed in the social sciences makes use of models constructed in such a way that they may become operative or functioning. Operating models are representations of a behaving system that attempts to reproduce processes in action. As such, operating models provide information about variables, components and relationship changes within a system over time.

Simulation provides a new econometric device to study models based on empirical investigation. It serves as a computational aid and an alternative to analysis in model construction. It may also be used as a data-organizing device, and may serve as a tool for anticipation and planning.

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[1] C. West Churchman, "An Analysis of the Concept of Simulation," Symposium on Simulation Models (Austin C. Hoggatt and Frederick E. Balderston, eds.), (Cincinnati: South-Western Publishing Co., 1963).

[2] Kalman J. Cohen and Richard M. Cyert, "Computer Models in Dynamic Economics," The Quarterly Journal of Economics, Vol. LXXV. 1961, pp. 112-27.

Advantages of Computer Simulation Models

In general, among the quantitative methods available, the simulation approach places the least restriction on problem representation. Practically the only requirement is that the variables be quantifiable and the relationships between variables be defined. Once there is a precise mathematical statement of the situation, the behavior of the model may be determined in two ways. First, the model may be amenable to analytical solution; second, the model may be simulated over time.

Simulation techniques and studies may be useful in the specification of operating characteristics in the following ways:

1. Simulation techniques enable the effective study of models containing large numbers of components, variables and relationships of almost any desired form.

2. Simulation techniques make it feasible to carry out sensitivity analyses on a model. The model can be run many times with the value of one or more parameters being altered between runs. The resulting variation in time paths of endogenous variables can be observed and related to the corresponding alterations of parameters. After determining the sensitivity of the results to specific differences in the size of parameters, the investigator is in a much better position to decide where to apply additional research effort in parameter estimation.

3. Simulation techniques permit specific values of the models to be determined. By doing so, they make it possible to carry out testing at various levels of aggregation, ranging from the level of individual components up to the level of highly aggregative phenomena. This is extremely

important because achievement of more adequate testing is one of the most serious problems facing model builders.

4. Simulation, or closely related Monte Carlo studies, can be useful in supplementing or extending modern multivariate statistical techniques of estimating parameters in operating characteristics. In effect, these techniques enable operating characteristics to be fitted to bodies of data by trial and error procedures. This capability may be of the greatest importance when dealing with various kinds of non-linear relationships for which other methods of estimation are either unknown or too costly.[3]

Simulation studies can also be used to improve our knowledge about how existing statistical techniques work in the face of specification errors of various sorts.

One Period Change Model Versus Process Model[4]

In an econometric model, the economic system is viewed as describable by a set of simultaneous economic relationships that guide economic behavior. The variables in this set of equations are classified into two main types, endogenous and exogenous. The endogenous variables are variables that are determined within the system of economic forces in a narrow sense: the

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[3] G. H. Orcutt, M. Greenberger, J. Korbel and A. M. Rivlin, Microanalysis of Socioeconomic Systems: A Simulation Study, (New York: Harper and Brothers, 1961); H. R. Hamilton, S. E. Goldstone, J. W. Milliman, A. L. Pugh III, E. B. Roberts and A. Zellner, Systems Simulation for Regional Analysis an Application to River-Basin Planning, (Cambridge, Mass.: The M.I.T. Press, 1969), pp. 15-32, 234-57.

[4] K. J. Cohen, Computer Models of the Shoe, Leather, Hide Sequence, (Englewood Cliffs: Prentice-Hall, 1960), pp. 8-16, 70-83.

exogenous variables are variables that represent forces outside of the system being modelled.

Given the known values of lagged endogenous variables in the year t-1 and of the exogenous variables in both years t and t+1, the equations in the model state something definite about the nature of the world in the year t, but they say nothing about the nature of the world in the year t+1.[5] In essence, a traditional econometric model, designated as a One Period Change Model, is intended to describe only changes from one period to the next period. Any lagged values of the endogenous variables are treated, in effect, as exogenous variables. They are assumed to be predetermined by outside forces rather than by an earlier application of mechanisms specified in the model. Thus, the output of econometric models is the determination of the values of the endogenous variables in a given time period. To determine these values for the next period, new values would have to be assigned to the lagged endogenous variables. For this reason, most econometric models should be regarded as determining the changes that take place in the world from one period to another. They should be contrasted with Process or Evolutionary Models, which attempt to exhibit the unfolding of dynamic processes over time.

Computer simulation techniques are used to simulate the models of economic theory. The theory is usually formulated in terms of a system of lagged simultaneous difference equations. The computer then traces out the time paths of each endogenous variable. The equations of the model, together

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[5]T. H. Naylor, J. L. Balintfy, D. S. Burdick and Kong Chu, Computer Simulation Techniques, (New York: John Wiley & Sons, Inc., 1966), pp. 223-31.

with the observed time paths of the exogenous variables, are treated as a closed dynamic system; in each period, the values of the lagged endogenous variables are the values generated by the model, rather than known or actually observed values.

The methodology of the closed dynamic system approach, i.e., the Process Model, differs from the methodology underlying more traditional econometric models mainly in the treatment of lagged endogenous variables. In the One Period Change Model, it is assumed that in each period, any errors resulting from the "determination" of the last period's endogenous variables are corrected so that there is a tendency for the One Period Change Model to be kept on course by the fact that it always has a correct starting place. Using the Process Model, on the other hand, the researcher is forced to live with any errors that may have been made by the model in "determining" the values of endogenous variables in previous periods; there is no automatic resetting of the error terms to assure a correct jumping off place for each period.

Experimentation on the Model

In any model, an implicit relation exists between the value of any given endogenous variable in any given time period and the values of all initial conditions, parameters, and exogenous variables in the model. One such relationship exists for the value of each endogenous variable for each time period. If readily available, and simple enough to be usable, these relationships would be the generalization required, and there would be no need to investigate the properties of a model by experimentation. However,

these relationships are not readily available for many models, nor would they be simple if available. This lack of feasibility leads to the use of an experimental approach.

Forecasting can take place by appropriate selection of initial conditions and by altering the number of periods the model is run. It can be unconditional or conditional, i.e., predicted on given specified external conditions. The results obtained in the model at the end of a single simulation run may be expected to differ from what actually happens in the real system being simulated. The difference might arise from several sources: (1) The units of the real system may not behave according to the assumed operating characteristics, or (2) stochastic variation in the real system is not likely to be exactly duplicated in any given simulation.[6]

Validation Experiments

Mathematical formulation is no insurance that a model will necessarily be a good one. Clearly, it is possible that a mathematically formulated model may be at variance with known facts and may also yield inaccurate predictions, as is true of nonmathematical models. However, mathematically formulated models do have the advantage that, in general, their logical consistency can be checked using the available operations of mathematics. While this task is not always easy, it does appear easier than checking the logical consistency of many nonmathematical models.

Model "validity" is not exactly an accurate term, since it implies that there is a simple dichotomy--the model is valid or not valid. In

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[6]Hamilton, pp. 234-57.

practice, the problem is never that simple. The real issue is whether the model is good enough to answer the model builder's questions. At present, objective tests that can be applied are few; perhaps none can give an answer relative to specific use of the model. The question therefore becomes one of whether the builder has confidence in his model for the use to which he plans to apply it--admittedly a subjective evaluation.[7]

In order to examine a model, the first step is to determine whether the micro structure of the model is reasonable. Have the appropriate variables been included? How sensible is the dependency between the variables? Is the form of the dependency reasonable? Is the direction of cause and effect correct? After examining all these questions, the statistical fit of the model should be tested. The sensitivity of the parameters derived from data should be examined. Finally, the reasonableness of the over-all behavior of the model must be verified. If the model is run over a period of time for which there is historical data, does it reproduce history reasonably well? This point--attempting to reproduce entire sets of historical values--merits additional comments that will be presented in the next section. It is one technique that most researchers think of when faced with the validity issue.

If some inference is to be made about the simulated results, the simulation model must be a "reasonably" valid representation of the real system. Some assurance of validity would be gained by showing that with at least one alternative version of the simulated system and one set of conditions, the simulated model produces results that are not inconsistent

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[7]Hamilton, pp. 93-98.

with the known performance of the real system. The model cannot be validated under all variations and conditions. If that were possible, there would be little point in the simulation. As Conway[8] indicated, this kind of validation is essentially a null test: A model that failed to pass would be exceedingly suspect, but no strong statement can be made for a model that passed.

There are several methodological positions for validating and verifying a simulation model: synthetic a priorism; ultraempiricism; positive economics; and multistage verification.[9]

Multistage verification is an approach that incorporates the methodology of synthetic a priorism, ultraempiricism and positive economics. Each of the above methodologies is a necessary procedure for validating simulation experiments, but no one of them is a sufficient procedure for solving the problem of verification. Therefore, first, a set of hypotheses must be formulated describing the behavior of the system of interest which is called synthetic a priori. Then, the hypotheses on which the model is based should be verified subject to the statistical tests. Finally, based on Friedman's view of positive economics, the model's ability to predict the behavior of the system should be tested. In this study, the use of multistage verification to validate the model has been attempted. First, twelve mathematical relationships have been hypothesized. Then, these hypotheses

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[8] R. W. Conway, M. B. Johnson and W. L. Maxwell, "Some Problem of Digital Systems Simulation," Management Science, VI. (October, 1959), 92-110.

[9] Thomas H. Naylor, Joseph L. Balintfy, Donald S. Burdick and Kong Chu, Computer Simulation Techniques, (New York: John Wiley Sons, Inc., 1966).

have been verified statistically by using regression technique along with several statistical tests. Finally, the model has been used for historical verification and forecasting.

Historical verification and verification by forecasting are two alternatives for testing the degree to which data generated by a computer simulation model conform to observed data. In order to verify the present bargaining model based on the historical data, the model is run under two modes: Process Model and One Period Change Model. The results are observed, and an effort is made to estimate from these results general relationships between the results obtained and the experimental manipulations performed. The validation results are evaluated in the following section.

Sensitivity Experiments

The dynamic characteristics of the model can further be understood by means of sensitivity experiments. These experiments yield information about the variability of results to alternative specifications of parameter values. The behavior of the model during simulation runs may depend critically on the specification of some parameters and may be grossly insensitive to the specification of others. For these kinds of experiments, a number of simulation runs should be made with parameter values being altered from run to run. One possible procedure would be to make one run with all the parameters set at what is regarded as their most likely values and then to make additional runs for which one parameter per run is set at a value different from that on the control run. Each run will generate time paths for all variables endogenous to the model. For each such run, the time paths obtained may be compared with the corresponding time paths of the

control run, and the observed differences may be related to the parameter change that was used. It may also be useful to relate percentage changes in results obtained to the percentage change in the parameter value giving rise to them. The results of the sensitivity analysis on the relative dependency and bargaining model are presented and evaluated in the following section.

Results of Simulation and Sensitivity Experiments

In this section, the results of the simulation and sensitivity runs on the models are presented. To run the simulation experiments on the model, historical data from the years 1950-1964 have been used. The reason for selecting this period for analysis was that data for this period were available for all the variables in the model. The period from 1967 to the present had to be omitted because of irregularities in the world crude oil market caused by the Arab-Israeli War and closure of the Suez Canal.

The scarcity of the data available has been the main barrier to this study as is the case in many statistical studies, especially the studies dealing with complex multi-equations models. (This problem has forced many researchers to validate their models with hypothetical data, which has often been used in simulation studies. Of course, hypothetical data reduce some of the value of the results but still are of great value in understanding the real world.)

In many cases, detailed petroleum statistics have been kept confidential, and most of the available data are crude and in aggregate form. In order to give more reality to the present model, a great effort has been

spent in selecting the sources, and collecting, compiling and transforming of the data available in the oil and petroleum periodicals, books, research papers and annual reports. This task was complicated by the fact that the data were scattered and reported in different units. Although it is unimportant if one variable in a regression equation has been expressed in terms of tons or barrels, the historical data for one variable should all be expressed in a common unit.

Simulation Results of One Period Change and Process Models

In order to compare the behavior of the relative dependency and bargaining power model constructed in this study with the real world, the model has been simulated in two modes: One Period Change and Process Model. This model has been simulated for the historical data from 1950-1964 and the simulation results are compared with the actual data in this period.

In Model I, the One Period Change Model, the lagged values of the endogenous variables are replaced by their actual observed values. Model II is a Process Model, i.e., a model in which after the initial period the values of the lagged endogenous variables appearing in its relations are the values that were generated by the model, not the actual values assumed by the variables. Since a Process Model asserts a great deal about the nature of the world, there is a strong likelihood that in some respects it is an incorrect description of the reality it is intended to show.

Both modes are used to generate time paths for the endogenous variables. Because of the difficulty of duplicating reality exactly in a model, the simulated results are not expected to be in complete agreement with real life; nor do we expect that time paths so generated would exactly

coincide with the observed time paths of the endogenous variables. To the extent that they do not, our models fail to be an adequate description of the world. Both models in the present study generate time paths that are reasonably close in agreement with the observed time paths. Over-all, the One Period Change Model seems to perform better than the Process Model, as was expected.

The simulation results are presented in three sections: United States, Western Europe and the oil-producing countries (OPEC). In each section, the actual values and the time paths generated for the four relevant endogenous variables are tabulated by the computer. These endogenous variables are demand, production, imports of oil and the relative dependency variable in the United States and Western Europe blocks, and exports of oil, revenues from oil, relative dependency of the international oil companies, and finally the relative bargaining power of the oil-producing countries in the OPEC block with respect to the international oil companies. In order to improve interpretation and comparison of the results, the time path generated for each endogenous variable in each model is graphed separately against the actual data via the computer's plotter. It may be observed that the time paths generated for the endogenous variables which do not depend on other endogenous variables are the same for both models.

Prior to the analysis of the behavior of the endogenous variables, some words of caution are in order. The relative dependency and bargaining power ratios are not standardized, i.e., they have not been expressed in a common standard unit. Comparisons of the sizes of the relative dependency ratios between the participants is not possible. It is possible, however,

to compare the direction and the degrees of change in their relative dependency ratios at any given year as compared to another year in the past. For example, the conclusion may be drawn that the Western European countries were more dependent on the oil-producing countries in 1964 than in 1963 because the results indicate a relative dependency ratio of 8.7 in 1964 as compared to the ratio of 8.5 in the year 1963. Also, it can be concluded that the relative dependency of Western Europe has risen faster than the United States during 1963-1964. However, the relative dependency ratio of the Western European countries (8.7 in the year 1964) cannot be compared to the relative dependency ratio of the United States (0.135 in this year); the conclusion cannot be drawn that West European countries were more dependent on the oil-producing countries in this year than the United States. This argument holds true for the relative bargaining power ratio as well: Both oil-producing countries and the international oil companies can determine whether they have a higher or a lower bargaining position with respect to each other in the year 1964 as compared to the other years in the past.

United States Block.--The time paths for the endogenous variables generated by the One Period Change Model and the Process Model in the United States block are generally a good duplication of the real world (Tables 1.1, 1.2 and 1.3). Some irregularity can be observed in time paths for the domestic demand for oil during 1954-1958 (Appendix I, Figures 1.a and 1.b). Actual demand for oil rose very sharply during the years 1954 to 1956, levelled off in 1956, sharply decreased in 1958 and showed a consistent increasing trend from this time on. The time paths generated by the two models do not perfectly detect this irregularity, but they behave quite well for the rest of the trend.

TABLE 1.1

UNITED STATES

ACTUAL RESULTS

YEAR	DOMESTIC DEMAND OF OIL IN U.S.*	DOMESTIC PRODUCT. OF OIL IN U.S.*	IMPORT OF OIL BY U.S.*	DEPENDENCY OF U.S. ON OPEC'S OIL
50	2156.00000	1974.00000	178.00000	0.08256
51	2420.00000	2248.00000	179.00000	0.07397
52	2483.00000	2290.00000	210.00000	0.08458
53	2591.00000	2357.00000	236.00000	0.09108
54	2571.00000	2315.00000	239.00000	0.09296
55	2763.00000	2484.00000	285.00000	0.10315
56	2959.00000	2617.00000	342.00000	0.11558
57	2974.00000	2617.00000	373.00000	0.12542
58	2816.00000	2449.00000	348.00000	0.12358
59	2933.00000	2575.00000	352.00000	0.12001
60	2964.00000	2575.00000	372.00000	0.12551
61	2998.00000	2622.00000	382.00000	0.12742
62	3080.00000	2676.00000	411.00000	0.13344
63	3180.00000	2753.00000	413.00000	0.12987
64	3233.00000	2787.00000	439.00000	0.13579

*In millions of barrels

TABLE 1.2

UNITED STATES

SIMULATED RESULTS OF THE CNE PERIOD CHANGE MODEL

CONTROL RUN WITH NO CHANGE IN PARAMETERS OF THE MODEL

YEAR	DOMESTIC DEMAND OF OIL IN U.S.*	DOMESTIC PRODUCT. OF OIL IN U.S.*	IMPORT OF OIL BY U.S.*	DEPENDENCY OF U.S. ON OPEC'S OIL
50	2190.90916	1987.87856	172.42950	0.08300
51	2488.95214	2242.43826	183.23510	0.07370
52	2563.33922	2265.93741	202.56080	0.08404
53	2574.28972	2353.12783	238.83400	0.09113
54	2606.38634	2328.43157	250.79200	0.09498
55	2717.68368	2481.44819	283.65180	0.10264
56	2792.89832	2637.07042	345.44720	0.11519
57	2829.94832	2603.95126	357.92570	0.12499
58	2881.57650	2449.00541	349.65950	0.12373
59	2908.99378	2564.47030	350.57180	0.11960
60	2967.65396	2591.03962	375.84170	0.12550
61	3033.62922	2619.12043	369.30630	0.12617
62	3112.77900	2672.78024	397.97010	0.13333
63	3202.84224	2750.89130	424.89310	0.13026
64	3307.71734	2790.42220	443.28180	0.13718

*In millions of barrels

TABLE 1.3

UNITED STATES

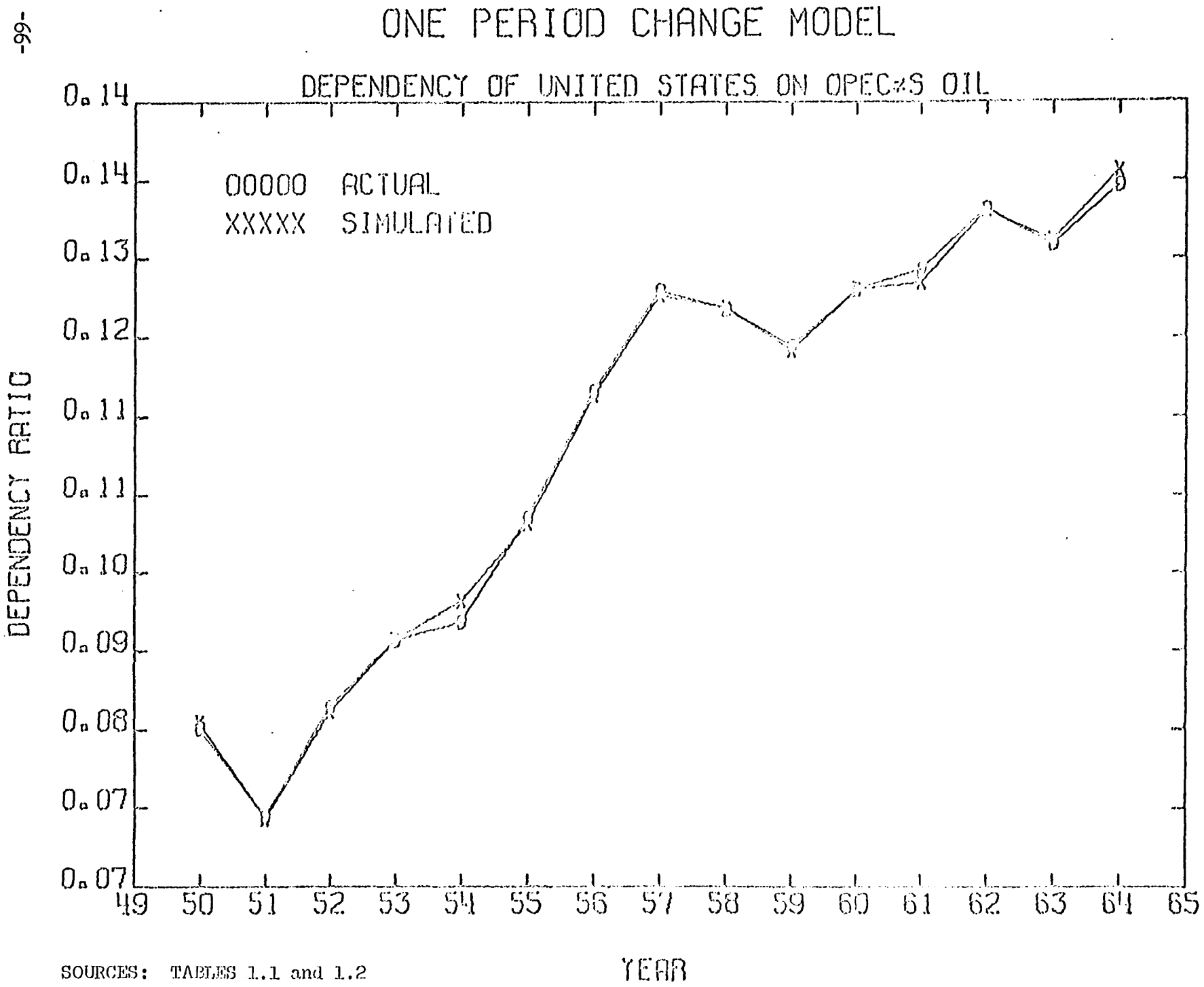
SIMULATED RESULTS OF THE PROCESS MODEL

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DOMESTIC DEMAND OF OIL IN U.S.*	DOMESTIC PRODUCT. OF OIL IN U.S.*	IMPORT OF OIL BY U.S.*	DEPENDENCY OF U.S. ON OPEC'S OIL
50	2190.90916	2013.03061	172.73809	0.08300
51	2488.95214	2292.11828	207.32246	0.07370
52	2563.33922	2323.82182	243.14470	0.08404
53	2574.28972	2341.08807	236.71319	0.09113
54	2606.38634	2353.92742	251.55814	0.09498
55	2717.68368	2448.79778	272.24068	0.10264
56	2792.89832	2517.39416	282.67131	0.11519
57	2829.94832	2500.16202	325.16714	0.12499
58	2861.57650	2481.84328	362.95961	0.12373
59	2906.99378	2547.17382	351.06143	0.11960
60	2967.65396	2593.67230	365.48810	0.12550
61	3033.62922	2644.79128	381.75687	0.12617
62	3112.77900	2696.39751	409.83089	0.13333
63	3202.84224	2767.34914	433.06223	0.13026
64	3307.71734	2844.25605	462.65548	0.13718

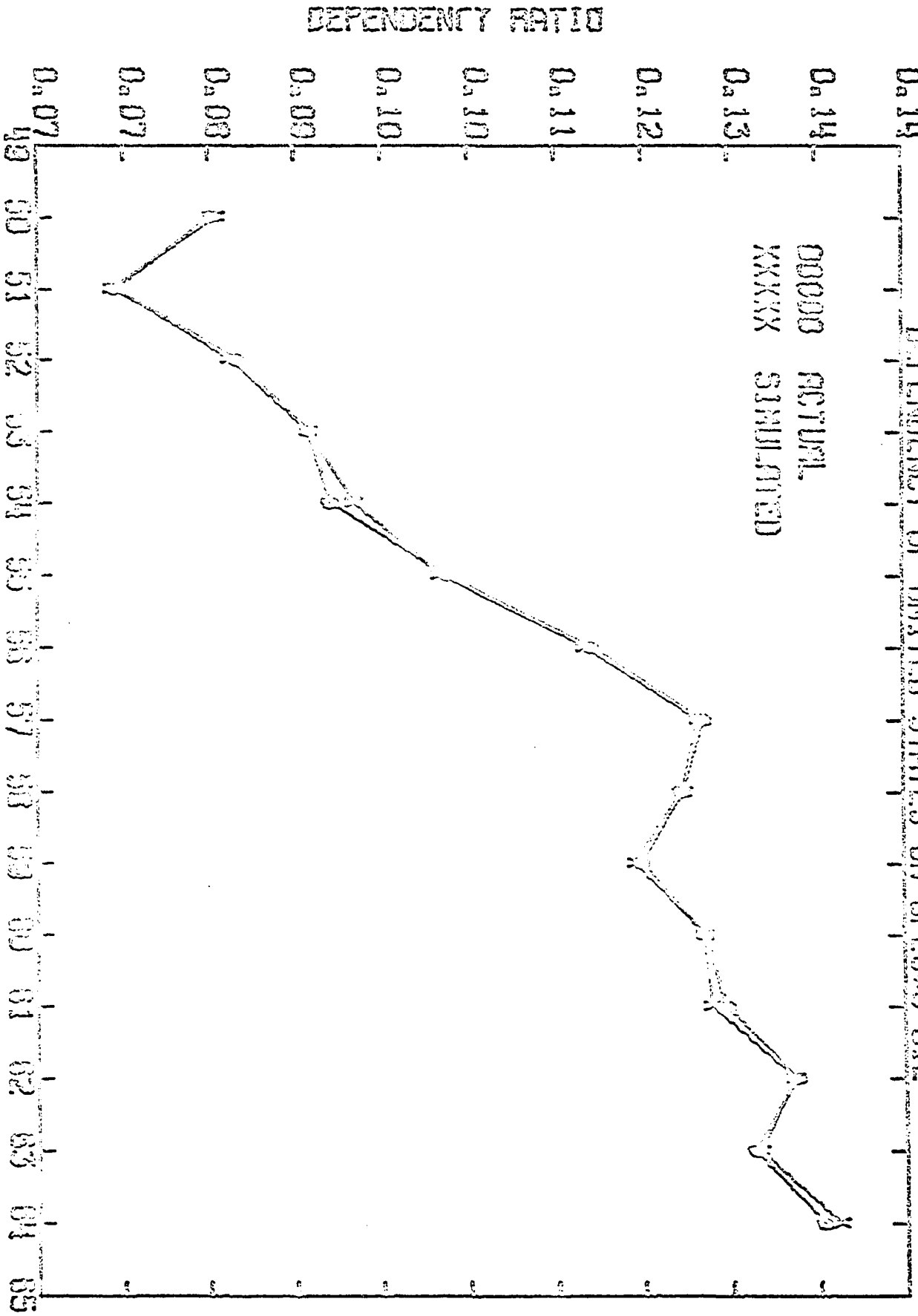
*In millions of barrels

FIGURE 1.1



SOURCES: TABLES 1.1 and 1.2

FIGURE 1.2



SOURCES: TABLES 1.1 and 1.3

The actual domestic production of oil in the United States has more or less followed the same trend with some irregularity during 1954-1958 (Appendix I, Figures 2.a and 2.b). The time path generated for production of oil in the United States by the One Period Change Model perfectly detects this irregularity as well as other ups and downs. The Process Model fails to detect the irregularities during this year; however, it follows the rest of the trend adequately.

The actual imports by the United States rose sharply during 1954-1956, when demand increased, and declined moderately in 1958, when demand decreased. The ups and downs of the import trend are fully detected by the One Period Change Model but not as well by the Process Model (Appendix I, Figures 3.a and 3.b).

The time paths generated by both models for the relative dependency of the United States on the oil-producing countries are almost exact duplications of the actual data, and they reflect all the ups and downs in the actual trend (Figures 1.1 and 1.2).

Western Europe Block.--The time paths generated for the endogenous variables in the Western Europe block are generally good representations of the real world (Tables 2.1, 2.2 and 2.3). The time paths generated by both models for the domestic demand of oil in Western Europe follow the trends throughout, with minor irregularities during 1950-1954 and some in 1957.

The time paths generated for the demand and production of oil in Western Europe by both models are for the most part good representations of actual trends (Appendix I, Figures 4.a, 4.b, 5.a and 5.b). A minor overestimate of actual data occurs in 1951; a minor underestimate appears in 1958 and 1959.

TABLE 2.1

WESTERN EUROPE

ACTUAL RESULTS

YEAR	DOMESTIC DEMAND OF OIL IN EUROPE*	DOMESTIC PRODUCT. OF OIL IN EUROPE*	IMPORT OF OIL BY EUROPE**	DEPENDENCY OF EUROPE ON OPEC'S OIL
50	60.00000	4.60000	395.00000	6.58333
51	71.30000	5.30000	566.00000	7.93829
52	78.00000	7.00000	719.00000	9.21795
53	84.20000	8.40000	819.00000	9.72684
54	93.00000	9.30000	936.00000	10.06452
55	113.20000	10.90000	999.00000	8.82509
56	128.10000	12.00000	1059.00000	8.26698
57	129.70000	13.50000	1089.00000	8.39630
58	152.50000	13.90000	1271.00000	8.33443
59	169.30000	14.80000	1464.00000	8.64737
60	196.90000	16.00000	1695.00000	8.60843
61	220.90000	17.20000	1933.00000	8.75057
62	255.80000	18.30000	2200.00000	8.60047
63	292.80000	19.20000	2491.00000	8.50751
64	334.30000	21.10000	2914.00000	8.71672

* In million tons of oil equivalent

** In millions of barrels

TABLE 2.2

WESTERN EUROPE

SIMULATED RESULTS OF THE CNE PERIOD CHANGE MODEL

CONTROL RUN WITH NO CHANGE IN PARAMETERS OF THE MODEL

YEAR	DOMESTIC DEMAND OF OIL IN EUROPE*	DOMESTIC PRODUCT. OF OIL IN EUROPE*	IMPORT OF OIL BY EUROPE**	DEPENDENCY OF EUROPE ON OPEC'S OIL
50	68.99515	4.38420	479.02280	9.02566
51	68.00631	6.41020	607.60187	9.20685
52	70.64446	7.12940	675.29930	9.91819
53	76.12745	7.89100	726.75578	10.47557
54	95.27604	9.40060	810.90850	10.83544
55	116.23243	11.01780	991.59308	10.37781
56	125.39685	12.29980	1128.69969	10.05671
57	137.70769	13.25820	1145.96853	10.04087
58	154.36446	13.33900	1334.87985	10.61366
59	170.37149	13.85500	1458.36567	10.34829
60	192.83100	15.77780	1686.92291	10.46751
61	225.22533	16.84100	1890.34301	10.01746
62	252.63203	18.30260	2201.48952	10.08894
63	292.44041	19.46180	2521.67632	9.51070
64	332.49738	21.78100	2890.74687	9.04370

*In million tons of oil equivalent

**In millions of barrels

TABLE 2.3

WESTERN EUROPE

SIMULATED RESULTS OF THE PROCESS MODEL

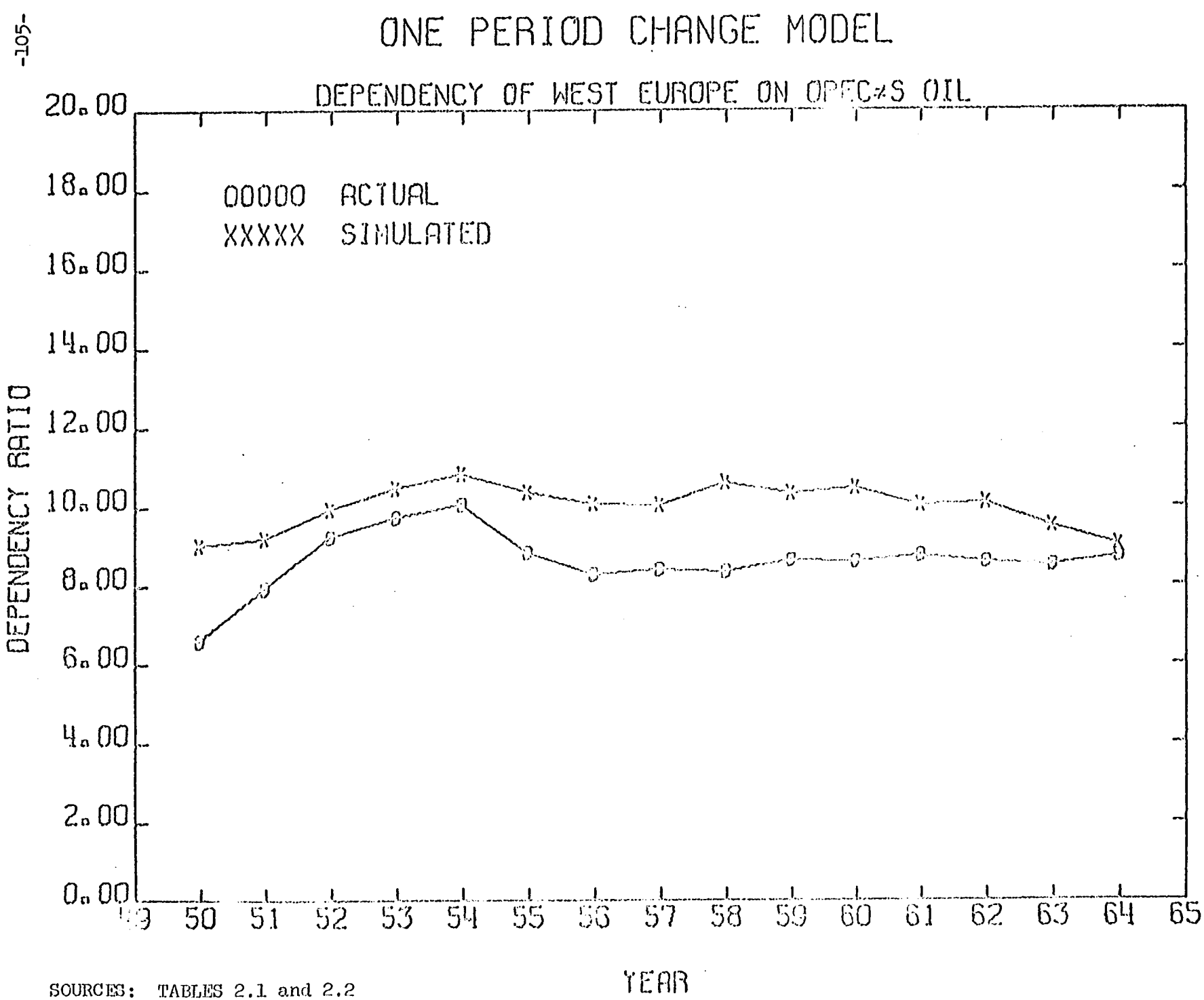
CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DOMESTIC DEMAND OF OIL IN EUROPE*	DOMESTIC PRODUCT. OF OIL IN EUROPE*	IMPORT OF OIL BY EUROPE**	DEPENDENCY OF EUROPE ON OPEC'S OIL
50	68.99515	4.38420	557.76544	9.02566
51	68.00631	6.41020	578.76924	9.20685
52	70.64446	7.12940	610.90964	9.91819
53	76.12745	7.89100	656.08948	10.47557
54	95.27604	9.40060	830.83273	10.83544
55	116.23243	11.01780	1018.13867	10.37781
56	125.39685	12.29980	1105.03659	10.05671
57	137.70769	13.25820	1216.06705	10.04087
58	154.36448	13.33900	1351.20132	10.61366
59	170.37149	13.85500	1467.74539	10.34829
60	192.83100	15.77780	1651.30329	10.46751
61	225.22533	16.84100	1928.20652	10.01746
62	252.63203	18.30260	2173.75743	10.08894
63	292.44041	19.46180	2518.52851	9.51070
64	332.49738	21.78100	2874.96691	9.04370

*In million tons of oil equivalent

**In millions of barrels

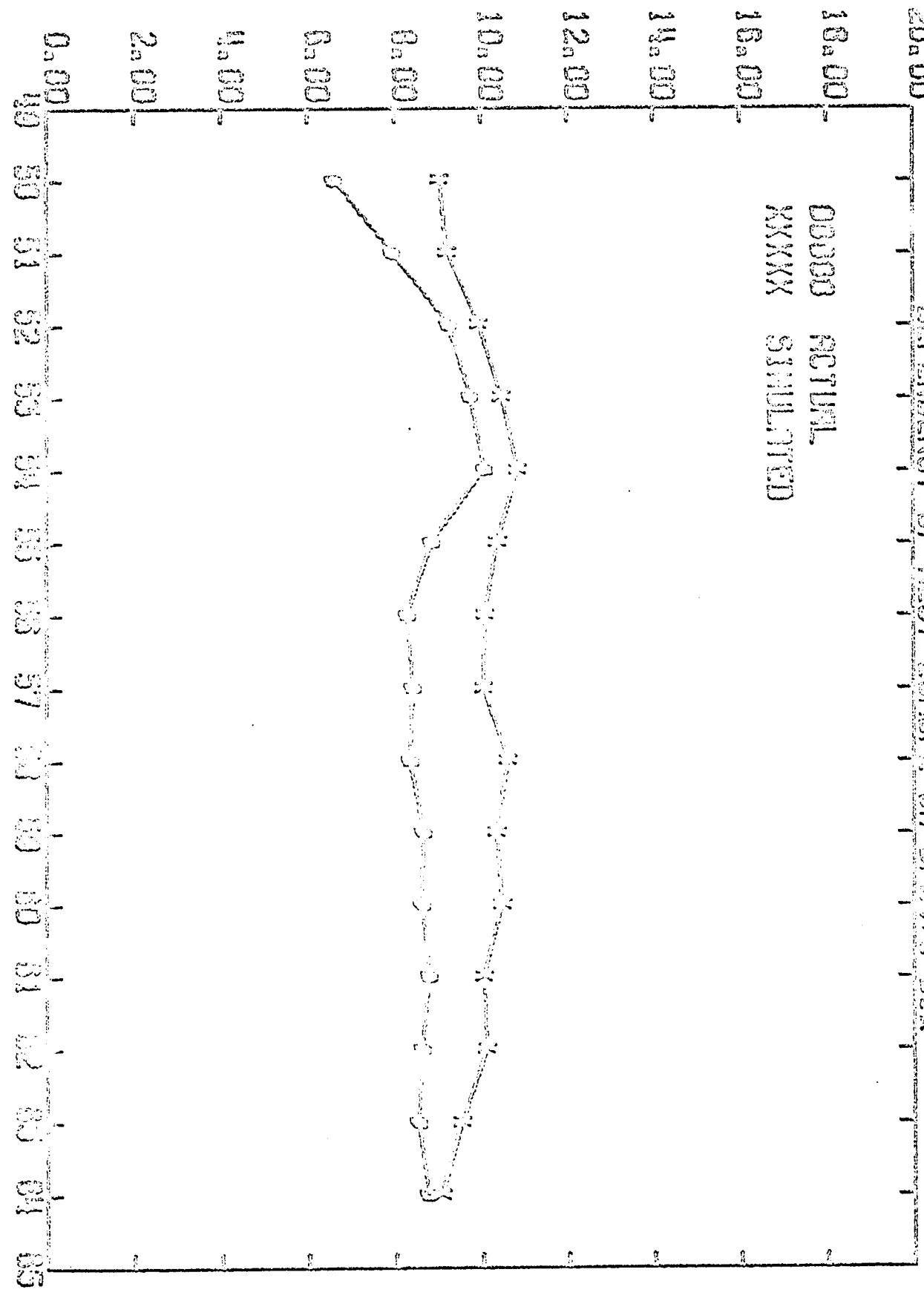
FIGURE 2.1



SOURCES: TABLES 2.1 and 2.2

FIGURE 2.2

PROCESS MODEL



SOURCES: TABLES 2.1 and 2.3

The time paths generated by both models for the imports of oil by Western Europe follow actual trends closely from 1959-1964 (Appendix I, Figures 6.a and 6.b). Actual data are underestimated during 1952-1954, however, and overestimated in 1956-1958. The One Period Change Model had a lower degree of overestimate and underestimate than the Process Model. This irregularity might have been due to the choice of variables, which is discussed in Chapter III.

The time paths generated for the relative dependency of Western Europe by both models fairly accurately detect the ups and downs (Figures 2.1 and 2.2). The models consistently overestimate the actual data throughout the trend, however.

OPEC Block.--The time paths for the endogenous variables generated by both the One Period Change Model and the Process Model in the oil-producing countries (OPEC) block generally duplicate the past history data quite accurately (Tables 3.1, 3.2 and 3.3). The time paths generated by both models for the oil exports by OPEC member countries follow the actual trend, with the exception of underestimation of the actual data in 1953 and overestimation in 1957 by the Process Model (Appendix I, Figures 7.a and 7.b).

The time path generated by the One Period Change Model for government revenues from oil exports exactly follows all the ups and downs and duplicates the actual data. The Process Model behaves similarly, but the generated path has a slight under- and overestimation through the trend line (Appendix I, Figures 8.a and 8.b).

The time paths generated for the relative dependency of international oil companies by both models detect almost all the ups and downs with underestimation or overestimation of some of the actual data (Figures 3.1 and 3.2).

TABLE 3.1

O.P.E.C. COUNTRIES

ACTUAL RESULTS

YEAR	OIL EXPORT BY OPEC	GOV. REVENUES FROM OIL EXPORT	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC V.S. OIL COMP.
50	89.70000	238.00000	80.20000	20.40000
51	80.90000	283.00000	81.40000	20.30000
52	87.80000	399.00000	86.70000	27.80000
53	102.20000	580.00000	87.90000	37.10000
54	115.80000	716.00000	90.20000	44.00000
55	137.30000	898.00000	93.20000	45.50000
56	143.60000	1003.00000	93.50000	44.90000
57	143.80000	1068.00000	92.90000	45.10000
58	175.30000	1278.00000	96.20000	60.90000
59	188.10000	1295.00000	95.80000	57.50000
60	215.40000	1441.00000	96.40000	60.20000
61	235.30000	1501.00000	92.80000	58.70000
62	264.40000	1553.00000	93.50000	58.80000
63	308.40000	1865.00000	92.60000	60.50000
64	366.90000	2111.00000	93.60000	65.70000

TABLE 3.2

O.P.E.C. COUNTRIES

SIMULATED RESULTS OF THE ONE PERIOD CHANGE MODEL

CONTROL RUN WITH NO CHANGE IN PARAMETERS OF THE MODEL

YEAR	OIL EXPORT BY OPEC	GOV. REVENUES FROM OIL EXPORT	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC V.S. OIL COMP.
50	71.96140	239.67713	80.74994	20.89746
51	85.11834	275.14983	81.47530	18.34064
52	92.29270	421.17697	85.20691	26.91417
53	99.26466	566.29513	89.71846	37.40772
54	107.99930	696.66180	90.74932	44.59969
55	129.64326	933.01002	93.27194	49.12198
56	145.97268	1033.91699	93.63835	47.74520
57	147.68566	1056.33197	93.81290	50.24764
58	169.60490	1244.22997	96.07277	59.52017
59	167.31984	1285.62914	93.07871	54.21101
60	215.34282	1443.94304	94.72393	57.45434
61	239.75782	1488.57530	92.17745	56.35497
62	275.47944	1683.38697	95.15015	59.09629
63	313.43804	1829.80190	94.15318	58.28624
64	355.61684	2130.98804	93.00482	67.18531

TABLE 3.3

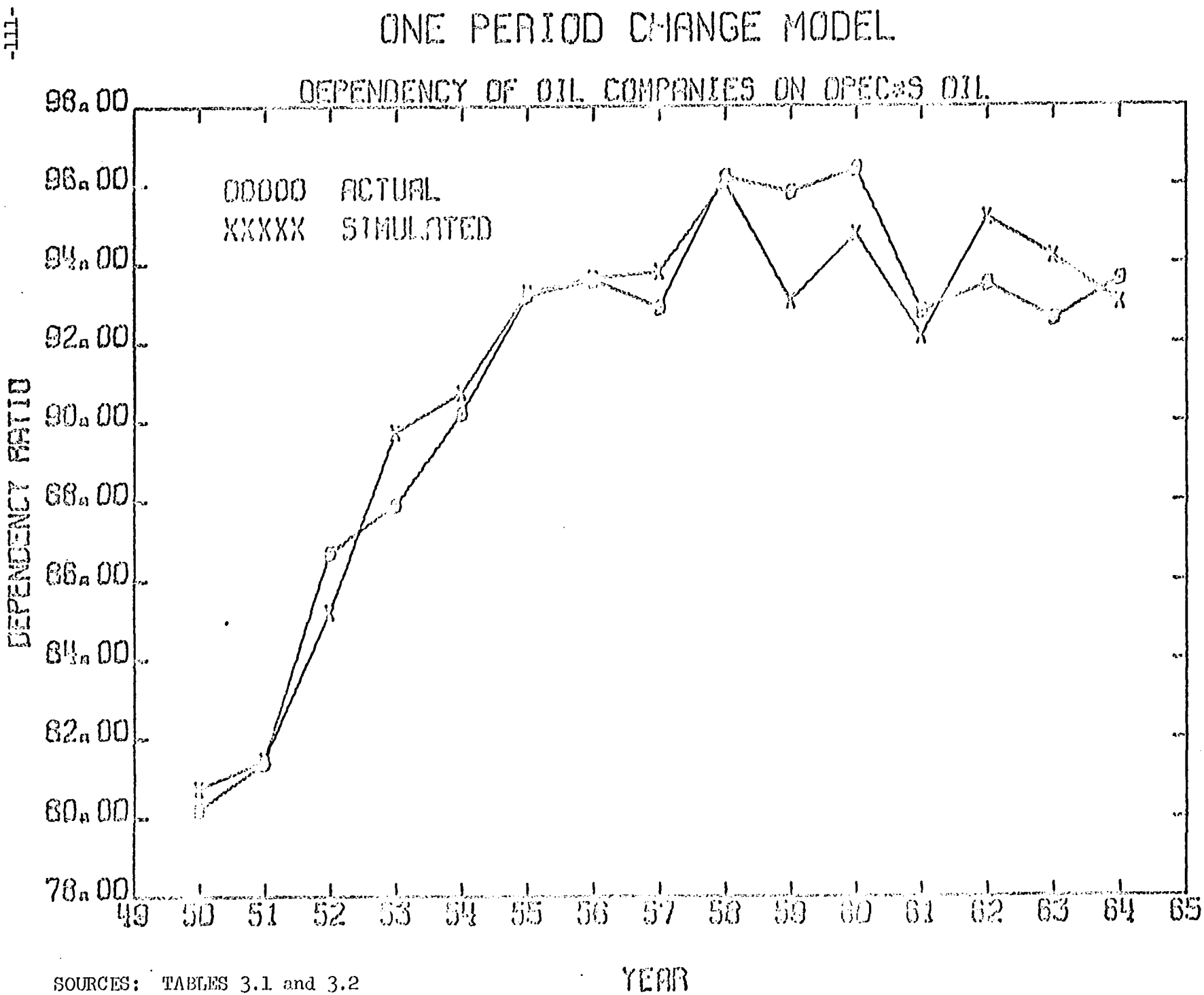
O.P.E.C. COUNTRIES

SIMULATED RESULTS OF THE PROCESS MODEL

CONTROL RUN WITH NO CHANGE IN PARAMETERS

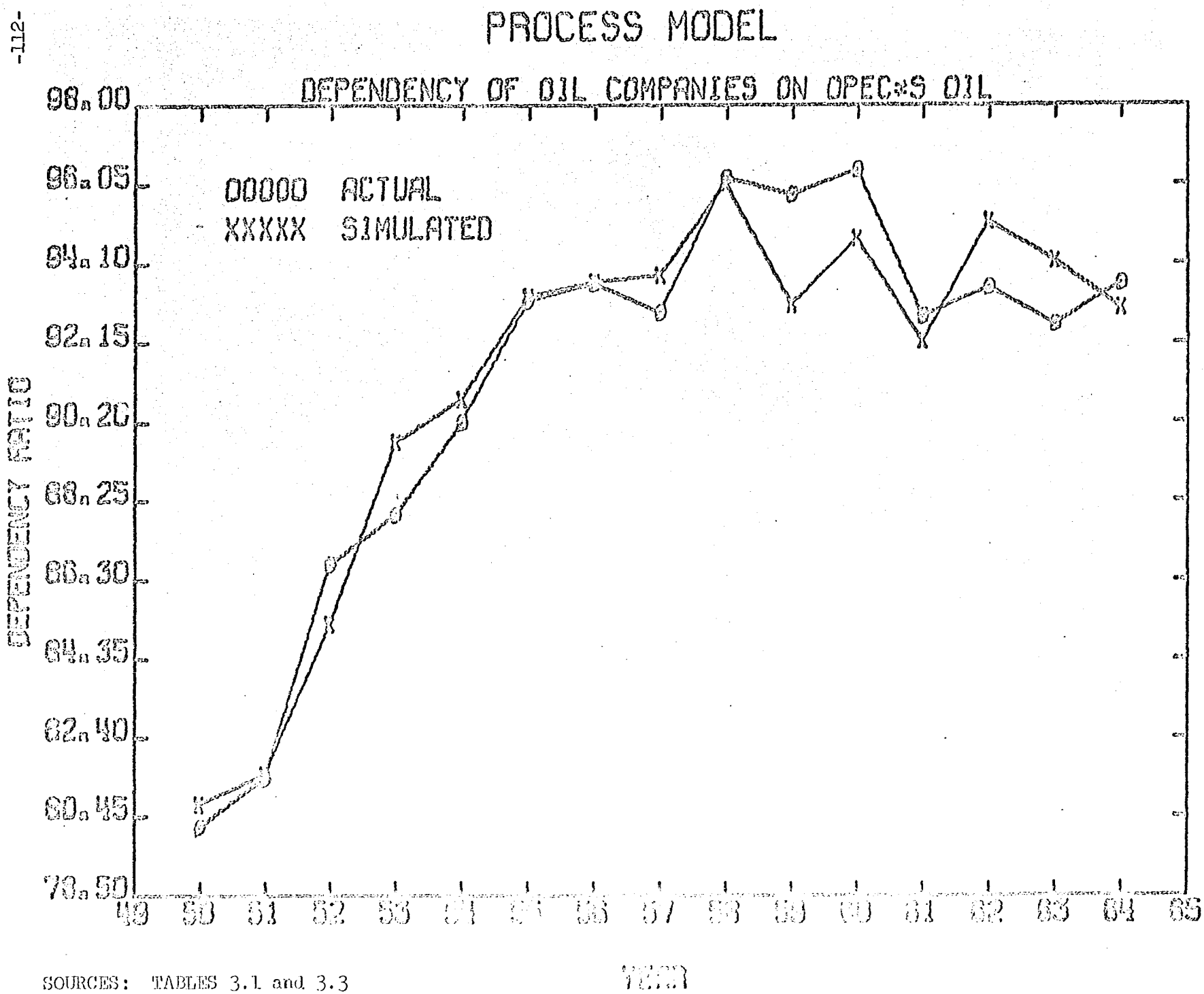
YEAR	OIL EXPORT BY OPEC	GOV. REVENUES FROM OIL EXPORT	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC V.S. OIL COMP.
50	81.26060	314.83601	80.74994	38.72864
51	82.26094	341.45093	81.47530	27.20525
52	85.41806	411.69082	85.20691	30.97889
53	91.01719	526.28156	89.71846	43.43783
54	110.53018	684.22334	90.74932	51.57472
55	132.39572	916.72022	93.27194	59.84745
56	142.13556	932.59827	93.63835	60.21874
57	154.79066	1033.13716	93.81290	61.99513
58	171.78929	1310.27857	96.07277	75.75110
59	186.23885	1234.08403	93.07871	64.99311
60	211.26656	1378.44222	94.72393	70.01717
61	244.35560	1474.09504	92.17745	64.31328
62	272.50638	1699.87200	95.15015	70.21405
63	313.22869	1913.65975	94.15318	66.24349
64	354.30077	2150.82541	93.00482	70.17304

FIGURE 3.1



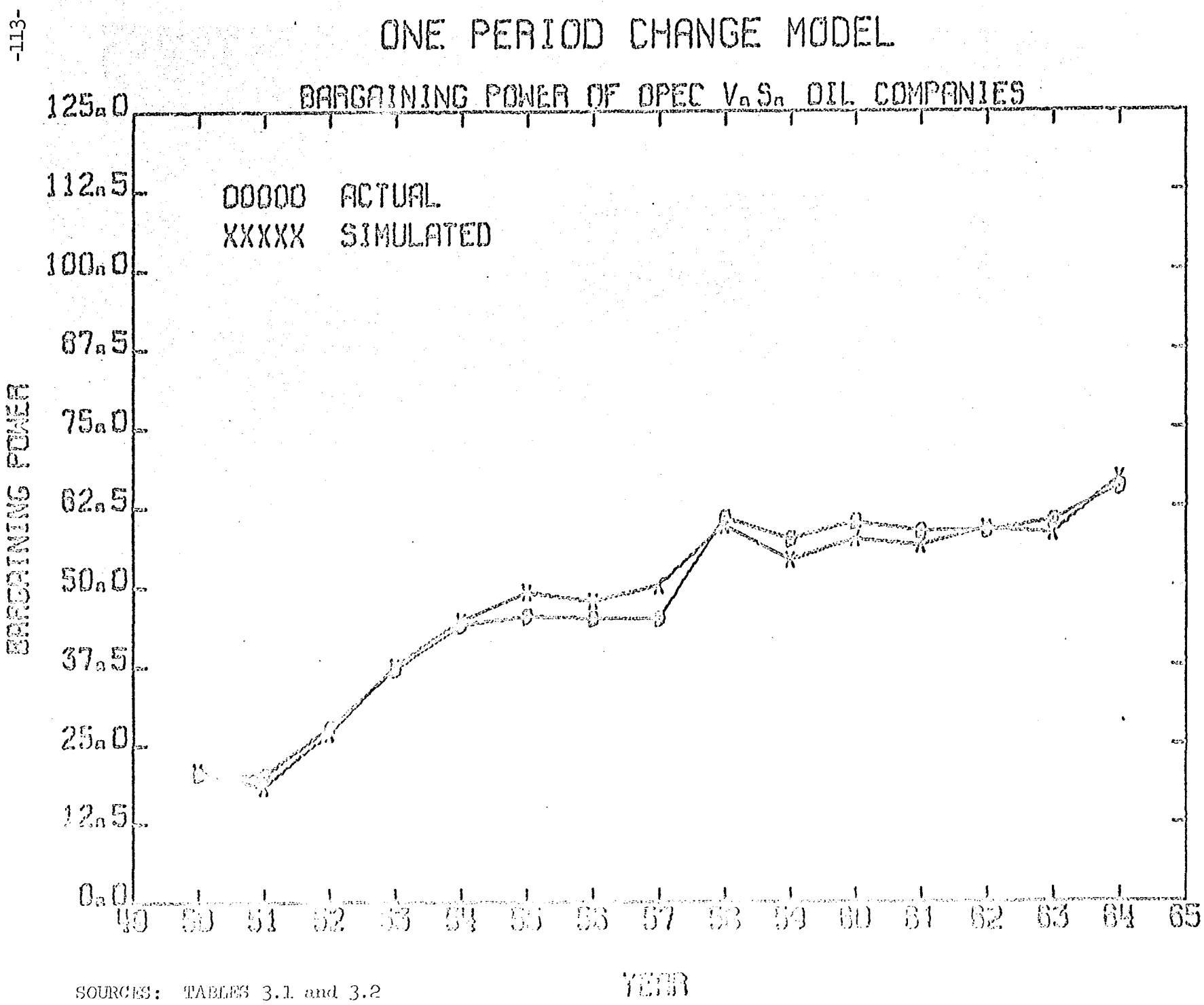
SOURCES: TABLES 3.1 and 3.2

FIGURE 3.2



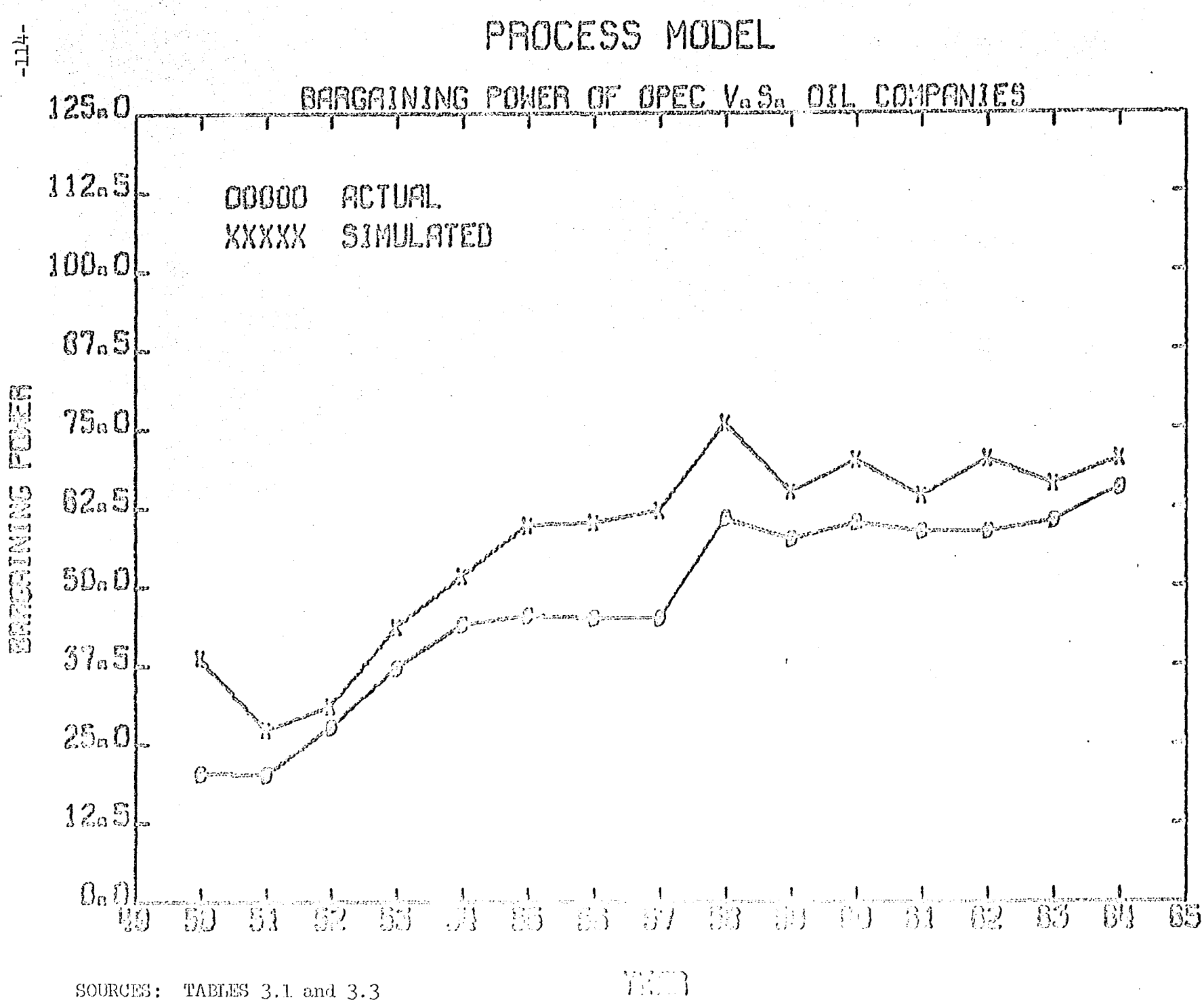
SOURCES: TABLES 3.1 and 3.3

FIGURE 4.1



SOURCES: TABLES 3.1 and 3.2

FIGURE 4.2



SOURCES: TABLES 3.1 and 3.3

The time paths for the relative bargaining power of the oil-producing countries vs. the international oil companies generated by the One Period Change Model moves along the actual trend line and detects all the ups and downs (Figures 4.1 and 4.2). The time path generated by the Process Model behaves the same way as the One Period Change Model but has a consistent overestimation of the actual data.

In addition to the graphical presentation and visual fits the following quantitative measures are presented in Tables III and IV to show how accurately the historical data has been duplicated by the One Period Change Model and the Process Model. The over- and under-estimated behavior of the time trend generated by these models are evaluated by the frequency of the occurance of these events during the simulation period, mean of the simulation error, as well as the percentages of simulation error with respect the actual data.

Sensitivity Analysis Results of the Process Model

Sensitivity analysis is useful to measure the impact of changes in any single parameter of the variables in the model on the time paths generated for the endogenous variables in the model. The endogenous variables of particular interest are the relative dependency of the United States, Western Europe and the international oil companies on the oil-producing countries, as well as the relative bargaining power of the oil-producing countries with respect to the international oil companies.

Changes in parameters in the real world can be interpreted as the result of changes in variables that affect the world crude oil market or any event that influences the condition of the market. Thus, United States

TABLE III.--One Period Change Model

No.	Dependent Variables	Overestimate			Underestimate		
		Frequency	Mean Simulation Error	% Simulation Error of Actual	Frequency	Mean Simulation Error	% Simulation Error of Actual
1	$DDoil_{(us)}$	10	43.6	1.5%	5	79.2	2.7%
2	$DPoil_{(us)}$	5	13.2	.5%	9	7.66	.3%
3	$IMoil_{(us)}$	8	5.8	1.7%	7	8	2.5%
4	$DEPop_{(us)}$	6	.00073	.6%	9	.00031	.2%
5	$DDoil_{(we)}$	7	4.1	3.1%	8	3.9	2.1%
6	$DPoil_{(we)}$	7	.34	2.8%	7	.51	4%
7	$IMoil_{(we)}$	7	47.7	3.6%	8	44.1	3%
8	$DEPop_{(we)}$	15	1.38	15.5%	--	--	--
9	$EXoil_{(op)}$	8	4.6	2.7%	7	5.2	2.7%
10	$GRoil_{(op)}$	7	19.8	1.7%	8	18.3	1.7%
11	$DEPop_{(co)}$	8	.9	.9%	6	1.2	1.2%
12	$BPIN_{(opco)}$	8	1.8	4.1%	7	2.1	4.3%

TABLE IV.--Process Model

No.	Dependent Variables	Overestimate			Underestimate		
		Frequency	Mean Simulation Error	% Simulation Error of Actual	Frequency	Mean Simulation Error	% Simulation Error of Actual
1	$DDoil_{(us)}$	10	43.6	1.5%	5	79.2	2.7%
2	$DPoil_{(us)}$	10	32.2	2.6%	5	59.2	1.3%
3	$IMoil_{(us)}$	7	19.1	5.2%	7	19.1	6.1%
4	$DEPop_{(us)}$	6	.00073	.6%	9	.00031	.2%
5	$DDoil_{(we)}$	7	4.1	3.1%	8	3.9	2.1%
6	$DPoil_{(we)}$	7	.34	2.8%	7	.51	4%
7	$IMoil_{(we)}$	8	59.5	5.2%	7	70.5	4.3%
8	$DEPoil_{(we)}$	15	1.38	15.5%	--	--	--
9	$EXoil_{(op)}$	7	6.5	3.3%	8	5.7	3.4%
10	$GRoil_{(op)}$	8	41.1	4.2%	7	49	3.9%
11	$DEPop_{(co)}$	8	.9	.9%	6	1.2	1.2%
12	$BPIN_{(opco)}$	15	9.8	40%	--	--	--

crude oil reserve or production of oil may be influenced by new crude oil reserve discoveries in Alaska, or imports of the United States may be influenced by reduction or elimination of the barrier of oil imports quotas. The impact of such events, and other changes on the variables in the model representing the relative dependency and bargaining power of the participants can be detected through sensitivity analysis.

In sensitivity analysis, it is possible to measure the impact of changes in one variable or the simultaneous changes in several variables in the model. When the impact of only one variable is measured, the other variables in the model are assumed to remain unchanged. This somewhat distorts the reality of the results obtained, since several variables may change simultaneously during a cycle of bargaining sessions in the real world. The net impact of this simultaneous effect on relative dependency and bargaining power will be the net result of the interaction of these variables.

For the purpose of sensitivity analysis, several variables have been selected and the impacts of changes in these variables have been measured on the time paths generated by the process model for the endogenous variables. It will be noted that the degree of change in relative dependency and bargaining power will not be the same as the degree of change in the variables. This is due to the presence of other variables in the model whose values have been kept constant. The significance of changes of the selected variables in the real world is extensively discussed in the Chapter VI.

In this section, results are presented of a number of sensitivity analyses carried out by using the Process Model. To aid in interpretation

and comparison, the results of the generated time paths have been tabulated and graphed via the computer.

(1) Assume that oil production in the United States has increased yearly by 1, 3, 5 or 10 per cent. The results generated by the Process Model indicate that as production of oil in the United States increases, the relative dependency of the United States, the international oil companies and Western Europe on the oil-producing countries will decrease. At the same time, the relative bargaining power of the oil-producing countries with respect to the international oil companies will decrease (Tables 4.1 - 4.6 and Figures 5.1 - 5.4).

(2) Assume that imports of oil by the United States have increased yearly by 1, 3, 5 or 10 per cent. The results generated by the Process Model indicate that as imports of oil by the United States increase, the relative dependency of the United States on the oil-producing countries will increase; the relative dependency of Western Europe on the oil-producing countries will remain unchanged; and the relative bargaining power of the oil-producing countries with respect to the international oil companies will increase (Appendix I, Tables 1.a - 1.f and Figures 9.a - 9.c).

(3) Assume that the rate of return of the international oil companies from their investment in the OPEC countries (as compared to their investment in West Europe) has increased yearly by 1, 3, 5 or 10 per cent. The results generated by the Process Model indicate that as the relative rate of return of the international oil companies from their investment in the OPEC member countries increases, the relative dependency of the international oil companies and Western Europe on the oil-producing countries will increase (Appendix I, Tables 2.a - 2.f and Figures 10.a - 10.c). The relative bargaining

TABLE 4.1

ACTUAL RESULTS

RELATIVE DEPENDENCY AND BARGAINING POWER

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08256	6.58333	80.20000	20.40000
51	0.07397	7.93829	81.40000	20.30000
52	0.08458	9.21795	86.70000	27.80000
53	0.09108	9.72684	87.90000	37.10000
54	0.09296	10.06452	90.20000	44.00000
55	0.10315	8.82509	93.20000	45.50000
56	0.11558	8.26698	93.60000	44.90000
57	0.12542	8.39630	92.90000	45.10000
58	0.12358	8.33443	96.20000	60.90000
59	0.12001	8.64737	95.80000	57.50000
60	0.12551	8.60843	96.40000	60.20000
61	0.12742	8.75057	92.80000	58.70000
62	0.13344	8.60047	93.50000	58.80000
63	0.12987	8.50751	92.60000	60.50000
64	0.13579	8.71672	93.60000	65.70000

TABLE 4.2

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02566	80.74994	38.72864
51	0.07370	9.20685	81.47530	27.20525
52	0.08404	9.91819	85.20691	30.97889
53	0.09113	10.47557	89.71846	43.43783
54	0.09498	10.83544	90.74932	51.57472
55	0.10264	10.37781	93.27194	59.84745
56	0.11519	10.05671	93.63835	60.21874
57	0.12499	10.04087	93.81290	61.99513
58	0.12373	10.61366	96.07277	75.75110
59	0.11960	10.34829	93.07871	64.99311
60	0.12550	10.46751	94.72393	70.01717
61	0.12617	10.01746	92.17745	64.31328
62	0.13333	10.08894	95.15015	70.21405
63	0.13026	9.51070	94.15318	66.24349
64	0.13718	9.04370	93.00482	70.17304

TABLE 4.3

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN PRODUCTION OF OIL IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08191	8.91842	80.49530	37.17262
51	0.07257	9.10038	81.24550	25.63687
52	0.08291	9.81738	85.01305	29.46966
53	0.09001	10.37720	89.53732	41.95665
54	0.09391	10.74229	90.58429	50.16555
55	0.10151	10.28100	93.10782	58.37533
56	0.11402	9.95805	93.47993	58.70953
57	0.12382	9.94216	93.65623	60.48329
58	0.12263	10.51623	95.89101	74.28668
59	0.11848	10.25011	92.89753	63.51545
60	0.12438	10.36821	94.53717	68.52626
61	0.12503	9.91487	91.97595	62.78175
62	0.13216	9.98729	94.96892	68.67738
63	0.12904	9.40225	93.94886	64.61557
64	0.13595	8.93655	92.81416	68.55294

TABLE 4.4

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

3 PER CENT YEARLY INCREASE IN PRODUCTION OF OIL IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.07860	8.59348	79.72374	32.45787
51	0.06913	8.77779	80.54921	20.88470
52	0.07950	9.51195	84.42566	24.89672
53	0.08663	10.07911	88.98848	37.46867
54	0.09066	10.46003	90.08424	45.89577
55	0.09808	9.98765	92.61053	53.91478
56	0.11047	9.65911	92.99992	54.13661
57	0.12025	9.64308	93.18152	55.90243
58	0.11929	10.22103	95.34028	69.84949
59	0.11511	9.95265	92.34854	59.03813
60	0.12099	10.06735	93.97128	64.00878
61	0.12158	9.60405	91.36540	58.14123
62	0.12862	9.67926	94.41980	64.02126
63	0.12534	9.07368	93.32976	59.68299
64	0.13222	8.61187	92.23649	63.64403

TABLE 4.5

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

5 PER CENT YEARLY INCREASE IN PRODUCTION OF OIL IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.07292	8.03567	78.39922	24.36422
51	0.06322	8.22400	79.35390	12.72681
52	0.07364	8.98763	83.41730	17.04650
53	0.08081	9.56740	88.04631	29.76430
54	0.08509	9.97550	89.22582	38.56599
55	0.09220	9.48407	91.75684	46.25751
56	0.10438	9.14593	92.17589	46.28642
57	0.11414	9.12965	92.36660	48.03860
58	0.11357	9.71426	94.39486	62.23230
59	0.10932	9.44200	91.40612	51.35207
60	0.11517	9.55088	92.99984	56.25377
61	0.11567	9.07048	90.31730	50.17500
62	0.12255	9.15048	93.47714	56.02826
63	0.11899	8.50962	92.26698	51.21539
64	0.12581	8.05451	91.24481	55.21706

TABLE 4.6

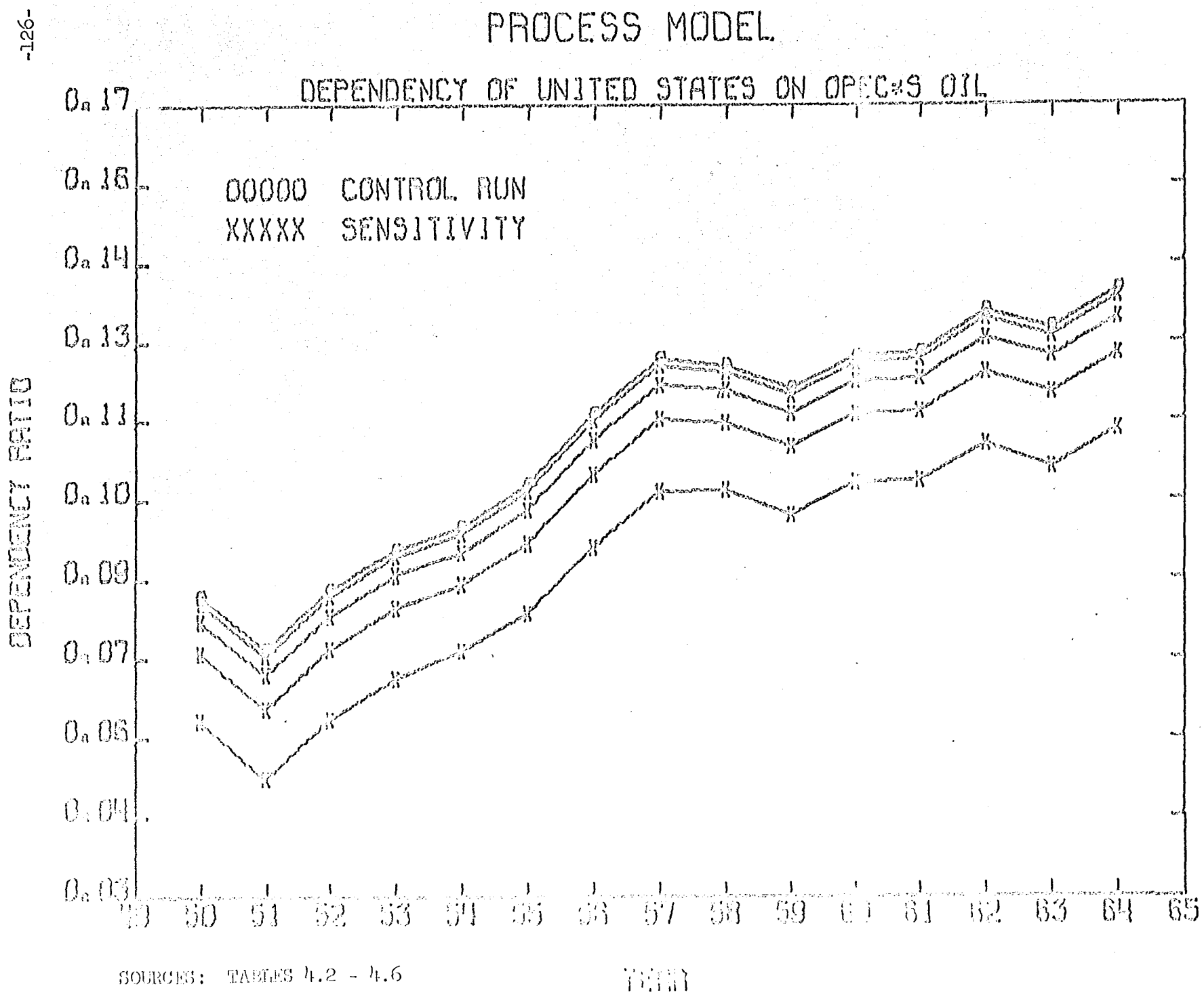
SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

10 PER CENT YEARLY INCREASE IN PRODUCTION OF OIL IN U.S.

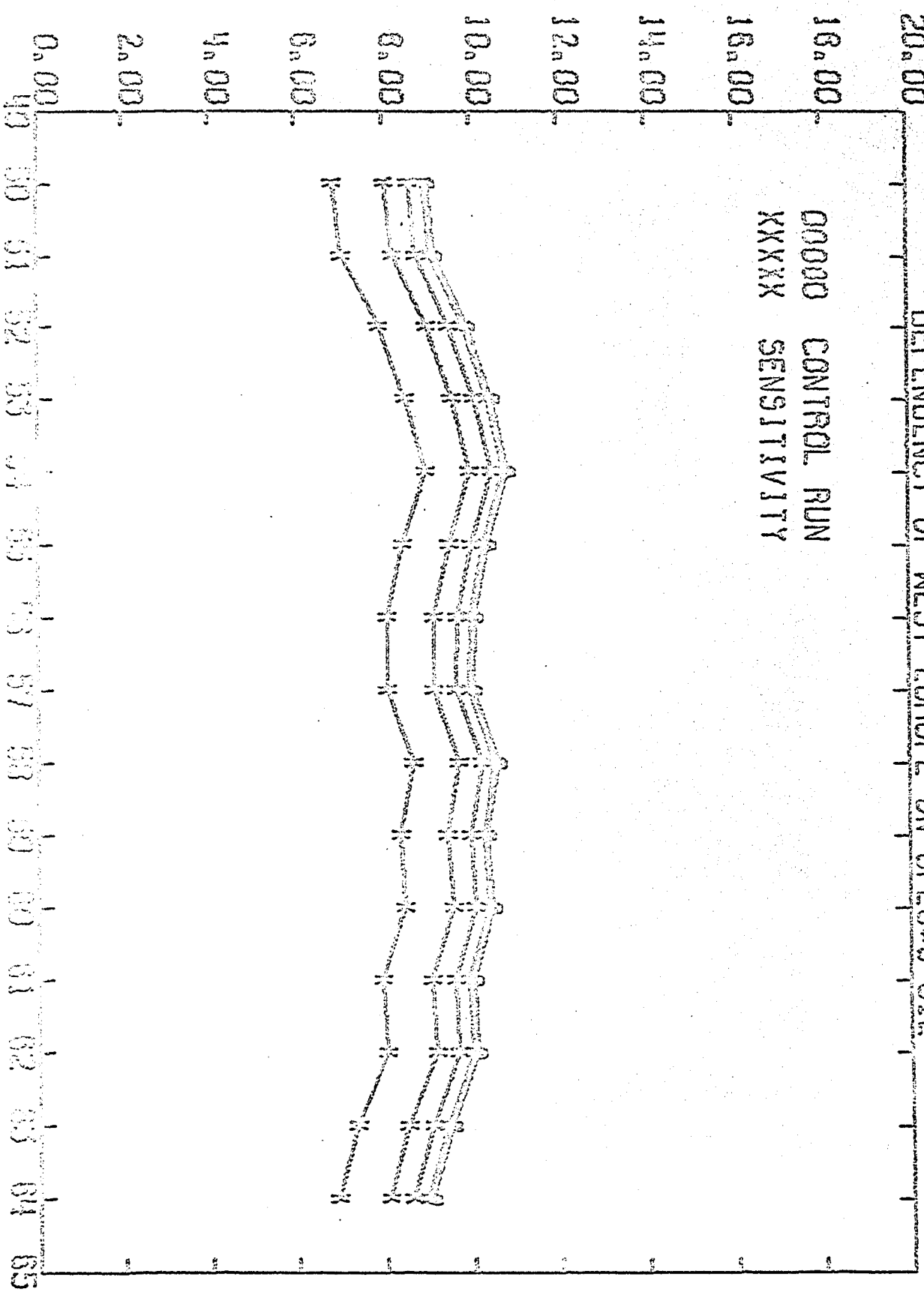
YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.06099	6.85427	75.61774	7.36755
51	0.05083	7.06105	76.34375	-4.40476
52	0.06133	7.88655	81.29974	0.56104
53	0.06861	8.49280	86.06775	13.58513
54	0.07338	8.95796	87.42315	23.17344
55	0.07986	8.42654	89.96411	30.17723
56	0.09159	8.06827	90.44544	29.80105
57	0.10129	8.05144	90.65527	31.52457
58	0.10154	8.65006	92.40948	46.23620
59	0.09715	8.36964	89.42703	35.21133
60	0.10295	8.46629	90.95982	39.96826
61	0.10325	7.94997	88.11629	33.44592
62	0.10980	8.04004	91.49755	39.24295
63	0.10565	7.32511	90.03515	33.43344
64	0.11236	6.88406	89.16228	37.52043

FIGURE 5.1



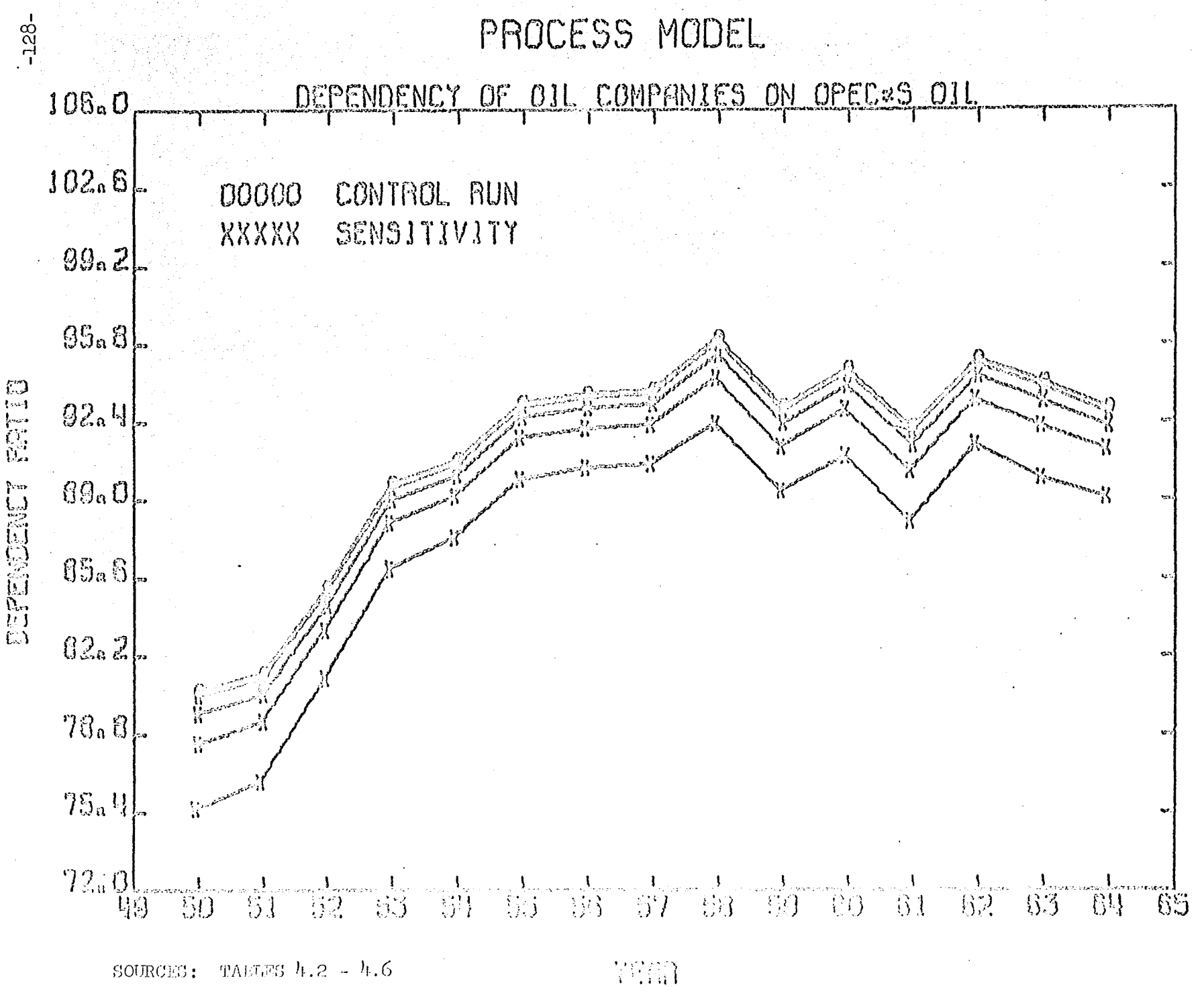
SOURCES: TABLES 4.2 - 4.6

FIGURE 5.2



SOURCES: TABLES 4.2 - 4.6

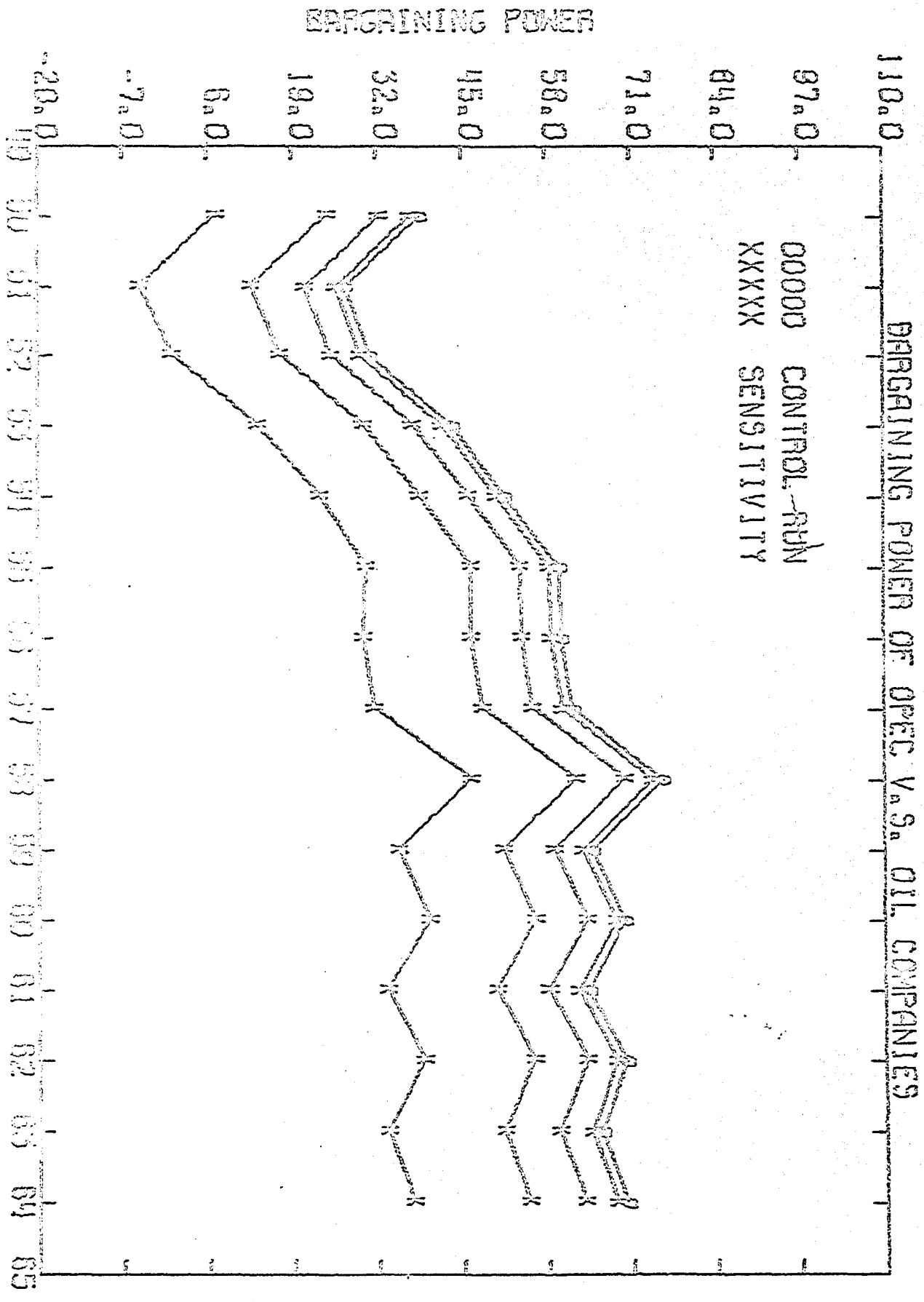
FIGURE 5.3



SOURCES: TABLES 4.2 - 4.6

FIGURE 5.4

PROCESS MODEL



power of the oil-producing countries with respect to the international oil companies will also increase.

(4) Assume that the capital expenditures on oil operations in the United States have increased yearly by 1, 3, 5 or 10 per cent, with the assumption that this rate of increase is required to maintain the present rate of crude oil reserve discovery and production. The results generated by the Process Model indicate that as the required capital expenditures on the oil operation in the United States increases, the relative dependency of the United States, the international oil companies and Western Europe on the oil-producing countries will increase (Appendix I, Tables 3.a - 3.f and Figures 11.a - 11.d). At the same time, the relative bargaining power of the oil-producing countries with respect to the international oil companies will increase. The results indicate that as the amount of investment required in the United States increases, the oil companies will be attracted to the OPEC countries, where further discoveries of crude oil require comparatively little investment.

In the sensitivity runs described above, one of the variables was changed and the other variables were kept constant. The following situation differs somewhat from the preceding cases. In this case, instead of determining the impact of changes in one variable on the relative dependency and bargaining power of the participants, the changes in several variables will be considered, which have simultaneous effects on the time paths generated by the model.

The problem is stated as follows: If the United States decides to increase crude oil reserve by one per cent per year, then its annual capital

expenditures on oil operation in the United States must be increased. Further assume the required increase in capital expenditures is 2 per cent or 5 per cent. How will these required increases affect relative dependency of the United States, Western Europe and the international oil companies on the oil-producing countries? How will they affect bargaining power of the oil-producing countries with respect to the international oil companies? Results generated by the Process Model indicate that the effect of a 5 per cent increase will be greater than that of a 2 per cent increase (Tables 5.1 - 5.6 and Figures 6.1 - 6.4). The generated results are quite reasonable. As required investments in the United States oil operations increase, the international oil companies will be attracted to the oil sources in the OPEC countries, where lower investments are required for oil operations.

In this chapter, an attempt has been made to show how this model can be used to solve the real problems of the world crude oil market. In the next chapter, more extensive discussion will be presented regarding the use of this model as a decision-making tool.

TABLE 5.1

ACTUAL RESULTS

RELATIVE DEPENDENCY AND BARGAINING POWER

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08256	6.58333	80.20000	20.40000
51	0.07397	7.93829	81.40000	20.30000
52	0.08458	9.21795	86.70000	27.80000
53	0.09108	9.72684	87.90000	37.10000
54	0.09296	10.06452	90.20000	44.00000
55	0.10315	8.82509	93.20000	45.50000
56	0.11558	8.26698	93.60000	44.90000
57	0.12542	8.39630	92.90000	45.10000
58	0.12353	8.33443	96.20000	60.90000
59	0.12001	8.64737	95.80000	57.50000
60	0.12551	8.60843	96.40000	60.20000
61	0.12742	8.75057	92.80000	58.70000
62	0.13344	8.60047	93.50000	58.80000
63	0.12987	8.50751	92.60000	60.50000
64	0.13579	8.71672	93.60000	65.70000

TABLE 5.2

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02560	80.74994	38.72864
51	0.07370	9.20685	81.47530	27.20525
52	0.08404	9.91819	85.20691	30.97889
53	0.09113	10.47557	89.71846	43.43783
54	0.09498	10.83544	90.74932	51.57472
55	0.10264	10.37781	93.27194	59.84745
56	0.11519	10.05671	93.83835	60.21874
57	0.12499	10.04087	93.81290	61.99513
58	0.12373	10.61360	96.07277	75.75110
59	0.11960	10.34829	93.07871	64.99311
60	0.12550	10.46751	94.72393	70.01717
61	0.12617	10.01746	92.17745	64.31328
62	0.13333	10.08894	95.15015	70.21405
63	0.13026	9.51070	94.15318	66.24349
64	0.13718	9.04370	93.00482	70.17304

TABLE 5.3

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN CRUDE OIL RESERVE IN U.S. AND

2 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES ON OIL OPERATION IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08348	9.17114	81.16951	40.22547
51	0.07426	9.34773	81.85213	28.70825
52	0.08449	10.04791	85.50202	32.30069
53	0.09151	10.60094	89.98134	44.66959
54	0.09532	10.95315	90.98140	52.71351
55	0.10290	10.49900	93.48627	60.95567
56	0.11533	10.17884	93.82179	61.24163
57	0.12503	10.16278	93.98076	62.94825
58	0.12379	10.73817	96.30017	76.75714
59	0.11970	10.47345	93.30836	66.03070
60	0.12554	10.59464	94.05694	71.03352
61	0.12620	10.15012	92.43640	65.37682
62	0.13329	10.21757	95.35730	71.18079
63	0.13026	9.64960	94.40287	67.32232
64	0.13711	9.17922	93.21831	71.16821

TABLE 5.4

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN CRUDE OIL RESERVE IN U.S. AND

5 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES ON OIL OPERATION IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08413	9.42560	82.27936	42.86690
51	0.07498	9.58687	82.65194	31.24269
52	0.08507	10.26042	66.32289	34.49207
53	0.09201	10.80361	90.73560	46.71388
54	0.09577	11.14125	91.66125	54.59244
55	0.10327	10.69016	94.14606	62.80018
56	0.11557	10.36846	94.43546	62.97570
57	0.12518	10.35143	94.57423	64.60526
58	0.12397	10.94027	97.02101	78.58080
59	0.11992	10.67595	94.02986	67.88296
60	0.12571	10.80151	95.89698	72.89015
61	0.12638	10.36885	93.24232	67.34728
62	0.13338	10.42351	96.05664	72.96311
63	0.13040	9.87573	95.20731	69.32078
64	0.13717	9.39607	93.94964	73.02160

TABLE 5.5

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

2 PER CENT YEARLY INCREASE IN CRUDE OIL RESERVE IN U.S. AND

2 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES ON OIL OPERATION IN U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08493	9.62804	82.59077	44.93282
51	0.07596	9.78818	83.12946	33.40253
52	0.08586	10.45136	88.51278	36.41868
53	0.09265	10.99007	90.88806	48.50766
54	0.09634	11.31791	91.78574	56.25886
55	0.10370	10.87367	94.25787	64.41024
56	0.11576	10.55580	94.47857	64.43893
57	0.12517	10.53889	94.59056	65.93880
58	0.12399	11.12490	97.10336	79.93432
59	0.12002	10.86202	94.11772	69.29963
60	0.12570	10.93965	95.78033	74.24718
61	0.12635	10.56310	93.34693	68.74732
62	0.13321	10.61628	96.10071	74.24207
63	0.13029	10.08120	95.23335	70.74119
64	0.13692	9.59927	93.98742	74.32468

TABLE 5.6

SIMULATED RESULTS OF THE PROCESS MODEL

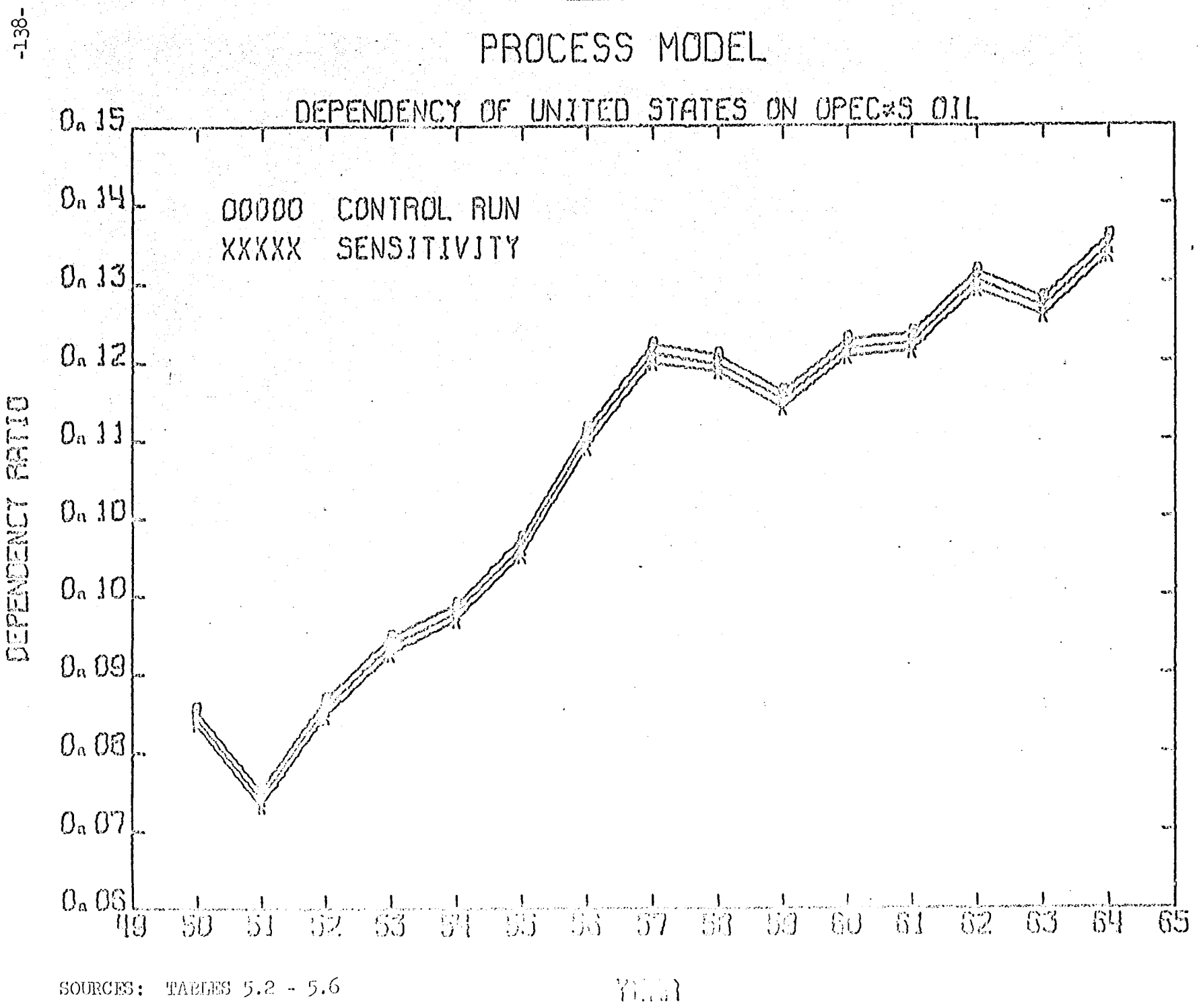
RELATIVE DEPENDENCY AND BARGAINING POWER

2 PER CENT YEARLY INCREASE IN CRUDE OIL RESERVE IN U.S. AND

5 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES ON OIL OPERATION IN U.S.

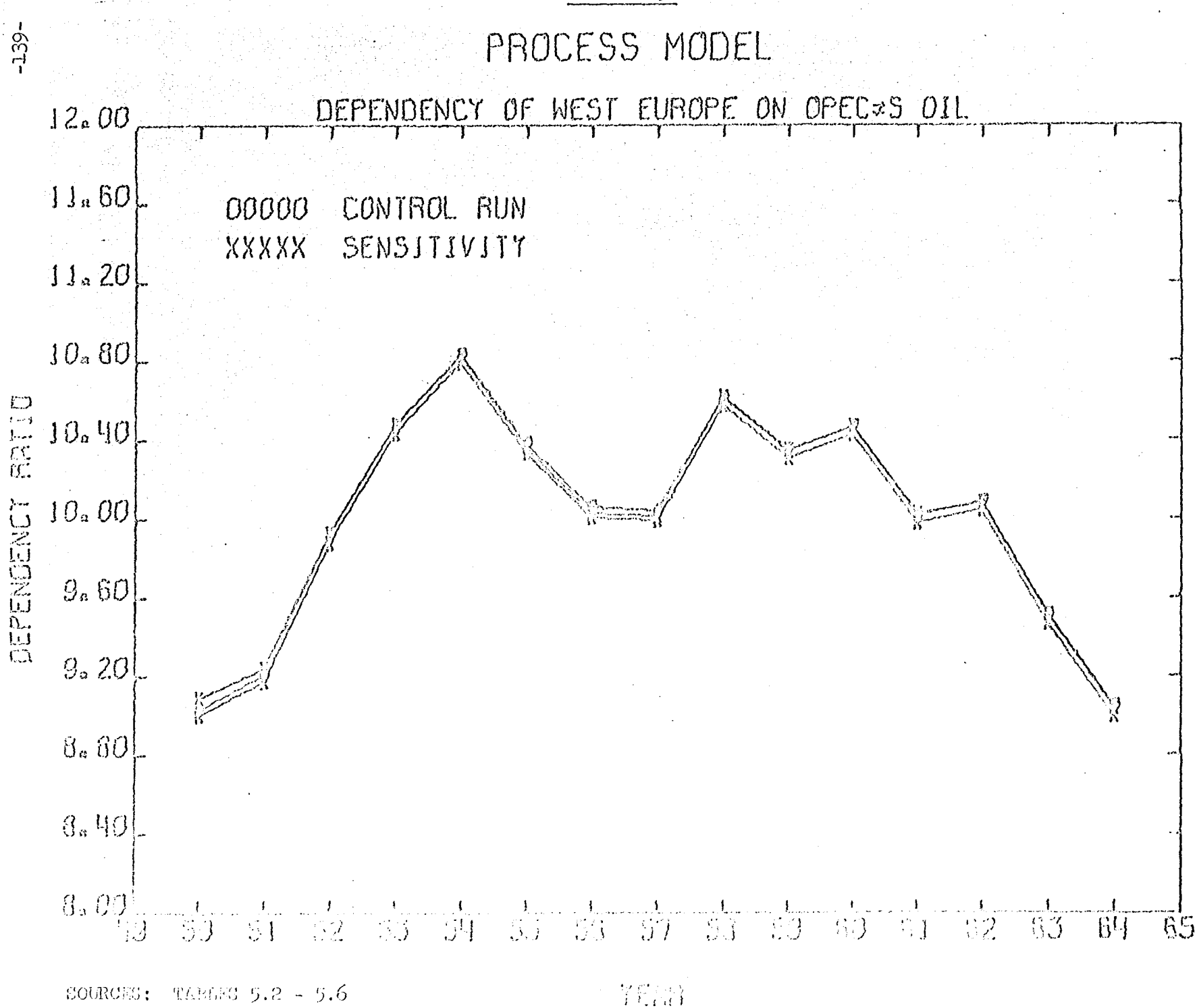
YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08563	9.93032	83.54900	48.04834
51	0.07707	10.07924	83.99079	36.50380
52	0.08675	10.71760	87.19602	39.13743
53	0.09340	11.24673	91.50199	51.04170
54	0.09701	11.55839	92.33095	58.59911
55	0.10422	11.12090	94.74872	66.69133
56	0.11604	10.80406	94.92706	66.55166
57	0.12527	10.78654	95.00830	67.91689
58	0.12413	11.38002	97.65015	82.03941
59	0.12023	11.11832	94.55844	71.46416
60	0.12580	11.25025	96.34093	76.37713
61	0.12645	10.83570	93.96516	70.98251
62	0.13317	10.87915	96.60862	76.27179
63	0.13032	10.36595	95.89172	73.00845
64	0.13681	9.87621	94.51332	76.41840

FIGURE 6.1



SOURCES: TABLES 5.2 - 5.6

FIGURE 6.2



SOURCES: TABLES 5.2 - 5.6

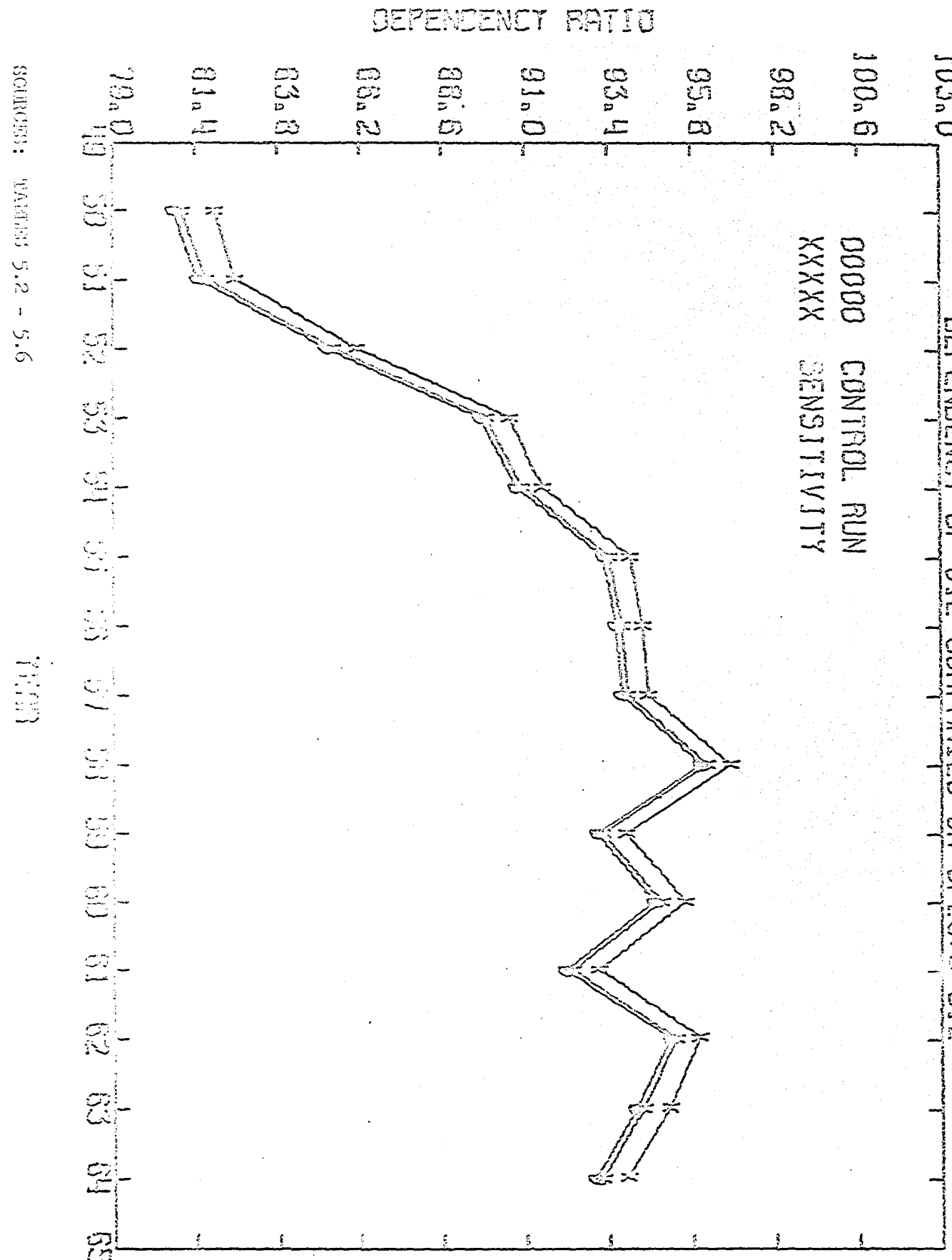
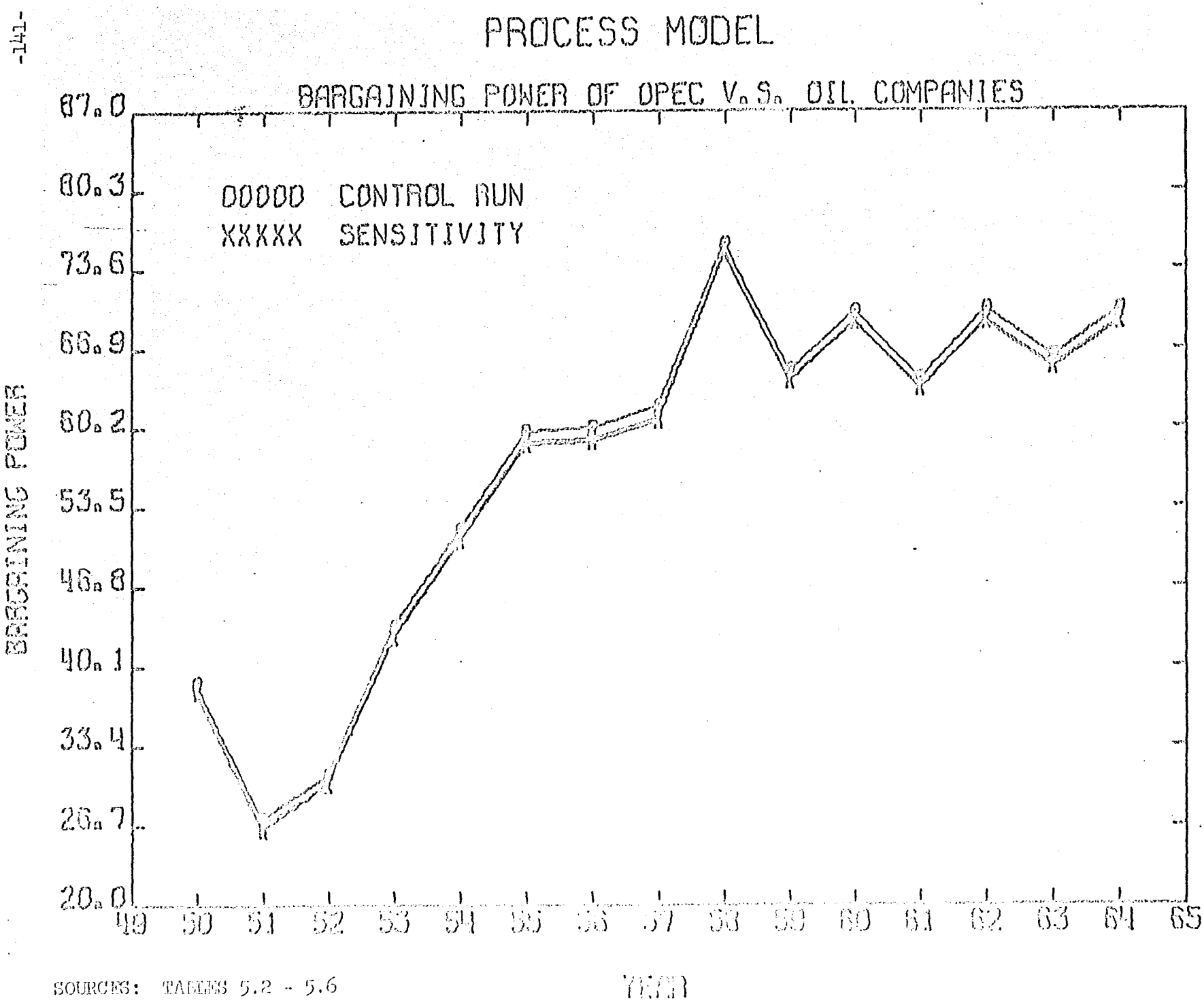


FIGURE 6.3

FIGURE 6.4



SOURCES: TABLES 5.2 - 5.6

CHAPTER VI

SUMMARY AND CONCLUSIONS

Four principal participants interact in the world crude oil market: The international oil companies, the oil-producing countries, the oil-importing countries, and the parent countries of the international oil companies. For many years, a complex bargaining process has continued between the participants in this market over the terms of oil concessions.

The main purpose of this study has been to evaluate the relative dependency and bargaining power of the oil-producing countries versus the international oil companies. In previous chapters, it has been concluded that the relative bargaining strength of these two main participants in the world crude oil market is a function of relative dependency of the United States, Western Europe and the international oil companies on the oil-producing countries and vice versa. The relative dependency (and consequently the relative bargaining power) of these participants is an economic phenomenon determined largely by variations in economic factors over time rather than by the power and tactics used by the negotiators in the bargaining sessions.

It has also been concluded that the power of the participants in the market is unequal, and that the reward to each participant might be increased through the bargaining process if he could improve his power position. It is postulated that the process of power adjustment will continue until it reaches some equilibrium point, where a balance of power is

achieved. What will happen to this equilibrium point? Will it remain stable, and will the balance of power of all participants remain equal at all times? The answer is, not necessarily. Equilibrium and the balance of power are expected to change. They are expected to remain stable as long as the participants are satisfied with the rewards they have obtained for their contributions and as long as they believe they have no advantage and that there is no opportunity to gain greater rewards.

As time passes, the oil-producing countries might be able to improve their bargaining position by broadening the base of their economies; obtaining better terms from new concessions granted to the new competitors in the world crude oil market; increasing their political stability and power; unifying their goals through the Organization of Petroleum Exporting Countries (OPEC); expansion and fully supporting state-owned national oil companies; increasing the crude oil reserve discoveries and reducing the production cost of oil; and in other possible ways. On the other hand, the international oil companies might improve their relative bargaining position through economic and administrative gains in the various parts of their operations from exploration to refining, transportation and marketing.

When some of these changes have taken place, relative dependency and balance of power between the oil-producing countries and the international oil companies have changed and the equilibrium has been disturbed. Consequently, the participants that have obtained relatively more power would start to renegotiate the terms of the concessions under which they have been operating. Thus, the process of power adjustment would recommence and continue until a new equilibrium point is reached, which may or may not differ

from the previous equilibrium point. This bargaining cycle will be repeated over and over until it is no longer possible for one party to continue to operate.

In order to evaluate analytically relative dependency and bargaining power between the oil-producing countries and the international oil companies, several research techniques have been considered. Among these techniques, econometrics and computer simulation have been selected as the most appropriate for analysis of conflict resolution, for evaluation of relative bargaining power and eventual determination of an equilibrium point. The techniques are used to measure interaction of the variables relevant to the bargaining strength and relative dependency of the participants in the world crude oil market.

For the purpose of this analysis, a model with twelve simultaneous equations has been constructed. These equations are grouped into four blocks: United States, Western Europe, Oil-producing Countries (OPEC) and, finally, a relative Dependency and Bargaining Power block. The first three consist of demand, production and imports of oil equations. The "Dependency and Bargaining Power" block comprises equations that measure the dependency and relative bargaining strength of one participant against the other participants in the world crude oil market. In this model, an attempt has been made to express the relationships of the relevant economic variables that affect the dependency and the relative bargaining strength or weakness of each participant in the market. A number of special, ratio-type indices have been constructed for the purpose of measuring some of the relationships involving the dependency and bargaining power variables in the model.

In order to measure the model's predictability power, the model has been simulated in two modes: a One Period Change Model and a Process Model. Simulation runs have been carried out for the years 1950-1964 in order to determine how accurately the model can reproduce the known historical performance of the real world. The results of these simulation runs are presented in the previous chapter. The results show that the hypothetical model presented is not only theoretically valid, logically consistent and statistically defensible, but that also it has a high predictability power.

Potential Applications of the Model

In this part of the study, several situations are hypothesized to demonstrate potential applications of the relative dependency and bargaining model to the real world. The impact of any one of these hypothetical events on the model can be measured by sensitivity analysis runs. The analysis of the results obtained could be important by suggesting the effect of any of the postulated events on the relative dependency and bargaining strength of the participants in the world crude oil market.

For example what would happen to the relative dependency and bargaining power of the oil-producing countries versus the international oil companies:

1. If crude oil reserve discoveries in Alaska cause certain yearly increases of crude oil production in the United States?

2. If atomic fuels are commercially developed that are competitive enough to reduce demand for crude oil in the United States and Western Europe?

3. If the natural gas reserves of the North Sea become commercially extractable and can be used as a partial substitute for oil consumption and imports of oil in Western Europe?

4. If electric automobiles partially replace motor vehicles powered by internal combustion engines?

5. If petrochemical industries discover new uses for oil in making industrial or food products (i.e., protein)?

6. If oil shale development costs in the United States decrease enough to make domestic oil competitive with crude oil imported by the United States from the oil-producing countries?

7. If production costs of solid fuels increase considerably, or demand for solid fuel decreases for other reasons in the United States or Western Europe?

8. If the United States reduces or eliminates restrictions on oil imports and allows cheap foreign oil to compete with the local producers?

9. If demand for oil in the United States and Western Europe increases due to increases in the number of motor vehicles and other energy uses?

10. If additional new crude oil reserves are discovered in Africa and replace part of the crude oil production and exports of the OPEC member countries?

11. If expenditures for research and development are sharply increased resulting in development of new methods for discovering crude oil reserves and recovering oil?

12. If greatly enlarged amounts are invested in super tankers by the international oil companies, the oil-producing countries or the oil-importing countries?

13. If costs of crude oil production decrease or increase in the United States or in the oil-producing countries?

14. If new oil concessions are granted to the smaller international oil companies with more favorable terms than previously?

15. If OPEC member countries put pressure on the international oil companies for increased production and greater revenues for their oil?

16. If the national oil companies of the oil-producing countries take the initiative in exploration, refining and marketing of their oil?

In order to demonstrate that this model is operational in the real world and can be used as a problem-solving tool, several of the events and questions listed above have been selected, and their impacts measured on the relative dependency and bargaining power of the participants in the world crude oil market by sensitivity analysis. Detailed analyses of the effects of these events, along with a number of other examples, are presented in Chapter V. To achieve better interpretation and comparison of the results, the time path generated by sensitivity analysis for the endogenous variables in each event is tabulated and graphed separately against the control run results via the computer.

As has already been mentioned in Chapter V, the relative dependency ratios have not been expressed in a common standard unit; comparisons of size between two dependency ratios should be avoided. It is quite possible, however, to compare the direction and the degree of change between the relative dependency ratios of the two participants for any given years.

(1) Assume that there will be a yearly increase of 1, 3, 5 or 10 per cent in production of oil in the United States, due to new crude oil reserve discoveries in Alaska, or reduced production costs, or some other pertinent factors. Ceteris paribus, what impact will this change have on the relative dependency and bargaining power of the participants in the market (Tables 4.1 - 4.6 and Figures 5.1 - 5.4)? Results of sensitivity analysis of the model show that the relative dependency of the United States, the international oil companies, and Western Europe on the oil-producing countries will decrease. The relative bargaining power ratios of the oil-producing countries to the international oil companies will decrease as well. The degree of change in relative dependency and bargaining power ratios of these countries will not be the same as the degree of change in production of oil in the United States, because of the impacts of the variables present in the model that have been kept constant.

(2) Next, assume that there will be a yearly increase of 1, 3, 5 or 10 per cent in imports of oil by the United States due to relaxation of the quotas on oil imports or other pertinent variables. Ceteris paribus, what impact will this change have on the relative dependency and bargaining power of the participants in the market (Appendix I, Tables 1.a - 1.f and Figures 9.a - 9.c)? The results obtained from the sensitivity analysis of the model show that the relative dependency ratio of the United States and the international oil companies to the oil-producing countries will increase; the relative dependency ratio of Western Europe to the oil-producing countries will remain unchanged; and the relative bargaining power of the oil-producing countries to the international oil companies will increase. In

this case, also, the degree of change in relative dependency and bargaining power ratios will not be the same as the degree of change made in imports of oil by the United States, again because of the impacts of the variables present in the model that have been kept constant.

(3) The following case is somewhat different from the first two cases. In this example, instead of finding the impact of changes in only one variable on the relative dependency and bargaining power of the participants in the market, changes will be considered in several variables that are interacting simultaneously in the model. The problem is as follows: What will happen to the relative dependency and bargaining power of the participants in the market, if the United States sets a goal of increasing crude oil reserves by one per cent annually? Assume that attainment of this goal will require an annual increase in capital expenditures of 2 per cent or 5 per cent. The results obtained from the sensitivity analysis of the model show that the changes in relative dependency ratios of the participants will be higher in the case of an annual increase of 5 per cent in capital expenditures than in the case of 2 per cent annual increase. At the same time, the relative bargaining power ratio of the oil-producing countries with respect to the international oil companies will be higher in the case of a 5 per cent increase than in the case of a 2 per cent increase (Tables 5.1 - 5.6 and Figures 6.1 - 6.4). These results are quite reasonable: As the amount of investment required in the United States increases, the oil companies will be attracted to the OPEC countries, where further discoveries of crude oil require comparatively little investment.

It may be concluded that this model is not only theoretically valid and statistically defensible, but above all it can be used as a decision-making device for solving some of the problems of participants in the world crude oil market.

Significance of the Bargaining Model for the Participants

How can the participants in the world crude oil market utilize the dependency and bargaining power model?

The international oil companies may use this model to forecast the demand for oil, production and imports of oil in the United States and Western Europe. With this model, they can also evaluate their relative dependency and bargaining power in relation to the oil-producing countries. Further, they can measure the relative dependency and bargaining power of the governments of the oil-producing countries. Because they can determine their own power as well as that of the other parties, they can begin negotiations prepared.

The oil-producing countries may use this model to forecast exports of oil as well as government revenues from oil. Furthermore, these countries can assess their degree of dependency and relative bargaining power with respect to the international oil companies.

The oil-importing countries may use this model to forecast their demand for oil, production of oil, imports of oil and the relative bargaining power of the other participants. The results of the bargaining process between the oil-producing countries and the international oil companies is of vital concern to the oil-importing countries, since the oil-producing

countries control about 90 per cent of the world exports of crude oil and the international oil companies have overwhelming control over world petroleum operations. Any unresolved conflict between these two participants will be very costly for the oil-importing countries. Furthermore, the oil-importing countries do not want to accept the burden of renegotiated terms that have been designed by the other two participants in their own interest. Increasingly, the oil-importing countries expect to be considered in renegotiating the terms of the concessions along with the other participants. In the past, they have exercised this right and partially improved their position by supporting one of the negotiators. Some of the importing countries (Japan and Italy, for example) have supported national oil companies in investing in oil operations in the oil-producing countries. It has already been concluded that the oil-importing countries are highly dependent on the oil-producing countries and the international oil companies. At the same time, it is important to realize that the revenues of the oil-producing countries and the international oil companies basically come from the oil-importing countries. These three participants are obviously dependent on each other.

The parent countries of the international oil companies may use this model to form decision policies on trade restrictions, investment taxes and protection of the international oil companies in case of emergencies.

What is the significance of this model for international welfare, international development and growth, and security of all the oil-producing countries, the international oil companies, and the oil-importing countries? Through the use of this model, all the participants may realize their degree

of dependency and relative bargaining power at any given period of time. With this knowledge, the participants can begin to estimate the limits to which they can exert their power, realizing that the exertion of power beyond this limit may lead to serious conflicts and sometimes dangerous consequences. As the result, the insights provided by this model may help to assure a continuous supply of oil for the importing countries, satisfactory return on the investments of the international oil companies and adequate revenues for the oil-producing countries.

APPENDIX

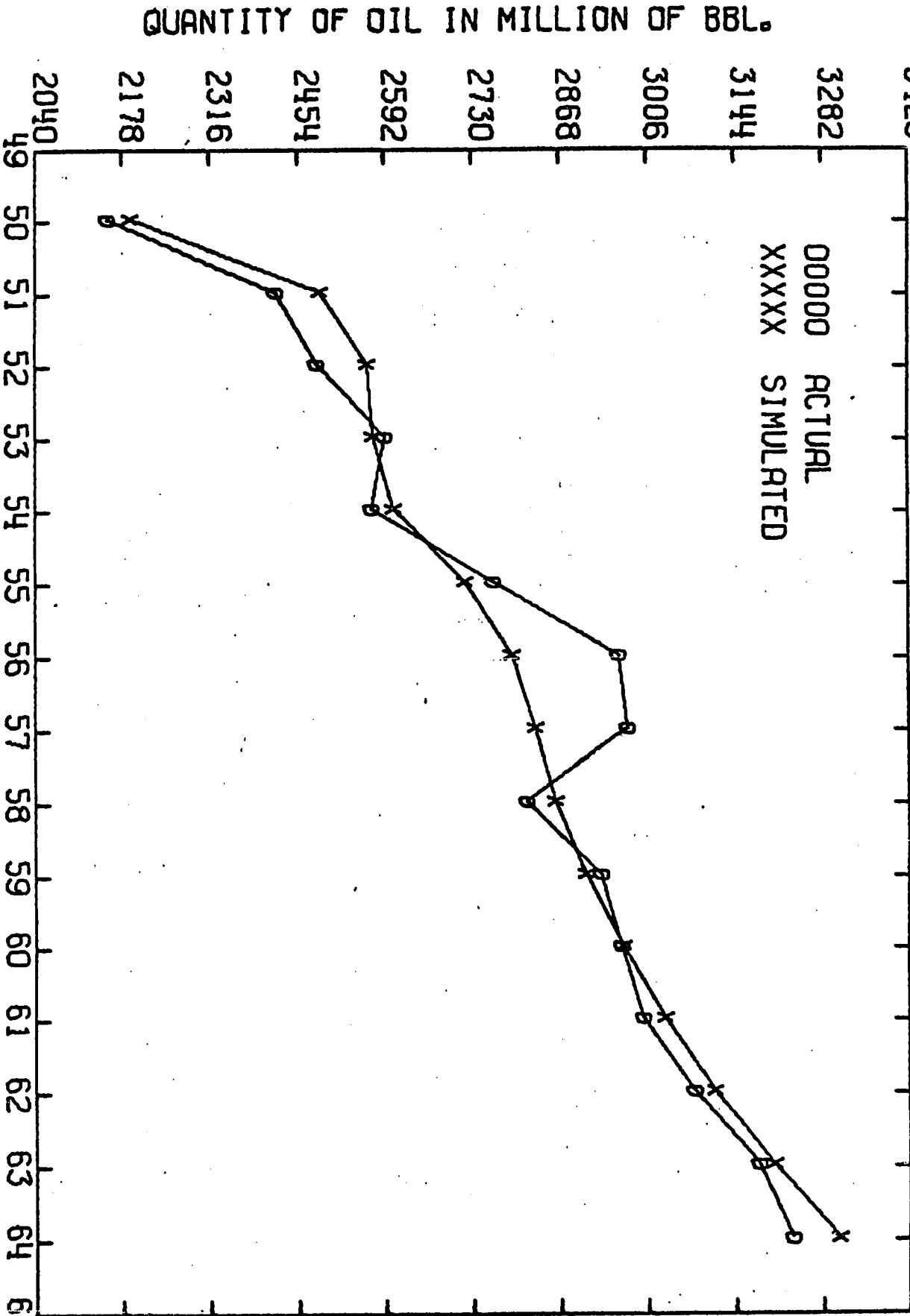


FIGURE 1.a

SOURCES: TABLES 1.1 and 1.2

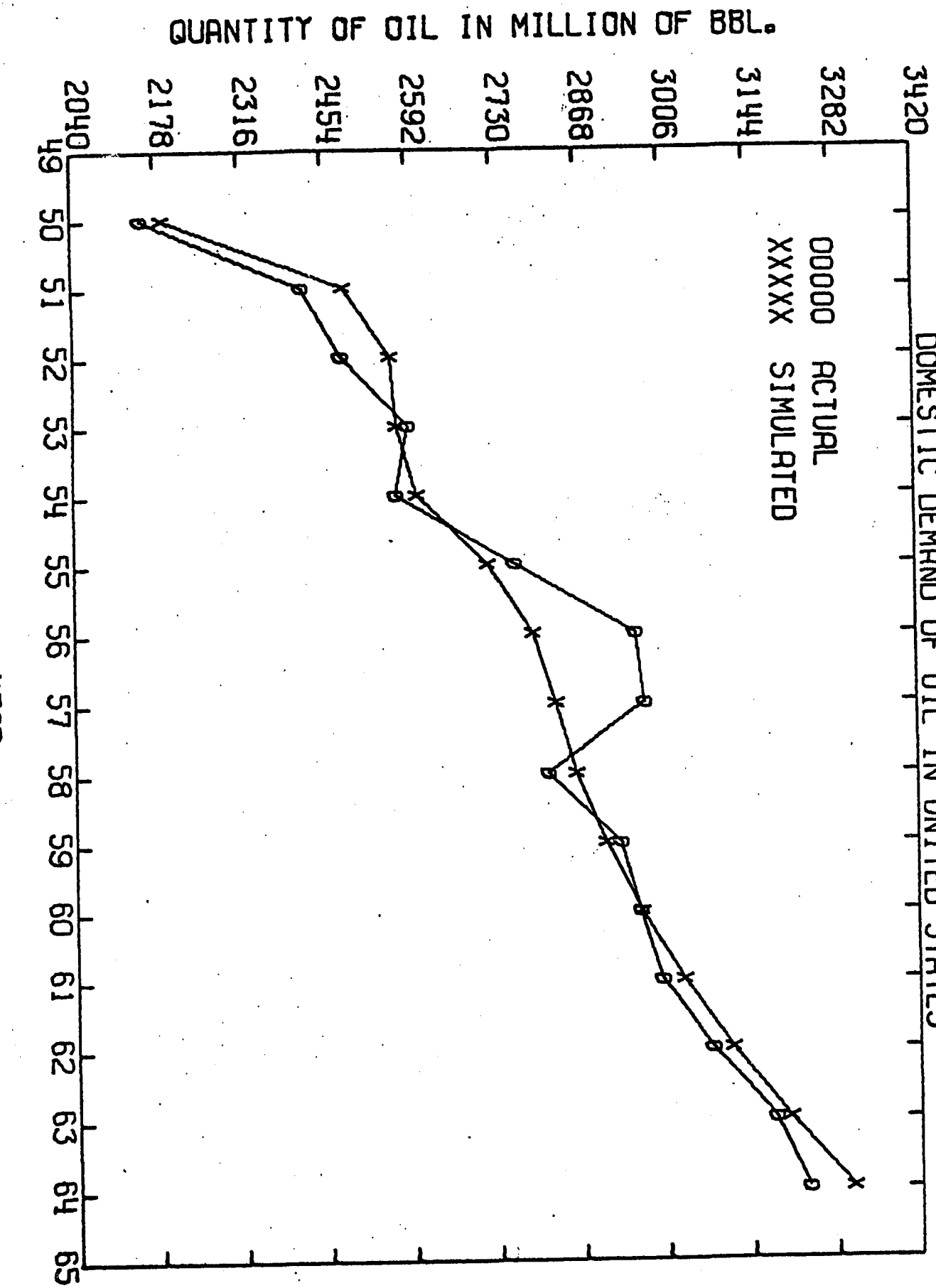
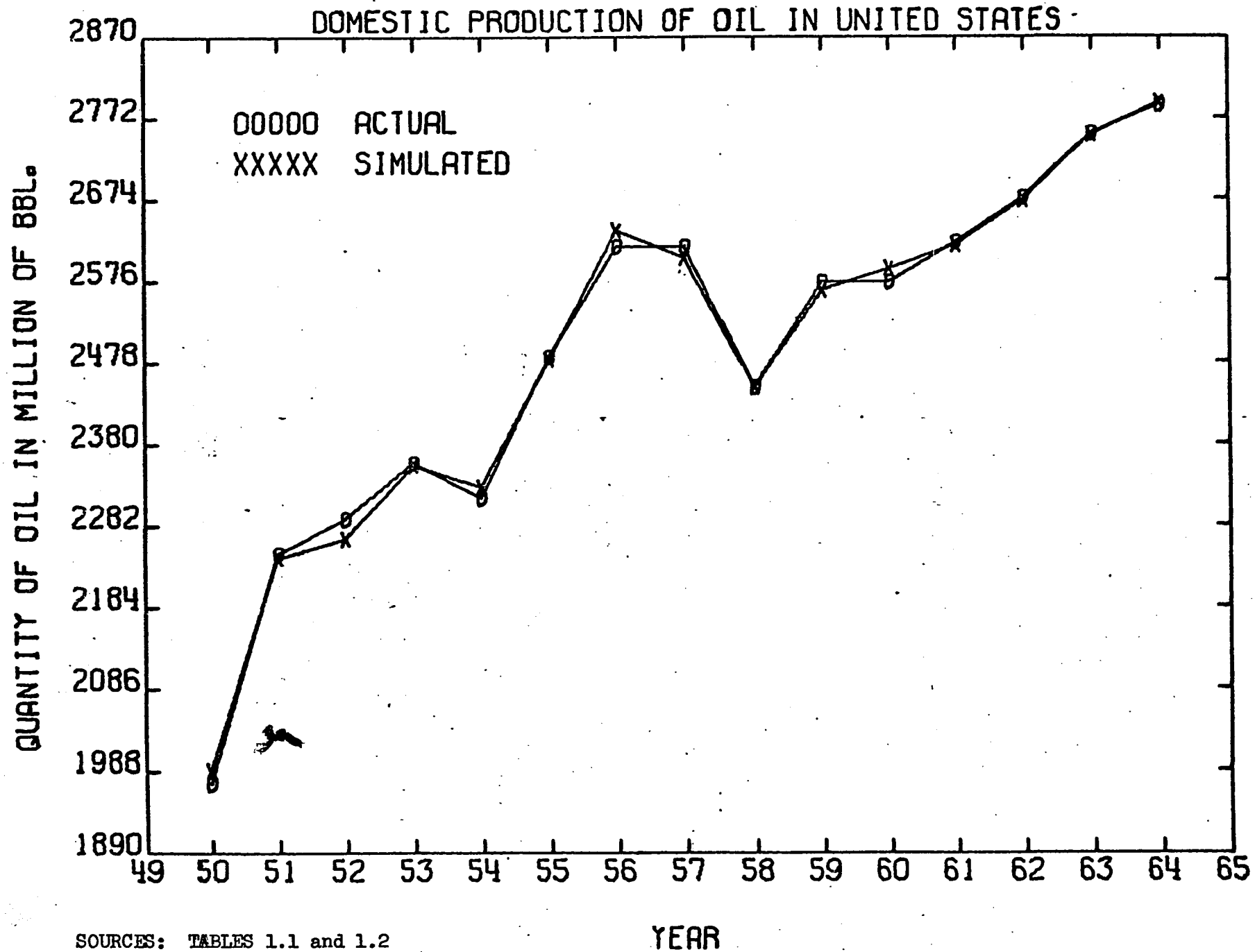


FIGURE 1.b

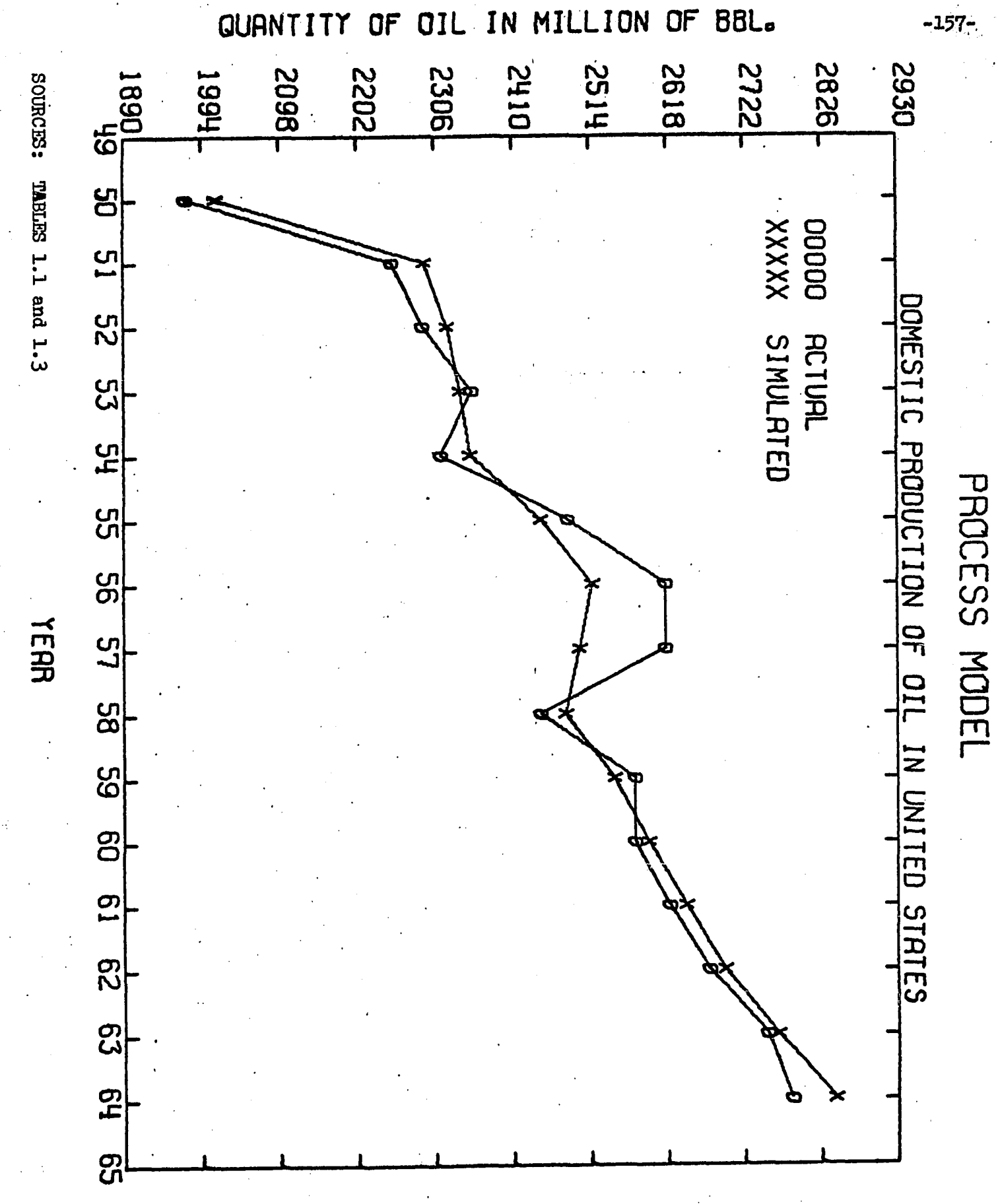
SOURCES: TABLES 1.1 and 1.3

FIGURE 2.a

ONE PERIOD CHANGE MODEL



SOURCES: TABLES 1.1 and 1.2

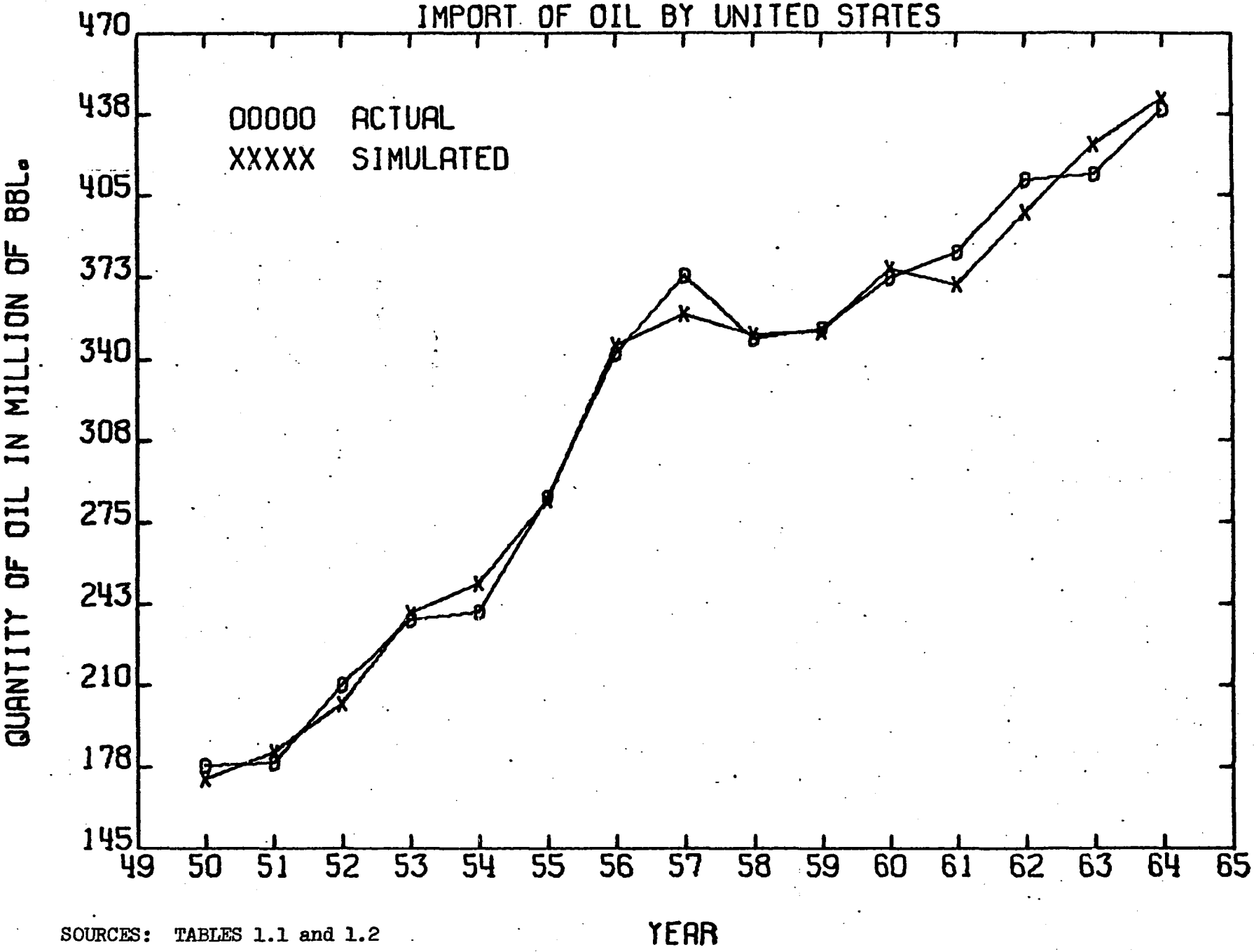


PROCESS MODEL

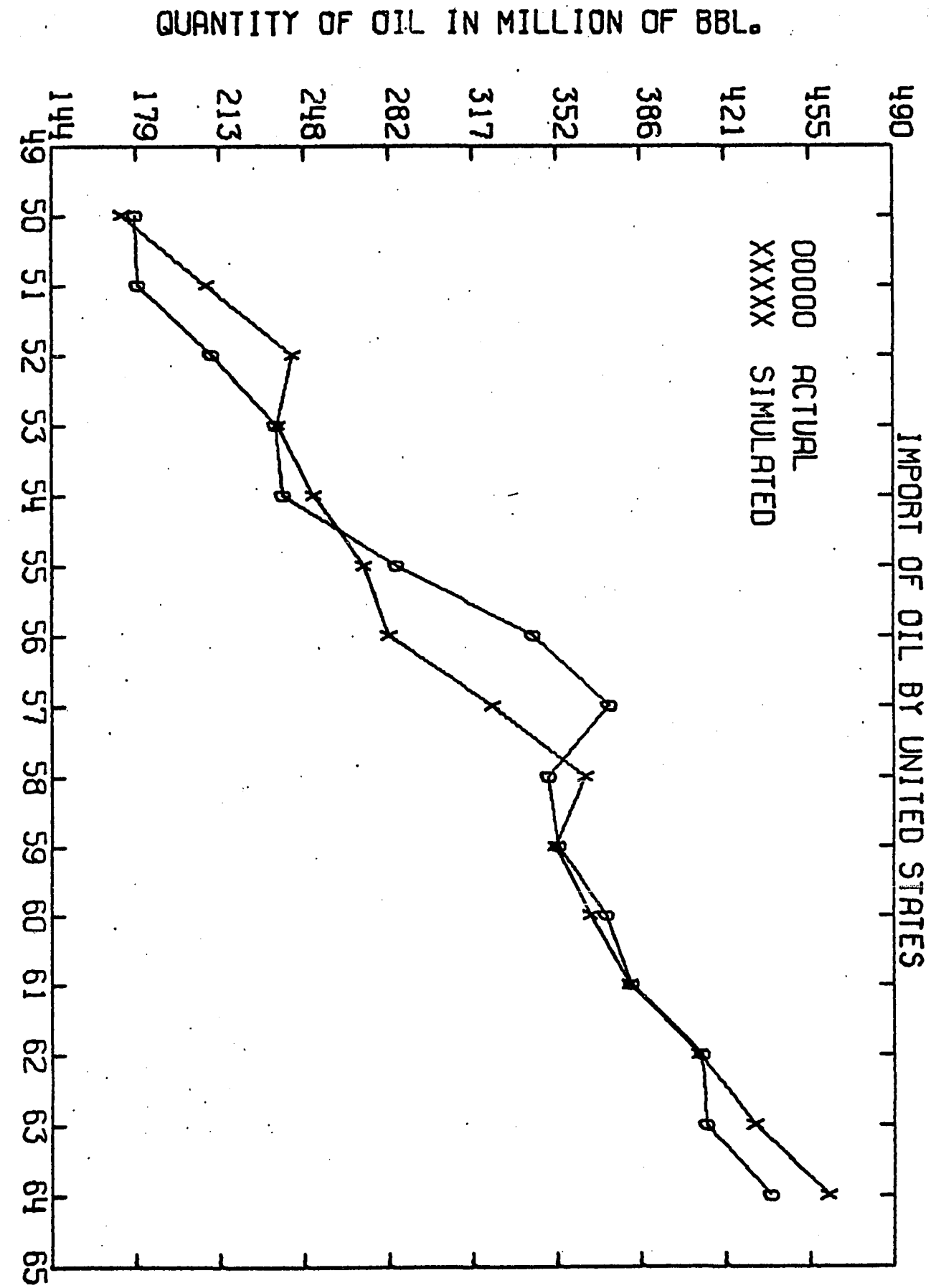
SOURCES: TABLES 1.1 and 1.3

FIGURE 3.a

ONE PERIOD CHANGE MODEL



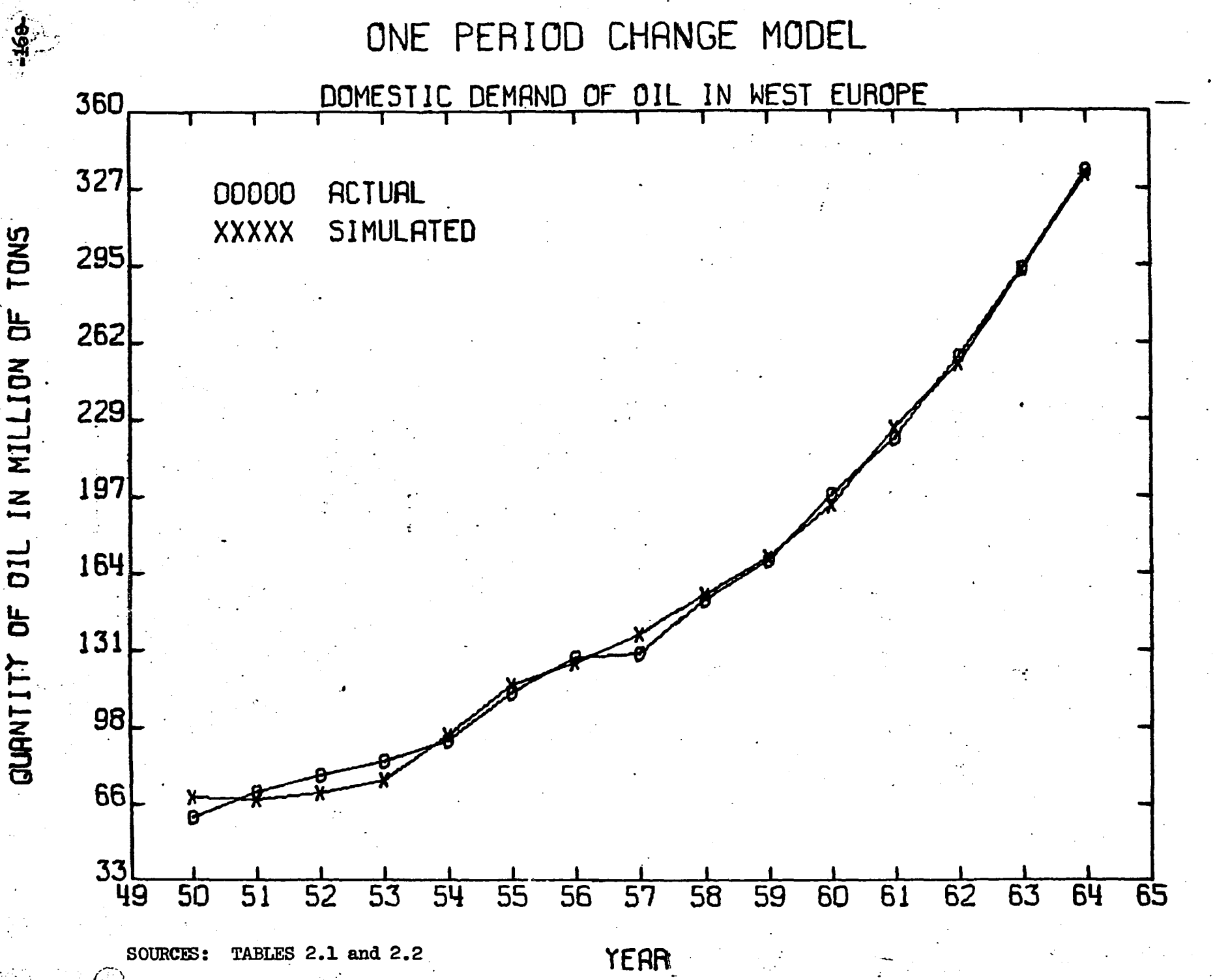
SOURCES: TABLES 1.1 and 1.2



PROCESS MODEL

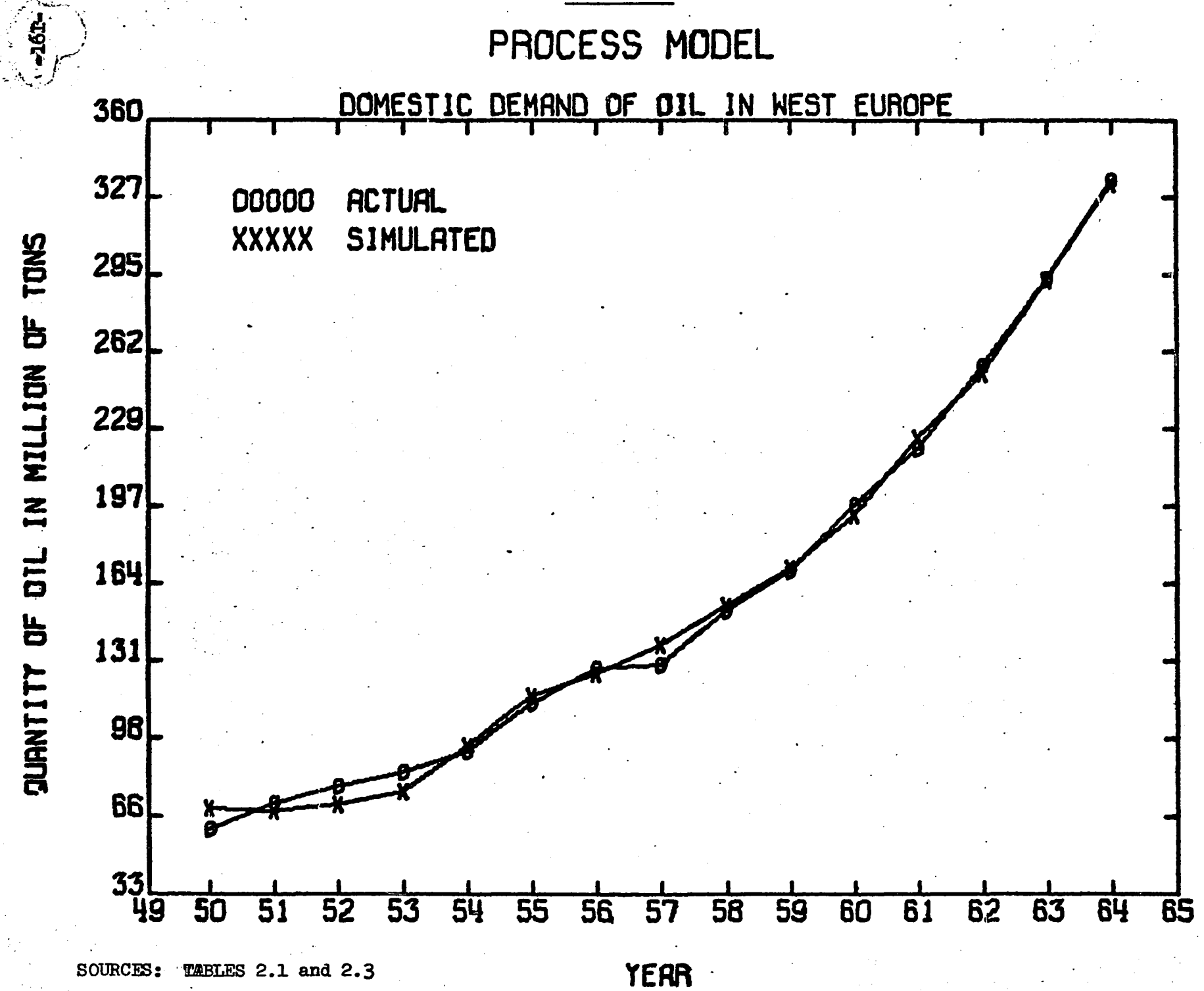
SOURCES: TABLES 1.1 and 1.3

FIGURE 4.a



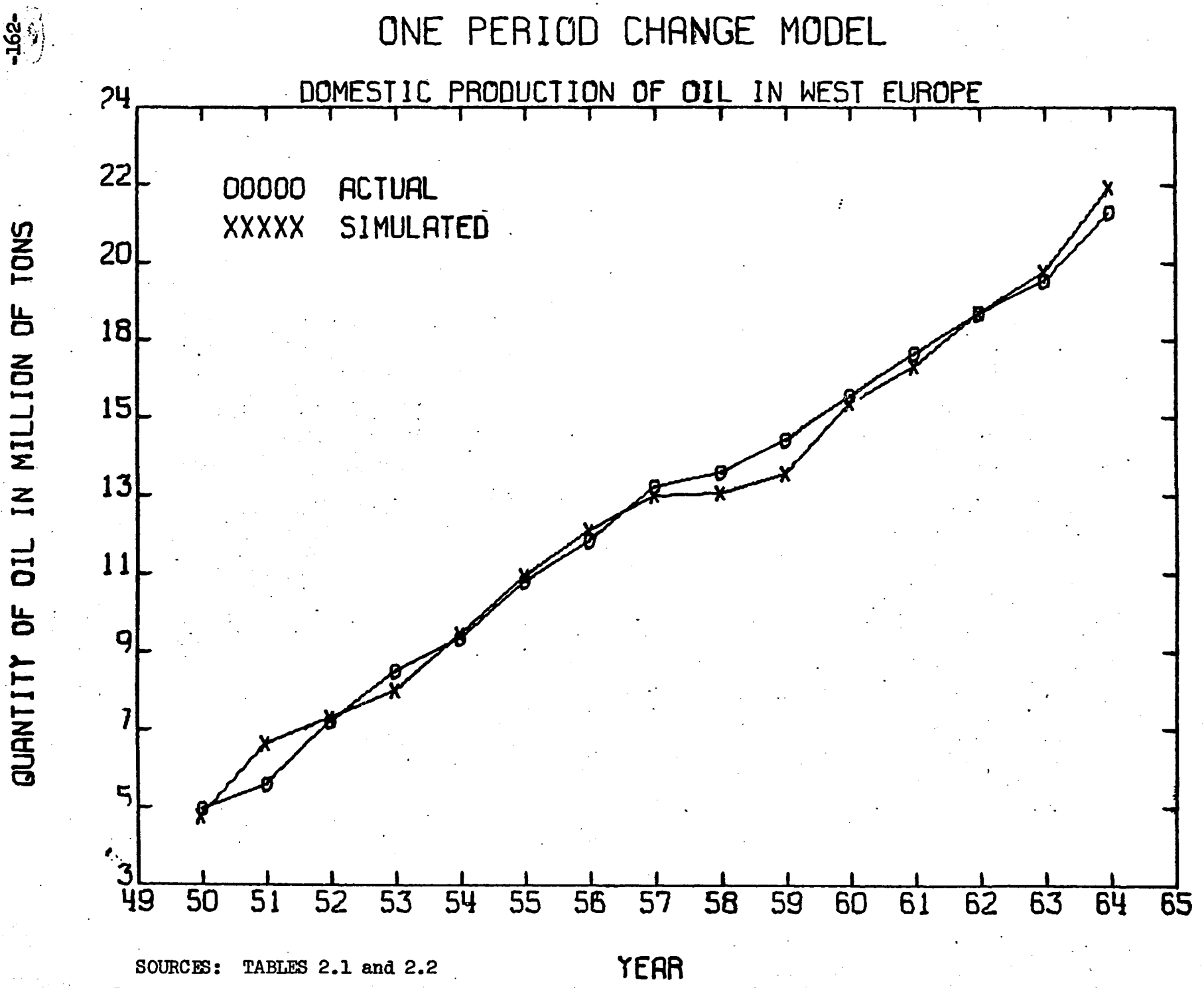
SOURCES: TABLES 2.1 and 2.2

FIGURE 4.b



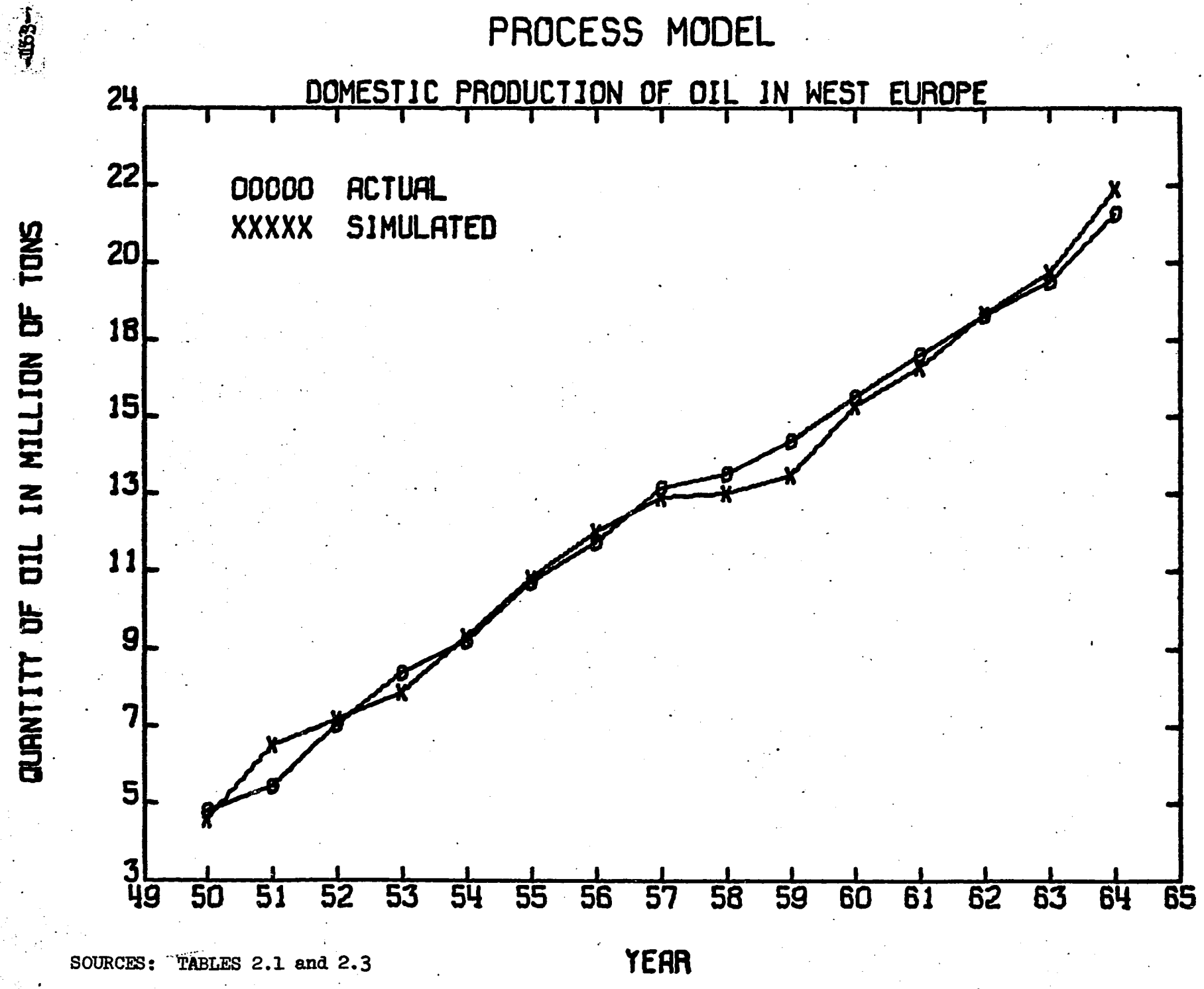
SOURCES: TABLES 2.1 and 2.3

FIGURE 5.8



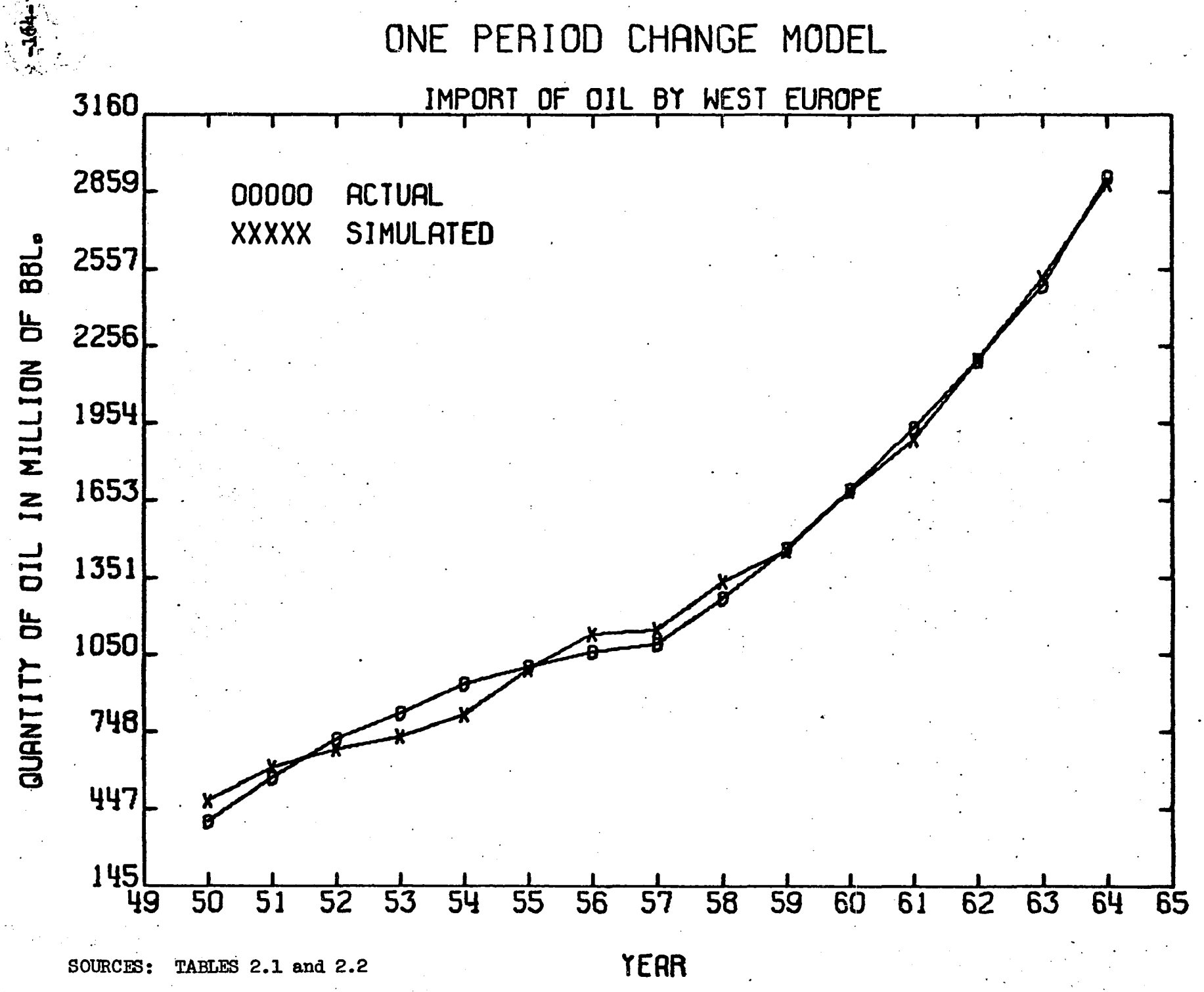
SOURCES: TABLES 2.1 and 2.2

FIGURE 5.b



SOURCES: TABLES 2.1 and 2.3

FIGURE 6.a



SOURCES: TABLES 2.1 and 2.2

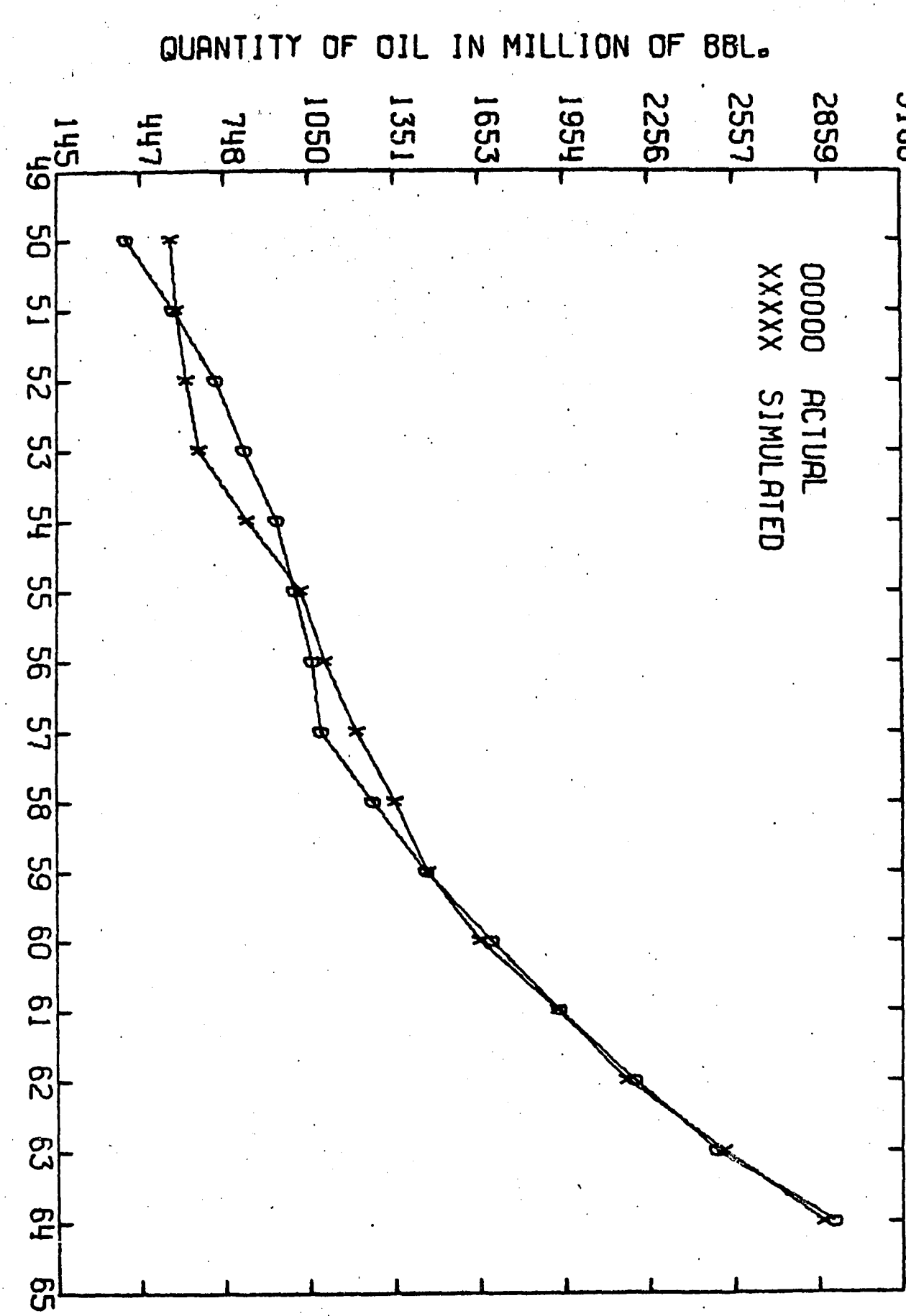
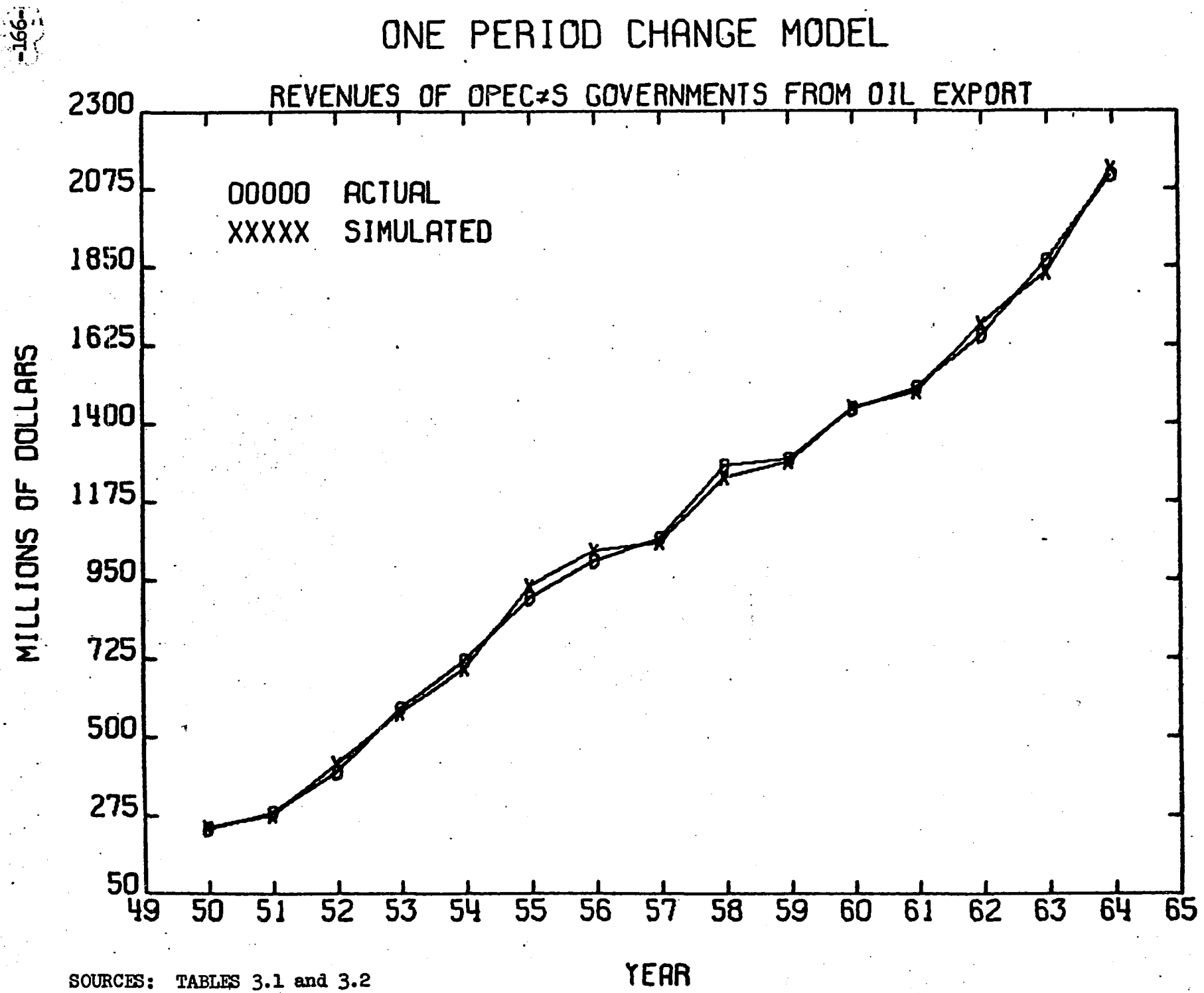


FIGURE 6.b

SOURCES: TABLES 2.1 and 2.3

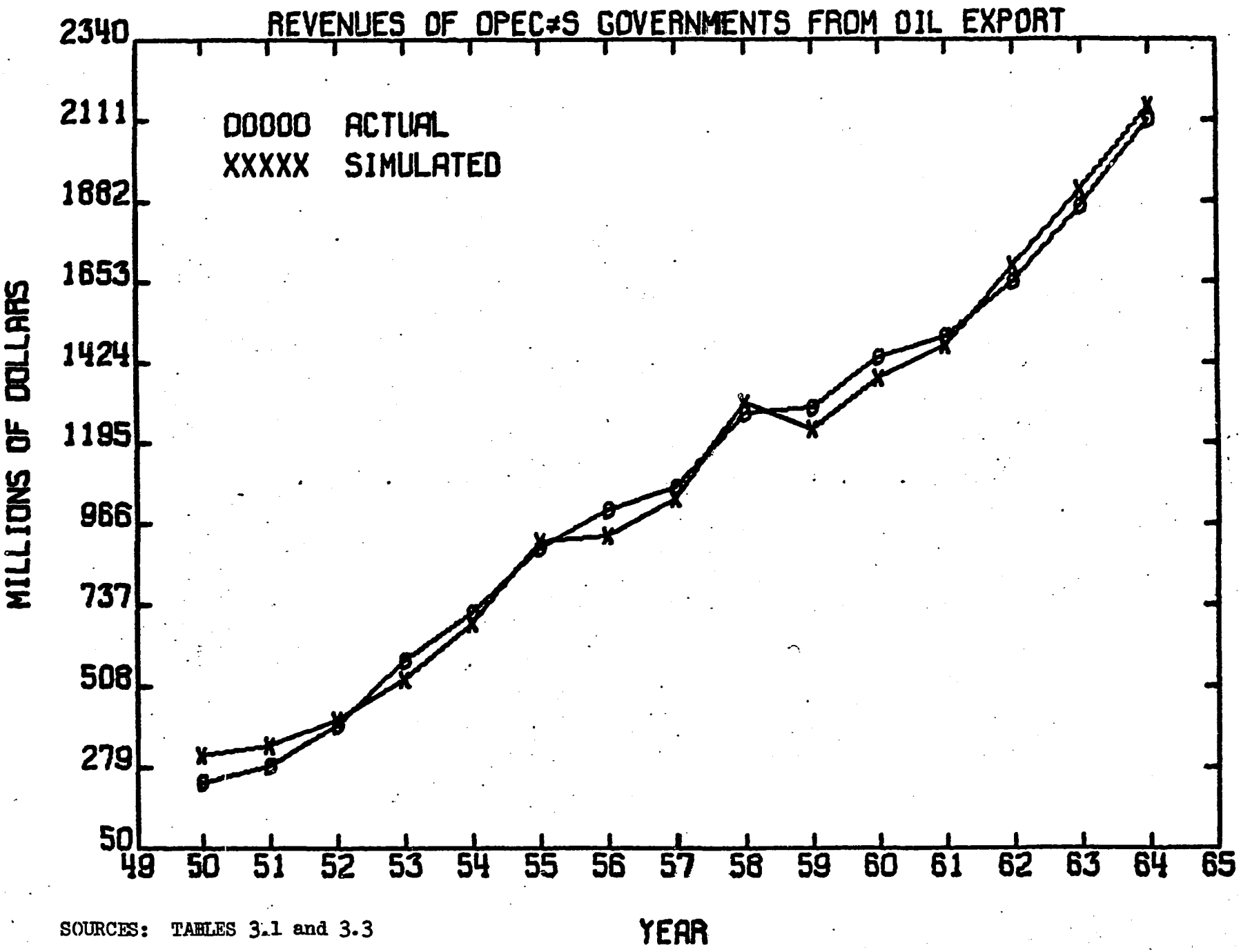
FIGURE 7.a



SOURCES: TABLES 3.1 and 3.2

FIGURE 7.5

PROCESS MODEL



SOURCES: TABLES 3.1 and 3.3

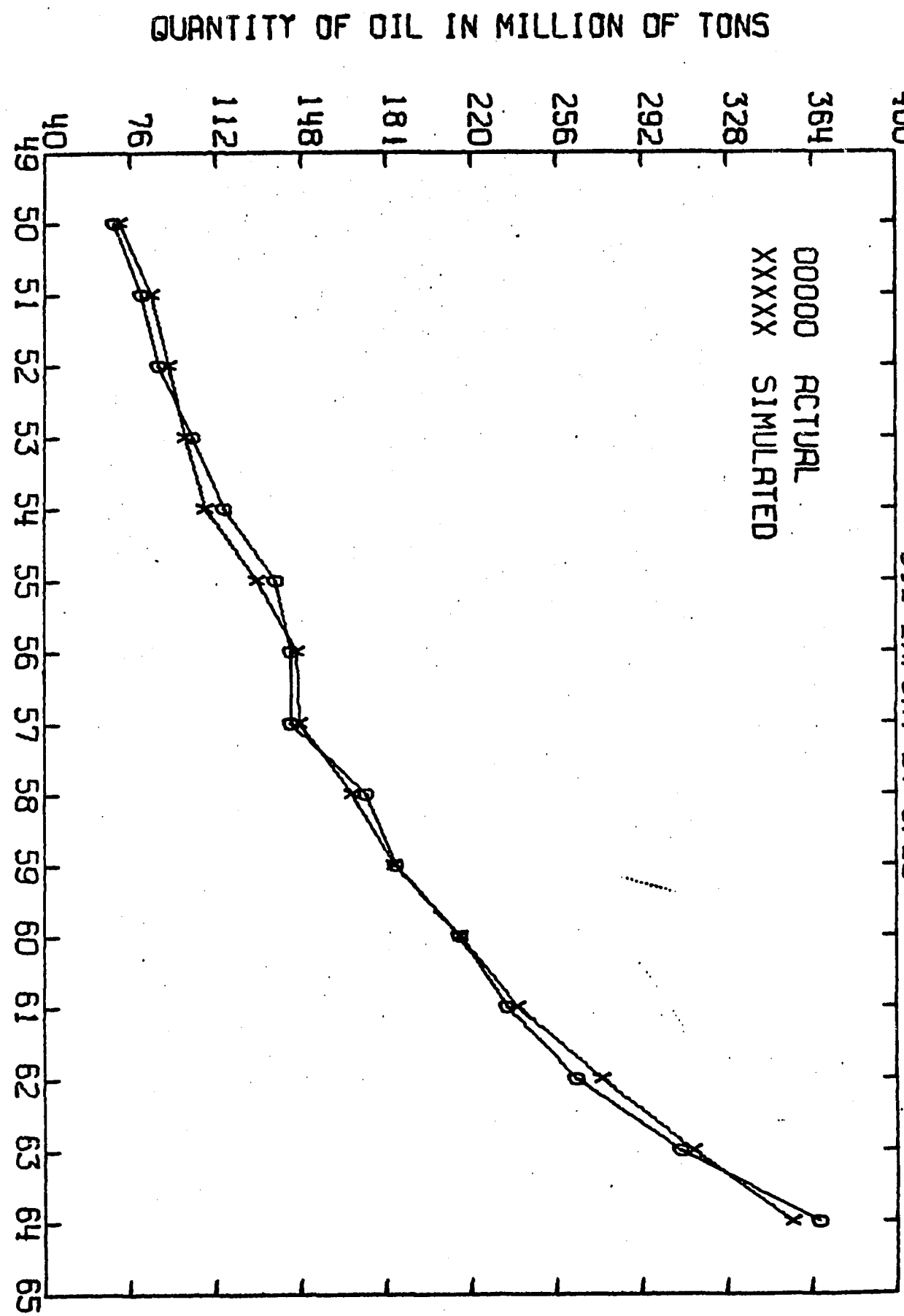
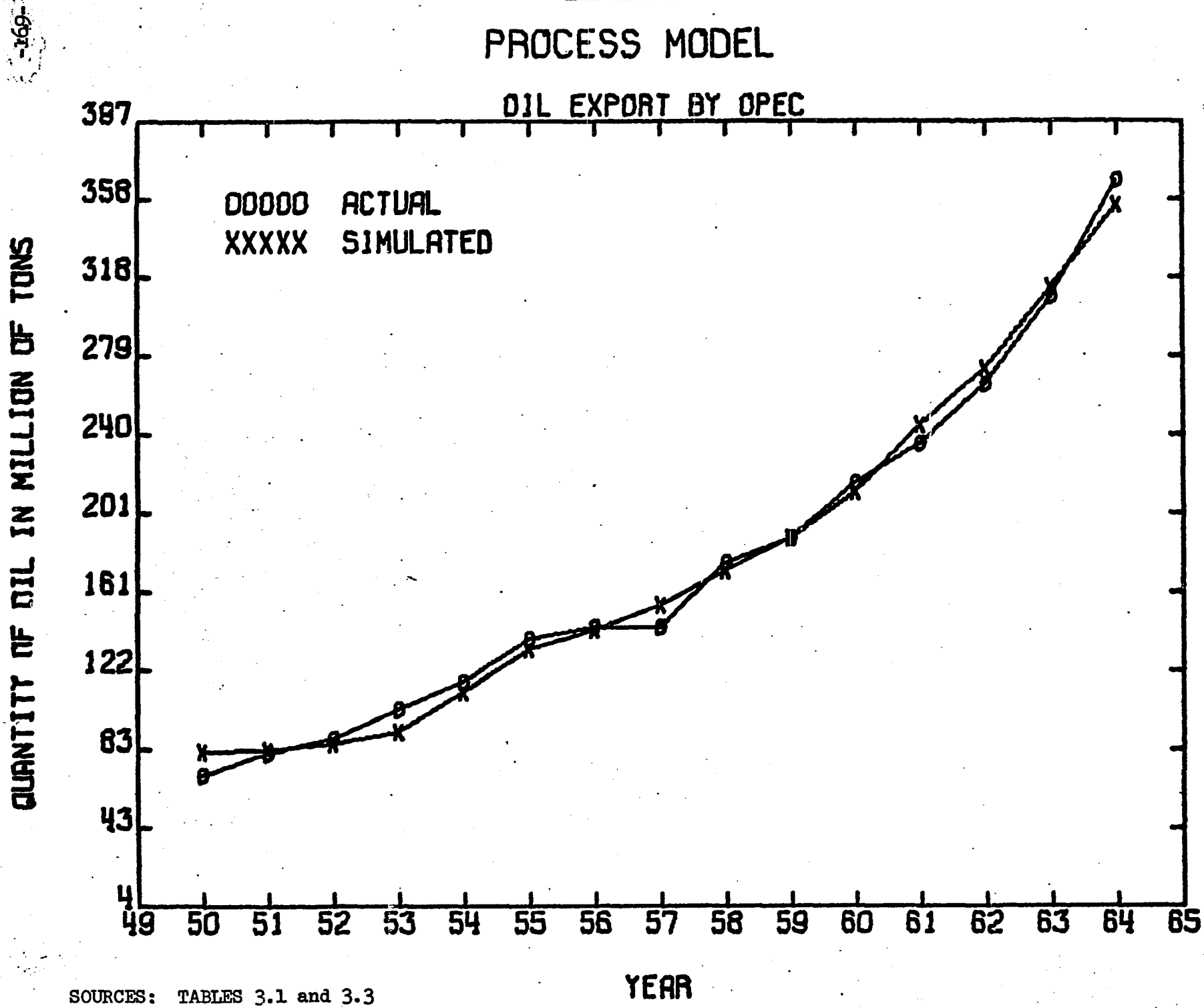


FIGURE 5.a

SOURCES: TABLES 3.1 and 3.2

FIGURE 8.b



SOURCES: TABLES 3.1 and 3.3

TABLE 1.a

ACTUAL RESULTS

RELATIVE DEPENDENCY AND BARGAINING POWER

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08339	6.58333	80.20000	20.40000
51	0.07471	7.93829	81.40000	20.30000
52	0.08542	9.21795	86.70000	27.80000
53	0.09200	9.72684	87.90000	37.10000
54	0.09389	10.06452	90.20000	44.00000
55	0.10418	8.82509	93.20000	45.50000
56	0.11674	8.26698	93.60000	44.90000
57	0.12667	8.39630	92.90000	45.10000
58	0.12482	8.33443	96.20000	60.90000
59	0.12121	8.64737	95.80000	57.50000
60	0.12676	8.60843	96.40000	60.20000
61	0.12869	8.75057	92.80000	58.70000
62	0.13478	8.60047	93.50000	58.80000
63	0.13117	8.50751	92.60000	60.50000
64	0.13715	8.71672	93.60000	65.70000

TABLE 1.b

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02566	80.74994	38.72864
51	0.07370	9.20685	81.47530	27.20525
52	0.08404	9.91819	85.20691	30.97889
53	0.09113	10.47557	89.71846	43.43783
54	0.09498	10.83544	90.74932	51.57472
55	0.10264	10.37781	93.27194	59.84745
56	0.11519	10.05671	93.63835	60.21874
57	0.12499	10.04087	93.81290	61.99513
58	0.12373	10.61366	96.07277	75.75110
59	0.11960	10.34829	93.07871	64.99311
60	0.12550	10.46751	94.72393	70.01717
61	0.12617	10.01746	92.17745	64.31328
62	0.13333	10.08894	95.15015	70.21405
63	0.13026	9.51070	94.15318	66.24349
64	0.13718	9.04370	93.00482	70.17304

TABLE 1.c

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN IMPORTS OF OIL BY U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08368	9.02566	80.83047	39.18966
51	0.07432	9.20685	81.54980	27.63172
52	0.08476	9.91819	85.29277	31.47040
53	0.09191	10.47557	89.81166	43.97142
54	0.09576	10.83544	90.84174	52.10383
55	0.10355	10.37781	93.38050	60.46893
56	0.11627	10.05671	93.76681	60.95414
57	0.12617	10.04087	93.95363	62.80076
58	0.12482	10.61366	96.20305	76.49693
59	0.12066	10.34829	93.20557	65.71937
60	0.12663	10.46751	94.85845	70.78728
61	0.12732	10.01746	92.31495	65.10045
62	0.13458	10.08894	95.29984	71.07096
63	0.13154	9.51070	94.30563	67.11622
64	0.13854	9.04370	93.16675	71.10008

TABLE 1.d

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

3 PER CENT YEARLY INCREASE IN IMPORTS OF OIL BY U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08572	9.02566	81.07448	40.58655
51	0.07621	9.20685	81.77553	28.92395
52	0.08693	9.91819	85.55291	32.95969
53	0.09427	10.47557	90.09408	45.58821
54	0.09810	10.83544	91.12179	53.70705
55	0.10630	10.37781	93.70943	62.35198
56	0.11952	10.05671	94.15604	63.18240
57	0.12974	10.04087	94.38003	65.24183
58	0.12812	10.61366	96.59780	78.75679
59	0.12387	10.34829	93.58997	67.91995
60	0.13004	10.46751	95.26605	73.12068
61	0.13080	10.01746	92.73158	67.48557
62	0.13837	10.08894	95.75338	73.66740
63	0.13540	9.51070	94.76754	69.76059
64	0.14264	9.04370	93.65742	73.90902

TABLE 1.e

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

5 PER CENT YEARLY INCREASE IN IMPORTS OF OIL BY U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08922	9.02566	81.49336	42.98455
51	0.07945	9.20685	82.16302	31.14228
52	0.09067	9.91819	85.99950	35.51631
53	0.09832	10.47557	90.57890	48.36368
54	0.10212	10.83544	91.60254	56.45924
55	0.11102	10.37781	94.27410	65.58456
56	0.12511	10.05671	94.82422	67.00759
57	0.13586	10.04087	95.11203	69.43233
58	0.13379	10.61366	97.27546	82.63620
59	0.12939	10.34829	94.24985	71.69761
60	0.13589	10.46751	95.96576	77.12637
61	0.13678	10.01746	93.44680	71.58002
62	0.14488	10.08894	96.53196	78.12462
63	0.14203	9.51070	95.56050	74.30009
64	0.14968	9.04370	94.49972	78.73104

TABLE 1.f

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

10 PER CENT YEARLY INCREASE IN IMPORTS OF OIL BY U.S.

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.09658	9.02566	82.37301	48.02034
51	0.08626	9.20685	82.97676	35.80077
52	0.09851	9.91819	86.93734	40.88521
53	0.10684	10.47557	91.59702	54.19219
54	0.11056	10.83544	92.61212	62.23883
55	0.12094	10.37781	95.45989	72.37298
56	0.13684	10.05671	96.22740	75.04047
57	0.14871	10.04087	96.64921	78.23238
58	0.14569	10.61366	98.69853	90.78298
59	0.14098	10.34829	95.63559	79.63069
60	0.14818	10.46751	97.43515	85.53830
61	0.14934	10.01746	94.94875	80.17837
62	0.15856	10.08894	98.16699	87.48477
63	0.15596	9.51070	97.22571	83.83305
64	0.16447	9.04370	96.26856	88.85726

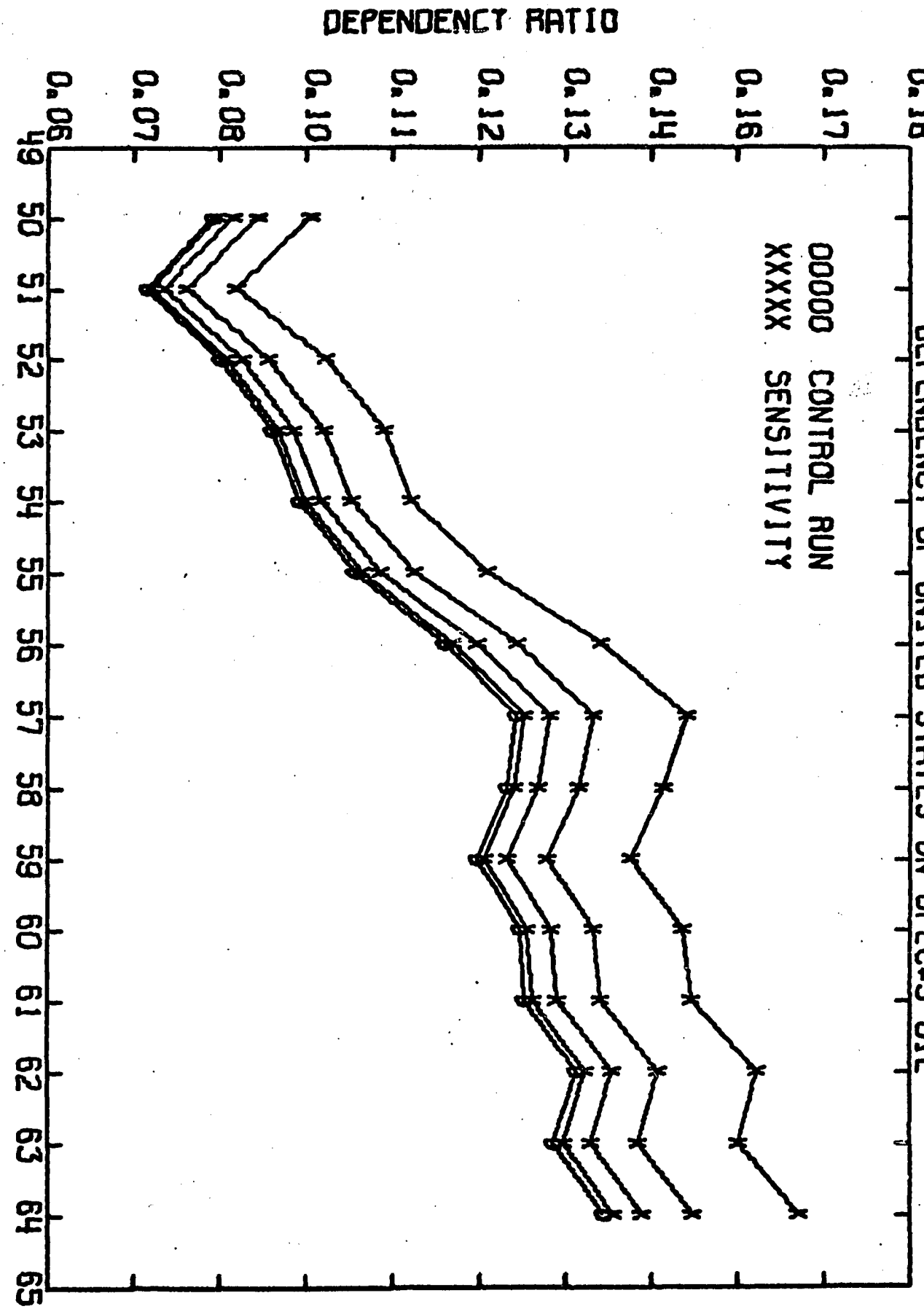
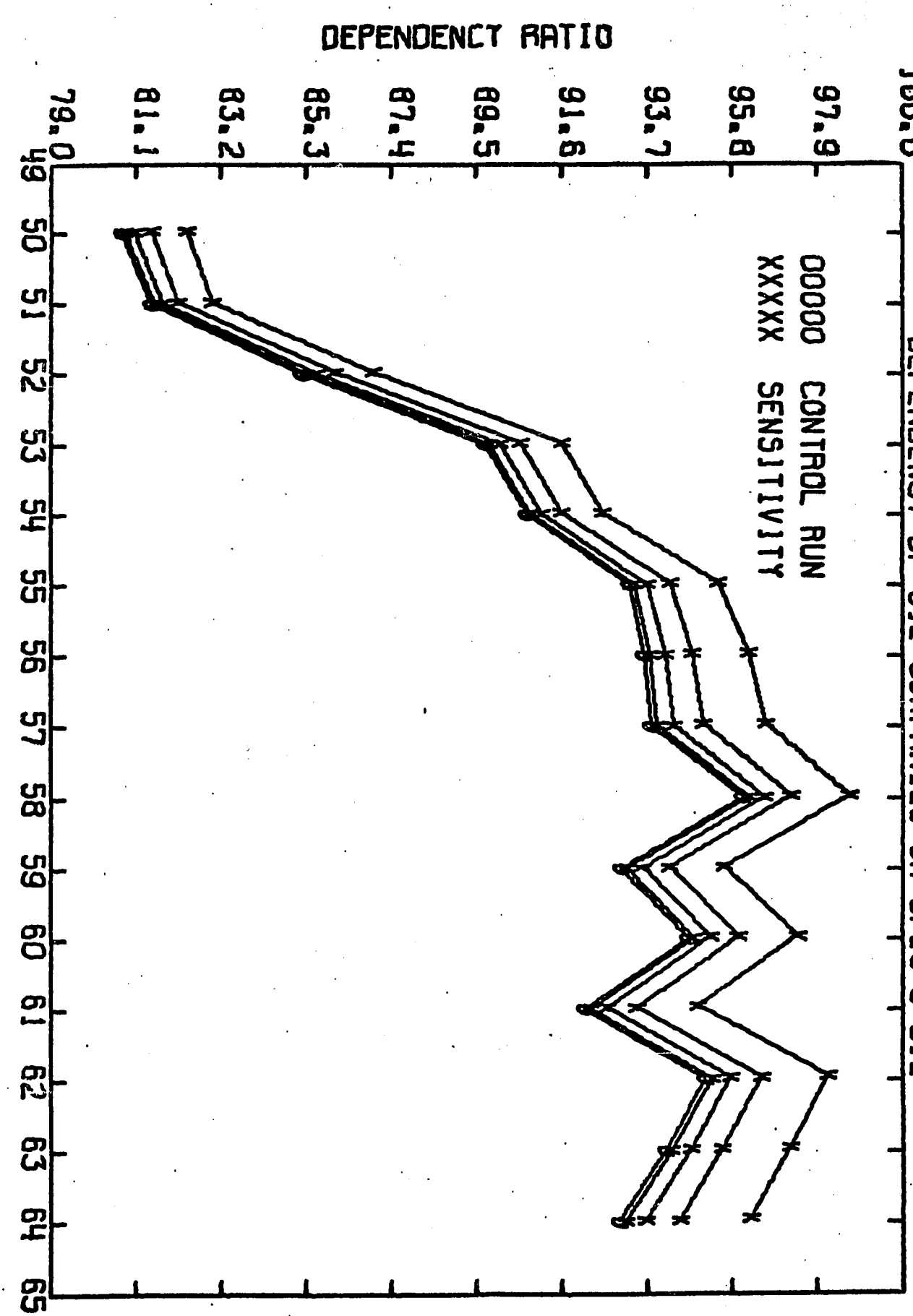


FIGURE 9.a

SOURCES: TABLES 1.b - 1.f

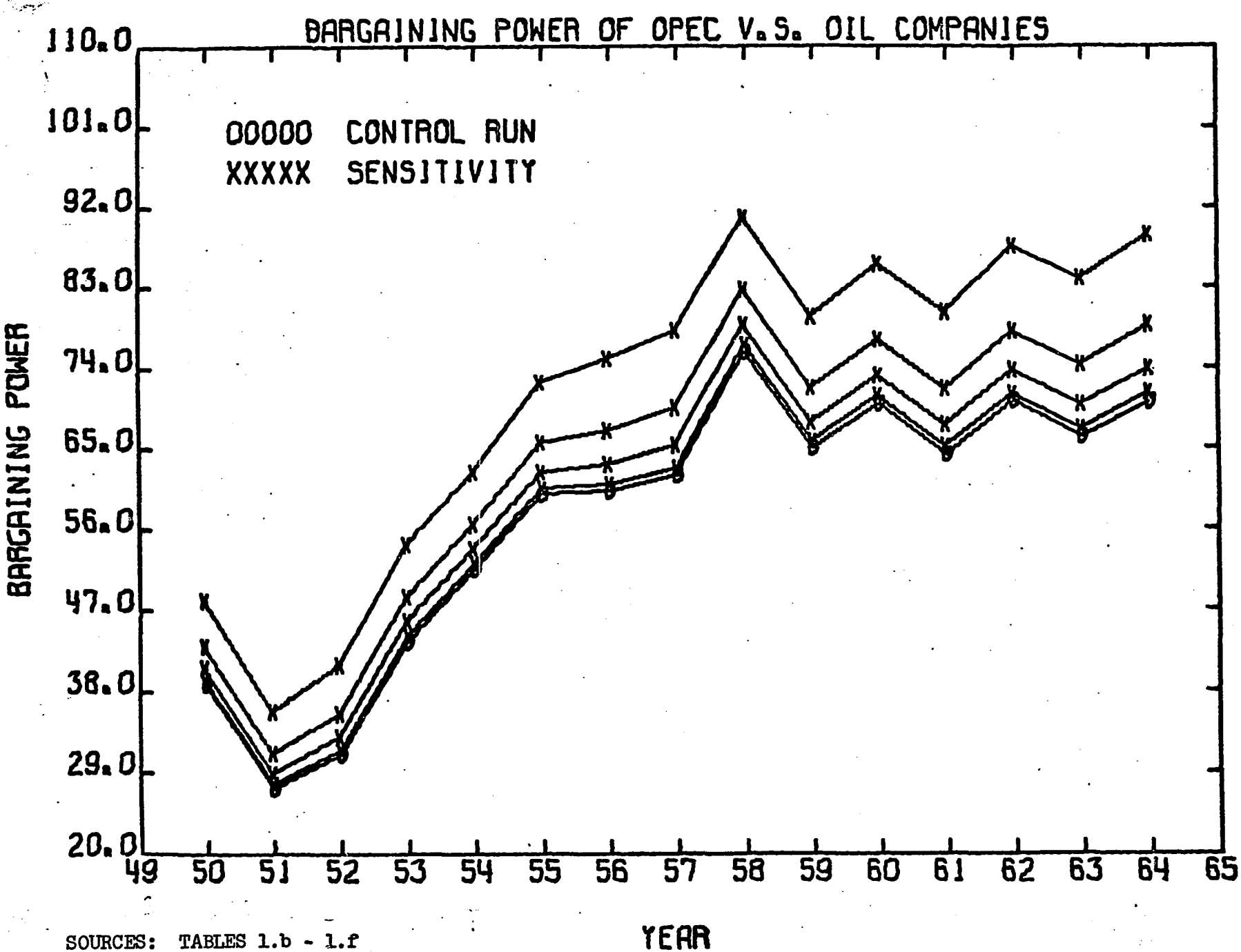


SOURCES: TABLES 1.b - 1.f

FIGURE 9.b

FIGURE 9.c

PROCESS MODEL



SOURCES: TABLES 1.b - 1.f

TABLE 2.a

ACTUAL RESULTS

RELATIVE DEPENDENCY AND BARGAINING POWER

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08256	6.58333	80.20000	20.40000
51	0.07397	7.93829	81.40000	20.30000
52	0.08458	9.21795	86.70000	27.80000
53	0.09108	9.72684	87.90000	37.10000
54	0.09296	10.06452	90.20000	44.00000
55	0.10315	8.82509	93.20000	45.50000
56	0.11558	8.26698	93.60000	44.90000
57	0.12542	8.39630	92.90000	45.10000
58	0.12358	8.33443	96.20000	60.90000
59	0.12001	8.64737	95.80000	57.50000
60	0.12551	8.60843	96.40000	60.20000
61	0.12742	8.75057	92.80000	58.70000
62	0.13344	8.60047	93.50000	58.80000
63	0.12987	8.50751	92.60000	60.50000
64	0.13579	8.71672	93.60000	65.70000

TABLE 2.b

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02566	80.74994	38.72864
51	0.07370	9.20685	81.47530	27.20525
52	0.08404	9.91819	85.20691	30.97889
53	0.09113	10.47557	89.71846	43.43783
54	0.09498	10.83544	90.74932	51.57472
55	0.10264	10.37781	93.27194	59.84745
56	0.11519	10.05671	93.63835	60.21874
57	0.12499	10.04087	93.81290	61.99513
58	0.12373	10.61366	96.07277	75.75110
59	0.11960	10.34829	93.07871	64.99311
60	0.12550	10.46751	94.72393	70.01717
61	0.12617	10.01746	92.17745	64.31328
62	0.13333	10.08894	95.15015	70.21405
63	0.13026	9.51070	94.15318	66.24349
64	0.13718	9.04370	93.00482	70.17304

TABLE 2.c

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN RATE OF RETURN TO OIL COMP. FROM OPERATION IN OPEC

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02850	80.77038	38.75654
51	0.07370	9.21058	81.50216	27.24190
52	0.08404	9.92379	85.24720	31.03387
53	0.09113	10.48386	89.77808	43.51921
54	0.09498	10.84208	90.79706	51.63988
55	0.10264	10.38360	93.31358	59.90428
56	0.11519	10.06138	93.67194	60.26458
57	0.12499	10.04539	93.84540	62.03949
58	0.12373	10.62288	96.13913	75.84167
59	0.11960	10.35553	93.13081	65.06422
60	0.12550	10.47682	94.79096	70.10865
61	0.12617	10.02556	92.23573	64.39282
62	0.13333	10.09678	95.20648	70.29094
63	0.13026	9.51910	94.21365	66.32602
64	0.13718	9.04615	93.02244	70.19710

TABLE 2.d

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

3 PER CENT YEARLY INCREASE IN RATE OF RETURN TO OIL COMP. FROM OPERATION IN OPEC

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.03711	80.83232	38.84107
51	0.07370	9.22190	81.58354	27.35298
52	0.08404	9.94076	85.36926	31.20048
53	0.09113	10.50898	89.95873	43.76578
54	0.09498	10.86219	90.94172	51.83732
55	0.10264	10.40114	93.43974	60.07648
56	0.11519	10.07552	93.77370	60.40347
57	0.12499	10.05908	93.94389	62.17391
58	0.12373	10.65083	96.34018	76.11607
59	0.11960	10.37748	93.28867	65.27967
60	0.12550	10.50506	94.99403	70.38582
61	0.12617	10.05011	92.41231	64.63384
62	0.13333	10.12051	95.37716	70.52389
63	0.13026	9.54457	94.39686	66.57608
64	0.13718	9.05358	93.07585	70.27000

TABLE 2.e

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

5 PER CENT YEARLY INCREASE IN RATE OF RETURN TO OIL COMP. FROM OPERATION IN OPEC

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.05189	80.93864	38.98618
51	0.07370	9.24132	81.72325	27.54366
52	0.08404	9.96989	85.57881	31.48649
53	0.09113	10.55210	90.26886	44.18906
54	0.09498	10.89672	91.19006	52.17627
55	0.10264	10.43126	93.65632	60.37208
56	0.11519	10.09981	93.94839	60.64191
57	0.12499	10.08259	94.11295	62.40466
58	0.12373	10.69882	96.68531	76.58714
59	0.11960	10.41515	93.55965	65.64954
60	0.12550	10.55353	95.34265	70.86164
61	0.12617	10.09226	92.71544	65.04758
62	0.13333	10.16124	95.67016	70.92379
63	0.13026	9.58830	94.71137	67.00535
64	0.13718	9.06632	93.16754	70.39514

TABLE 2.f

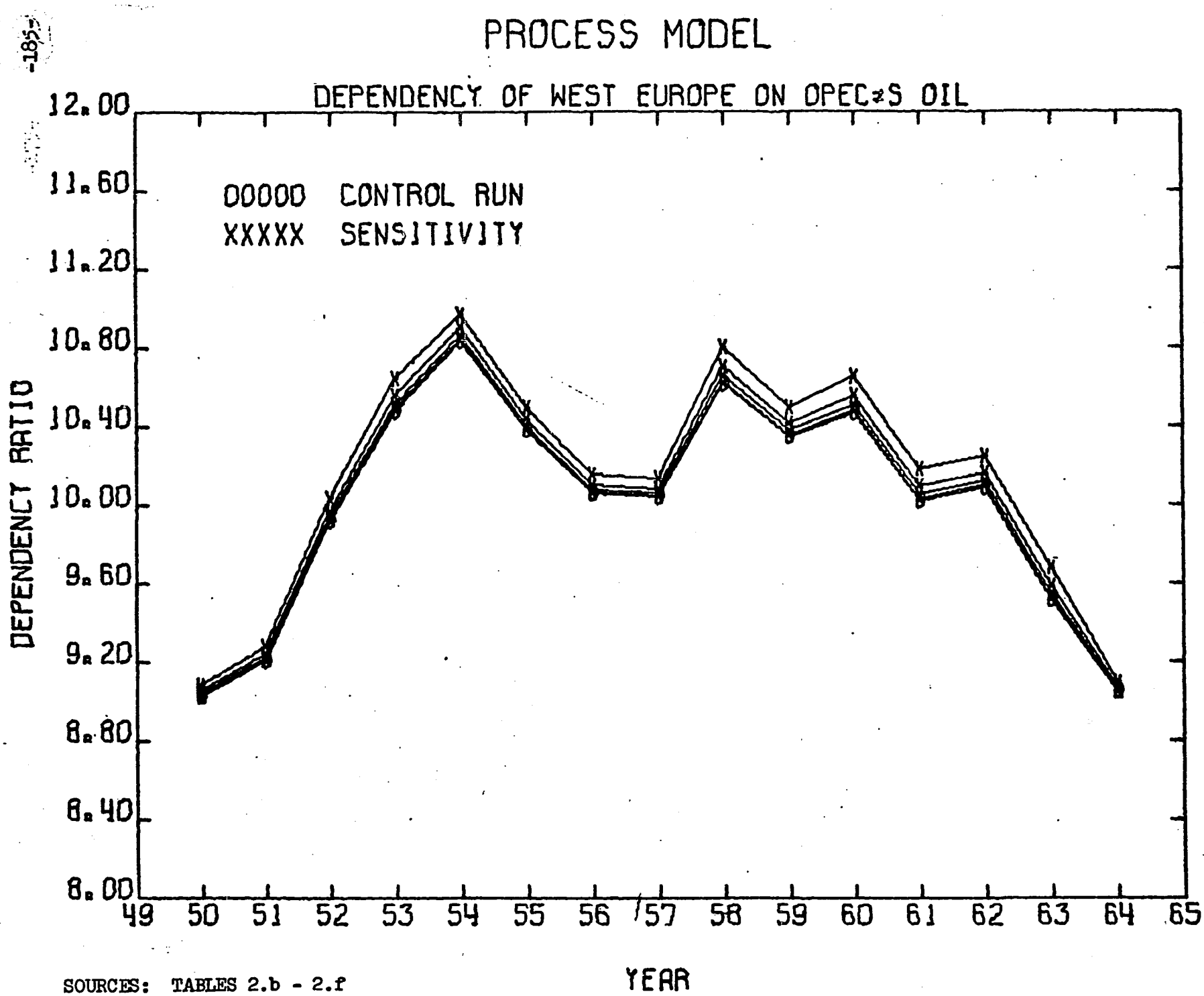
SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

10 PER CENT YEARLY INCREASE IN RATE OF RETURN TO OIL COMP. FROM OPERATION IN OPEC

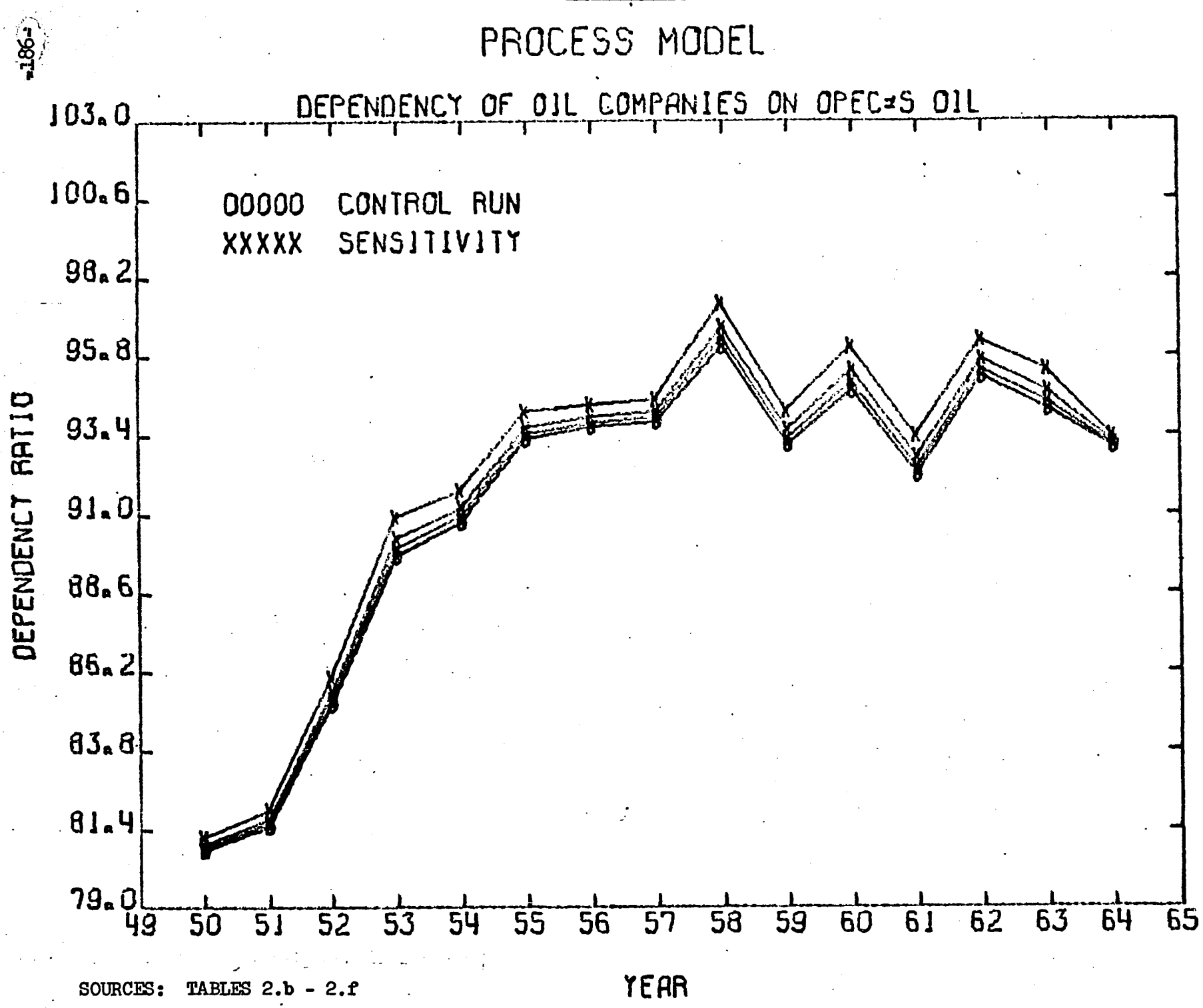
YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.08293	81.16191	39.29092
51	0.07370	9.28211	82.01662	27.94408
52	0.08404	10.03108	86.01887	32.08711
53	0.09113	10.64265	90.92012	45.07795
54	0.09498	10.96923	91.71156	52.88806
55	0.10264	10.49449	94.11113	60.99283
56	0.11519	10.15082	94.31525	61.14262
57	0.12499	10.13195	94.46799	62.88924
58	0.12373	10.79959	97.41010	77.57638
59	0.11960	10.49427	94.12873	66.42625
60	0.12550	10.65531	96.07474	71.86084
61	0.12617	10.18076	93.35203	65.91643
62	0.13333	10.24679	96.28545	71.76359
63	0.13026	9.68013	95.37185	67.90682
64	0.13718	9.09309	93.36009	70.65794

FIGURE 10.a



SOURCES: TABLES 2.b - 2.f

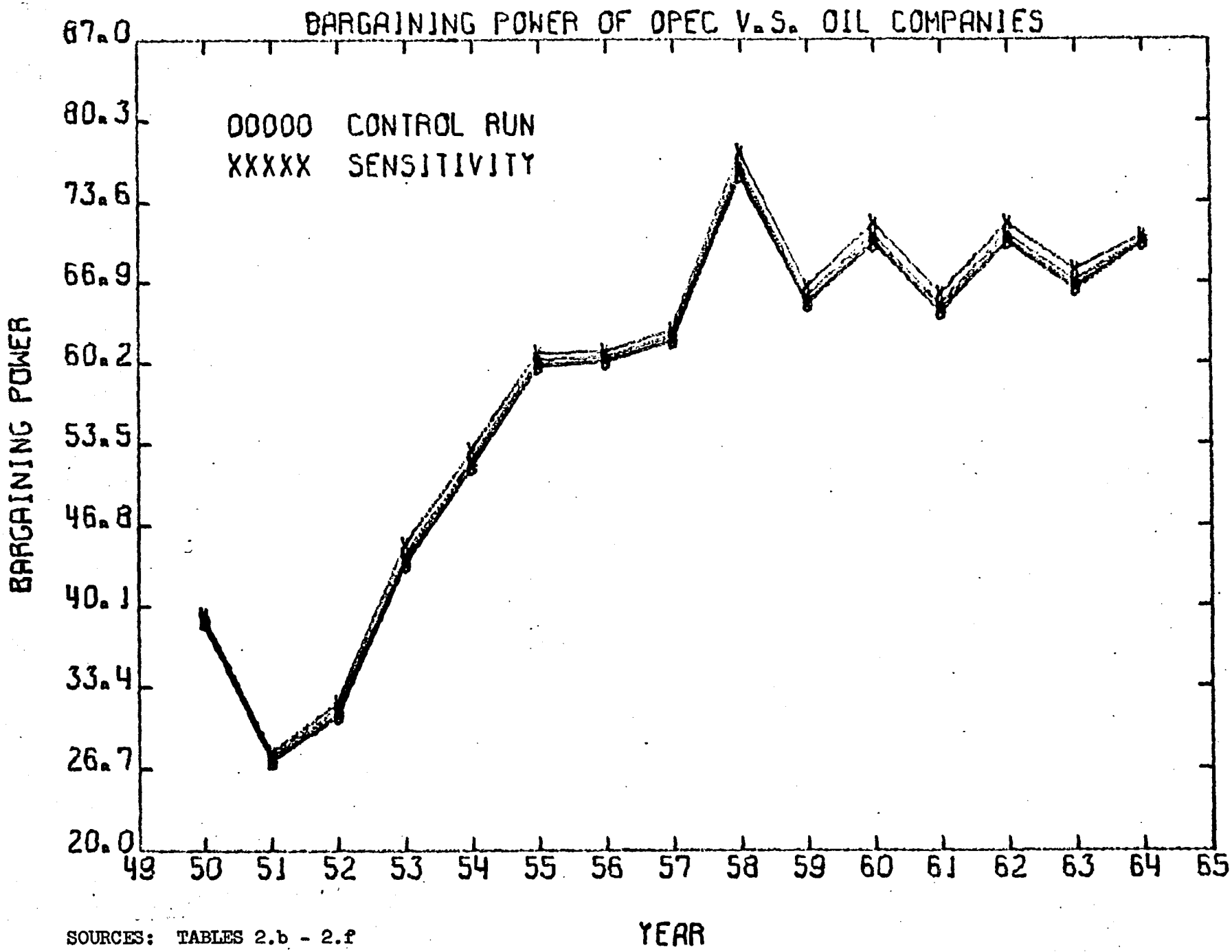
FIGURE 10.b



SOURCES: TABLES 2.b - 2.f

FIGURE 10.c

PROCESS MODEL



SOURCES: TABLES 2.b - 2.f

TABLE 3.a

ACTUAL RESULTS

RELATIVE DEPENDENCY AND BARGAINING POWER

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08256	6.58333	80.20000	20.40000
51	0.07397	7.93829	81.40000	20.30000
52	0.08458	9.21795	86.70000	27.80000
53	0.09108	9.72684	87.90000	37.10000
54	0.09296	10.06452	90.20000	44.00000
55	0.10315	8.82509	93.20000	45.50000
56	0.11558	8.26698	93.60000	44.90000
57	0.12542	8.39630	92.90000	45.10000
58	0.12358	8.33443	96.20000	60.90000
59	0.12001	8.64737	95.80000	57.50000
60	0.12551	8.60843	96.40000	60.20000
61	0.12742	8.75057	92.80000	58.70000
62	0.13344	8.60047	93.50000	58.80000
63	0.12987	8.50751	92.60000	60.50000
64	0.13579	8.71672	93.60000	65.70000

TABLE 3.b

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

CONTROL RUN WITH NO CHANGE IN PARAMETERS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08300	9.02566	80.74994	38.72864
51	0.07370	9.20685	81.47530	27.20525
52	0.08404	9.91819	85.20691	30.97889
53	0.09113	10.47557	89.71846	43.43783
54	0.09498	10.83544	90.74932	51.57472
55	0.10264	10.37781	93.27194	59.84745
56	0.11519	10.05671	93.63835	60.21874
57	0.12499	10.04087	93.81290	61.99513
58	0.12373	10.61366	96.07277	75.75110
59	0.11960	10.34829	93.07871	64.99311
60	0.12550	10.46751	94.72393	70.01717
61	0.12617	10.01746	92.17745	64.31328
62	0.13333	10.08894	95.15015	70.21405
63	0.13026	9.51070	94.15318	66.24349
64	0.13718	9.04370	93.00482	70.17304

TABLE 3.c

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

1 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES IN U.S. OIL OPERATIONS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08307	9.06575	81.00206	39.14957
51	0.07376	9.24303	81.70283	27.58511
52	0.08409	9.94871	85.39885	31.29934
53	0.09117	10.50409	89.89780	43.73725
54	0.09503	10.86143	90.91272	51.84752
55	0.10268	10.40365	93.43444	60.11875
56	0.11523	10.08165	93.79520	60.48061
57	0.12503	10.06554	93.96802	62.25411
58	0.12378	10.64227	96.25273	76.05156
59	0.11964	10.37681	93.25810	65.29261
60	0.12555	10.49691	94.90885	70.32589
61	0.12622	10.04918	92.37695	64.64636
62	0.13337	10.11748	95.32959	70.51363
63	0.13031	9.54286	94.35548	66.58124
64	0.13723	9.07371	93.19358	70.48819

TABLE 3.d

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

3 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES IN U.S. OIL OPERATIONS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08326	9.18251	81.73639	40.37557
51	0.07393	9.34840	82.36552	28.69151
52	0.08423	10.03760	85.95790	32.23270
53	0.09131	10.58715	90.42015	44.60934
54	0.09515	10.93710	91.38863	52.64208
55	0.10280	10.47891	93.90773	60.90894
56	0.11535	10.15429	94.25205	61.24335
57	0.12515	10.13738	94.41982	63.00842
58	0.12391	10.72562	96.77689	76.92666
59	0.11978	10.45989	93.78059	66.16494
60	0.12569	10.58255	95.44743	71.22508
61	0.12636	10.14158	92.95803	65.61651
62	0.13351	10.20058	95.85221	71.38618
63	0.13046	9.63655	94.94470	67.56497
64	0.13737	9.16114	93.74338	71.40611

TABLE 3.e

SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

5 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES IN U.S. OIL OPERATIONS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08355	9.36785	82.90200	42.32160
51	0.07420	9.51567	83.41742	30.44771
52	0.08446	10.17870	86.84527	33.71422
53	0.09152	10.71899	91.24928	45.99362
54	0.09534	11.05722	92.14406	53.90330
55	0.10299	10.59837	94.65900	62.16321
56	0.11553	10.26960	94.97721	62.45404
57	0.12533	10.25141	95.13697	64.20573
58	0.12412	10.85791	97.60888	78.31571
59	0.11999	10.59177	94.60995	67.54958
60	0.12590	10.71848	96.30232	72.65236
61	0.12660	10.28824	93.88039	67.15642
62	0.13372	10.33249	96.68177	72.77117
63	0.13070	9.78527	95.87997	69.12644
64	0.13759	9.29991	94.61608	72.86313

TABLE 3.f

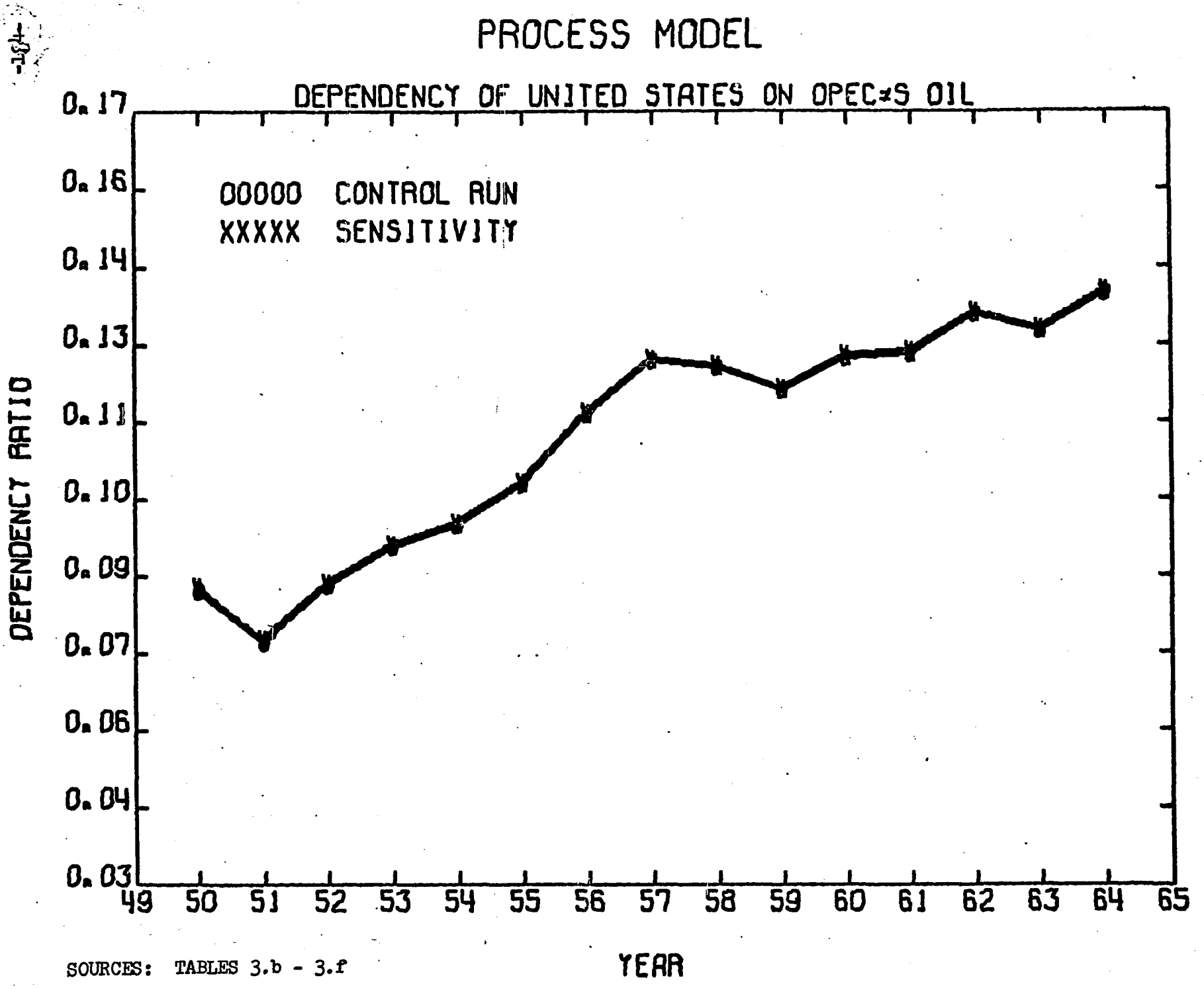
SIMULATED RESULTS OF THE PROCESS MODEL

RELATIVE DEPENDENCY AND BARGAINING POWER

10 PER CENT YEARLY INCREASE IN CAPITAL EXPENDITURES IN U.S. OIL OPERATIONS

YEAR	DEPENDENCY OF U.S. ON OPEC'S OIL	DEPENDENCY OF EUROPE ON OPEC'S OIL	DEPENDENCY OF OIL COMP. ON OPEC'S OIL	BARGAINING POWER OF OPEC VS. OIL COMPANY
50	0.08409	9.70484	85.02128	45.85984
51	0.07468	9.81978	85.32996	33.64079
52	0.08487	10.43525	88.45869	36.40789
53	0.09190	10.95870	92.75679	48.51049
54	0.09569	11.27562	93.51755	56.19642
55	0.10334	10.81557	96.02492	64.44369
56	0.11587	10.47925	96.29569	64.65529
57	0.12566	10.45875	96.44087	66.38266
58	0.12451	11.09845	99.12159	80.84126
59	0.12037	10.83154	96.11786	70.06712
60	0.12630	10.96564	97.85666	75.24741
61	0.12703	10.55490	95.55739	69.95626
62	0.13410	10.57232	98.19007	75.28935
63	0.13114	10.05567	97.58045	71.96549
64	0.13800	9.55221	96.20281	75.51225

FIGURE 11.a



SOURCES: TABLES 3.b - 3.f

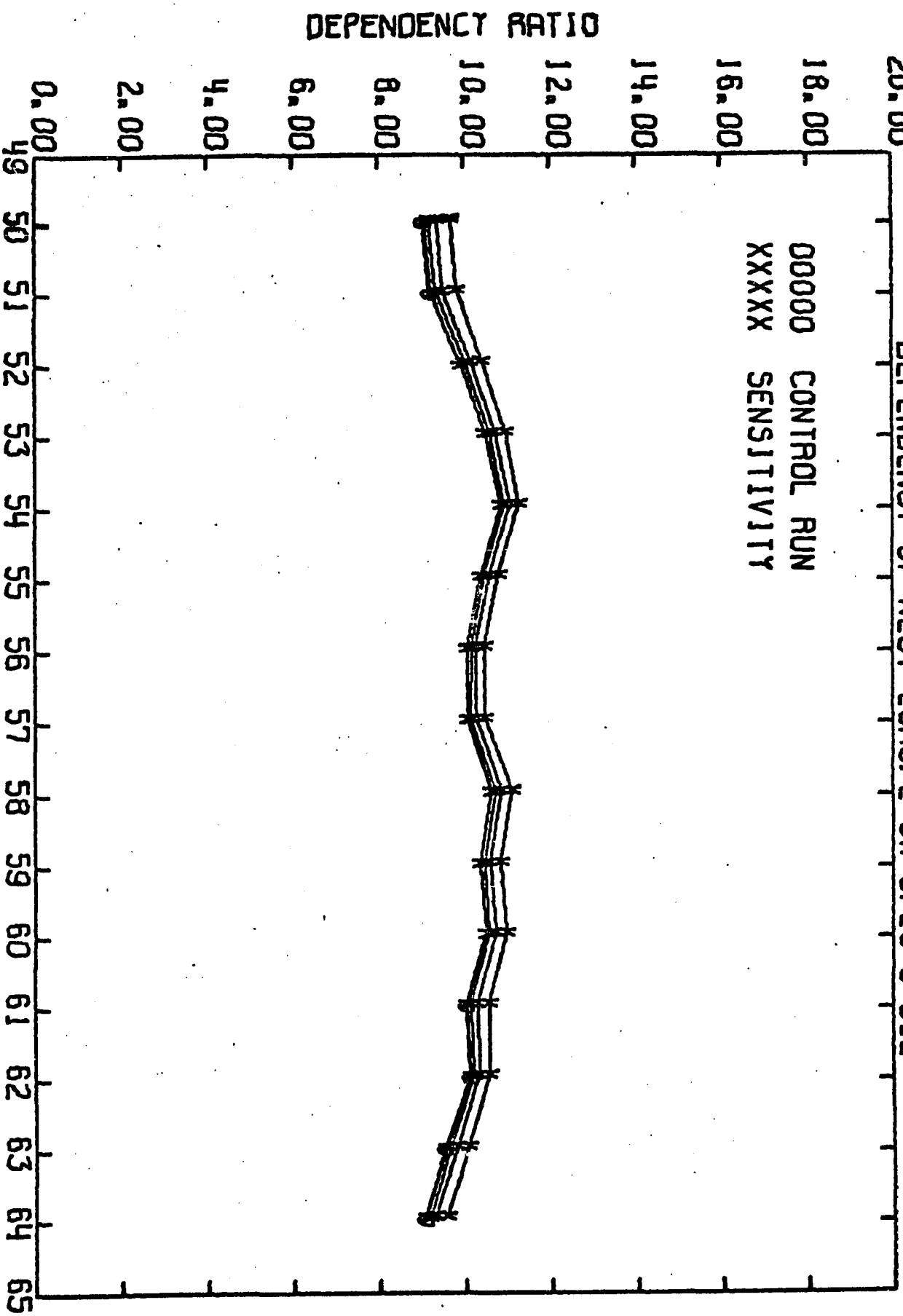


FIGURE 11.b

SOURCES: TABLES 3.b - 3.f

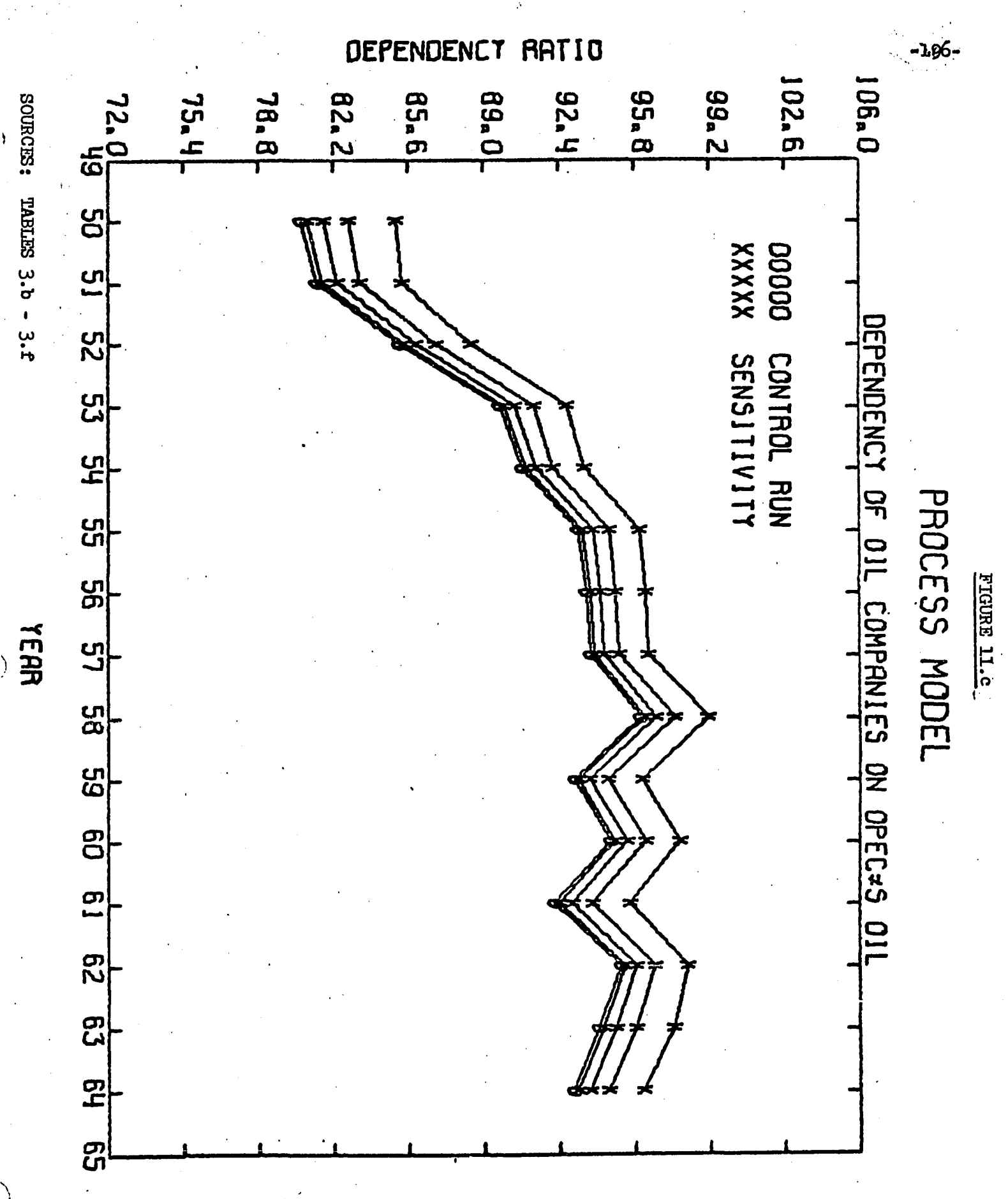
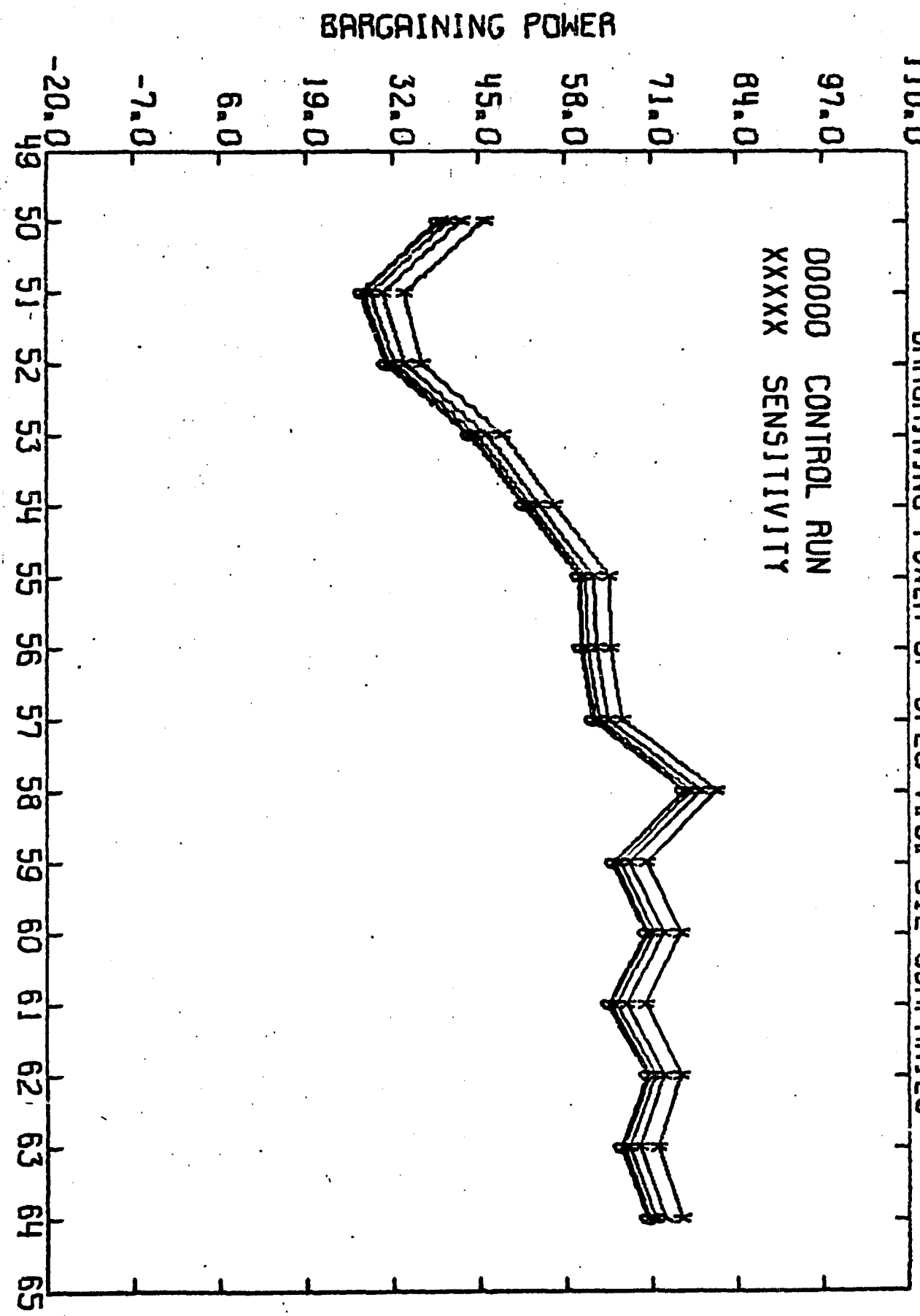


FIGURE II.c

SOURCES: TABLES 3.b - 3.f



PROCESS MODEL

FIGURE 11.d

SOURCES: TABLES 3.b - 3.f

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