Estimating U.S. Crude Oil Resources: Organizational Interests, Political Economy, and Historical Change

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ESTIMATING U.S. CRUDE OIL RESOURCES

Organizational Interests, Political Economy, and Historical Change

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Resource estimates are generally assumed to be the direct product of geological and engineering information. Historical analysis, using a perspective suggested by the sociology of science, demonstrates that social factors influence the magnitude and variation among resource estimates made during the same historical period. In terms of magnitude and variation, three chronological patterns in the estimates of United States crude oil resources can be discerned, and it is argued (1) that each pattern reflects the ideological orientation present at that time, and (2) that changes from one ideological orientation to another can be traced to changes in the political-economic environment of the oil industry.

> We encourage many of our distinguished colleagues to periodically make estimates of how much oil is left and we find these estimates extremely interesting and helpful and they make good dinner conversation [Hedburg, 1963].

Dr. Hedberg's comment points out the essential paradox in all estimates of undiscovered oil and gas; the estimates are of massive importance, especially in attempts to formulate a reasoned scenario of alternative energy futures (see Epple, 1975; Kim and Thompson, 1978; Landsberg and Arrow, 1979), yet lack of reliability among the estimates makes their value for policy planning highly questionable. Indeed, as Wildavsky and Tenenbaum (1981) have recently shown, the use of resource estimates in the formulation of public policy is a highly politicized affair.

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Unlike policy-oriented research, which treats the resource estimate as a technical input into the policy-making process, this article treats the resource estimate as a dependent variable. It will be argued that much of the variation in resource estimates can be accounted for by social factors, in particular political-economic and ideologic factors, that systematically influence the estimation process.[1] This position, suggested by the new sociology of science (Barnes, 1974; Bloor, 1976; Mulkay, 1979; Collins, 1981), holds that resource estimates can no longer be viewed as a simple function of the amount of oil or gas remaining in the ground, but must be viewed as a complex function including both scientific and nonscientific factors. As a result, the estimates may appear unreliable when compared with one another, but they are unreliable in a reliable manner.[2]

Specifically, the lack of reliability among these estimates does not come solely from differences in the classification or methodology utilized by the various estimators. These factors can generate variability (Ascher, 1978), but they do not determine it in the manner that the estimators believe. The differences among the estimates result largely from the variety of assumptions that underpin the classifications and methodologies utilized. The probability of specific assumptions being used, however, is closely tied to industry and public opinion about the future supply of oil. As such, the use of particular assumptions reflects the conventional wisdom of a historical period.

Resource estimators view differences in classificatory schema as one of the major villains accounting for the lack of agreement among their estimates. This view, although not unfounded, is overstated; a careful attention to detail can avoid most classificatory problems.[3] To facilitate comparison I deal here only with estimates of ultimately recoverable reserves (i.e., resources). In addition, the comparison has been limited to the estimates

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made of crude oil existing in the United States.[4] Some of these estimates are not strictly comparable because they relate to different geographic areas. For example, some estimates include Alaska and offshore areas, while others do not. Unless otherwise noted, all estimates include both Alaska and the continental shelf regions. Other estimates are not strictly comparable because they are estimates of total liquid hydrocarbons rather than of crude oil. In these cases, following Hubbert (1962) and others, adjustment was made by computing crude oil as 85% of total liquid hydrocarbons. Other estimates are not strictly comparable because they refer to remaining resources (i.e., they exclude past production). In these cases adjustment was made by adding the amount of past production to the estimate. Figures published by the American Petroleum Institute (1981) were used to compute the cumulative production. Other estimates are not strictly comparable because they differ in the level of cumulative recovery that is assumed. In these cases adjustment was made to a 40% cumulative recovery factor.[5] In short, a variety of controls have been implemented to assure that the various estimates are essentially comparable. The most serious distortion results from an inability to control for the difference in geographic area covered by the estimates. The magnitude of variation that exists among estimates which refer to the same geographic area, however, mitigates against the suggestion that this factor accounts for the majority of variation examined here.

The following argument consists of two distinct parts. The first is a chronological presentation of the data. It will be shown that the estimates of crude oil resources in the United States can be lumped into three chronological periods on the basis of the magnitude and variation among resource estimates made in the same year. The second part consists of a social-historical interpretation of the factors that gave rise to these various periods. It will be argued that the characteristics of the estimates of a particular historical period reflect the political-economic environment of the oil industry at that time because the environment influences the prevailing ideology of the industry and, in turn, the subjective judgment of estimators.[6]

THE HISTORY OF A CONTROVERSY

Table 1 presents all of the publically available, authoritative estimates of U.S. crude oil resources made between 1942 and 1978. As can be seen from an examination of Figure 1, these estimates fall into a distinctive pattern. Throughout the period under examination there exists a continuous sequence of low estimates, estimates that rise slightly through time as the amount

TABLE 1
Estimates of U.S. Crude Oil Resources, 1942-1978

Date	Estimator	Geographical Area (1)	Estimate (barrels)
1942	Pratt	C	100 x 10^9
1945	Pratt	C	100
1948	Weeks	C	110
1950	(2)	C	140
1952	Schultz	C	170
1955	(2)	C	140
1956	Pratt	C	145
	Hubbert	C, S	150
	Pogue and Hill	C, S	165
	Knebel	C, S	173
	U. S. Department of Interior	C, S	300
1957	Oil and Gas Journal, Company A	U	150
	Company B	U	300
	Company C	U	200
	Company D	U	300
	Company E	U	350
	Company F	U	325
	Hill, Hammer and Winger	C, S	250
1958	Oil and Gas Journal	U	300
	Weeks	C, S	204
	Miller	C, S	275
	Davis	C, S	165
	Netschert	C, S, A	372
1959	Weeks	C, S	391
1961	Averitt	C, S, A	425
1962	Hubbert	C, S	175
	Moore	C, S, A	364
	National Fuels and Energy Study	C, S, A	450
	Zapp	C, S, A	590
1964	McAfee and Davis	C, S, A	275
1965	McKelvey and Duncan	C, S, A	360
	Hendricks	C, S, A	400
1966	Hubbert	C, S	170
	Link	C, S, A	240
	Moore	C, S, A	425
	Hendricks and Schweinfurth	C, S, A	500
1967	Hubbert	C, S	170
	Ryman	C, S, A	200

(Continued)

TABLE 1 (Continued)

1968	Elliot and Linden	C, S, A	450
1969	Hubbert	C, S, A	190
	Schweinfurth	C, S, A	450
1970	Arps, Mortanda and Smith	C, S	165
	National Petroleum Council	C, S, A	291
	Moore	C, S, A	353
1971	Hubbert	C, S, A	200
	Cram	C, S, A	349
1972	National Petroleum Council	C, S, A	324
	U. S. Department of Interior	C, S, A	550
	Theobald	C, S, A	578
1973	Hubbert	C, S, A	200
1974	Hubbert	C, S, A	213
	Moody	C, S, A	230
	Jodry	C, S, A	235
	Berg, Calhoun and Whiting	C, S, A	400
	McKelvey	C, S, A	440
	Ford Foundation	U	628
1975	Moody and Geiger	C, S, A	236
	Resource Appraisal Group	C, S, A	243
	Miller	C, S, A	250
	National Academy of Science	C, S, A	258
1976	Exxon	C, S, A	245
1978	Nehring	C, S, A	240

(1) Geographical area codes:

A Alaska
C Continental United States
S Continental shelves
U United States, unspecified or undetermined as to exact area

(2) Unreferenced estimates, cited in Ascher (1978).

of proved reserves and past production increases. Beginning in 1957 and continuing through 1973, however, there exist a number of considerably higher estimates. Thus, the criteria of magnitude and variation among estimates made in the same year define three historical periods: 1940-1956, 1957-1973, and 1974-1978. Structural changes appear to have occurred in 1956 and 1973.[7]

Several additional facts must be noted before attempting to explicate the patterns shown in Figure 1. First, no true consensus has emerged about the best method for estimating undiscovered resources. Indeed, methodologies have increased in number as resource estimation has become more important (Grenon, 1975; Haun, 1975). Second, the later estimates of those individuals who produced estimates in both the first and second periods (e.g., Weeks, Hill) are higher than their earlier estimates. The exception to this trend is Hubbert, who has made essentially consistent

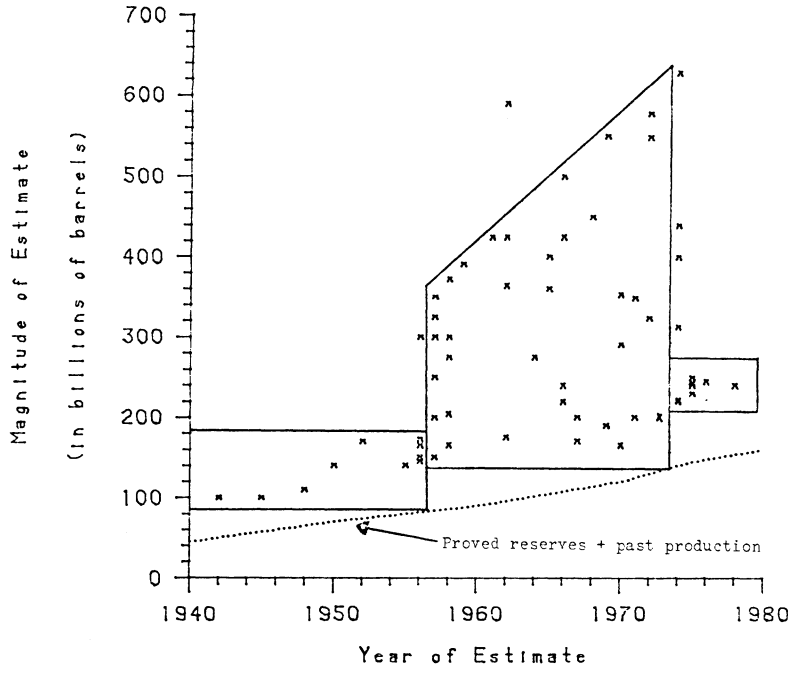

Figure 1: Historical Periods in the Estimation of U.S. Crude Oil Resources

estimates for a period of nearly thirty years. Third, major methodological disputes have arisen at three points: (1) at the transition from the first period to the second (Davis, 1958; Oil and Gas Journal, 1957, 1958), (2) in the middle of the second period, when Hubbert failed to revise his estimate upward (Hubbert, 1965, 1966; Ryan, 1965, 1966), and (3) at the transition from the second period to the third period (West, 1974; Gillette, 1974). Fourth, and most noteworthy for the substance of the argument presented here, these methodological disputes reflect differences in world view and are intimately tied to the nature of the assumptions embedded in the estimation technique. To illustrate this point, two estimates that have generated a considerable amount of controversy will be examined (see Bowden, 1982, for an expanded treatment).

Zapp (1962) postulated that the exploration for petroleum in the United States would not be completed until exploratory wells with an average density of one well per each two square miles had been drilled either to the basement rock of the basin or to a depth of 20,000 feet in all the potential petroleum-bearing basins. He estimated that to drill this pattern of wells in all the necessary areas of the continental United States and the adjacent continental shelves would require about 5 billion feet of exploratory drilling. Zapp also argued that during recent decades there had been no decline in the amount of oil found per exploratory foot of drilling. His 1962 estimate was based upon 1.1 billion feet of cumulative drilling and cumulative discoveries of 130 billion barrels, yielding an average of 118 barrels per foot of exploratory drilling. If the same rate of recovery held for the entire 5 billion feet of exploratory drilling, then the ultimate recovery would be 590 billion barrels.

Zapp's methodology involves an assumption that must be regarded as optimistic.[8] He assumed that future oil exploration would continue to yield the same rate of return per foot of exploratory drilling as had occurred previously. As Hubbert (1973: 44-48) has shown, this relationship has not continued; the rate of return per foot of drilling has declined over time. In essence, Zapp presumed a random discovery model; the future returns of oil can be extrapolated from the past because past discoveries are a representative sample of all discoveries. The problem with this model is that exploration geologists are paid high salaries precisely because they can direct the exploration process away from a random search; most of the world's oil is located in giant and super-giant fields (Nehring, 1978), which are usually located fairly early in the exploration history of an area.

Hubbert's estimation technique is based upon the statistical extrapolation of past production trends and is not dependent at all upon geological information. In essence, Hubbert (1962) applied the life cycle concept to the production life of the petroleum industry and argued that the exploitation history of any given region must begin at zero, undergo a period of more or less continuous increase, reach a culmination point and then

decline, eventually reaching a zero rate of production. He further reasoned that the amount of producton before the time of peak production would equal approximately half of the total production. Thus, by estimating the year of peak production and the cumulative production to that point, Hubbert was able to arrive at a figure for the total resources that would be recovered during the entire life cycle of the industry.

While Zapp's methodology can justifiably be called optimistic, Hubbert's can justifiably be called pessimistic. Not only does his method emphasize the inherent finiteness of the available resources, it also conveys a ponderous black-box determinism. Even though Hubbert does not identify the factors that account for his determinism, he expects us to accept the fact that we cannot influence the process in a manner that would alter the outcome.

To summarize, the estimates of crude oil resources remaining in the United States can be categorized into three chronological groups on the basis of the magnitude and variation among estimates made at approximately the same time. Figure 1 presents these estimates as divided into such groups. The first period, from 1942 until 1956, is marked by the emergence of well-thoughtout methodologies for generating resource estimates and by increased industry interest in such estimates. The estimates themselves were characterized by both a methodological similarity and a relatively high degree of consensus.

The second period, beginning in 1957 and running through 1973, is characterized by both an increasing variance between the estimates made in a given year and an overall tendency toward higher estimates. In addition, a wider variety of estimation techniques were utilized. All of these factors stand in marked contrast to the characteristics of the first period.

The third period, beginning in 1974 and running through 1978, is characterized by a renewed consistency in the magnitude of the estimates of the existing U.S. crude oil resources. Thus, recent estimates are both lower and show less variation than those of the second period. It is important to note, however, that the variety of methods employed in resource estimation has not diminished in the present period.

Particular note should be taken of the appearance of methodological arguments among the estimators. These are important because geologists tend to see methodological differences as the primary reason for the discrepancies between their estimates. The nature and timing of these debates adds additional credence to the boundaries that have been established for the periods, and suggests that a change in world view accompanies the transition between periods. The traditional rationale advanced by estimators to explicate the differences in their estimates does not account for the facts as they exist. If an increase in methodological diversity accounted for the growing inconsistency among the estimates that characterized the period between 1956 and 1974, then how does one account for the consistency that has emerged since 1974 without suggesting that the methods have become more standardized? An alternative explanation that avoids the logical paradox embodied in the methodological differences account is examined in the following section.

IDEOLOGY, POLITICAL ECONOMY, AND HISTORICAL CHANGE

Structural factors related to the political economy of the oil industry, operating through the intervening variable of industry ideology, can account for both the character of resource estimates within a particular period and the change in character between periods. Implicit in this argument is the suggestion that ideology and political economy, to a greater extent than methodology, account for the historical pattern of resource estimates. Since the causal connection between such social aspects of the environment and the pattern of resource estimates is not obvious, the nature of this connection must first be delineated. Two aspects are involved: (1) structural factors in the political economy of the oil industry, and (2) the relationship between the structural factors of political economy, the ideology of the oil industry about the future availability of oil, and the exercise of subjective judgment in the estimation process. It will be argued here that the interaction of these structural factors is responsible for the

industry's conventional wisdom about the future availability of oil, and that this ideology in turn influences the exercise of subjective judgment in the estimation process.

Tanzier (1969) has noted several structural factors that influence the political economy of the international oil industry: (1) the international oil corporations, (2) the Western home governments of the companies, and (3) the oil-exporting underdeveloped countries. Other important structural factors include the current supply situation and the trend in U.S. proven reserve additions.

The international oil companies can be lumped into two classes: the seven major vertically integrated international oil companies, and the thirty or more international minors. All these companies share the basic aim of profit maximization, but there exist important differences between the two classes. The majors are integrated (i.e., they possess production, refining, and marketing facilities) and collectively dominate access to the world's low-cost oil resources. The minors have shown considerable success in finding low-cost oil, but due to a lack of refining and marketing facilities, have been unable to gracefully fit this oil into the world market.

Most of the major Western powers have at least one international oil company headquartered in their country. The specific aims of these governments are: (1) to ensure the availability of energy supply, (2) to minimize the negative impact or maximize the positive impact of oil on their international balance of payments, and (3) to provide support for those international oil companies headquartered within that country.

The major role of the oil-exporting underdeveloped countries involves placing pressure on the international oil companies for larger and larger shares of the oil revenues. However, several factors mitigate against the nationalization of international oil company property within oil-exporting underdeveloped countries: (1) no single oil-exporting country dominates the international oil trade, (2) each of the majors can obtain large quantities of oil from more than one of the exporting countries, (3) the oil sector of the economy has traditionally been isolated from the rest of the exporting country's economy (although this

has changed considerably in the last decade), and (4) the oil-exporting governments are either directly or indirectly dependent upon the Western nations for maintaining their power. Short of nationalization, the exporting countries have attempted to increase their take from the oil revenues by pressuring for increased production, higher prices, a greater share of the revenues, and increased participation in the industry by indigenous corporations.

While the specific ideological expressions of the interactions among these structural factors will be elaborated later, my argument here is that discrepencies among the resource estimates result primarily from the influence of social factors that affect the exercise of subjective judgment within the context of structural constraints on the operation of the oil firms. Subjective judgment enters the estimation process at two points. First, the particular method chosen to estimate the amount of undiscovered oil in an area embodies certain assumptions (Ascher, 1978). Selection of one estimation technique as opposed to another implies endorsement of the assumptions contained within that technique. Thus, utilization of Zapp's method implies endorsement of the optimistic view that oil will continue to be found at the same average rate of return per foot of exploratory drilling that has characterized the industry in the past. Alternatively, utilization of Hubbert's method implies endorsement of the pessimistic view that natural resources are finite, will eventually run out, and that changes in economics and technology have little affect upon the length of time until the resources run out.

Second, subjective judgment enters the process when estimators are allowed to exercise considerable judgment in the selection of criteria and the classification of data prior to the application of the estimation technique (Robinson, 1963). This problem is especially evident in the method of geological analogy utilized by Weeks. Moody and Geiger (1975) reported Mobil Oil's inability to predict production on the basis of an analysis utilizing 160 geological parameters. Thus, it is unlikely that Weeks' much less sophisticated attempt could yield objective results; the parameters he attempts to interrelate in his classification of geologically similar basins interact in much too complex a fashion

to allow accurate application of this method. An extreme example of the operation of subjective judgment in the selection of criteria is found by comparing Zapp (1962) and Hendricks (1965). Zapp argued that future oil will be discovered at the same average rate per foot of exploratory drilling as in the past. Hendricks, with virtually no explanation of the change, applied Zapp's methodology but assumed that the discovery index of future oil would be only one half that of oil already found.

The exercise of subjective judgment, however, is a constrained process, which takes place within a social milieu that definitely restricts and may partially control such judgments. Ideology within the oil industry (i.e., the existing conventional wisdom) about the future availability of oil is the primary factor constraining the exercise of subjective judgment in the estimation process. Thus, the three historical patterns of relations among the resource estimates that were identified in the previous section can be seen as the product of three distinct ideological/political-economic environments.[9] After examining the connection between each social environment and its resultant pattern of resource estimates, a brief historical analysis will be provided to explicate the transition from one ideological/political-economic environment to another.

THE OIL INDUSTRY FROM WORLD WAR II UNTIL 1956

During this period the United States supply-and-demand situation was characterized by a general glut. The end of the war relieved some of the export pressures on the U.S. oil industry, although it continued to export considerable amounts (Stoff, 1980). Growing demand within the United States and the use of conservation laws to control production enabled the corporations to effectively balance supply and demand (Darmstadter and Landsberg, 1976; Nash, 1968; Sampson, 1975). Internationally, the Soviet Union was not involved in the export of petroleum. Thus, the period was relatively free of the tensions that characterize superpower competition for the support of less developed

countries (Hartshorn, 1967). In addition, there was a growing comprehension that the center of oil production was shifting from the United States to the Middle East.

Despite the relative abundance of supply to quench the growing U.S. demand for oil, the U.S. government was actively involved in measures aimed at ensuring a continued supply. These involved governmental intrusion into the industry both nationally (e.g., in attempts to establish a national oil company), and internationally (e.g., in attempts to negotiate an Anglo-American Oil Agreement) (Stoff, 1980). Producing country governments in the Third World were willing to sign long-term concessions primarily with the major oil companies, thus providing a relatively stable source of future crude oil supply (Vernon, 1976; Sampson, 1975; Krueger, 1975; Blair, 1976). Aspects of the political environment, most notably the nationalization of the Iranian oil industry by Mossadeq, prevented the companies from viewing the foreign sources of supply as completely secure. Within the industry intratype competition prevailed over intertype competition, especially in the international market. As a result, the industry was largely dominated by the actions of the seven largest oil companies (Sampson, 1975; Blair, 1976). In short, the political economy of the U.S. oil industry at this time was characterized by (1) a continuing ability to provide for the oil demand within the United States, (2) a fear of government intervention and regulation, (3) a reasonably secure source of foreign oil, and (4) a lack of competition within the industry.

Ideologically, the U.S. oil industry was sure of their ability to provide for the future needs of the country. This consensus of industry opinion arose largely as the result of an influential report by the Independent Petroleum Association of America (IPAA, 1952). Although this report did not make an estimate of the remaining resources, it did more to influence the later pattern of resource estimates than any other single publication. Its effect was felt in two major ways: It justified the optimistic ideology that was to characterize the industry until 1973, and it provided the rationale for the estimation procedure that was to produce most

of the later high estimates (i.e., that of Zapp, 1962). The IPAA report's justification of an optimistic resource future was based upon three lines of evidence. First, the report argued that it was illogical to believe that the United States was running out of oil because such suggestions had been advanced in the past and had proven false (see Table 2). Second, U.S. oil production was at an all time high in 1952 and continuing to increase. Third, the magnitude of U.S. proven reserves was greater in 1952 than at any previous point in history. These lines of evidence were buttressed with data suggesting that the oil industry showed a consistency of performance that would allow the linear extrapolation of historical trends into the future. In particular, the report sought to establish the existence of a correlation between drilling activity and the discovery of new reserves. This correlation was accepted by the United States Geological Survey (USGS) and formed the basis of many of their later estimates. In addition to these explicit effects, the report also had a major implicit effect. The tone of the report implied an overwhelming faith in the progress of science and technology; faith that these forces would be able to overcome any obstacles that man or earth may put in the way of the flow of natural resources.

This poses an interesting problem: Why were the estimates of this period low, in relation to those of the following period, if the industry ideology was optimistic? Four factors can be advanced to account for this apparent anomaly. First, the government statements made during and after the war had created a fear of shortage among the public (Stoff, 1980). Second, despite the availability of supply, the industry was plagued with distribution problems resulting from the Iranian expropriation (1951-1954), the need to increase supply to the Far East during the Korean War, and the closure of the Suez Canal in 1956 (Jacoby, 1974). Third, the industry feared intervention and regulation by the U.S. government (Krueger, 1975; Stoff, 1980). Fourth, most industry estimators believed that the estimates they were making were conservative. As Weeks (1958: 432) noted, most resource estimates of this period were based upon extrapolation from the proven reserves, and thus "If the geologist's estimates of proved reserves are conservative, his predictions of the amount of oil still

TABLE 2
Oil Prophecies and Realities

Date	Prophecy	Reality
1866	Synthetics available if oil production should end (U.S. Revenue Commission)	In next 82 years the U.S. produced 37 billion bbls. with no need for synthetics
1885	Little or no chance for oil in California (U.S. Geological Survey)	8 billion bbls produced in California since that date with important new findings in 1948
1891	Little or no chance for oil in Kansas or Texas (U.S. Geological Survey)	14 billion bbls. produced in these two states since 1891
1908	Maximum future supply of 22.5 billion bbls. (U.S. Geological Survey)	35 billion bbls. produced since 1908, with 26.8 billion reserve proven and available on January 1, 1949
1914	Total future production only 5.7 billion bbls. (Official of U.S. Bureau of Mines)	34 billion bbls produced since 1914, or six times this prediction
1931	Must import as much foreign oil as possible to save domestic supply (Secretary of the Interior)	During next 8 years imports were discouraged and 14 billion bbls. were found in the U.S.
1939	U.S. oil supplies will last only 13 years (Radio broadcasts by Interior Department)	New Oil found since 1939 exceeds the 13 years supply known at that time
1947	Sufficient oil cannot be found in United States (Chief of Petroleum Division State Department)	4.3 billion bbls. found in 1948, the largest volume in history and twice U.S. consumption
1949	End of U.S. oil supply almost in sight (Secretary of the Interior)	Petroleum industry demonstrated ability to increase U.S. production by more than a million bbls. daily in the next five years

Adapted from: Independent Petroleum Association of America (1952), p. 7.

to be discovered . . . are likewise almost certain to be very conservative."

In short, the industry ideology of this period can best be classified as "restrained optimism." This restraint accounts for

the fact that the estimates of this period are lower than would be expected, given the nature of the ideological orientation of the period. If this interpretation is correct, then one would expect the estimates to rise with the removal of the restraints, which did occur as a number of forces came together following 1956. The most important of these forces was the resolution of the Iranian expropriation. The major oil companies were able to exclude Iranian oil from the market and to force the Iranian government to return the expropriated properties. Thus, the resolution signaled the establishment of unquestioned control by the major oil companies over the Middle East concessions (Sampson, 1975; Blair, 1976). Although the majors were establishing their dominance over the oil-exporting governments of the Middle East, they were also encountering an increase in competition resulting from the entry of independent oil companies into the Middle East (Jacoby, 1974; Sampson, 1975; Krueger, 1975). At the same time, there was a notable shift in government policy, the U.S. government removed itself from any attempts to regulate the industry and even stopped keeping an independent set of statistics on the industry (Nash, 1968; Stoff, 1980; Krueger, 1975). In other words, in 1956 a number of events and processes came together in a manner that led the political economy of the industry to an approximation of the free enterprise ideal to which the industry pays so much lip service; the government removed itself from the marketplace and the competition between companies increased, and the logistical problems posed for international distribution were resolved. As a result the restraints that had been in place were removed and many estimates of the following period were considerably higher.

THE OIL INDUSTRY FROM 1957 UNTIL 1973

A number of distinct trends characterized the supply and demand situation of this period, most notable of which was the large increase in the consumption of energy that characterized the entire world, especially prominent in the U.S. The increasing need for petroleum brought on by this trend was exacerbated by a

disproportionate increase in the use of oil (Penrose, 1970; Jacoby, 1974; Darmstadter and Landsberg, 1976). The combination of foreign tax credits and low production costs led to a geographic shift in which the Middle East became the focus of oil production (Krueger, 1975; Darmstadter and Landsberg, 1976). Increasing aggregate demand, declining U.S. reserve additions, environmental constraints on the use of coal, lags in the completion of nuclear plants, and infrequent leasings of exploration properties combined with the above trends to cause an increasing U.S. dependence upon imported oil (Darmstadter and Landsberg, 1976).

During this period the U.S. government assumed that multinational oil companies based in the United States could be trusted to act in the country's best interest. No effort was made to regulate the international petroleum industry (Krueger, 1975; Stoff, 1980). The government even gave up all attempts to maintain an independent data base. As a result, it was dependent upon information provided by the industry (Krueger, 1975). This situation arose as a political expedient; the U.S. government abdicated the responsibility for foreign relations with the Arab countries to the oil companies, which allowed the U.S. government to maintain a presence in the region while formally supporting Israel (Sampson, 1975). Similarly, U.S. government intervention in the U.S. petroleum industry was minimal during this period (Nash, 1968). OPEC was formed in 1960, and the OPEC countries gradually gained an enhanced bargaining position. Two main factors were responsible for this change. First, a growing number of companies were competing for oil. The entry of independents into the region also led to an increased vulnerability to pressures from the exporting countries because they were largely dependent upon sources of oil located in a single country and thus could not juggle their supply sources in the manner that the majors had done during the period of the Iranian expropriation of the early 1950s. Second, the OPEC countries increased their ability to gather and interpret the relevant information (Vernon, 1976). As a result, the oil exporting governments achieved an increased level of participation in the

industry (Krueger, 1975; Penrose, 1970; Sampson, 1975; Vernon, 1976). The oil industry was characterized by a major increase in the level of competition both nationally and internationally. Nationally, the increase resulted primarily from the aggressive marketing strategies of the independent companies (Allvine and Patterson, 1974). Internationally, the increase in intertype competition resulted from the entry of independents into the Middle East (Jacoby, 1974; Penrose, 1970; Vernon, 1976; Sampson, 1975). Thus, throughout much of this period the major oil companies faced the dual problems of declining market share and declining profits (Vernon, 1976). In addition, the Soviet Union was exporting both oil and socialism during much of the period (Hartshorn, 1967). In short, the political economy of this period was characterized by (1) the consistent ability of the industry to fulfill the growing U.S. demand for oil, (2) a lack of government involvement in the industry, (3) a secure source of foreign oil, and (4) intense competition within the industry. It should also be noted that the growth in U.S. proven crude oil reserves, which had characterized the industry from 1945 until 1956, leveled off between 1956 to 1970 and declined thereafter (Blair, 1976).

Ideologically, the industry of this period was unrestrainedly optimistic about the future availability of oil. Initially, this appears paradoxical when juxtaposed against the concurrent change in the discovery of new petroleum reserves within the United States. The explanation, however, is quite straightforward. Both the industry and the government had good reasons for assuring the public of the future availability of oil. For the industry the reasons were primarily financial; foreign tax credits and lower production costs in the Middle East had led to a decline in the profitability of the U.S. petroleum industry. Thus, the industry advanced large estimates of available petroleum resources as a means to justify the exclusion of foreign oil from the U.S. market and, thus, prevent a further decrease in the profitability of the industry. Largely as a result of the assurances, the U.S. government instituted an Oil Import Quota in 1957 (Blair, 1976). The government's reasons are equally clear. By the middle of the fifties the government had essentially abandoned

any attempt to regulate the petroleum industry. The abdication of government policy and planning in an area of such vital national interest could only be justified by convincing the public that enough resources existed within the United States to satisfy any conceivable conditions. The large estimates of remaining resources produced by the USGS during this period served such purpose. The terminology advocated by the USGS for classifying reserves and resources also fostered a belief in the abundance of U.S. petroleum resources (Cook, 1975). In general, the public of this period was unconcerned about the future availability of oil (the industry was able to meet the increasing demand while decreasing the cost in absolute dollar terms) and optimistic about the ability of technology and the human intellect to solve problems. In addition, the actual market conditions closely approximated the industry ideal of laissez faire capitalism; and the international sources of oil had remained stable despite the almost constant political turmoil within the Middle East.

Against this background of optimism, one major event successfully reoriented the entire world's attitude toward the future availability of petroleum. That event, of course, was the Arab Oil Embargo of 1973. Due to the increasing reliance upon imported oil, the U.S. companies were unable to provide the cushion of supply that they had previously been able to supply (Darmstadter and Landsberg, 1976; Jacoby, 1974). Although this was partially the result of a systematically induced supply shortage designed by the majors to squeeze out the independent producers and marketers in the United States (Allvine and Patterson, 1974), the major factor involved was the shift of control over production and pricing decisions from the major oil companies to the governments of the oil-exporting nations (Vernon, 1976; Sampson, 1975; Jacoby, 1974). It is noteworthy that the public did not blame the Arab governments for the supply shortages of heating oil and gasoline that the consumers were forced to endure. Only 7% of the American population blamed the Arab states for the energy crisis, compared to 34% who blamed the oil industry and 46% who blamed the U.S. government (Gallup Opinion Index, 1974). The inability of both the government and the industry to

maintain their optimistic estimates in the face of massive supply shortages and tremendous public outrage is not particularly surprising. It is important to note, however, that the major justification advanced by the OPEC countries for the curtailment of supply and the rise in prices was conservation; they claimed that the world was rapidly running out of petroleum. Thus, the OPEC nations claimed they actually were doing the world a favor by forcing the importing nations to come to grips with their dependence upon an oil-based economy.

THE OIL INDUSTRY FROM 1974 UNTIL 1978

Following the oil embargo a markedly different situation characterized the supply-and-demand situation. When political turmoil in the Middle East had previously created temporary problems, the major oil companies had been able to juggle their supplies and prevent any associated rise in prices. In 1973 they were unable to accomplish this and the price of oil rose dramatically (Blair, 1976). Initially, the demand for petroleum remained price-inelastic, but as the price continued to rise the Western consuming nations adjusted and demand leveled off. More important than changes in demand trends, however, was the control that OPEC governments now exerted over production decisions. Unlike the major oil companies that had preferred to take their profits through high volumes of sales, the OPEC governments preferred to sell smaller volumes of oil at higher prices (Sampson, 1975).

A massive shift in public opinion occurred as a result of the energy crisis of 1973. As a result, the U.S. government began to reassert its policy role in the oil industry (Krueger, 1975; Vernon, 1976). The government also began to collect independent data on industry behavior. Internationally, the energy crisis showed the petroleum exporting countries how much power they had. As a result, OPEC quickly came to exert almost absolute control over all production and pricing decisions that took place in a number of countries. The effect on the oil industry of this shift in power was not as great as one would have expected. Although a

number of independent producers got squeezed out of the market, the soaring profits that were realized by the major oil companies quickly led them to understand that industry control of the entire process from exploration to marketing is not necessary (Allvine and Patterson, 1974; Sampson, 1975; Vernon, 1976). Thus, the industry shifted its alliance from the consuming public to the governments of the oil-exporting countries (Sampson, 1975; Jacoby, 1974). In short, the political economy of this period was market by (1) an inability of the oil industry to guarantee supplies of crude oil to the West, (2) the reassertion of the policy and regulatory functions of the government, (3) the control of production and pricing decisions by the exporting governments, and (4) a decline in intertype competition and an increase in profitability within the industry.

These factors, combined with the fact that U.S. proven reserves had been falling since 1970, brought about a swift and profound change in the industry ideology toward the future availability of oil.[10] This shift took place in two phases. First, the industry experienced an initial pessimism resulting from the loss of control over production and pricing decisions. Second, as the companies began to realize massively increased profits and the opinion polls showed that the public blamed the oil companies for the shortages, the industry adopted OPEC's rhetoric of conservation. The rhetoric of conservation, however, is of little use if the estimates show that large quantities of crude oil remain within the United States. Thus, the political economic forces produced a situation in which lower estimates would be of practical value to the companies. Such ideological pessimism was also predominant in the government after 1974. The wrath incurred as a result of the energy crisis necessitated the reentry of the government into policy formulation and regulation of the U.S. oil industry. This was especially important since it was clear that U.S.-based companies could not be trusted to conduct U.S. foreign policy in the Middle East. The generation of lower estimates justified this move by the government back into the formulation of national resource policy. Thus, forces affecting both the oil industry and

the U.S. government after 1973 led to an ideological environment favoring lower resource estimates.

SUMMARY AND CONCLUSIONS

Periods characterized by specific types of resource estimates are associated with concomitant changes in the U.S. proven reserve figures. The period from 1945 until 1956 was characterized by increasing domestic petroleum reserves. This, along with other factors, led to the optimistic ideology that characterized the industry until 1974. Up until 1956, however, that ideology was restrained by political economic factors; distribution of the available supply was uncertain, and the economic environment did not correspond to the industry ideal of free enterprise. In 1956 two major changes took place; the growth of domestic reserves leveled off and the political economic constraints on the industry dissolved. As a result, both the industry and the government, although for different reasons, entered political-economic situations in which larger resource estimates could serve to justify their actions. Thus, the estimates of remaining U.S. oil resources notably increased over those of the preceding period. By 1970 the trend in domestic reserves had taken a downturn and the Oil Import Quota had been removed. The increasing dependence of the United States on imported oil was brought home to everyone by the energy crisis of 1973. This event caused a massive change in opinion among the industry, the government, and the public. Ideological pessimism, although carrying different meaning among the different groups, created an atmosphere in which lower resource estimates served to benefit everyone involved. Thus, in all three periods it appears that the prevailing political economy gave rise to an associated ideological environment within those companies employing the estimators which generated resource estimates in support of the current actions of the organization involved in the generation of the estimate. The primary factors determining the ideological environment appear to be (1) the state of proven domestic reserves, (2) the short-term supply situation, and (3) the extent to which the political

economy of the industry matches the industry ideal of free enterprise. When proven reserves are remaining stable or growing, short-term supply is assured, and the industrial economy approximates free enterprise, then large resource estimates are generated. Deviation from these conditions restrains the size of the estimates. Understanding how resource estimates are affected by political economic factors sheds new light on the basic of several past public controversies. Appreciation of the process is necessary for informed decision-making on certain future policy choices.

NOTES

1. As Barnes (1974: 125) has noted,

> Both descriptions and evaluations may be referred to as ideological, although the sense is slightly different in the two cases. In a nutshell, values are described as ideological, whereas descriptions or empirical claims are evaluated by the designation. A set of values or a professed ethical code associated with an occupation may be termed an ideology, perhaps because of its connection with the communally defined aims and purposes of the occupational group. This does not imply that the values are inadequate, unnatural, or wrong. When empirical claims are termed ideological, however, it is generally implied that they are incorrect, or at least ungrounded.

In this article the term ideology and its derivatives are used in the descriptive sense; they refer to an attribute of an occupation or organization.

2. I do not address the question of validity. The resource estimates examined here are "blue sky" estimates; the true value of the quantity is unknown. Thus, the estimates represent informed and methodologically sophisticated guesses. Undoubtedly, some of the estimates are more accurate than others. It would be presumptuous of me to pass such judgment, however, since all of the estimators involved are eminently more qualified for that task than I am.

3. For the purpose of this article I have adopted the conceptual schema advanced by Ion (1975: 3-4). The major terms in that scheme are defined as follows:

(1) *Resource Base:* The total amount of the energy source occurring in the world in commonly recognizable form. In the nonrenewable resources of the fossil fuels the amount of oil-in-place or gas-in-place is finite because the current rate of formation is infinitesimal.

(2) *Resource:* The total amount of the resource base estimated to be potentially recoverable for the benefit of man. This estimate is based on both knowledge and reasonable conjecture regarding location and potential recovery techniques, but is a very imprecise term. Another term for the same thing is *ultimately recoverable reserves.*

(3) *Reserves:* The total amount of the resource that can be defined as recoverable in stated terms of economic and operational feasibility. Whenever possible the degree of feasibility will be given by qualifying reserves as: *(A) Possible reserves:* The amount about which geological knowledge is insufficient to give any but the most vague recovery costing or indicate optimum recovery method, yet are still within

the range of possibility. This is again imprecise and dependent upon individual judgment. *(B) Probable reserves:* The amount about which geological and engineering information is insufficient for an explicit statement that it could be recovered under current economic and operating conditions but can be judged to become economically recoverable with only a slight increase in knowledge of either the deposit or operating techniques or both. *(C) Proved reserves:* The amount that is reasonably certain could be produced in the future under current economic and operational conditions from deposits established on known geological and engineering data.

These categories are listed in order of increasing feasibility, both economic and technical.

4. Examination of the estimates of natural gas remaining in the United States shows the same trends as described here. This can be partially accounted for as a result of the manner in which some of the estimates of natural gas resources are computed; a conversion factor is applied to the estimate of crude oil resources. Thus, the data sets are not completely independent. Crude oil was chosen as the subject for this analysis because it possesses the stronger data base. Despite the lack of total independence, analysis of the natural gas estimates lends additional credence to the interpretation presented in this analysis.

5. Cumulative recovery varies markedly from pool to pool depending upon geological conditions. At present the average cumulative recovery factor is about 30% (Ion, 1975). One can reasonably argue that the recovery factor represents one aspect of the forecasting process that is subjectively determined and, hence, affected by social factors. Thus, controlling for differences in recovery factor reduces some of the variation in the estimates. The fact that social factors appear as important as they do, given this conservative treatment of the data, strengthens the main contention of this study.

6. This article focuses upon the macro-level changes in ideological orientation and only alludes to the mechanism whereby such changes affect the subjective judgment of particular estimators. Bowden (1982) details the mechanism involved at the micro-level by examining the relationship between arguments among geologists over the methodological validity of particular estimation procedures and the world views embodied in the operating assumptions of those procedures. In essence, that paper argues that resource estimators are subject to the types of institutional constraints detailed by March and Simon (1958) and others. Thus, by controlling the premises of the decision-making process, the organization is able to influence the outcome of the estimation process. Thus, estimates made by individuals within organizations tend to support the policy desires of those organizations. This should not be taken to imply that the estimates are made in "bad faith" or are intentionally fudged, but to suggest that such estimates are subject to nonscientific forces not, at present, recognized. This, again, is a conservative position. It would be naive to assume that, given the massive amounts of money involved, estimators never consciously influence the estimation process in order to achieve results justifying company policies. An acceptable explanation of the variation in estimates, however, must account for the fact that the majority of estimates are made in good faith.

7. Careful readers will have noted that the breaks between periods, although distinct, are not completely clean: one high estimate was made in 1956 and several were made in 1974. Two lines of evidence can be adduced to account for these apparent anomalies. First, the dates refer to the date of publication and not necessarily to the date the estimate was made. Second, and more importantly, estimates are made by a variety of organizations that function in different organization environments and have differential access to the latest geophysical data. Thus, some organizations can be expected to react more quickly to

changes in this environment. Given these considerations the precision of the breaks is quite stunning.

8. The notions of optimism and pessimism carry a considerable weight in this analysis. They are meant to indicate both the relative magnitude of the estimate and an associated ideological orientation. They are not meant to imply judgment of the estimate in relation to some true value.

9. In the following analysis the political economy and ideology of a period have been treated as if they were essentially constant. This is a heuristic device; most of the characteristics involved are extremely fluid and are best conceptualized as part of an interacting process.

10. The decline in proven reserves indicates that production was outdistancing new discoveries. It is not clear, however, what caused this phenomenon. Some authors (e.g. Hubbert, 1974; Vernon, 1976) argue that the decline reflects the limitation of physical resources. Other authors (e.g., McKelvey, 1974; Simon, 1981) suggest that the decline merely reflects an economic slump in the U.S. oil industry resulting from a shift of capital and expertise to the Middle East. Both explanations remain plausible.

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