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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE FOG OF COMMERCE:
The Failure of Long-term Oil Market Forecasting

Michael C. Lynch
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Ken Oye, Director

MIT E38-648
292 Main Street, Cambridge, MA 02139

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FOREWORD AND ACKNOWLEDGEMENTS

This report represents a collection of observations and analysis on the subject of long-term oil market forecasting, parts of which have appeared in previous publications. The size of the subject makes it difficult to be exhaustive, (though that is a long-term goal of the author) and there remains significant amounts of data work to be done, particuarly as a more complete collection of forecasts is put together. However, the primary arguments are presented here in full.

Data Sources

Note that throughout the report, except where specifically noted, all prices are in 1990 U.S. dollars with the implicit price deflator for the gross national product used for conversion. All references to the U.S. Department of Energy's forecasts (referred to as DOE) are taken from the International Energy Outlook and its predecessors, the Annual Energy Outlook, for the years 1983-1986, and variously as volumes II or III of the Annual Report to Congress from 1978 to 1982. The year of the report originally lagged the publication date, so that the 1978 forecast volume was published in early 1979. In 1989, this was changed and the volume was labelled according to the year of its appearance, so that there is no volume labelled 1988. Throughout this report, references to the year of a DOE forecast refers to the year of its appearance, meaning that the 1978 to 1988 forecasts are from the volumes labelled t-1. (Thus, references here to the 1979 forecast are to that appearing in the 1978 Annual Report to Congress.) Except where noted, supply, demand and price data are from these reports. Thus, the refiner's acquisition cost of imported crude oil as reported in the International Energy Outlook is used for the actual price of oil, again, except where noted.

Please note that while certain forecasts and forecasters are repeatedly referred to, most notably DOE, this usually reflects the availability and detail of their forecast, not the fact that their work was in any way inferior to that done by most others. To provide a complete review of all forecasts, the great majority of which would closely resemble those presented here, would require a separate volume and, as will be shown in the report, DOE is in fact representative of the "conventional wisdom" or consensus.

Also, although some forecasts are continuous, depending on the forecaster, the variable and the source, often projections are given only for specific years, such as 1990, 2000, 2010, etc. In graphing a comparison of forecasts, the individual points were interpolated linearly in order to make them more legible.

Finally, one recurring problem in discussing future market behavior concerns the use of terms like "optimistic" and "pessimistic", since producers and consumers have different views of what is good or bad. Although precision in use will be attempted, note that the terms "bullish" "pessimistic" and "Malthusian" are used to refer to expectations of scarcity and higher prices. (Thus, being pessimistic about consumption refers to an expectation of higher consumption, not lower.) On the other hand, "bearish" "optimistic" and "Cornucopian" are used as indicative of expectations of resource abundance and stable or lower prices, at least in a relative sense.

Acknowledgements

Over the years, both in the initial development of this presentation and the preparation of the paper, a number of people have made various contributions. M. A. Adelman, Nazli Choucri, William Leffler, Marian Radetzki, and Robert Weiner have given me valuable insight, while Hillard Huntington, Edward Porter, and Leo Schrattzenholzer have graciously provided me with data. The contents of the paper, however, remain the responsibility of the author.

ABSTRACT

The prevailing consensus, or paradigm, in the oil industry for the past fifteen years has been that real oil prices would have to rise at several percent per year. A belief in the 'Hotelling Principle' was one reason for such expectation, as was the insistence that, given the finite nature of mineral resources, increasing scarcity and rising costs were inevitable for the petroleum industry.

In fact, these expectations have repeatedly incorrect, as prices have fallen for a decade and supply expectations have consistently proven too pessimistic. A careful examination of both the theory and evidence supporting the existing paradigm suggests that they are incorrect, or being exaggerated, and the price forecasts have been based largely on assumptions, not analysis. Throughout the past decade, the initial price, sales of oil by OPEC, and world oil demand have all varied enormously, as have future expectations for those variables. Yet the forecast rate of change in prices has been incredibly consistent, usually on the order of 3% per year, suggesting that it represents an exogenous assumption, not the result of analysis.

Thus, not only should oil and gas market forecasts be reevaluated, but all policy-making which relies on oil price expectations as an important input. Similarly, the results suggest that 'scientific' consensus does not, necessarily, act as an indicator of accuracy, and that analysis generally should be closely scrutinized for signs of bias.

THE FAILURE OF LONG-TERM OIL MARKET FORECASTING

"The object of the Author in the following pages has been to collect the most remarkable instances of those moral epidemics which have been excited, sometimes by one cause and sometimes by another, and to show how easily the masses have been led astray, and how imitative and gregarious men are, even in their infatuations and crimes." [Mackay 1932, p. xvii]

I. INTRODUCTION

A decade and a half ago, the question of the price and availability of oil was of such concern that the U.S. president launched a major initiative, referred to as "the moral equivalent of war" because, "[t]he oil and natural gas we rely on for 75 percent of our energy are simply running out." [New York Times 4/19/77, p. A24.] Now, although the oil market is largely ignored, the future price of oil remains an important input into many policy questions. For example, the Bush Administration's National Energy Strategy [DOE NES] argues that the rising price of oil will help hold down consumption and reduce pollution. Environmentalists assert that "oil supplies are finite" and "the end of the fossil-fuel age is in sight" to bolster arguments for conservation or renewable energies, [Flavin and Lenssen, 1990, p. 5] while the IPCC argues that global warming will be significantly enhanced, all else being equal, because of the need for massive coal use. [Takahashi 1992] And some worry that the nation won't be able to afford rising oil imports at higher prices.[1]

But the lack of attention to the oil forecasts themselves has led many to overlook the historical record of these expectations, which has been so bad that long-term oil market forecasting has often been described as virtually impossible. In fact, an entire cottage industry has sprung up devoted to collecting quotes on the difficulty of predicting the future, which forecasters trot out to exculpate themselves. Many organizations no longer circulate their forecasts in order to avoid criticism of their performance, while others have argued that, since long-term projections are not worthwhile, it is futile to make them. Of course, not making a projection equates to an implicit forecast of stability. Indeed, such a 'conservative' strategy would have resulted in enormous losses in the past decade.

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[1] For example, [Powers 1992] says that the "[f]ailure of the government to enact a practical National Energy Strategy (NES) is sending the U.S. economy speeding towards bankruptcy," according to his interpretation of a recent Office of Technology Assessment report.

There are many theoretical questions which an analysis of oil market forecasting can illuminate. For example, scientific consensus is often described as a meaningful basis on which to make policy, particularly with reference to the global warming controversy. [Gelb 1992] Additionally, one element of the debate over industrial policy concerns the relative degree of foresight possessed by the government versus the private sector, and the failure of foresight in this instance should be illuminating in that context. Finally, the failure of long-term oil market forecasting can serve as a case-study for both Herbert Simon's theory of bounded rationality and Thomas Kuhn's work on paradigm shifts, or scientific revolutions.

Thus, rather than simply note the poor forecasting record, it should be asked:

- **Why have forecasts been so wrong?** and
- **What does this tell us about not only current oil market forecasting, but consensus and insight more generally?**

I.A. Current Expectations

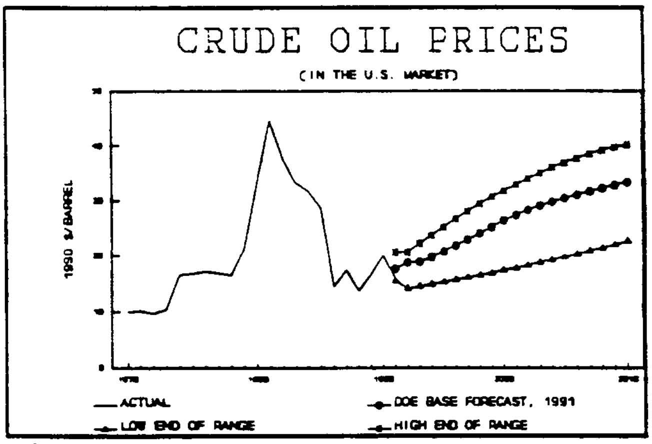

Figure 1-1
Source: [DOE IEO 1991]

As Figure 1-1 shows, the U.S. Department of Energy (DOE) is forecasting gradual price growth over the next two decades. The apparent gentle upsweep in prices, particularly compared to recent history, makes this forecast appear, if not conservative, then at least fairly moderate. (As we shall see, DOE's forecasting efforts very much reflect what could be called the "conventional wisdom" or consensus about oil prices.) However, comparing this projection with long-term historical oil prices, as shown in Figure 1-2, indicates that for most of the industry's history, prices, while sometimes volatile, have been much lower than either the post-1973 period or the levels currently being forecast!

Figure 1-3, from the current survey by the International Energy Workshop (IEW), indicates that most forecasters covered by the survey would agree with DOE's price expectations. Similarly, the computer models analyzed as part of Energy Modelling Forum #11 (EMF11) concurred that higher prices are all but inevitable. [EMF11 1991]

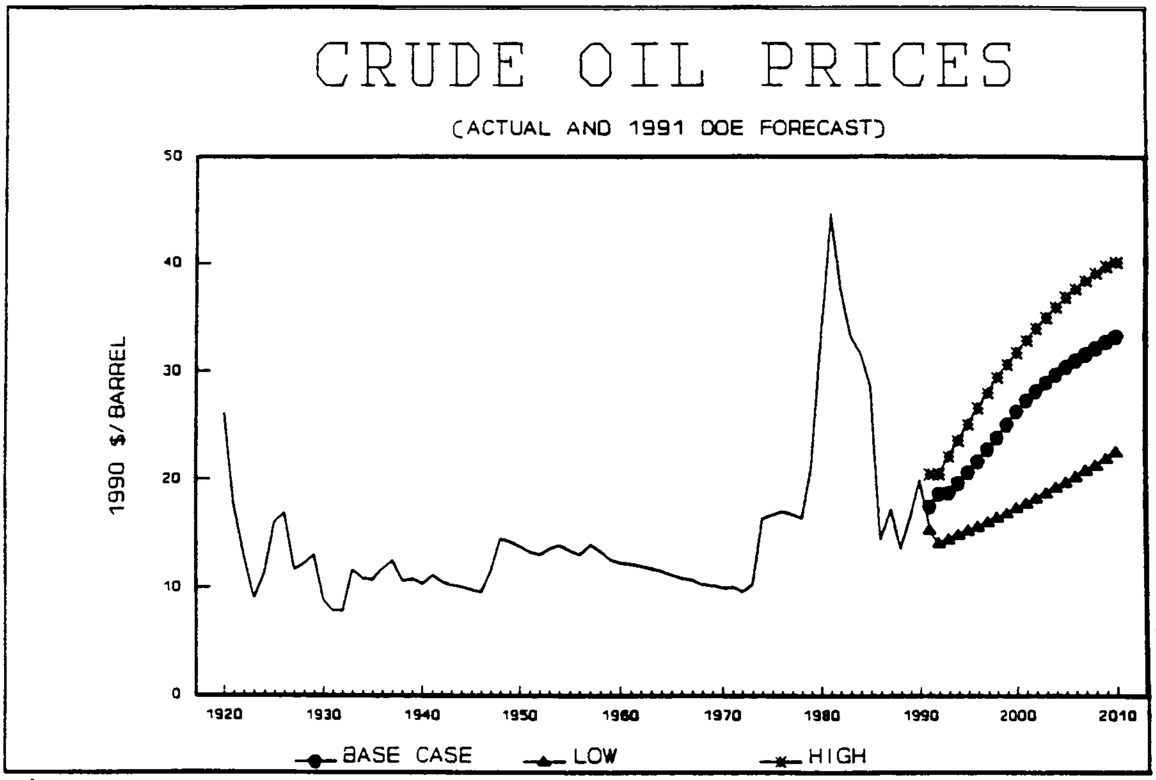

Figure 1-2
Sources: Forecast from [DOE IEO], prices from [DOC] and [DOE AER], and deflator from [ERP].

Clearly, the fact that prices have historically been lower than those projected does not prove that the forecast is incorrect. But it does suggest that a good explanation is needed to support such a forecast, and unfortunately, the presence of consensus on the issue has been of little value.

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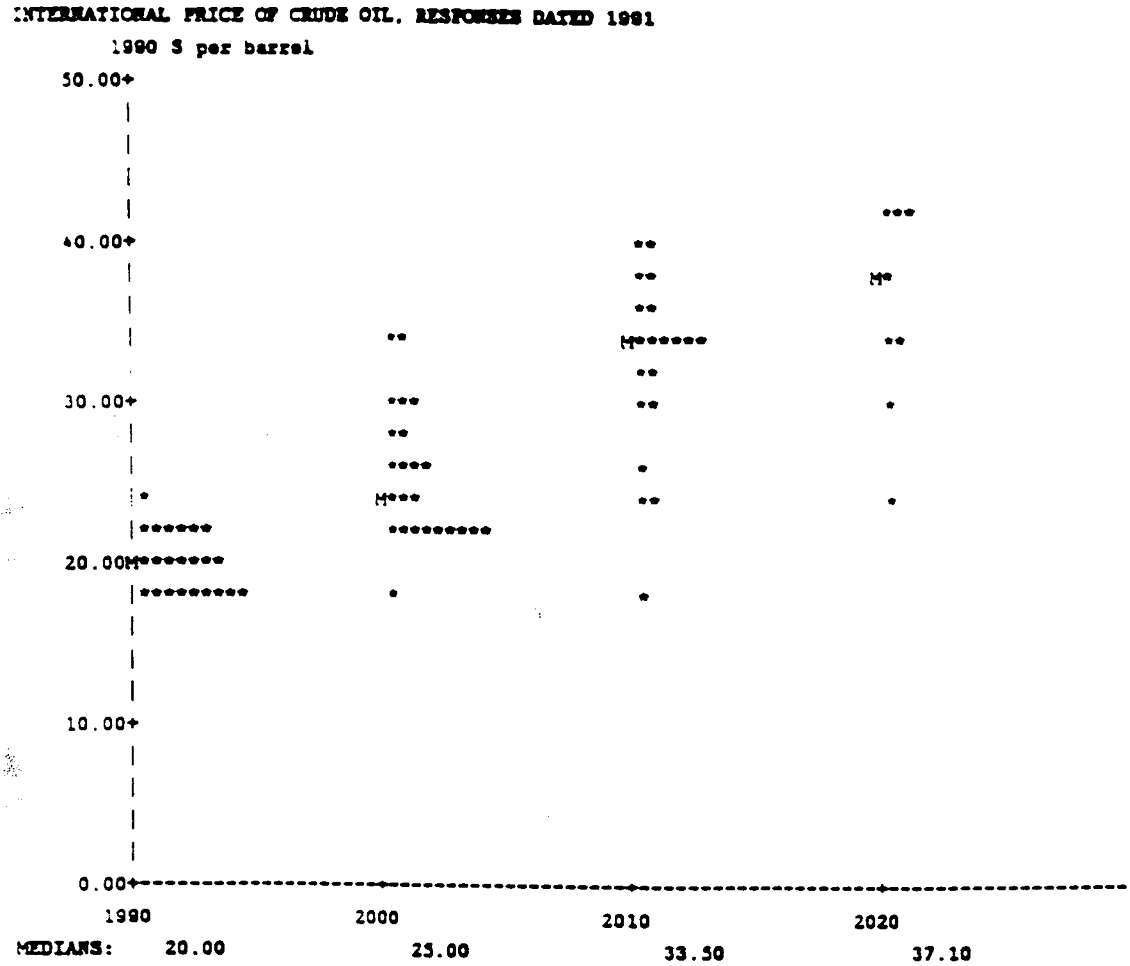

Figure 1-3
Source: [IEW]

II. THE ROLE OF CONSENSUS

> *"The moral, therefore, is that if a user is equally interested in many economic indicators then he will probably do best to use the consensus. This will minimize the risk of error."* The Economist, 7/27/91, p. 61.

> *"Anyone taken as an individual, is tolerably sensible and reasonable--as a member of a crowd, he at once becomes a blockhead...."*[2]

That there has been consensus for many years in oil market forecasting is not disputed. [Franssen 1978, p.5] referred to the "zeitgeist" or "the spirit of the time", while [CERA 1984] defined different periods or "vintages" of consensus about oil price expectations. The Delphi effect is a well-known phenomenon, where people exposed to surveys of forecasts, for instance, tend to change their own answers to bring them closer to the mean.[3]

Recently, scientific consensus has been a major factor in both the debate on global climate change and particularly the role of greenhouse gases, with proponents of emission-reducing policies citing the existing scientific consensus as reason to proceed immediately with actions such as carbon taxes, demand side management, and other environmentally friendly policies. But ten years ago, it was rare to find anyone in either Europe or America who didn't believe that the world was running out of oil or that prices must inevitably rise, even from the then-elevated levels.[4]

And in fact, the consensus proved to be wildly incorrect, a not unheard of occurrence, even in the physical sciences.[5] For example, for many centuries it was believed that a 10 pound weight would fall twice as fast as a 5 pound weight. This seems eminently logical, but is incorrect, as was demonstrated by Galileo.[6]

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[2] Schiller's dictum, cited by Bernard Baruch in the foreword to [Mackay 1932].

[3] At one EMF11 meeting, several modelers expressed relief that their results fell within the consensus, despite the fact that it had been previously noted that the outlier at EMF6, the IPE model, had the best forecast in the 1980s.

[4] Peter Odell of Erasmus University was the prominent European exception, and M. A. Adelman of M.I.T. another. See [Odell 1980] and [Adelman 1980] respectively.

[5] See [Kuhn 1970] for the way in which consensus exists around a scientific paradigm as well as the way in which paradigms (and consensus) are altered.

[6] Although it is now believed that Galileo did not, in fact, perform empirical observations.

II.A. Why is There Consensus?

Consensus in oil market expectations is partly due to a variety of strong psychological and institutional factors. The motivations to conform vary depending not only on the issue, but also on the status of the analyst. But both individuals (academic and consultants) and large organizations have a bias towards the consensus.

II.A.1. Independent Forecasters

> "*[We] are just doing [energy modeling] in our spare time.*" [Houthakker 1977, p. 120]

In the case of independent forecasters (consultants and academics), it is all but impossible to disagree with the consensus. The uncertainties about exogenous factors, like GNP growth rates and OPEC policies, make forecasting supply and demand difficult under the best of circumstances. Yet most individual analysts lack sufficient resources for both broad and deep analysis, so that the level of assumptions inherent in their forecasts is much higher than for large organizations. This leaves the forecaster open to criticism should he or she deviate from the conventional wisdom, as those disagreeing with a price projection are able to attack the areas where little or no analysis has been done.

Virtually everyone is vulnerable to such charges, providing a strong incentive not to vary from the consensus, rather like the oft-cited Japanese proverb about the nail which sticks up getting hammered down. Deviation from the consensus requires a public (if implicit) presumption of superiority over the great majority of forecasters, which is not only difficult psychologically, but can obviously be poor strategy.[7]

Thus, individuals analyzing complex systems like long-term oil markets not only are strongly motivated to adhere to the consensus, but their work is particularly vulnerable to bias because of the necessity of heavy reliance on assumptions.

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[7] If you are asked to pick a number from one to ten, and your competitor chooses eight, picking seven gives you the best chance of being closer to the number than your competitor. Thus, if you think prices will be flat, but everyone else argues they will increase, choosing the lowest level of increase will allow you the greatest probability of being closest to the correct amount.

II.A.2. Consensus in Large Organizations

> *"Over half the respondents [in the CIA] to the task force's survey said that forcing a product to conform to a view thought to be held by a manager higher up the chain of command occurs often enough to be of concern."*[8]

> *"Without looking up from his desk where he was writing, Mussolini asked: 'And what are the most dangerous gases, Ambassador?' 'Incense is the most lethal of all,' the ambassador replied, referring to incense as meaning praise or flattery."*[9]

The situation is different in a large organization, where analysis can contain both breadth and depth, notwithstanding the inherent uncertainties.[10] For one thing, it is always safer, from a bureaucratic point of view, to be with the crowd than against it. Additionally, should even an entire planning department disagree with the conventional wisdom, it must still convince others, from a board of directors to institutional investors, that its assessment is valid. And by definition, those outside the planning department do not really have time to perform their own assessment of the situation, and so, are more inclined to accept the consensus.

In effect, the reliance on consensus for planning serves as an example of the impact of Herbert Simon's 'satisficing', or compromising due to limited time for the acquisition and consideration of information. While it is certainly an overstatement to argue that, in the end, the amount of analysis going into a decision is limited to that which the most senior person can absorb, nonetheless, this does form a constraint.

II.B. The Power of Consensus: Short-term Oil Market Projections

In Figure 2-1, a summary of forecasts for change in OPEC production in the coming year is presented. The source is Petroleum Intelligence Weekly (PIW) which annually reports the anonymous results of a survey of 6-10 oil companies and 2-4 governmental forecasters. Additionally, the forecast from the U.S. Department of Energy's Short-Term Energy Outlook is added, although it may be redundant with one of PIW's governmental forecasters.

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[8] Central Intelligence Agency Director Robert Gates in NYT 3/28/92 p. A1. Such behavior was also attributed to Gates (see [NYT 9/19/91 A1]), but should be recognized as the norm, rather than the exception, and a function of human nature instead of a bureaucratic oddity.

[9] TVG 11/23/85 p. 21

[10] The fact that an organization is large does not mean that its oil market forecasting is not limited to a handful of analysts, or even an individual.

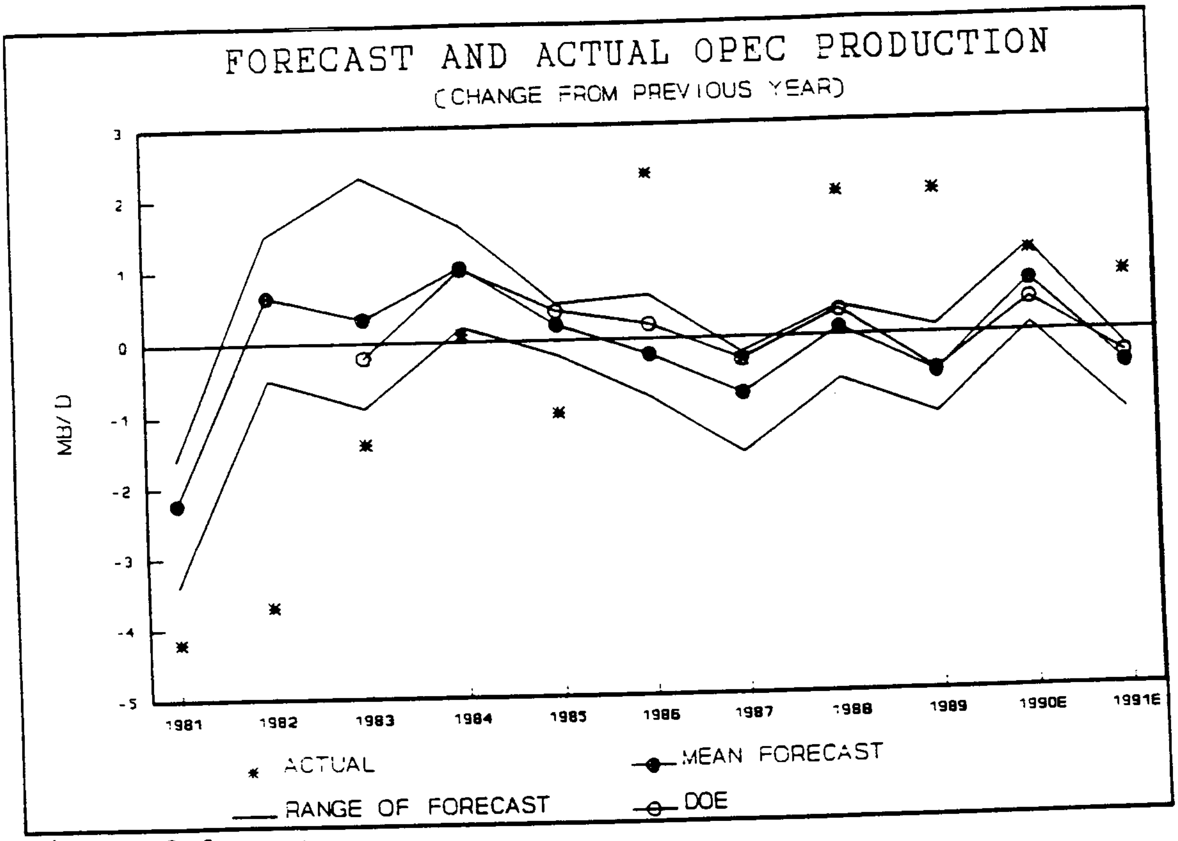

Figure 2-1
Source: Petroleum Intelligence Weekly, [DOE STEO]

A number of lessons can be drawn from this graph. First is the fact that these forecasts tend to be extremely conservative. The mean predicted change in OPEC production each year is very small, and changes little over the years, the noted exception being in the first year which came just after the oil price shock and during a worldwide recession. In fact, the actual changes observed are not only far more dramatic than the mean prediction, but usually well outside the highest and lowest forecasts (the solid lines). Too, it should be noted that the DOE forecast falls well within the group every year, and is usually close to the mean, bolstering the argument that DOE serves as a surrogate for the conventional wisdom.

Also interesting is the fact that, excepting 1981, there is very little change in the forecasts, even though after the oil price crash of 1986, the most basic laws of supply and demand should result in higher demand for OPEC oil, as in fact occurred. Yet the forecasts hardly change, and continue to show only small changes on a year-to-year basis, in what can only be described as counterintuitive behavior.

Aside from the obvious conservatism and counterintuitive economics, the graph strongly supports arguments about forecasters' psychological or bureaucratic need for consensus. From 1982 to 1990, 60% of the forecasts fall within 0.5 mb/d of no change, and 82% within 1 mb/d. (From 1985 on, 68% are 0.5 mb/d of no change, and 91% within 1 mb/d). Yet the actual change is within 1 mb/d only three times in ten years, and ranges from a drop of 4.2 mb/d to a 2.3 mb/d increase.

Year in and year out, the forecasters show great solidarity, but also timidity and conservatism, despite repeated demonstrations that OPEC production is wildly (but rarely illogically) variable. Conforming to the consensus clearly takes precedence over precision, and as the history of oil market forecasting below shows, the consensus has been wrong for many years now.

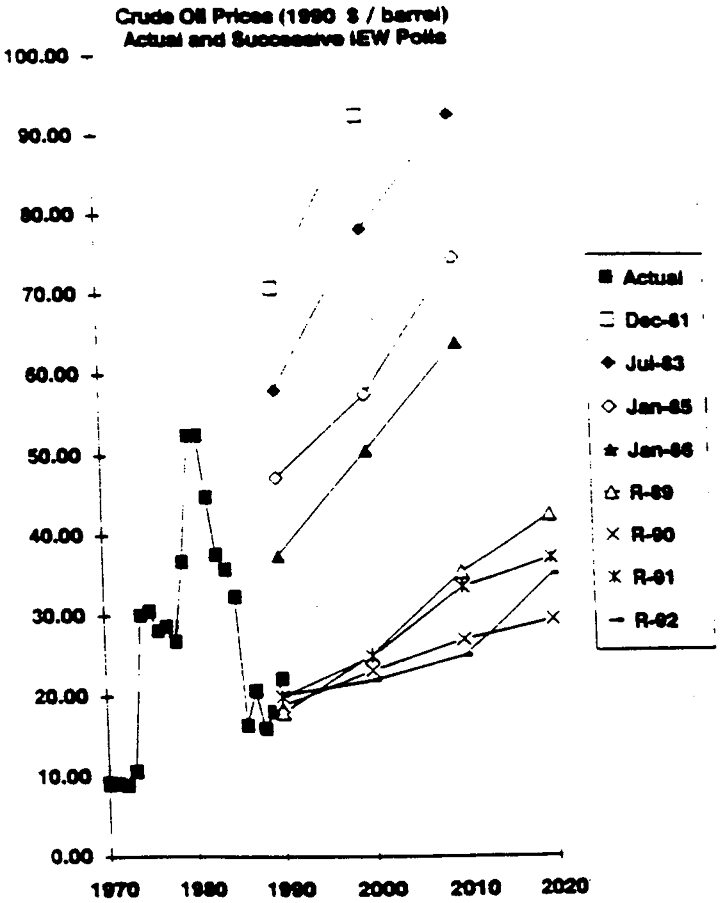

Figure 3-1
Source: [IEW 1992]

III. THE FORECASTING RECORD

> *"We should assume that we can't predict a price for the year 2000 in any useful manner." U.S. government forecaster.* [CERA 1984, p. i]

In effect, there is and has been a widespread consensus about oil prices, namely that they will increase. However, forecasters no more determine future oil prices than King Canute could control the tide. Indeed, as Figure 3-1 shows, the forecasters surveyed by the IEW have been repeatedly too high, and repeatedly adjusted downward; Figures 3-2 to 3-4 show the evolution of DOE price forecasts, and the repeated reduction in the forecasts. Nor have other computer models fared much better. In Figures 3-5 and 3-6, the price forecasts from [EMF6 1982] (which were made during 1980/81) are shown, adjusted to 1990$, and it can be seen that they, too, were wildly optimistic.[11]

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[11] Note that I was involved in the original design and subsequent updates of the International Petroleum Exchange (IPE) model. See [Choucri 1981] for a description of the initial model composition.

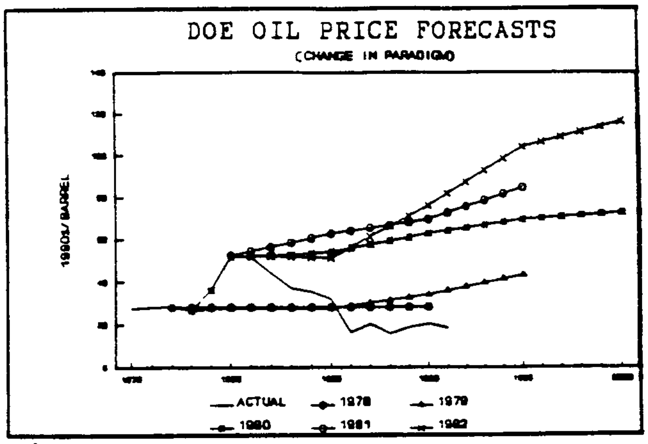

Figure 3-2
Source: [DOE], [DOE AER]

Still, it can legitimately be argued that, due to the influence of OPEC, prices are largely independent of supply and demand in the short- and even medium-term, so that the failure to predict price does not reflect a short-coming of the economic analysis so much as the inability to perceive OPEC intentions and power accurately. This problem can be surmounted by examining OPEC revenue forecasts, since revenue is equal to world oil demand, minus non-OPEC supply, times price, thus incorporating the major elements of the oil market, and allowing an accurate assessment of the models' economic insight, rather than their ability to predict OPEC behavior. And as Figure 3-5 and 3-6 show, not only were all of the forecasts too high, but they tended to be so to an extraordinary degree, with the average 1990 error equal to 220%! (Remember that these forecasts resembled the consensus, and are not being singled out as particularly erroneous.)

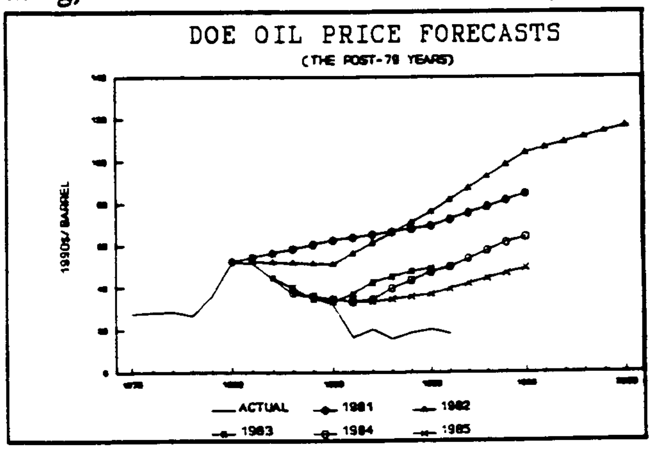

Figure 3-3
Source: [DOE], [DOE AER]

While the shear size of the errors is striking, certain elements stand out. First, there has been forecast consensus across the spectrum; the errors are not derived solely from alarmist environmentalists, advocates of Third World resource sovereignty or OPEC apologists. Such forecasts have included the great majority of individuals and institutions, including governments and the major oil companies.[12]

[12] There have been a number of efforts to compile forecasts, including [IEW] and [DOE IEO], however, coverage in the early 1980s is far from perfect. Examples of specific forecasts include [Exxon], [Chevron], [Conoco], [DOE IEO], [Brown, Flavin, and Norman 1979] and [World Bank].

Second, note especially where the trend in forecasts are shown, namely for the IEW, that the error has been in the slope of the curve, while the correction has repeatedly been to the endpoint, i.e., retaining the slope. This is a point which shall recur throughout this paper.

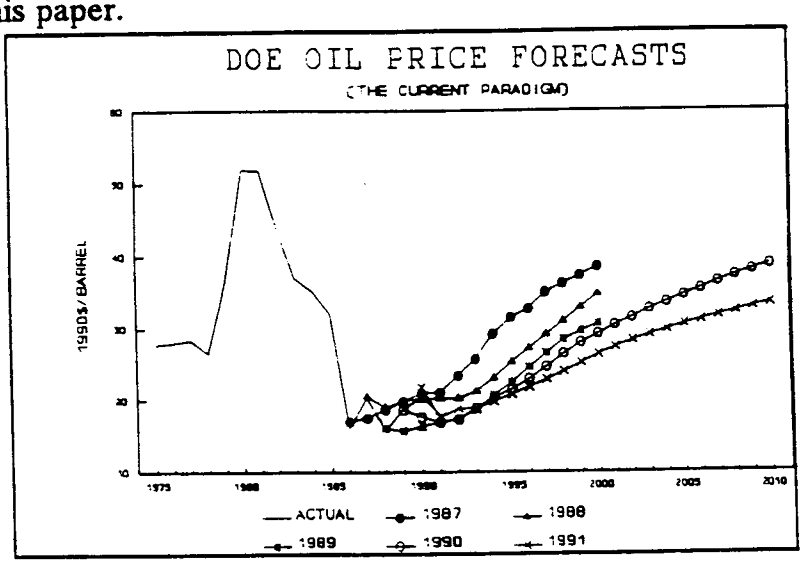

Figure 3-4
Source: [DOE IEO]

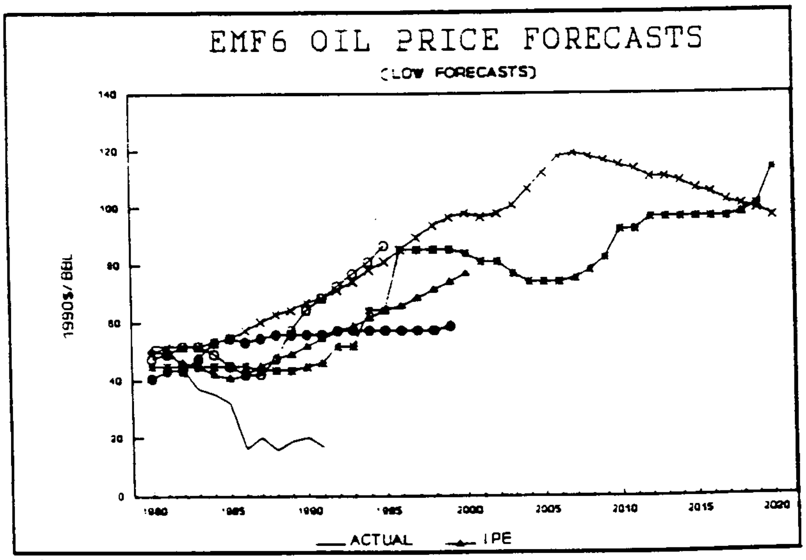

Figure 3-5
Source: [EMF6], [DOE AER]

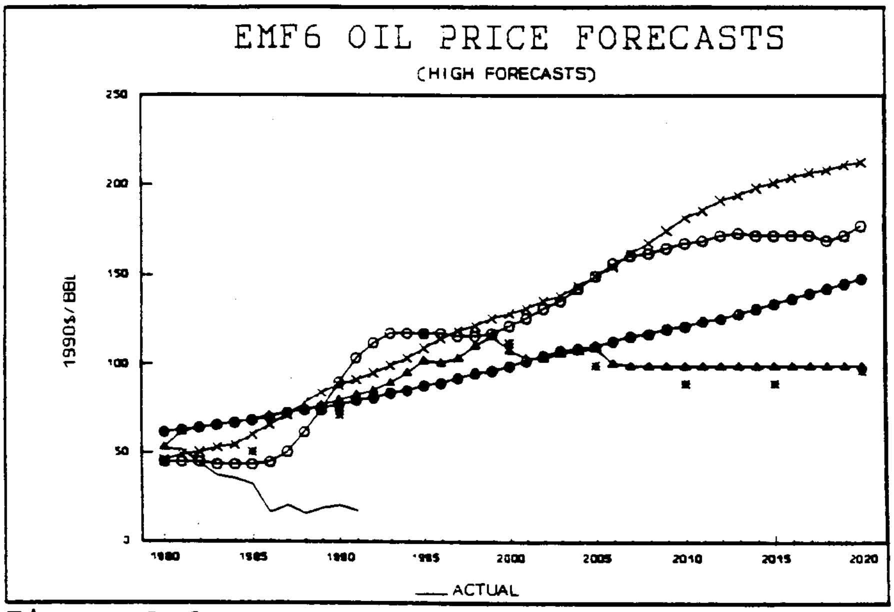

Figure 3-6
Sources: [EMF6 1982], [DOE AER]

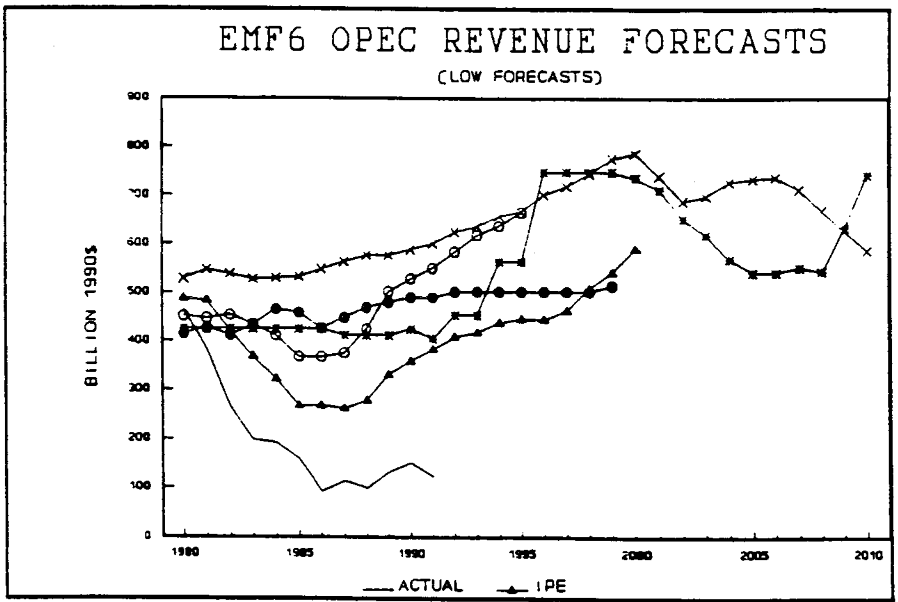

Figure 3-7
Source: [EMF6 1982] [DOE AER]

III.A. The Late 1970s Paradigm Change

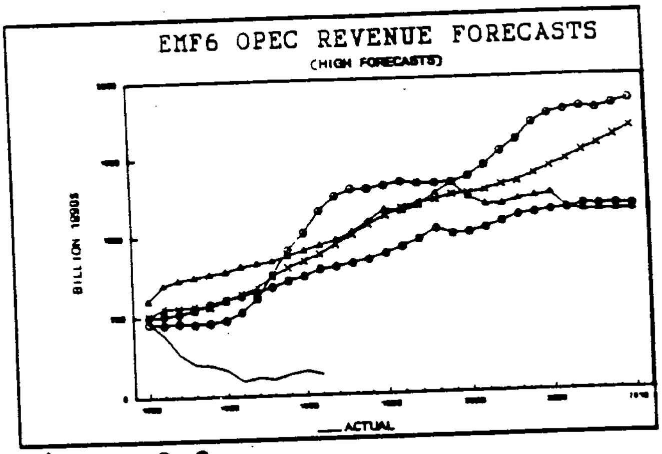

Figure 3-8
Sources: [EMF6 1982], [DOE AER]

It would be appealing to think that, at the root of the bullish forecasts lies wishful thinking, namely, the desire of oil companies, OPEC nations, and even environmentalists to see higher prices. But in reality, before the first oil price shock, most forecasts called for flat prices,[13] and even after the 1973/74 oil price explosion, nearly every forecast continued to assume that prices would be flat, although a number of "academic" studies argued that the new, approximately $10/barrel prices were too high for OPEC to maintain, and that a decline to $7/barrel should be expected.[14]

However, "official" forecasts continued to call for flat prices, and, using assumed elasticities of supply and demand, took a very different view of the world oil market than that which prevailed by the end of the decade. For instance, both Project Independence and the 1974 OECD report Energy Prospects to 1985, assumed flat prices, but forecast the virtual cessation of U.S. oil imports, as demand weakened and oil production rose. Additionally, a major study sponsored by the Ford Foundation, the Energy Policy Project, [EPP 1974] which was widely criticized as being too economically liberal,[15] not only didn't predict soaring prices due to scarcity, but largely ignored price (one of the reasons for the criticism).

Indeed, price forecasting had not really come into its own, as witness the 1978 IEA review of long-term oil market forecasts which didn't even consider price as a variable.[16] And as the first long-term forecast by the newly created U.S. Department of Energy put it in 1977, "*Assuming 'current practices,' most of the projection series embody the assumption of a constant real price of imported oil....*" [DOE 1977, p. 9]

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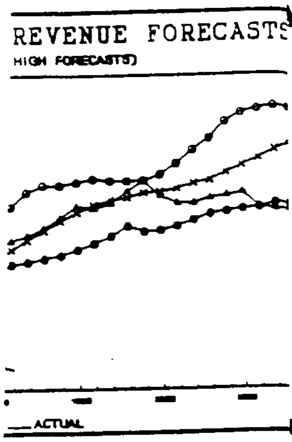
[13] See [Schultz 1970] as an example.

[14] See the review in [Choucri 1979].

[15] See, for example, [ICS 1975] and [Tavoulareas and Kaysen, 1977].

[16] [Brodman and Hamilton, 1979] In [Franssen 1978], a price is given, but the overview tables in Chapter V cover only supply and demand, apparently because many of the forecasters reviewed did not include prices.



.1 The Turning Point

"*It is assumed that it will be the policy of these countries [OPEC] to produce sufficient oil to cover world needs; that over the long term world oil prices will increase generally in line with world inflation....*" Exxon Company U.S.A.'s "Energy Outlook 1979-1990," December 1978, p. 3.

"*It is assumed that over the long term, world oil prices will increase at a rate greater than world inflation....*" Exxon Company U.S.A.'s "Energy Outlook 1980-1990," December 1979, p. 3.

t changed between these two forecasts, and the many others which were altered ng this period? Perhaps the Iranian Revolution, which seemed to confirm ments about the inevitability of higher oil prices, was a factor, but the reality is by 1977, the consensus began to shift. A major element was the accession to er of the Carter Administration, with its somewhat puritanical ideology which hasized scarcity and the need for sacrifice (especially compared to the equent Administration).

government quickly moved to support the political arguments with policy studies, nost influential of which were two CIA reports, summaries of which were made icly available in a major departure from past procedure. The first, [CIA 1977a] e a variety of technical arguments concerning the Soviet oil industry, insisting mismanagement would result in a collapse of production, causing exports to e and even necessitating as much as 4.5 mb/d of imports by 1985. (The reality exports doubling to 2 mb/d.[17]) This report not only bolstered fears of a Soviet sion of the Middle East, particularly Iran, and was used to support the lopment of the Rapid Deployment Force, a military unit designed to move kly to the Arabian/Persian Gulf, but also became part of the new, pessimistic ctations for world oil supply, as we shall see below.

le this CIA report has been often cited (and derided) for being so egregiously rror, most analysts have ignored the follow-up report, [CIA 1977b] which wed the entire world oil industry and concluded that:

> "*In the absence of greatly increased energy conservation, projected world demand for oil will approach productive capacity by the early 1980s and substantially exceed capacity by 1985. In these circumstances, prices will rise sharply to ration available supplies no matter what Saudi Arabia does.*"

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[17] Although the report covered only the Soviet oil industry, the forecast was for all CPE rts, i.e., including China and Eastern Europe, but the Soviets dominate the others in production and exports.

This was echoed by, among others, [WAES 1977], a report published under the auspices of a major academic institution, which acquired regional supply and demand projections from a great number of experts and, like the CIA, concluded that without higher prices, slower economic growth, and/or drastic political intervention, oil supply would be inadequate to meet demand by the late 1980s.[18]

III.A.2. Hardening Expectations

The combination of the CIA, with its massive resources and access to confidential information,[19] and the WAES report, with its prestigious academic cachet, were difficult to resist. The fact that the Iranian Revolution, with its tripling of oil prices, occurred shortly thereafter certainly undermined arguments that long-term oil prices would not rise.

But while the 1979 oil crisis was clearly due to short-term factors, namely the Iranian Revolution which not only cut off 6 mb/d of supply for several months but created panic buying,[20] many analysts chose to interpret the event in terms of long-term resource availability. For its part, the CIA came forth with the interpretation that:

> "*The gas lines and rapid increases in oil prices during the first half of 1979 are but symptoms of the underlying oil supply problem--that is, the world can no longer count on increases in oil production to meet its energy needs.*" [CIA 1979, p. iii.]

Thus, the conventional wisdom changed, from expectations of rising supply and demand with flat prices, to rising prices and limited supply. The core elements of the consensus are:

1) oil supplies are finite, and severely constrained outside the Middle East;
2) demand for oil is relatively price inelastic and difficult to restrain;
3) oil prices thus will inevitably rise, and therefore (and because);
4) oil producers will be better off holding oil in the ground where it will retain its value better than other investments.

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[18] Ibid, p. 236. See [Greenberger et. al., 1983] for a discussion of the findings and particularly the impact of various energy reports issued during this period.

[19] It has been privately alleged to me that the CIA reports were not representative of the viewpoints of the Agency, but were done by a sole analyst, who was able to make them "official" because they coincided with those of the political leadership. Of course, this may simply be a rationalization.

[20] See [Lynch 1986] and [Verleger 1982] for discussions of some of the elements affecting prices during this period.

As the above review of these forecasts showed, these beliefs proved incorrect, and with rather dramatic results for not only the petroleum industry, but the world. Yet only the last element has been abandoned by producers and most analysts.

IV. WHAT WENT WRONG?

That oil market forecasts have been bad is hardly surprising, given the enormous inherent uncertainties. The many inputs into oil demand include economic activity, climate, energy prices, taxes, and subsidies, population size, growth, and density, etc., such that not only does the normal uncertainty range for each create problems, but the number of variables means the size of the task is enormous, even if only the developed economies are considered.

But even given an understanding of oil supply and demand, there are still many exogenous factors that are unpredictable. For example, the range of possible economic activity over two decades is quite large, equating to uncertainty on the order of millions of barrels a day in demand. Low oil prices, the end of Communism, and so forth naturally add to the uncertainty about long-term economic growth rates. Recall that [Huntington 1991] found that much of the error in the EMF6 models' predictions stemmed from the use economic growth assumptions which proved to be too high, while [Nelson, Peck, and Uhler 1989] found the same problem with electricity demand forecasts.

The unpredictability of political events adds another element of error, both in terms of the probability and the timing of a given event. For example, knowing in 1975 that a major oil producer might undergo a revolution in 1980 plus or minus two years would not enable a forecaster to predict adequately oil market behavior, since in 1978 (when the Iranian revolution began) oil markets were tight with only small amounts of spare production capacity, but by 1982, new supplies from the North Sea, Mexico and Alaska would have substantially ameliorated the situation.

Perhaps more disturbing is the lack of consensus about the oil demand elasticities for the U.S., which is one of the most intensely studied parameters in energy economics. In Figure 4-1, the inferred elasticities are shown which calculated from model outputs submitted to EMF11 [EMF11 1991], and the range is substantial. In other words, even with identical price and GDP inputs, there is an enormous disparity among demand forecasts.

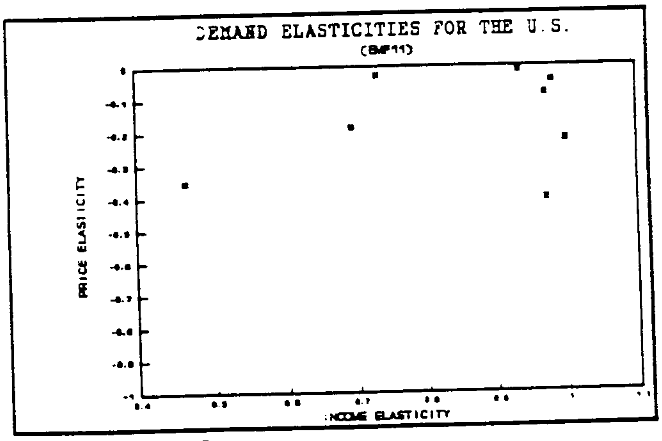

Figure 4-1
Source: [EMF11 1991]

But, there seems to be more involved than just an innocent choice of incorrect inputs. The evidence suggest rather strongly that most forecasts are biased, with errors in the Malthusian direction, that is, supporting higher oil price forecasts.

IV.A. Bias in Forecasting

> "*[The theory of rational expectations] suggests that individuals do not make systematic forecasting errors; on the contrary that their guesses about the future are on average correct.*"[22]
>
> "*The practice of forecasting the decidedly uncertain future of anything so complex as energy is a highly hazardous occupation that involves a great deal more art than science. I'm convinced that any great prophet will only achieve success through a series of fortuitous errors.*" [West (1973), p. 295].

The above quote sums up the problem very nicely: with unbiased estimators, the unavoidable errors in a forecast should still yield something close to the actual. Similarly, if forecasters are rational and unbiased, the aggregate of their forecasts should be approximately correct. And [McNees 1988] found that for forecasts of U.S. macroeconomic variables, the consensus was, in fact, a reliable estimator.[23]

But few energy forecasters have achieved the series of 'fortuitous errors' which West hoped for above. One prominent example is described in [Landsberg 1985], who examined the 1963 Resources for the Future forecast for U.S. energy consumption, and discovered that despite numerous problems at the disaggregate level, the tendency for the errors to offset resulted in a relatively accurate forecast overall. Of course, the initial work was done before Malthusian bias came to dominate energy forecasting.

The fact is that no forecast is perfect, nor can it ever hope to be, but, if the forecast is unbiased, the aggregate result of its components should be close to correct, as West states. Similarly, if forecasters are generally unbiased, then the consensus forecast should be approximately correct. Unfortunately, neither has often been the case for oil market forecasting.

[22] The definition of rational expectations, from The MIT Dictionary of Modern Economics, third edition, Pearce, David W., ed., 1986, MIT Press, p. 360.

[23] See also "Disagreeing about the Consensus," The Economist, July 27, 1991, p. 61.

TABLE 4-1
ERROR IN DOE 1982 FORECAST FOR 1985

	FORECAST for 1985	ACTUAL	ABSOLUTE ERROR	RELATIVE ERROR
PRICE IN 1990$	$32.88	31.98	0.9	2.8%
Consumption				
U.S.	18.4	15.7	2.7	17.2%
CANADA	1.9	1.5	0.4	26.7%
W. EUROPE	12.8	11.6	1.2	10.3%
JAPAN	4.9	4.3	0.6	14.0%
TOTAL OECD	38.0	33.1	4.9	14.8%
OPEC	3.2	3.6	-0.4	-11.1%
OTHER	9.7	9.9	-0.2	-2.0%
TOTAL NCW	50.9	46.6	4.3	9.2%
Production				
U.S.	10.6	11.2	-0.6	-5.4%
CANADA	1.5	1.8	-0.3	-16.7%
OECD EUROPE	3.4	4.3	-0.9	-20.9%
OTHER NON-OPEC	8.8	9.5	-0.7	-7.4%
TOTAL NON-OPEC	24.3	26.8	-2.5	-9.3%
CPE Exports	1.0	2	-1.0	-50.0%
OPEC Production	25.8	17.2	8.6	50.0%

Source: DOE International Energy Outlook 1982 for forecast 1985 for actual.

IV.A.1 Evidence of Bias in Oil Forecasting

Consider Table 4-1, the 1982 DOE forecast for 1985, a mere three years into the future, and without major discrepancies in price. It can be seen that the error in nearly every regional supply and demand variable is on the order of 10-20%. Yet the mistake in OPEC production, the residual of the other variables, is 50%, and while the error in price was small, the discrepancy between actual and the forecasts of the early 1980s soared in the following year (1986).

In Table 4-2, the errors from EMF6 are shown for the different variables, and while the components do not indicate perfect bias, with some errors on the bullish side (favoring higher prices) and some on the bearish side, for the aggregate variable, OPEC production, it can be seen that only one model was too low, (IPE) suggesting that the forecasts are biased in the Malthusian or bullish direction, i.e., in favor of OPEC. And clearly, all were much too high on prices, the lowest error being the IPE model. (Note that the unanticipated price collapse in 1986 raised demand substantially, thereby reducing the forecast errors.)

In terms of the IEW price forecasts, from 1983 to 1985, there were a total of 81 forecasts of the 1990 price of oil, only two of which were too low. (See Figure 4-2.) It was not until 1986, after the price collapsed, that the ratio between optimistic and pessimistic errors became close to 6/4. Only in 1988 was balance achieved, a mere two years before the year being forecast, which hardly creates confidence in the unbiased nature of long-term forecasting.

Table 4-2
EMF6 Forecast Errors for 1990

	Demand:			Supply:		
	WOCA	OECD	NonOECD	OPEC	NonOPEC	Price
Averages:						
Simulation	-2.1%	-0.2%	-11.8%	15.6%	-16.7%	213.7%
Optimization	-1.7%	-3.6%	-0.6%	26.5%	-36.8%	240.0%
All	-2.1%	-1.5%	-10.0%	18.0%	-21.7%	221.6%
Models:						
OMS	2.6%	4.5%	-1.9%	14.1%	-8.5%	188.6%
IPE	-6.4%	-4.0%	-12.3%	-10.0%	-4.2%	132.9%
OILTANK	-10.6%	-8.0%	-16.9%	18.9%	-28.9%	294.4%
Opeconomics	-6.2%	5.3%	-34.4%	8.8%	-19.0%	148.6%
WOIL	2.6%	1.1%	6.5%	18.9%	-15.8%	199.3%
OILMAR	5.1%			36.5%	-23.6%	300.7%
Gately				22.1%		231.2%
Salant-ICF	-1.7%	-2.1%	-0.6%	28.5%	-29.2%	247.5%
Kennedy-Nehring	-2.9%			24.5%	-44.4%	255.6%
ETA-Macro		-5.9%				216.8%

Source: [Huntington 1991], p. 4.

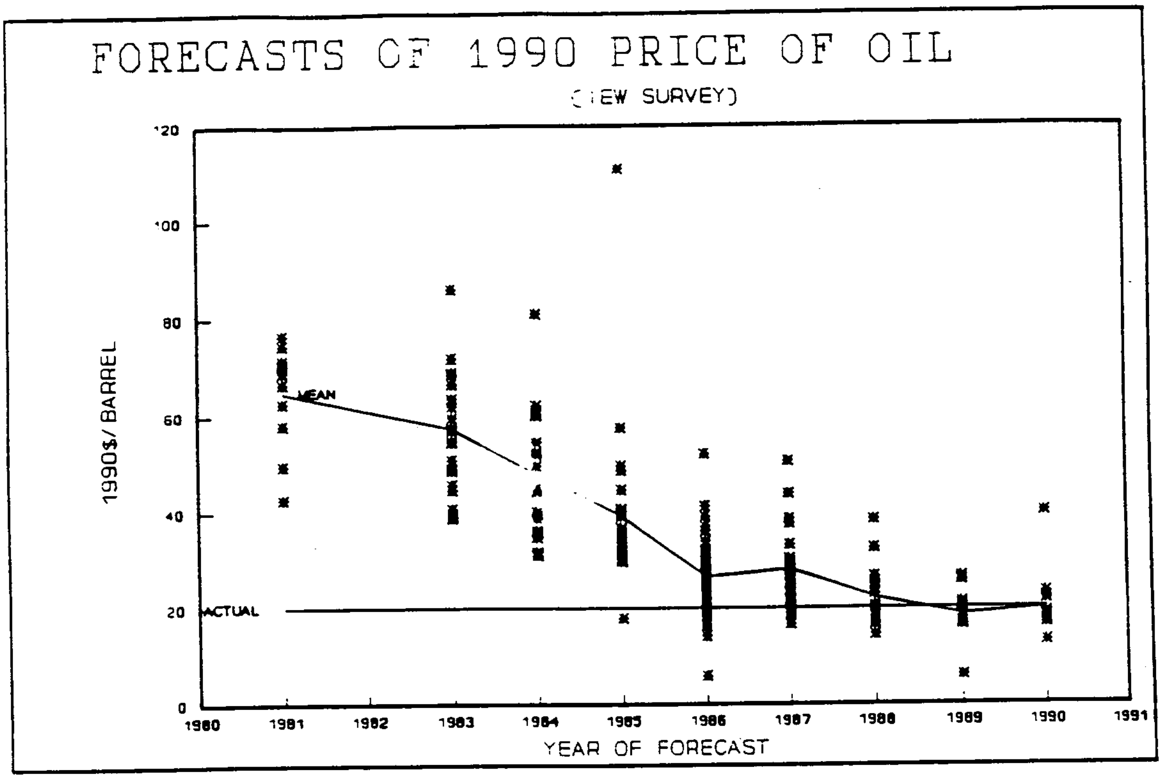

Figure 4-2
Source: [IEW]

IV.A.2. Sources of Bias in Oil Forecasting

It might be thought that for a discipline so quantitative as economics, it would be difficult for a researcher to rely on his or her own subjective opinions in guiding a forecast. However, there is sufficient uncertainty not only about theory but also over parameters to allow a forecaster to mold the results in line with his or her own preconceived ideas.

The disagreement among analysts over demand elasticities, as indicated in Figure 4-1, for example, is but another area where a forecaster can choose the demand behavior he or she prefers, optimistic or pessimistic, and cite authoritative sources to support the choice. In fact, there continues to be disagreement among energy economists over whether the price elasticity of demand is symmetrical or assymetrical. (See [Shealy 1990]). Since an assumption of symmetry will result in substantially greater demand after a decrease in prices, a belief in symmetry should result in substantially different demand forecasts under present market conditions.

Even on questions of theory, though, analysts tend to have choices. The ongoing debate about the Hotelling theory, discussed below, provides a perfect example. One recent tome[24] on energy economics cites [Solow 1974] in support of the role of the Hotelling Principle in determining prices, while ignoring [Adelman 1974] in the same volume, which adopts a different point of view, then cites [Miller and Upton 1985a] which found a strong relationship between expected price change and the rate of interest, without mentioning [Miller and Upton 1985b] which was unable to duplicate the earlier results.

IV.A.3. Bias in Computer Models

> "*Model builders and forecasters, when asked about it, all readily agree that their trade is not fully scientific and that they revert to post hoc adjustments, use intuition when choosing data, modify variables, and bend equations so that reasonable results do emerge from their travail. But in official presentations, they fall back on a discussion of discounted least squares, adaptive growth curves, Kalman Filters, ARIMA Models, the Poisson Smoothing Process, and so on.*" [Baumgartner and Midttun, 1987 p. 4]

This quote highlights an important caveat, namely that computer models, for all that they appear to be scientific, are all too often Maelzaelian machines. Baron Maelzael, it will be recalled, travelled through Europe and the U.S. in the eighteenth century demonstrating a chess-playing machine, which, it was later discovered, was not an automaton, as claimed, but contained a small person who manipulated it from inside.[25] Similarly, computer models can easily be driven by the subjective inputs of their creators so that the models' output simply resembles their opinions rather than any objective analysis.

As one of many potential examples, [Keepin and Wynne, 1987, pp. 38-39] remark that in examining one large computer model, "*[t]he unavoidable conclusion is that the major, dynamic results of the scenarios are essentially prescribed in the input assumptions themselves and the apparently extensive analysis performed by the models is equivalent to a back-of-the-envelope calculation. In fact, in many cases, the energy models serve as a simple identity transformation from the inputs to the outputs.*"

IV.B. The Role of Assumptions

Thus, it increasingly appears that economic analysis is often overshadowed by assumptions in energy forecasting. Assumptions are the primary source of entry for bias into a forecast. In theory, given perfect data, all inputs to a forecast or model would be generated econometrically and thus be unbiased. Yet not only does there

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[24] [Heal and Chichilnisky 1991] pp. 15-16.

[25] See [Poe 1908]. I am indebted to C. M. Kent for the citation.

remain substantial disagreement about even the most intensively-analyzed parameter, the price elasticity of U.S. demand, but all forecasting efforts are, by necessity, required to rely on a multitude of assumptions, whether concerning exogenous inputs, parameters, or sometimes even regional outputs. And the evidence suggests that the assumptions used are the main source of bias in oil price forecasting.

IV.B.1. Evidence of Bias in Assumptions: The NERC Fan

Some examples are enlightening in this regard. First, repeated errors in rate of changes in a forecast are not restricted to the oil industry, as Figure 4-3, the NERC fan, shows. This summarizes a history of expected demand for electricity in North America, collected by the North American Electric Reliability Council and analyzed in [Nelson, Peck and Uhler 1989].

They noted two particular sources of error. One, the failure of forecasters to predict the drop in economic growth rates after the first oil crisis, an exogenous factor. But additionally, they found that the forecasters "did not fully appreciate the impact of price on customers' demand for electricity," (p. 105) behavior similar to that in both short-term and long-term oil market forecasts, as seen above. Naturally, too, the inability of the forecasters to adjust in any reasonable period of time to the changed conditions confirms the previous arguments about analysts' conservatism, and again, the repeated errors in the slope, with corrections to the endpoint, should be noted.

The NERC Fan.

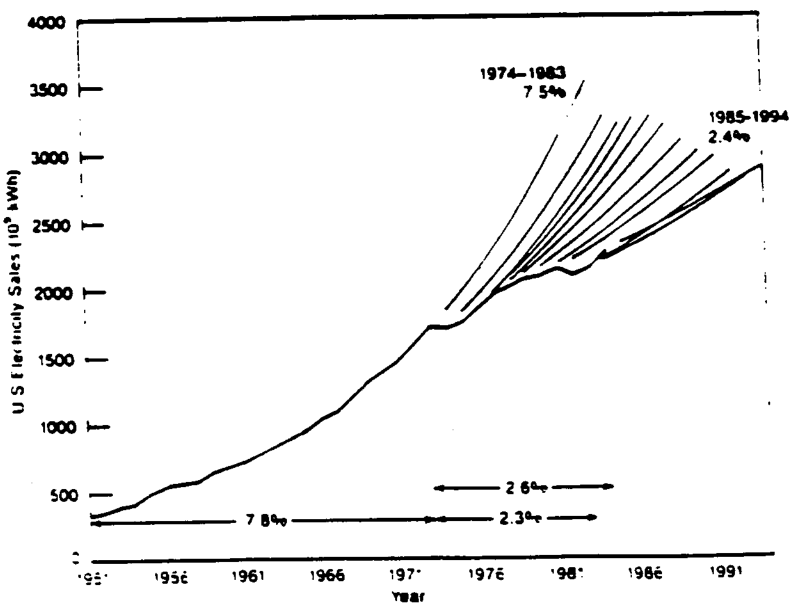

Figure 4-3
Source: [Nelson, Peck, and Uhler 1989]

IV.B.1. Evidence of Bias: U.S. Natural Gas Price Forecasts

In an example closer to the oil industry, Figure 4-4 shows some of the annual DOE forecasts for domestic natural gas prices over the past decade, and again, we see the pattern of a consistent expectation of rising prices, with the rate of change (slope of the curve) fairly constant, even while prices collapsed and remained weak. As a result, the endpoint had to be moved repeatedly.

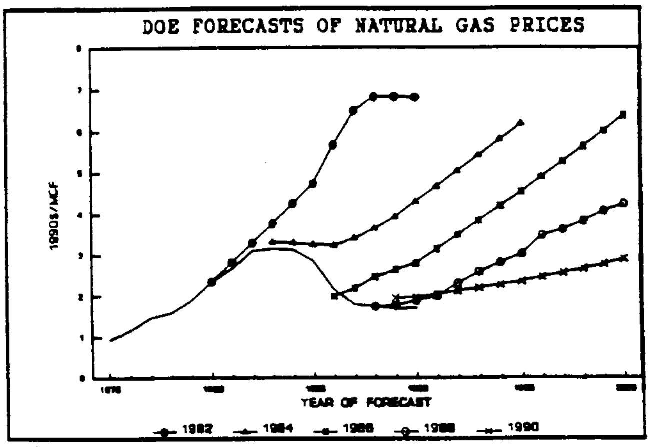

Figure 4-4
Source: [DOE AEO]

In fact, the rate of growth in wellhead gas prices which DOE forecast has typically exceeded that for oil prices, given both the belief that gas, as a "superior" fuel, would come to be favored over oil, and the lack of competition from foreign sources due to high transportation costs. Naturally, the U.S., being a "mature" petroleum province, was foreseen as inevitably suffering from rising production costs.[26] That DOE was not simply following the consensus can be seen in Figure 4-5, which shows the U.S. wellhead gas price forecast made by the Gas Research Institute.

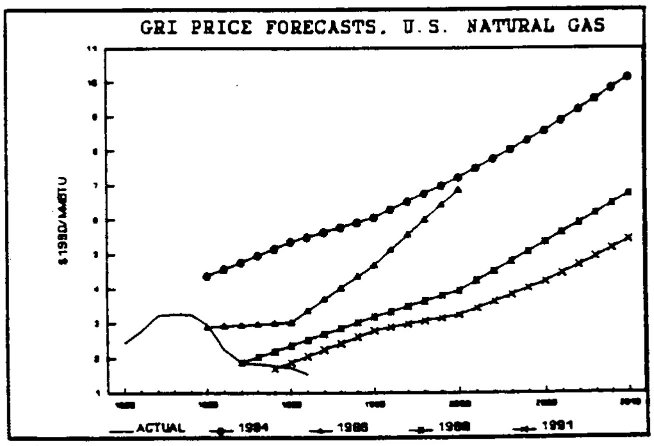

Figure 4-5
Source: [GRI]

Aside from this evidence that the consensus has, again, proven badly in error, the fact that forecasts of the U.S. gas market have historically been forced to rely on assumptions much more than oil market forecasts is of particular relevance for this report. Decades of price regulation meant demand was constrained for many years by lack of supply. Thus, measuring the price elasticity of demand, for example, becomes difficult, if not impossible. And since prices were regulated, a supply curve could not be measured.

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[26] [Adelman and Lynch 1985] was a primary exception to the bullish price forecasts.

Ultimately, then, it becomes clear that assumptions, by necessity, played a much larger role in forecasts of U.S. natural gas prices than in oil market forecasts, suggesting that here, too, the underlying rate of change is being assumed, not predicted. That the same pattern of repeated errors in the slope with corrections to the endpoint appears as in oil price forecasts is probably not coincidence.

IV.B.2 Evidence of Bias: CPE Oil Exports

Finally, the forecasts of CPE oil exports comprise the most compelling example of bias. As can be seen in Figure 4-6, the same repetition of slope occurs, again in contradiction to repeated actual behavior: rapid declines are predicted, rapid increases occur. Since the publication of the 1977 CIA report on the Soviet oil industry, CPE oil exports have been commonly forecast to decline, usually to zero. For example, from 1978 to 1985, of the 28 forecasts of CPE 1990 net oil exports reviewed by DOE in its <u>International Energy Outlook</u>, 10 called for precisely zero exports, a further 7 called for net imports, and <u>none was higher than or equal to the actual amount</u>. (See Figure 4-7. DOE has ceased to include CPE exports in its compilation of forecasts.) Indeed, over the past fifteen years, the most likely forecast for CPE exports in the long-term has been either negative or zero, while the best estimator has been for 5 to 8% annual increases.

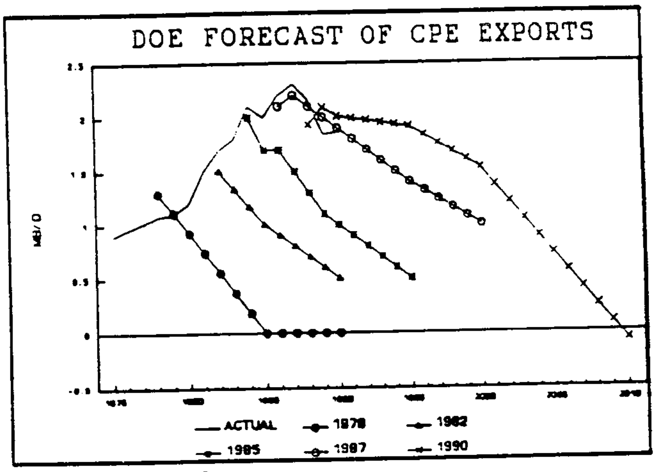

Figure 4-6
Source: [DOE IEO]

And there is little dispute that CPE export projections are nothing more than assumptions. Analyzing the Soviet oil industry is very difficult, and most forecasters make no pretense at having performed such an analysis.[27]

Thus, we have the perfect case of a <u>pure assumption</u> showing an identical pattern of behavior which forecasts of oil prices (and natural gas prices, and electricity demand, etc.) possess: namely, a repeated error in the <u>slope</u>, with the correction being to the <u>endpoint</u>. And that the consensus forecast has been biased seems indisputable.

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27 See the discussion in [Adelman and Lynch 1986]. One forecast, in fact, went so far as to describe a reference case assumption that CPE exports would fall to zero as "not an unreasonable assumption, given recent trends in CPE supply and demand" on the same page that the trend was shown as increasing. [CERI 1988, p. 152.]

But this also highlights an important element of forecasting error, namely that the problem does not derive from simple extrapolation, as in some cases.[28] CPE oil exports had not begun to decline when the consensus forecasts became pessimistic, and oil prices have never shown gentle, sweeping rises. Instead, the consensus oil price forecast of the past fifteen years appears to have very specific roots. In the next section, these roots are examined.

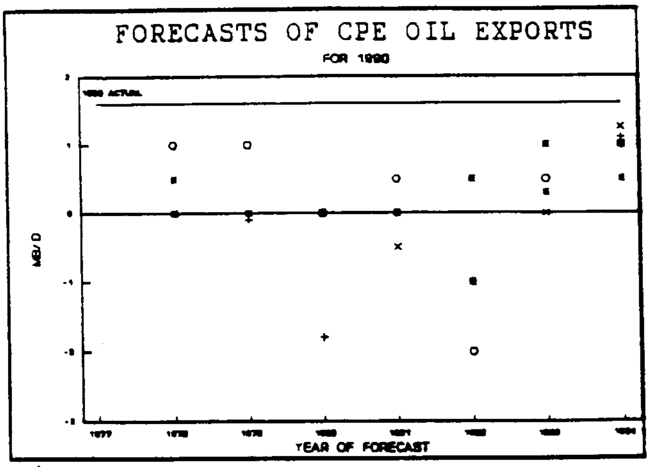

Figure 4-7
Source: [DOE IEO]

[28] The NERC fan, for example, was largely due to continued extrapolation of the previous growth rates, and many forecasters' base case, sometimes called 'Business as Usual' involves an extrapolation of historical prices or demand growth rates. See [EPP 1974] or [OECD 1974] for examples.

V. THE THEORETICAL SOURCES OF THE RISING-PRICE PARADIGM

If oil price forecasts are based on assumptions, rather than definitive analysis, as argued above, what are the sources of these assumptions and how did they come to be embodied in the conventional wisdom? As mentioned, they weren't just the product of wishful thinking, or the paradigm would have been different previously, and obviously they didn't represent simple extrapolation, as Figure 1-2 clearly shows.

This section argues that there are two major theoretical errors which have been used to support these expectations, namely that economic theory 'proves' that mineral prices must rise at the real rate of interest, and that oil supplies are finite, and therefore, costs and prices must inevitably increase. The next section addresses the role of supply, while this discusses the Hotelling Principle, but also, in influence of OPEC's long-term strategy.

V.A. Hotelling Revisited

> "*...the ideas of economists and political philosophers, both when they are right <u>and when they are wrong</u>, are more powerful than is commonly understood. Indeed, the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences are usually the slaves of some defunct economist.*" [Keynes 1936, p. 383, emphasis added.]

Many oil market observers have come to rely heavily on what is referred to as the "Hotelling Principle", said to "prove" that mineral prices must rise at the rate of interest over the long term, as supposedly described in [Hotelling 1931]. In fact, as several recent papers have argued, not only can this be empirically shown to be false, but it represents a theoretical misinterpretation.[29]

In the first place, Hotelling was referring to a mineral asset, which would be of fixed amount, not of entire commodities. Additionally, Hotelling referred to net prices (i.e., price minus cost, or profits) not the market price. While some proponents of the Hotelling Priniciple have noted the distinction, prices are nonetheless described as having to rise "exponentially". [Solow 1974, p. 4] Other economists have not been so circumspect, but have instead made the straight interpretation that prices must rise at the rate of interest, partly on the strength of the argument that in the Middle East, costs are so low that net prices and gross prices are nearly identical.[30]

The Hotelling Principle having been accepted in total or in part by such prominent individuals as a Nobel Prize-winning economist and the head of the U.S. Council of

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[29] See [Adelman 1990a], [Schmidt 1988], [Simon 1991], and [Watkins 1992].

[30] [Miller & Upton 1985a&b], [Dasgupta and Heal 1979], and [Boskin et. al 1985].

Economic Advisors, it is easy to see why many would find it persuasive. However, as [Manthy 1978] pointed out, historical mineral prices have not followed such a path, raising doubts about its theoretical, or at least practical, validity. For analysts with such doubts, there is another argument in favor of a rising price paradigm.

V.B. OPEC's Preferred Price Path

Further support for the rising price paradigm comes from the proposed strategy which OPEC agreed to (but never implemented) of seeking a gradual increase in prices to the level of the cost of alternative fuels. While acknowledging uncertainty about appropriate price levels (and rates of increases) in 1979, OPEC's Long-Term Strategy Committee proposed that real prices should increase at roughly the rate of real GDP growth in the industrialized countries, slightly less than 3% per year, until they reached the level of alternative energy costs.[31]

V.C. The 3% Solution

Thus, there are two reasons for analysts to anticipate a rate of price growth on the order of several percent per year. And, as can be seen, forecasts have tended to adopt this level almost religiously. In Figure 3-1, we saw the IEW mean price forecasts, and if one examines the <u>slope</u> of those lines, which constitute the annual growth rate, one finds that they approach 3%/year, as Table 5-1 shows. But if one goes further, and looks at the individual forecasts (rather than the survey means) one finds that although there is substantial variance, if one wanted to predict what any given, randomly chosen forecaster would predict, an oil price forecast of 3% per year real increase would be the best estimator.

The same is seen for DOE, in Figure 5-1, where rate of real price change from the initial year to the final year of the forecast is shown, along with the initial year price. However, given the variance in the initial year price, and the fact that many of the price forecasts include a few initial years of weakness, the rate of price change from the lowest point to the end of the period is also shown for each forecast. Naturally, the rate of growth is higher, closer to 5% per year than

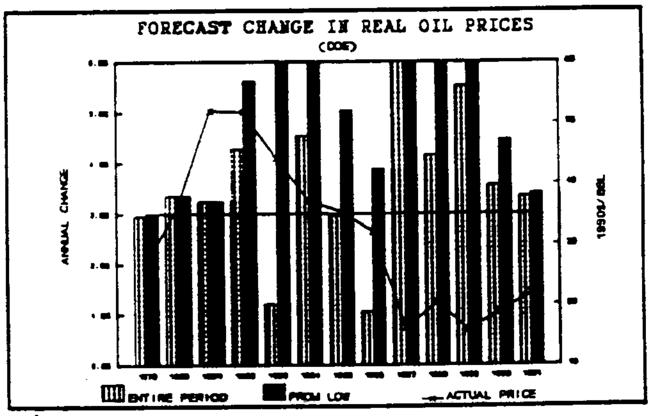

Figure 5-1
Source: [DOE IEO]

[31] See PIW 5/12/80 for a summary of their report.

3%. (Note that although many price forecasts have an initial period of weakness, none show any price decline after the first few years.) Unfortunately, a similar analysis cannot be done for the IEW survey of forecasts, because initial year prices are not given.

TABLE 5-1
LONG-TERM OIL PRICE FORECASTS
(1990$/BBL)

YEAR OF FORECAST	PRICE IN YEAR OF FORECAST	----FORECAST FOR 1990--- HIGHEST	LOWEST	AVERAGE	ANNUAL GROWTH 1990/2000	NUMBER OF FORECASTS
1983	37.06	111.0	39.0	59.3	2.6%	25
1984	35.24	81.0	31.0	48.2	2.4%	23
1985	31.98	111.0	18.0	39.0	2.0%	23
1986	16.17	111.0	52.0	26.0	3.8%	42
1987	20.29	51.0	17.0	28.0	2.7%	25
1988	15.77	38.4	17.0	22.5	3.9%	17
1989	18.81	19.4	16.4	26.4	3.8%	15
1990	21.78	n.a.	n.a.	n.a.	2.2%	16

SOURCE: [IEW], [DOE IEO]

VI. THE SUPPLY CONSTRAINT

"Behind all the prospective energy gaps and imbalances that appear beyond 1985 is the inescapable fact that the time when the production of oil will plateau and then decline is clearly in sight." [WAES 1977, p. 17]

Pessimism about oil supply and a belief in scarcity have been major factors behind the paradigm shift to a belief in the inevitability of rising oil prices as seen in studies like [CIA 1979] and [WAES 1977]. At present, the prevailing expectation is that non-OPEC supply will not only be unable to keep up with demand, but will in fact fall, while OPEC members will be unwilling or unable to keep up with the resulting demand for their oil. Returning to EMF6, Figure 6-1, taken from [Porter 1990] shows the forecasts of non-OPEC supply made by the various models, expressed in change from the base year (1980). While most of the models show increases, with the exception of the IPE model, all are too pessimistic. (See also [Huntington 1991]).

It should be reiterated that this belief did not begin to prevail as the consensus until the late 1970s, and that prior to that time, not only was non-OPEC supply expected to continue rising, but there was also little argument about the adequacy or availability of OPEC production. Even Sheikh Yamani, in 1978, predicted that OPEC production would rise by 50% to 45 mb/d by 1987,[32] as opposed to the subsequent consensus of an aggregate ceiling of 30 mb/d.[33]

That all began to change in the late 1970s, when the more Malthusian, or pessimistic, paradigm became part of the consensus. Underlying these expectations is the all-too-reasonable premise: Given that the Earth is finite, the supply of oil is obviously finite, and society must, therefore, be running out. Few people realize how great a leap of logic it is from this belief to the conclusion that prices must rise not only inevitably but imminently.

Certain points recur in the projection of oil supply: resources are finite; costs are rising and require higher prices; all of the easy fields have been found; non-OPEC supply has peaked and will imminently decline; non-Persian/Arabian Gulf OPEC production has peaked and will imminently decline, leaving only the large Gulf producers as exporters; and finally, that OPEC is unable or unwilling to produce enough oil to meet world demand. Therefore, prices must inevitably rise. All of these assertions are either invalid or irrelevant.

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[32] MEES Supplement 7/18/78, p. 6.

[33] Early examples were [CIA 1979] p. 5, and [WAES 1977] p. 138.

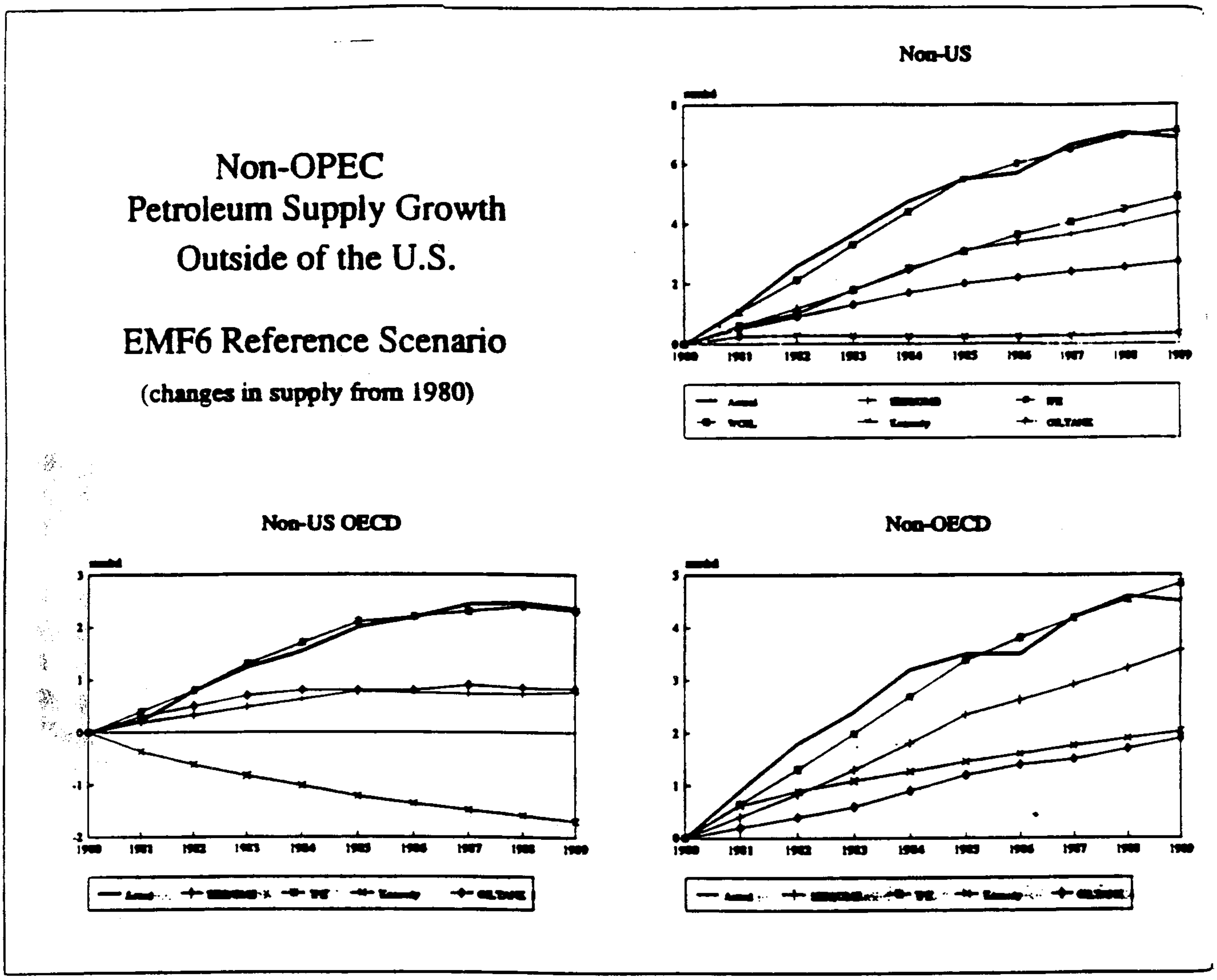

Figure 6-1
Source: [Porter 1990], p. 11.

VI.A. The Inherent Difficulties in Forecasting Supply

> "*A paradigm can, for that matter, even insulate the community from those socially important problems that are not reducible to the puzzle form,....*" [Kuhn 1970 p. 37]

> "*Analysis of likely developments in the world oil market is ultimately dependent on some method of forecasting oil supply from key regions. Unfortunately, data problems tend to dominate work in this area, and much of the analysis task reduces to making the best use of the limited information that is available.*" [Adelman and Jacoby 1977, p. 1]

Having already indicated that oil demand forecasting remains suffers from a high degree of uncertainty, supply forecasting is probably more difficult. For example, [Hogan 1989] refers to the "lack of any acceptable theory of oil market development dynamics" (p. 17).[34]

Partly, this represents the nature of oil (and gas) supply, where discovery is unpredictable and production rates (both immediate and ultimate) depend on geology as well as economics. Supply-side data are often much more difficult to locate than for demand, where consumption, price and tax data for major countries are all readily available. Additionally, taxes not only vary enormously from country to country, but require analysis of contract terms, which few analysts are willing to undertake. (Kemp being one prominent example.)

These problems make many economists leary of dabbling in supply analysis, as witness the fact that in energy economics journals, the ratio of articles published on demand to those on supply is typically about six to one. In effect, there is a greater reliance on assumptions when projecting supply than for demand, making the earlier arguments about bias as valid here, if not more so.[35]

VI.B. Paradigm Lost: The End of Optimism

As noted earlier, supply forecasts were not particularly pessimistic until the late 1970s. For most areas, supply was typically projected to increase, although sometimes U.S. production was predicted as peaking soon, Hubbert being the most

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[34] But he did argue that "at a highly aggregate level, and with a very simplified structure of the market dynamics, it is possible to describe the history of non-OPEC oil development with reasonable accuracy and plausible parameter estimates." Ibid., p. 17.

[35] Note that DOE, for one, refers explicitly to its capacity projections as assumptions, even for non-OPEC areas. Non-OPEC production should be closely correlated to capacity, given the competitive nature of most producers.

prominent (and earliest) exponent of that view in recent decades. (See [Blair 1978] p. 14, for example.) Others, like [Shultz 1970 p. 41], saw that with prices flat at $11/bbl, U.S. production would still increase to 13.5 mb/d by 1980 from 10.6 mb/d in 1968.[36]

Indeed, after the first oil price shock, the early forecasts lar· relied on relatively simple formulas, such as an assumed price elasticity of supp under which quantity responded only to price change. The tripling of prices naturally led to optimistic forecasts of U.S. oil production, including projections of increases from 1973 to 1985 of 50% by the U.S. government[37] and 67% by the [OECD 1974], respectively, again, despite prices that were projected to remain flat! Figure 6-2 reviews a number of forecasts of 1980 U.S. production made during the late 1960s and early 1970s, and the contrast between the optimism during the low price period and the subsequent pessimism is remarkable.

After the change in the late 1970s to paradigm of rising prices, supply forecasts responded accordingly. In its 1978 report, (published in early 1979) DOE forecast that U.S. oil production in 1985 would be 10.6 mb/d, an increase of 0.4 mb/d from the 1978 level. This proved to be too low by 0.6 mb/d. However, when the price of oil tripled in 1979/80, DOE lowered its forecast by 1.1 mb/d, increasing the error![38] [Lynch 1989, p. 9] Given that the only relevant changes between the two forecasts were an increase in expected 1985 prices of 125%, deregulation of domestic oil prices, and a strong increase in drilling, all of which should have spurred supply, it is clear that DOE's forecast was not responding to changed events, but to an alteration in theories about supply behavior, i.e., a paradigm shift. That they became more pessimistic, and underforecast production significantly despite having a price forecast that was 100% too high demonstrates how severe the bias was. And in fact, whereas all of the regional demand estimates were reduced in line with the higher price expectations, all but one of the regional supply projections was also diminished, despite the contradiction with basic economic principles.

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[36] The $11/bbl price ($3.30/bbl in 1969 dollars) was higher than world prices due to U.S oil import controls, and the Schultz task force presented alternative cases of prices declining to either $8.25/bbl ($2.5/bbl in 1969$) or $6.60/bbl ($2.00/bbl in 1969$). In the latter case, U.S. production would have been only 9.5 mb/d by 1980, although the middle case would still allow a slight increase, to 11 mb/d.

[37] [Project Independence 1974] p. 5. With "accelerated development" and prices flat, the study projected that U.S. oil production would have reached 17 mb/d, outpacing demand.

[38] Exxon, for its part, lowered its forecast of 1990 U.S. conventional oil production from 7.2 mb/d in the December 1978 report to 6.3 mb/d in the December 1979 report. [Exxon]

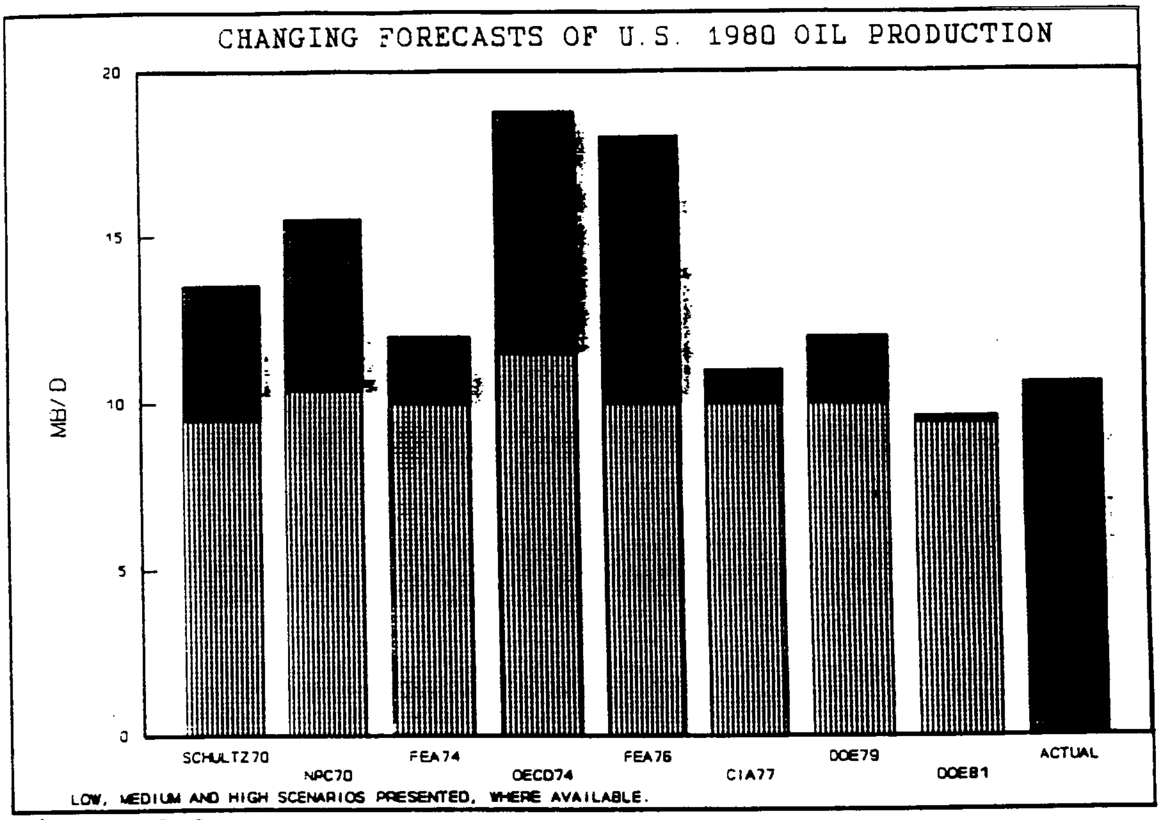

Figure 6-2
Sources: [Schultz 1970], [NPC 1970], [FEA 1974], OECD 1974], [FEA 1976], [CIA 1977], [DOE ARC 1979], [DOE ARC 1981], and [DOE IEO].

Another piece of evidence can be seen in the U.K. Dept. of Energy forecasts of U.K. production. Figure 6-3 shows the errors in their forecasts, with each set of bars representing the errors in the forecasts made in a given year for the subsequent years. Prior to 1980, the U.K. DOE was regularly optimistic, overestimating production, but subsequently, the projections became not only too pessimistic, but repeatedly so, only coming close to being correct in 1986. (Accidents on North Sea platforms in the late 1980s have reduced production significantly and made the forecasts' accuracy meaningless in recent years.)

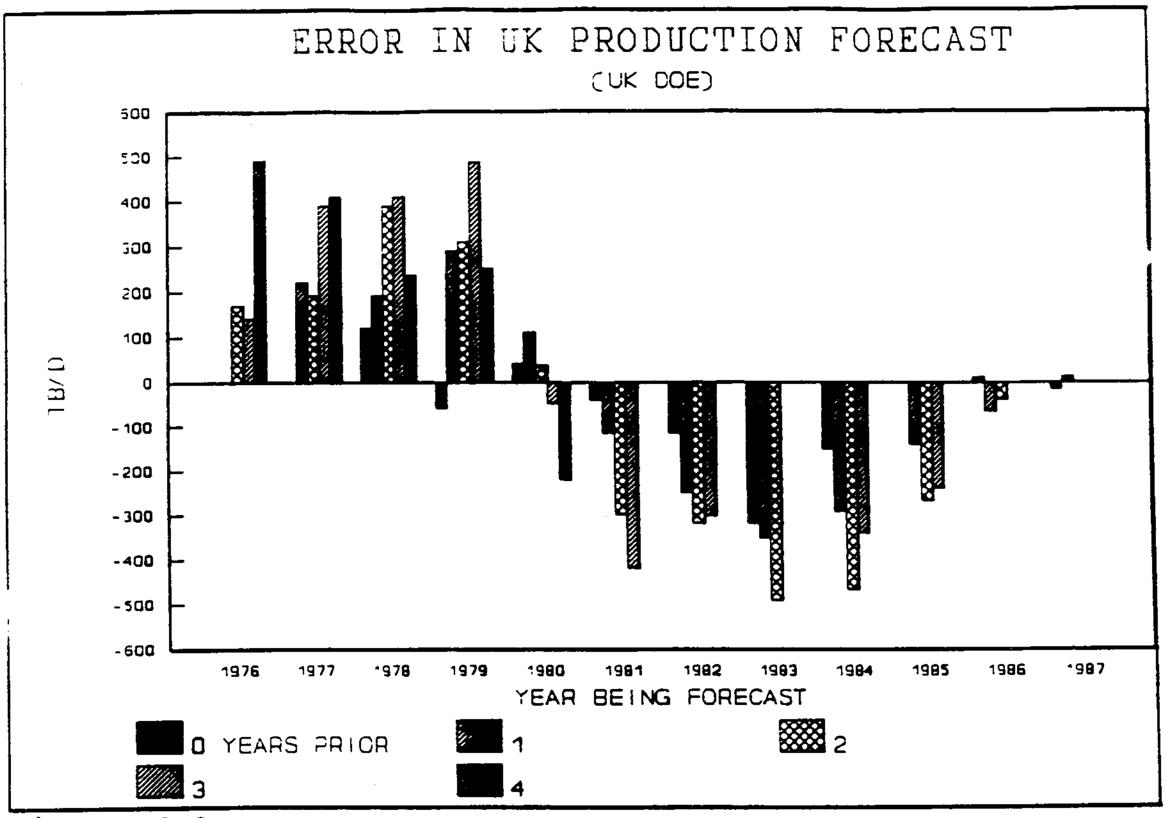

Figure 6-3
Source: [Lynch 1989]

VI.C. The Finite Nature of Resources

> "*Homo sapiens...'inherited' a priceless fortune: the planet Earth and the riches it contained. Part of that one-time bonanza is, of course, the great deposits of fossil fuels that have powered industrial civilization. Even politicians and economists have gradually become aware of the finite nature of the fossil-fuel supply.*" ([Ehrlich & Ehrlich, 1990], p. 25)

> "*Periodically ever since I was a small boy, there has been an agitation predicting an oil shortage, and always in the succeeding years the production has been greater than ever before.*" (Pew, 1925, cited in [Yergin 1991], p. 222)

The belief that limitations of the world's resources are or should be of imminent concern is hardly new, Malthus' theories on overpopulation and the limits of the planet's agricultural capacity being but one modern example. This belief (or ideology) dates back at least to the ancient Greeks, some of whom attributed the Trojan War to the concern of the gods that mankind had outgrown the carrying capacity of the Earth and needed to be 'culled.' [Tuchman 1984, p. 47] These were predecessors of modern-day Malthusians, notably the Club of Rome, aptly characterized by The Limits to Growth, which, having set arbitrary limits on the amount of mineral resources available, proceeded to find that at some point, they would be exhausted, [Meadows et. al., 1972] and their arguments have been continued by Paul Ehrlich's 1968 book, The Population Bomb, and related works, as well as their own recent sequel, Beyond the Limits.

But do these expectations constitute bias? Perhaps most telling in this regard is the 1980 bet between Ehrlich and Julian Simon, labelled by [Tierney 1990] as "Malthusian" and "Cornucopian" for their respective pessimism and optimism about the Earth's resources. As a practical demonstration of their disagreement about depletion and scarcity, they wagered on the level of mineral prices in 1990, the former that mineral prices would be higher, the latter that prices in 1990 would have fallen. While it may not be surprising that Simon, the "Cornucopian," won the argument, the timing of the bet tells us something about the dominant role of ideology and bias on the part of the Malthusians.

Even if Ehrlich were correct and the world's resources were becoming scarce, his expectation that 1990 prices would be higher than those in 1980 was unrealistic. Given that short-term events--the hyperinflation of the late 1970s and the Iranian Oil Crisis--had triggered a burst of inflation in mineral prices, he should have suggested that 1978 or 1976 be used as a base year, recognizing that post-1980 prices could be expected to retrench before resuming an upward march.

That Ehrlich bet prices would continue to rise from their peak, that he incorporated short-term and politically-driven price movements into his beliefs about long-term mineral scarcity, implies that his expectations are founded in assumptions, not analysis, and that the underpinning is more ideological than analytical. (Note the similarity to the argument in [CIA 1979] report in which they interpreted the Iranian Oil Crisis as indicative of the global scarcity of resources.)

The history of the oil industry is littered with instances of prominent people arguing that the limits of the resource base had now been reached, and new provinces unlikely to appear. ([Yergin 1991] pp. 52, 194, 222, 395; and Bradley 1989]) Two particular arguments will be considered briefly: measures of the world's "ultimately recoverable resources" and the concern that all of the "easy" fields have been found, meaning costs must surely rise.

V.C.1. Physical Aspects of Scarcity

One standard datum used by many forecasters is the total amount of oil remaining in the world, known as "Ultimately Recoverable Resources" (URR). Repeated attempts to estimate this variable empirically have been made throughout this century, with a variety of techniques employed.[39]

Unfortunately, what is largely ignored by the lay audience is that URR does not actually describe the world's total resources. In fact, the estimate has grown substantially over time in response to improvements in knowledge and technology. In the 1940s, the typical estimate was about 500 billion barrels; since the 1970s, it has been in the 2000 billion barrel range.[40] But is it appropriate to assume that the current estimates will continue to grow?

The Malthusians often argue that past estimates reflected a poor scientific understanding of petroleum geology, and that new techniques, both geophysical and statistical, allow for a more accurate analysis of the world's global petroleum potential. Even so, a core problem is being ignored, namely that Ultimate Recoverable Resources are defined so as to exclude substantial amounts of the world's petroleum resources.

In particular, what is often left implicit in the description of the worlds "total" oil resources is the assumption that the amounts described are <u>those available at the current price and technology</u>. Everything else is labeled "unconventional" resources, and lumped in with shale oil, liquified coal, photovoltaics and so forth. But as technology advances, more and more of the resource moves from the unconventional to the conventional side of the ledger, and URR grows according. In other words, there is no reason to belief that the world's so-called "total" resources will not increase in the future, unless one believes that price and especially technology will never change.

Considering the definition of "available" resources, and the historical context, the understatement of world petroleum resources is obvious. For example, prior to 1950, there was little offshore drilling, as the technology was still primitive. Thus, offshore oil was defined as "unconventional" and not included in estimates of URR. Yet today, offshore oil accounts for as much as one-third of non-Communist

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[39] See [Moody & Geiger 1975], [Nehring 1978] and [Harris and Meyers 1983] as examples.

[40] For one review of historical estimates of URR, see [Parent 1983], p. 64. For the most recent authoritative estimate, see [Masters et. al. 1991].

production.[41] Similarly, there remain areas that are not currently considered when URR is measured because of water depth, inaccessible terrain, and so forth. Also, huge quantities of very heavy oil, such as the 2 trillion barrels in the Orinoco Belt in Venezuela, are not included because they require additional processing to render conventional oil products. While the cost of some of this resource may be significantly above current oil prices, nevertheless it remains far below what was considered likely for conventional oil prices only a few years ago, and as such, hardly justifies excluding these resources from estimates of world petroleum resources. Consumers seem unlikely to reject using gasoline that came from tar sands instead of East Texas. And as Table 6-1 shows, the amounts of unconventional oil already known remains enormous, albeit at uncertain cost.

Table 6-1
Known Petroleum Resources

Source	Known resource	Time frame	Cost
Orinoco heavy oil	200 bn barrels	Now	<$10/b
	300 bn barrels	Up to 25 years	<$20/b
Tar sands: Canadian	150 bn barrels	Now	$20-25/b
	200 bn barrels		
Natural gas synfuels	300 bn barrels	Now	$25-30/b
Coal liquefaction	Up to 1 trillion barrels	10-15 years	<$30/b
Shale oil	200 bn barrels	Now	<$40/b
	2 trillion barrels	25 years	
Total under $30/b	About 2 trillion barrels		
Current proved oil reserves	900 bn barrels		
Conventional discoveries, conservative assumption	500 bn barrels		
Total liquid fuels under $30/b	3.4 trillion barrels		

Source: [Lynch 1989], p. 94.

41 The technological level of the Soviet/Russian oil industry is such that very little of their production comes from offshore.

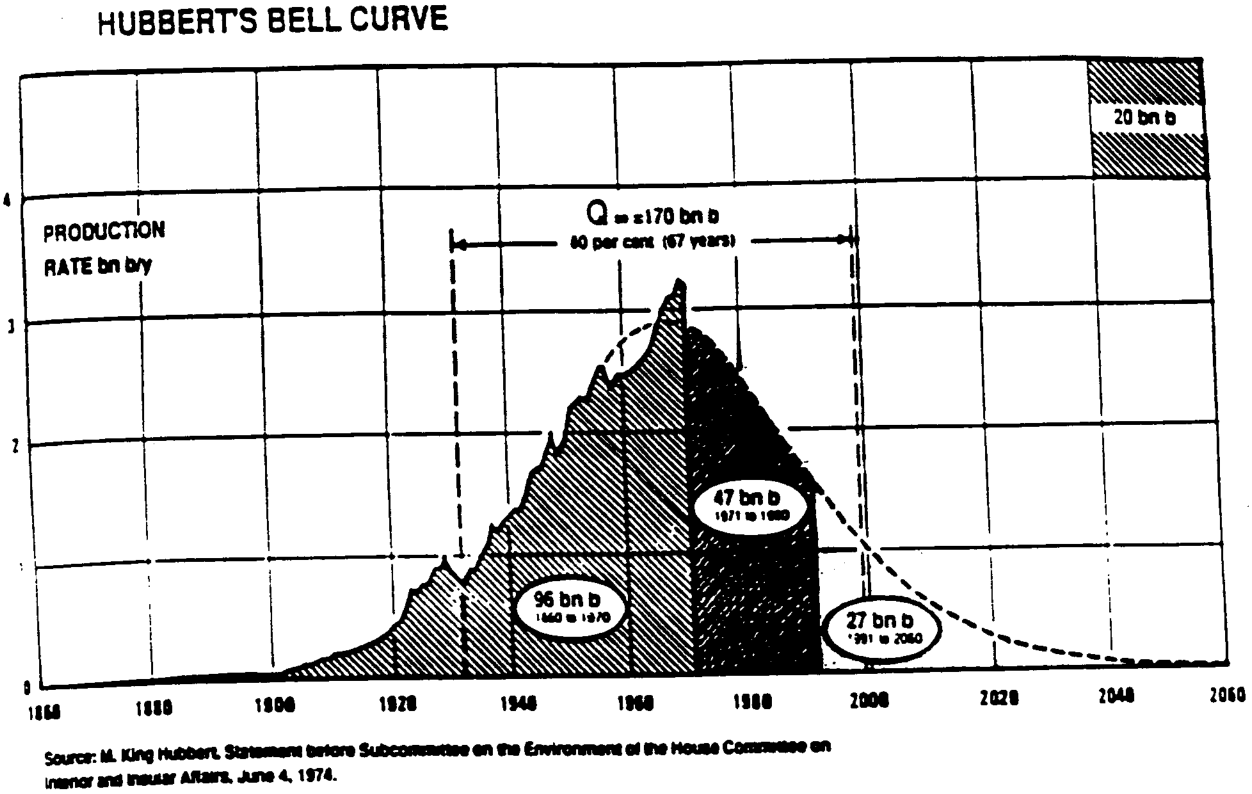

Figure 6-4
Source: [Blair 1976], p. 14.

The U.S. provides an excellent example of the limitations of this methodology. No other petroleum region has been more intensively drilled or analyzed, yet the USGS estimate of undiscovered oil increased by 33 billion barrels between their 1975 and 1991 estimates, or 2 billion barrels per year (60% of production during the period). The rate of future revision can not be predicted, but certainly there is no reason to believe that either knowledge or technology have peaked. Yet a number of production forecasts, particularly those relying on the Hubbert method, rely explicitly on an estimate of URR to determine future production, as can be seen in Figure 6-4. Thus, every upward revision of URR will mean that the production curve must be revised and extended.

At the field level, one clear example of the error which results from reliance on estimates of ultimately recoverable resources comes from an examination of [Nehring 1978], who estimated the world's resources at 2 trillion barrels, in line with the consensus, by examining the world's giant fields which contain the bulk of known oil (proved reserves). He listed the world's giant fields, with a range of estimates of "total recovery" for each one. For the U.S., his estimates can be tested by comparing them to the most conservative measures for the fields, namely past production and remaining reserves, which is published annually by the Oil & Gas Journal. This measure excludes the future growth in field reserves from additional drilling or enhanced recovery, and can be considered the most pessimistic possible.

Of the 42 giant oil fields Nehring lists, 39 are still listed in OGJ.[42] Of them, 22 fields now have more oil than Nehring estimated for the high end of their range of "total recovery".[43] (See Figure 6-5.) Excluding Prudhoe Bay, which dominates the list in terms of size, the fields in aggregate now contain slightly more oil than the high end of his estimates. That so many of these fields, most of them decades old, yet still growing in size, already contain more oil than was thought possible a mere fifteen years earlier is perhaps the best indication of the failure of such estimates to inform us as to the true extent of the world's resources.

The U.S. is hardly the only example of Malthusian bias in estimates of total resources. The U.S. Geological Survey, which has produced detailed estimates of URR for the U.S. and the world, estimated in 1984 that there was a 5% probability of another 199 billion barrels being found in the Middle East. Yet, since then, known resources have increased by about 300 billion barrels.[44] It is less startling that the low probability was exceeded so rapidly than that so pessimistic an estimate would be made for such a lightly explored region. Again, this offers evidence of Malthusian bias, and indicates the limitation of relying on estimates of ultimately recoverable resources.

[42] The others may have ceased production or be carried under other names.

[43] Nehring admits that some of the estimates are conservative, but providing a range of 'total recovery' which does not extend as far as possible would seem to defeat the purpose of providing the range, but certainly indicates that the estimates do not represent evidence of the amount of total resources.

[44] This is described in [Adelman 1990] p. 2.

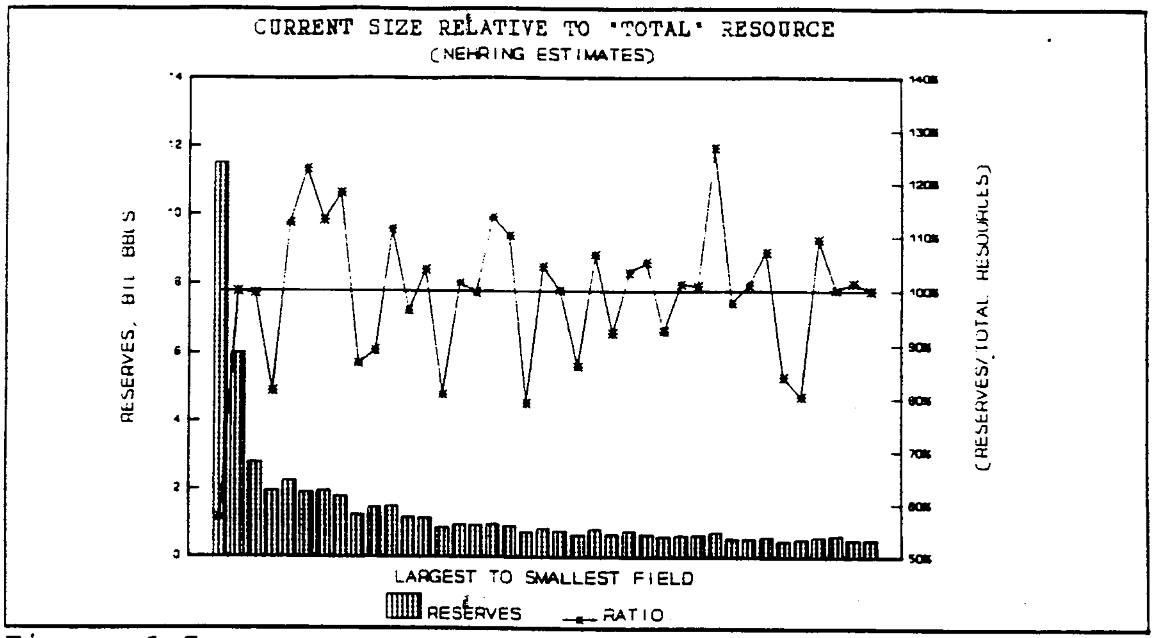

Figure 6-5
Source: [Nehring 1978]

V.C.2. A Dearth of "Easy" Oil: Cost Trends

> *"Not many of our big oil fields remain prolific producers. That doesn't leave much for the immediate future, let alone for our descendants."*[45]

> *"The more we use these fuels, the closer we get to running out of supply or, more exactly, to finding that the remaining supplies are too expensive to use."* [IIASA 1980 p. 5]

Even for those who accept that petroleum resources are not constrained, some still insist that depletion is driving prices higher. That is, society has been using up the large oil fields, and all that remains are the smaller ones, which are by definition "harder" to produce or more expensive.[46] This is the economic version of the Malthusian argument, namely that when resources become scarce, this will be reflected in their cost (and price), so that consumers will simply cease to use them in favor of other goods. Even analysts who accept that "[t]he world is not running out of energy..." will still argue that "[h]igher energy costs cannot be avoided..."

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[45] Ekonomika i Zhizn article, cited in Oil & Gas Journal, 1/27/92, pp. 36-40.

[46] See, for example, [Nehring 1978] or Riva [1991]. Typical of even the trade press is the headline, "Oil is Running Out" (referring to Egypt) in Petroleum Economist March 1991, p. 20.

because "bringing new sources into the supply stream will be costly". [Darmstadter et. al., 1983, p 6.]

There is no doubt but that mineral costs, should, in theory, rise. Unlike manufactured goods, where economies of scale can be realized, mineral production is dependent on geology, which varies with every deposit. Since seismic studies allow the explorationist some idea of the probable cost of potential deposits, they can drill the cheapest first, then move on to the next cheapest, and so forth. Thus, as drillers are forced to seek increasingly more expensive deposits, costs should rise, <u>all else being equal</u>. This is noted, for example, by [Ivanhoe 1983] who estimated that the average decline in return on drilling is 7% per year.

Unfortunately, all else is never really equal, since advances in productivity, both technology and knowledge, are usually ongoing, and local cost elements, such as infrastructure, also change, frequently, though not always, for the better.[47] Thus, while there are factors militating for increasing oil production costs, they are offset in part or in whole by other factors, and both the level and trend in costs becomes an empirical question.

V.C.3. The Paucity of Actual Evidence

As mentioned previously, most energy economics research focuses on demand, not supply, and this is particularly true of research on production costs. The reality is that, outside of Britain, Canada and the U.S., valid data is largely nonexistent, as [Adelman and Jacoby 1977] noted.[48] Company investment data is frequently aggregated, both by region (U.S. versus non-U.S., data by hemisphere) and type (oil and gas investment combined, or production and refining, etc.), making it fairly useless. Additionally, irrelevant expenses are often included, such as social infrastructure development required by local governments, or inflated costs due to demands for local content. Still, a substantial literature exists, which can be divided into several types: general surveys, trend analysis, aggregate analysis, and surrogate estimation.

The general surveys typically cover oil and sometimes alternative energies (gas, coal, synfuels) providing broad ranges for both amounts and costs. (See [Desprairies, de

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[47] [Kendrick and Grossman 1980] estimated that, in the U.S. mining sector, productivity improvement from 1948-1976 was 1.7% per year, which appears to be the closest estimate to the petroleum sector.

[48] See, for example [Adelman 1992] for the U.S. and [Eglington and Uffelman 1983] for Canada. They found that long-term cost trends tended to be moderate before the oil price shocks, after which they rose, although the effect of the investment boom makes it difficult to treat this as definitive, particularly given cost moderation which has followed the 1986 oil price collapse.

la Tour, and Lacour 1986], [Roumasset, Isaak and Fesharaki 1983], and [Barnes 1991].) The methodology relies heavily on interviews, and most provide little supporting data. Unfortunately, as they are typically only a snap-shot of present costs, none is informative about long-term trends.

Trend analysis consists primarily of work which refers to trends (usually exponential) for various cost factors, most notably returns to drilling. Actual costs are rarely considered, so that the effects of drilling cost changes are ignored.[49] (The exceptions being the work done on U.S. and Canadian costs noted above.)

The aggregate estimates rely on investment and production (or discovery) data to give approximate ranges for either marginal costs or "finding" costs. (See [Andersen, 1985] as one of many examples.) However, the aggregation not only combines exploration and development investment but some appear to include total investment, i.e., including pipelines, refineries, and so forth. The "finding" cost estimates are not meaningful, and the marginal cost estimates typically seem much too high, even surpassing prices by a wide margin. [Lynch 1990a]

The best example of "surrogate cost" research is [Adelman and Shahi 1989], which relies on physical data such as well depth and productivity and U.S. cost factors to indicate what capacity in various countries would cost if local cost factors (labor, raw materials, etc.) were identical to those in the U.S.[50] This provides important insight into trends in the physical aspects of marginal costs, such as well productivity, without addressing drilling cost trends, such as productivity improvements.

V.C.4. Evidence of Current Cost Levels

Ultimately, the precise level of marginal costs of oil production around the world has not been definitively demonstrated. However, the notion that costs are now or will in the next few years put pressure on oil prices can be discredited by a variety of means. First, the fact that non-U.S. investment continues to increase at a rapid rate suggests that the current prices are still well above marginal costs. Second, taxes and royalties on production, which vary from country to country, and even from contract to contract, still appear to be on the order of 50% or more of price in most countries, indicating that costs are well under half the current price level. [Barrows 1989]

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49 See [Kaufmann and Cleveland 1991] as an example. More frequently, analysts merely refer to one or another trend suggestive of increasing difficulty, particularly the declining returns to drilling, as indicating scarcity or rising costs. See also [Banks 1987] and [Ivanhoe 1983].

50 [Adelman and Lynch 1986] and [Lynch 1990] also use surrogate costs as one approach to estimating the marginal costs of Soviet gas and oil production, respectively.

Finally, by using the capacity estimates in [Adelman and Shahi 1989], an approximate range can be provided to what costs are likely to be. It will be recalled that Adelman and Shahi calculated capacity costs using U.S. cost factors, in other words, what the capacity would cost if it were in the U.S. Taking $10,000/daily barrel as the approximate breakeven cost at which a field is still viable to produce,[51] and dividing the Adelman and Shahi estimate into it, yields the multiplier indicating how much higher local costs have to be than those in the U.S. in order for marginal costs to be breakeven, i.e., at U.S. levels. Thus, in Angola, with a multiplier of 14, it would have to cost 14 times as much for the same drilling activity as in the U.S. for marginal costs to be similar to those in the U.S.

The results are shown in Figure 6-6, which graphs the cost multiplier against the level of production in 1985, and while some countries do, indeed, show costs close to the U.S. level (a multiplier of one), less than half of the larger producers do. For most of the large producers, costs would have to be 15 to 30 times as much as in the U.S.

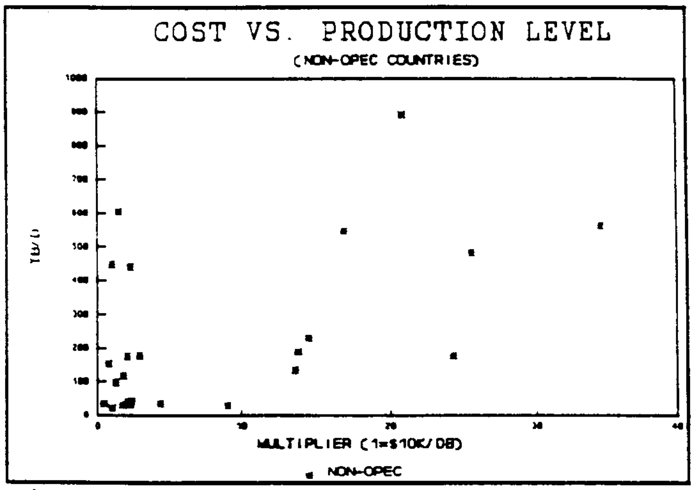

Figure 6-6
Source: [Adelman and Shahi 1989]

V.D. Conclusion: Supply is Not Constrained

Forecasts of competitive oil supply have been repeatedly too low, and are clearly biased. The shift to a Malthusian paradigm in the late 1970s appears to be the source of this bias, since the evidence suggests that neither resource availability nor current cost levels (or trends) are constraining oil supply, or having any affect on prices. The next section demonstrates the impact on actual supply forecasting.

[51] Actual viability will depend on field life, the discount rate, expected price and taxes, but $10,000/db appears to be U.S. marginal costs in the late 1980s (see Adelman 1992), a level at which investment continues, albeit not quite high enough to maintain production.

VII. THE IMPACT OF MALTHUSIAN BIAS ON SUPPLY FORECASTS

Given the uncertainty surrounding resource availability, cost trends and so forth, it might be argued that pessimism about supply represents realism, or at worst, appropriately conservative expectations. But the reality is that such pessimism has played a major role in the failure of oil price forecasting in the past fifteen years, and there are numerous examples to demonstrate it. The first and most telling remains the forecasts of CPE exports, as shown in Figures 4-6 and 4-7, which have repeatedly been too low. Additionally, at EMF6, the mean non-OPEC production forecast for 1990 was 22% too low, despite a mean price forecast that was three times the actual! [Huntington 1991 p. 4]

VII.A. The Micro Failing the Macro[52]

Another example of Malthusian bias is seen in the many supply projections using oil-field data-bases to develop a detailed, often country by country, forecast of future supply. For example, [Curcio 1989] and [Esser 1991] did this for non-OPEC, non-U.S. countries, while [GRI] does it for the U.S. In virtually every case, the end result is that the supply being analyzed is projected to peak in the near future.

Figure 7-1 shows Curcio's forecast for non-OPEC, non-U.S., non-Communist supply. This type of curve is readily recognizable to oil industry observers, appearing often in supply forecasts made for individual countries. Production from existing fields is shown as declining rapidly, offset in part by discovered fields not yet in production and as-yet- undiscovered fields. While such behavior is not, <u>in theory</u>, incorrect, what stands out in the Curcio forecast is that production for existing fields is projected to decline at approximately 10% per year. Indeed, Table 7-1, created from a number of published production curves, shows that this kind of forecast of production decline is common for individual country oil production forecasts.[53]

This rate of decline should immediately raise suspicions, because it is close to what is known as the "decline rate," which is the percent of a field's reserves produced in a given year, and as such, represents the <u>theoretical maximum</u> rate of decline.

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[52] This section is based on [Lynch 1990b].

[53] These forecasts themselves may be biased. Note that all are for English-speaking countries, which may reflect sampling bias on the part of the journal in which they were reported. It may also simply reflect the nature of the oil industry in these countries, which includes many existing fields, developed by (mostly) private companies. However, the absence of Norway, Egypt, etc., from the table cannot then be explained. Nonetheless, the breadth of the sample, both in time and type of forecaster (private and public, oil company and governmental), suggests they are fairly representative.

Essentially, if 10% of a field is produced, production will decline by 10% if nothing else is done to the field.

This qualification is crucial, because typically there is substantial room for new investment to offset the depletion of the field. Additional wells are drilled or secondary or enhanced recovery is employed to raise production relative to the base case of no investment. In the U.S., 80% of the average amount of new reserves added each year is from just such additions to existing fields, and Figure 7-2 shows one estimate of the way in which fields grow over time. [DOE Resource 1990] And indeed, [Drew and Schuenemeyer 1992] found that while their 1980 forecast of reserve additions in an area of the Gulf of Mexico underestimated the number of fields by 9%, the forecast error for reserves was 50%, because the model did not adequately adjust for growth in old fields.

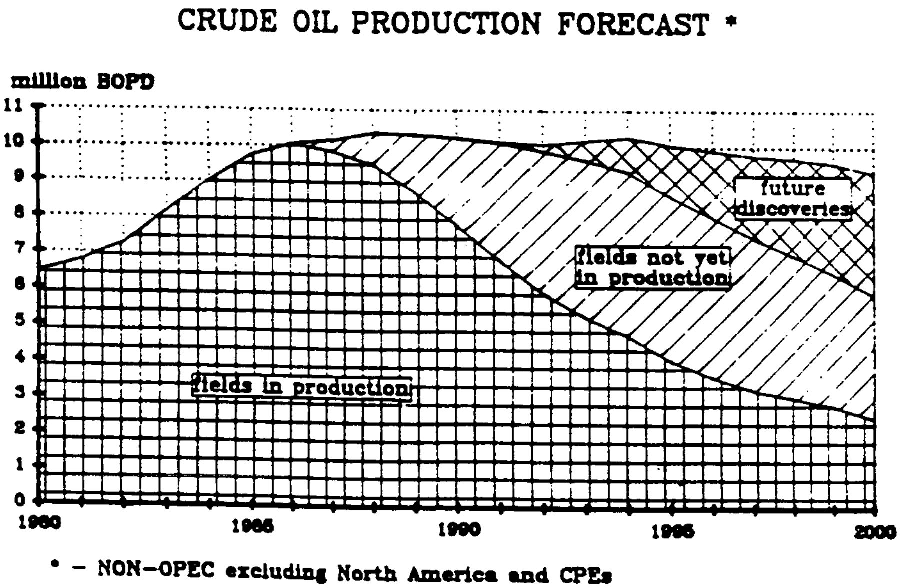

Figure 7-1
Source: [Curcio 1989]

TABLE 7-1

A. PRODUCTION FORECASTS FOR EXISTING RESERVES (PERCENT PER YEAR)

FORECASTER	1980/90	1985/90	1990/2000	2000/10	SOURCE
	PERIOD				
A. U.S.					
TGT	-13.9%		-10.9%		OGJ 11/2/81, p. 80.
API		-16.9%	-11.0%		OGJ 9/19/83 p. 74
CHEVRON		-9.1%	-10.6%		OGJ 5/5/86, P. 70
B. ALASKA					
DAMES & MOORE	-1.3%		-10.2%		OGJ 4/12/82, P. 51
ALASKA DEPT. OF NATURAL RESOURCES			-12.3%	-15.4%	OGJ 9/25/89 P. 27
C. U.K.					
ESSO PETROLEUM LTD.		-9.1%	-15.3%		OGJ 1/2/84 P. 30
BRITOIL		-11.7%	-15.9%		OGJ 10/1/84 P. 80
UKOOA		-7.0%	-2.1%		OGJ 10/8/84, p. 32
UKOOA			-16.3%	-17.5%	OGJ 10/2/89, P. 28.
D. AUSTRALIA					
ESSO AUSTRALIA	-14.0%				OGJ 12/1/80 P. 114
ESSO AUSTRALIA			-7.8%	-6.8%	OGJ 8/28/89 p. 17
AUST. PETRO. EXPLORATION ASSOCIATION		-5.5%	-11.3%		OGJ 2/20/84 P. 37
E. CANADA					
IMPERIAL OIL	-10.0%		-6.9%		OGJ 7/10/78, P. 31
SHELL CANADA	-3.5%		-9.6%		OGJ 11/24/80 P. 44

B. PRODUCTION FORECASTS INCLUDING NEW DISCOVERIES (PERCENT PER YEAR)

FORECASTER	1980/90	1985/90	1990/2000	2000/10	SOURCE
	PERIOD				
A. U.S.					
TGT	-0.6%		-1.8%		OGJ 11/2/81, p. 80.
API		-0.5%	-0.3%		OGJ 9/19/83 p. 74
CHEVRON		-1.8%	-1.7%		OGJ 5/5/86, P. 70
B. ALASKA					
DAMES & MOORE	0.2%		-5.0%		OGJ 4/12/82, P. 51
ALASKA DEPT. OF NATURAL RESOURCES			-10.5%	-9.8%	OGJ 9/25/89 P. 27
C. U.K.					
ESSO PETROLEUM LTD.		-3.9%	-2.7%		OGJ 1/2/84 P. 30
BRITOIL		-11.7%	1.8%		OGJ 10/1/84 P. 80
UKOOA		-5.7%	-2.5%		OGJ 10/8/84, p. 32
UKOOA			-1.4%	-2.9%	OGJ 10/2/89, P. 28.
D. AUSTRALIA					
ESSO AUSTRALIA	-3.6%		-6.9%		OGJ 12/1/80 P. 114
ESSO AUSTRALIA			-4.8%	-3.2%	OGJ 8/28/89 p. 17
AUST. PETRO. EXPLORATION ASSOCIATION		0.6%	0.4%		OGJ 2/20/84 P. 37
E. CANADA					
IMPERIAL OIL	-0.7%		0.8%		OGJ 7/10/78, P. 31
SHELL CANADA	-1.5%		-2.4%		OGJ 11/24/80 P. 44

Note: Imperial Oil forecast is for 1990/95, not for 1990/2000.

API = American Petroleum Institute
OGJ = Oil & Gas Journal
TGT = Tennessee Gas Transmission
UKOOA = U. K. Offshore Operators Association

In effect, projecting that production will drop by the decline rate is the most conservative projection possible[54] and proves not to be supported empirically. Data problems make analysis of world-wide long-term oil field behavior difficult, but Table 7-2 shows a compilation of field production for a variety of fields in various countries at different historical periods as reported in the OGJ annual production survey.

Figure 7-3 presents a graphical view of the forecasted annual change in production with the empirical analysis, the right-hand side of the figure representing the forecasts, while actual field behavior is on the left. Existing fields are shown by the boxes, and the solid line represents change in production for each country as a whole, that is, including new discoveries and fields too small to be reported. Obviously, the forecasts tend to be far more pessimistic than observed behavior, and while the many inconsistencies in the data do not allow precise analysis, it appears as if the major difference in the two is that existing fields tend to decline far less in reality than those presented in the forecasts. Apparently, most forecasts using field data have ignored the tendency for further investment to increase reserves and offset depletion. The result is that production forecasts at the micro (or individual country) level are too pessimistic and, when aggregated, yield a macro (or global) forecast which is too low. Correcting for this bias, would raise non-OPEC, non-U.S., oil production in 2000 by 2-3 mb/d from Curcio's forecast, for example.

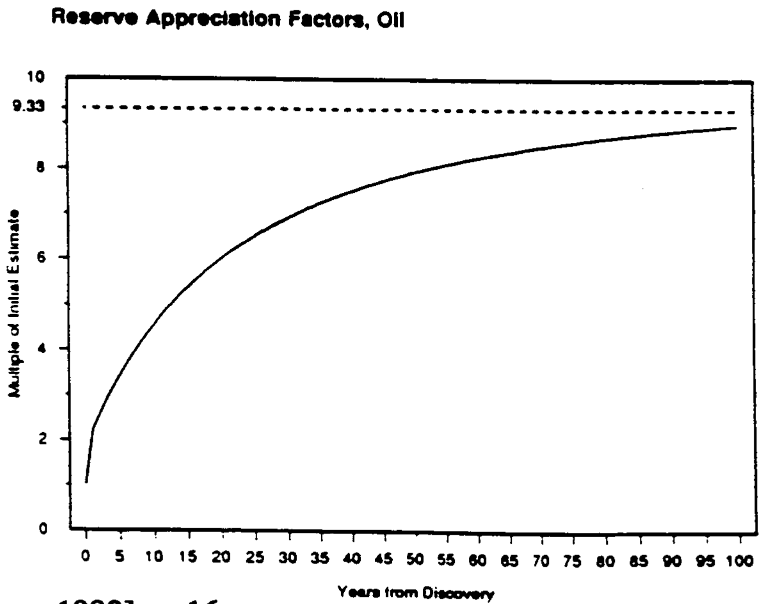

Figure 7-2
Source: [DOE Resource 1990] p. 16.

[54] Ignoring the impact of factors like OPEC quotas causing fields to be shut in, or unusual events or problems at the field.

TABLE 7-2
EMPIRICAL ANALYSIS OF FIELD PRODUCTION DECLINE

COUNTRY	PERIOD	ANNUAL RATE OF CHANGE ---FIELDS LISTED--- (WTD AVG)	(UNWTD AVG)	TOTAL PRODUCTION	CALCULATION COVERS PERCENTAGE OF: FIELDS LISTED (INIT YR/FINAL YR)	TOTAL PRODUCTION (INIT YR/FINAL YR)	NUMBER OF FIELDS USED
ARGENTINA	1965/75	3.4%	5.8%	4.6%	100%/78%	100%/89.5%	7
	1975/85	1.1%	-3.0%	1.1%	100%/90%	99%/99%	9
BRAZIL	1965/75	-0.3%	2.4%	6.5%	53%/44%	98%/45%	7
	1975/85	-5.0%	-5.1%	11.8%	94%/23%	93%/18%	17
COLOMBIA	1965/75	-2.2%	-2.3%	-1.9%	65%/61%	58%/56%	17
	1975/85	-4.9%	-0.8%	0.0%	68%/40%	84%/51%	19
EGYPT	1965/75	-3.2%	-4.2%	5.3%	30%/19%	19%/8%	3
	1975/85	6.0%	-1.9%	15.1%	38%/14%	66%/29%	7
INDONESIA	1955/60	7.0%	-6.1%	4.6%	76%/55%	75%/49%	20
	1960/70	-9.1%	-5.5%	8.8%	62%/57%	52%/9%	25
AUSTRALIA	1970/75	8.1%	-2.6%	27.8%	80%/57%	99.5%/43%	4
	1975/85	-8.1%	-6.1%	2.7%	71%/12%	99.9%/33%	5
CANADA	1970/75	3.2%	4.1%	-0.5%	38%/95%	45%/56%	42
	1975/85	-4.2%	-5.2%	0.2%	77%/72%	56%/35%	34
NETHERLAND	1965/75	-4.6%	-6.5%	-9.9%	83%/45%	98%/98%	5
	1975/85	-2.3%	-3.3%	7.1%	100%/45%	98%/39%	5
U.S.	1950/70	1.6%	1.8%	2.8%	21%/48%	45%/35%	127
(lower 48)	1970/80	-2.8%	-4.4%	-2.9%	56%/76%	46%/47%	148
	1980/85	-4.0%	-5.5%	0.4%	88%/82%	53%/42%	169
	1985/89	-6.0%	-7.0%	-5.0%	86%/82%	45%/43%	181

Note: All data from Oil & Gas Journal.

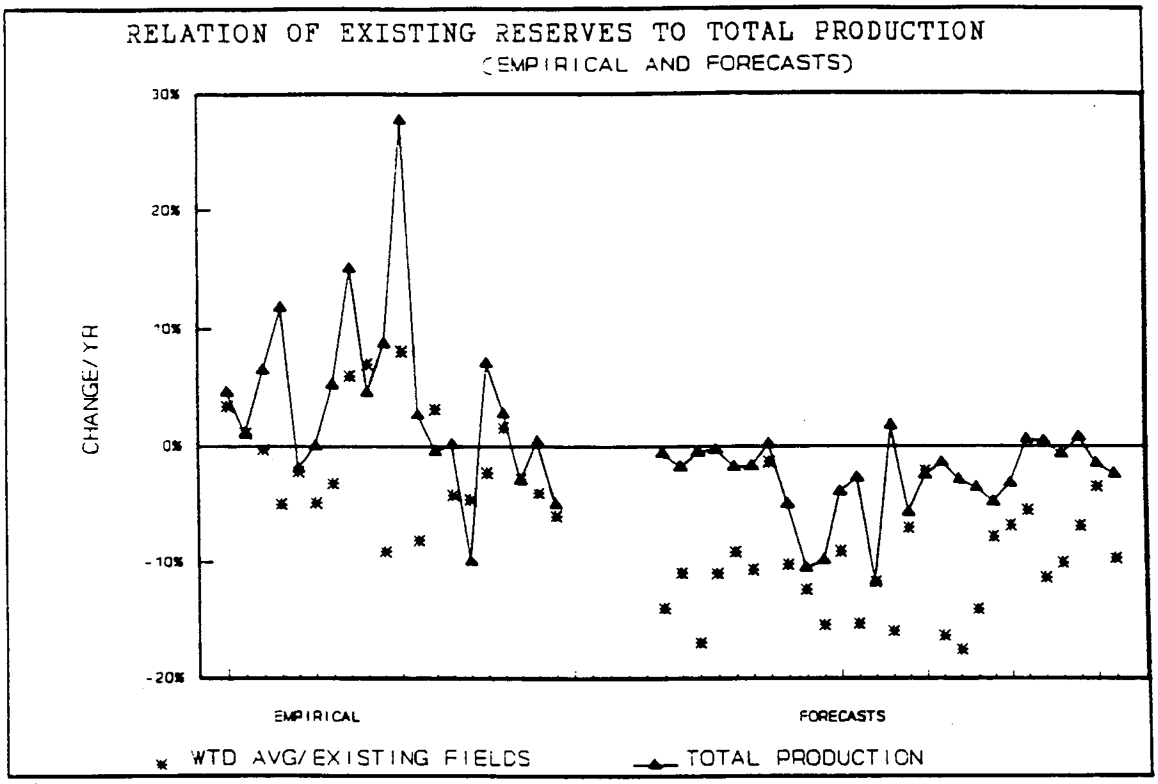

Figure 7-3
Source: [Lynch 1990b]

VII.B. Expectations for Third World Supply

As mentioned, supply forecasts did not become Malthusian until the late 1970s. In Figure 7-4, DOE's forecasts for non-OPEC, Third World oil production can be seen as they evolved over time. Originally, DOE expected strong growth (although in the late 1970s, Mexico was expected to account for much of the increase); in recent years, they have become pessimistic, forecasting flat or declining production, despite the fact that production has been continued to rise sharply.

Is this a realistic expectation? Aside from the fact that non-U.S. investment has been increasing by double-digit percentages[55] in recent years, and that drilling rig activity, which has plummeted in the U.S., has remained solid in the Third World (see Figure 7-5), there are numerous indicators suggesting non-OPEC developing countries' oil production has a long way to go before it peaks. The primary uncertainties have to do with the adequacy of resource, on the one hand, and the willingness of producing governments to exploit their resources on the other.

[55] Estimated annually by Salomon Brothers and reported in, e.g., [IPE 1991], p. 273.

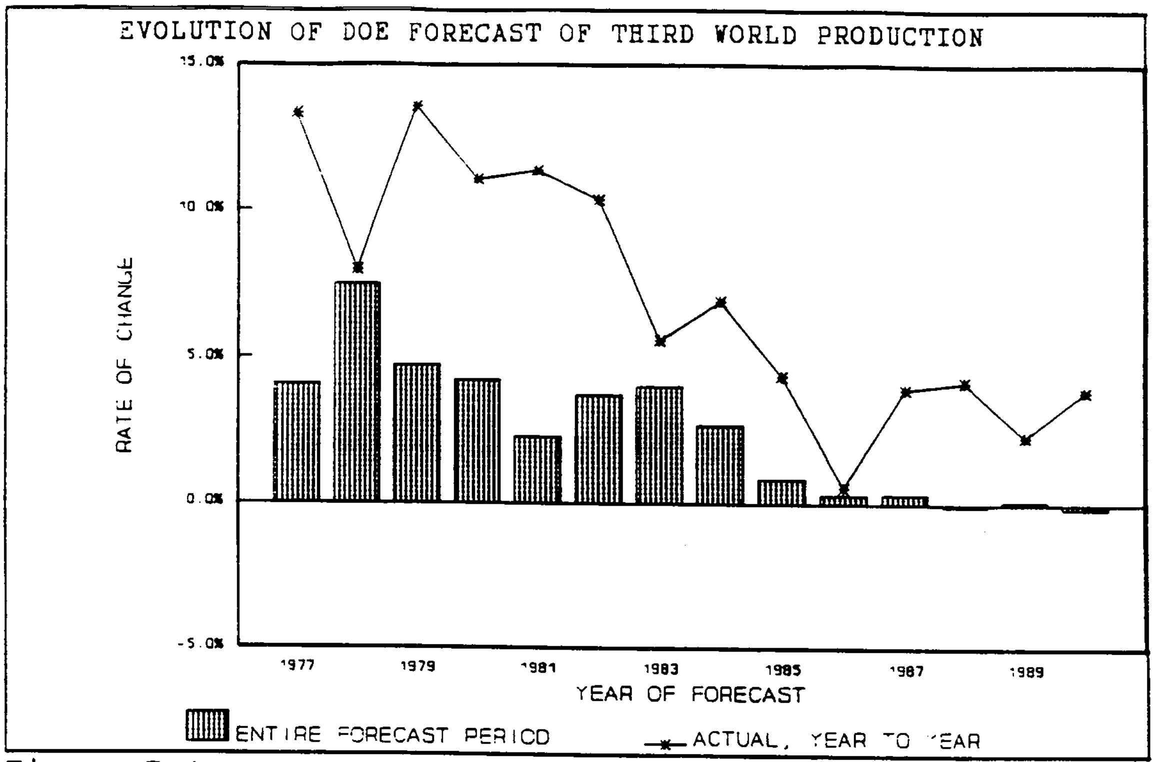

Figure 7-4
Sources: [DOE IEO], [BP]

First, the level of oil resource exploitation is much lower in the Third World than in the U.S., as Figure 7-6 demonstrates. In 1970, the year oil production in the continental U.S. peaked, the cumulative number of wells drilled was about 2,750,000, ten times the number in the total Third World in 1985! When the much greater petroleum prospective area of the Third World is considered, the ratio becomes much greater, 33 wells per 100 square km in the U.S. vs. 0.62 in the Third World.[56] Similarly, production per well in 1990 was 190 bbl/day in the Third World, versus 12 bbl/day in the U.S., again indicating that the Third World cannot credibly be said to be suffering from resource constraints. (See Figure 7-7.)

Nor are there policy or political constraints. While a producer whose costs are very high might be well advised to withhold production, especially if prices are expected to rise, it is very difficult to find any governments that are actually doing so. Most of the problems foreign investors encounter are due to nationalism, not a desire to keep oil in the ground as an appreciating asset. Indeed, at present, most producing countries are encouraging investment in the oil industry through tax and regulatory reform, including privatization of national oil companies. [Morse 1990/91]

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[56] See OPEC Bulletin 2/88, p. 8.

Certainly, some non-OPEC countries have provided a degree of support for OPEC in its efforts to stabilize prices, but these have been short-term contributions. The extent to which countries like Egypt will defer revenue to assist OPEC members such as Saudi Arabia seems limited. And since some of the largest non-OPEC, Third World producers (notably India and Brazil) are actually net importers, they can hardly be expected to support oil prices by increasing imports.[57]

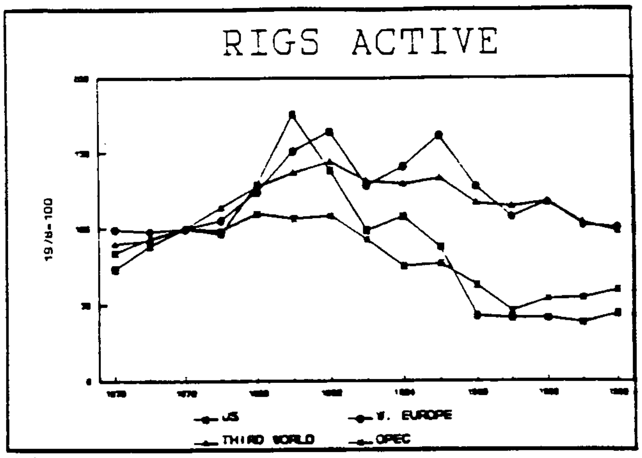

Figure 7-5
Source: [ESS 1991]

VII.C. Predictions for Non-Gulf OPEC Production

Another example of Malthusian influence on supply expectations can be seen in DOE's projection of expected capacity for the smaller OPEC members as it has evolved over time. For much of the past decade, the conventional wisdom has held that the smaller members were "mature" producers whose capacity must "inevitably" decline due to resource constraints, rather than any desire to conserve their oil or raise the world price.[58] Thus, in Figure 7-8, DOE's assumed capacity changes for OPEC members in 2000

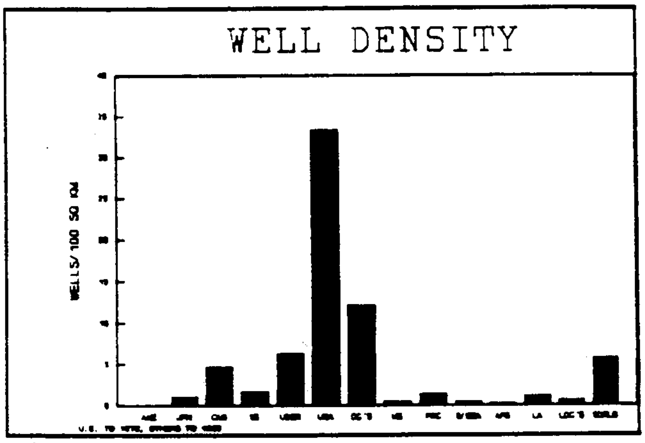

Figure 7-6
Source: [Lynch 1989]

[57] Naturally, this is not meant to suggest that every oil producing country, at all times, will seek to increase production, without regard for other economic and political considerations. Brazil and Venezuela are recent examples of investment cutbacks motivated by budget constraints.

[58] See [CIA 1979] p. 6, and [DOE 1991], p. 7, as examples. In fact, there have been predictions that by 2000, only the Arabian/Persian Gulf members would still be exporting. Of course, identical predictions have been made for the past decade (see PIW 9/8/80 for projected production in OPEC in 1990), and failed to occur. This behavior appears to be similar to the tendency, shown above, of price forecasters to err in predicting the slope, and repeatedly correcting the endpoint.

is shown, and it can be seen that only the Persian/Arabian Gulf members' capacities are expected to increase.

But the past several years has seen evidence that this view is too pessimistic, as the non-Gulf members have initiated new drilling programs and discovered more oil, predictions of their future capacity have had to be repeatedly revised upwards, by 20% in 3 years, as, in fact, Figure 7-9 shows. For example, Venezuela began an aggressive drilling program in the late 1970s, more than doubling reserves in the 1980s, and plans substantial capacity increases in coming years, (although short-term budget constraints have delayed current investments). Yet DOE has only slowly raised their assumptions of future Venezuelan (and other small members') capacity to reflect these developments.

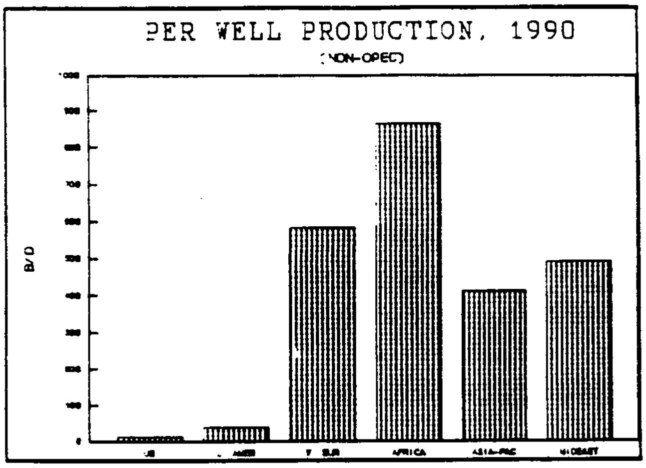

Figure 7-7
Source: [World Oil 8/91]

VII.D. Conclusion: Pessimism about Supply Reflects Malthusian Bias

Since the late 1970s, pessimism about oil supply has been a constant of oil market forecasting and has repeatedly proven to be exaggerated or incorrect. In terms of CPE exports, Third World supply, and even much of OPEC, the prevailing belief that oil has become too expensive, that the easy fields are all found, and that production must "inevitably" decline has led forecasters to produce projections which are biased in the pessimistic or Malthusian direction. That the same pessimism appears in forecasts for regions like Siberia and the non-OPEC Third World, where the exploitation level is so much lower and giant discoveries continue, as for the U.S., where costs are high and yields are low, indicates that Malthusian bias, not realistic expectations, underlies the pessimism in these forecasts.

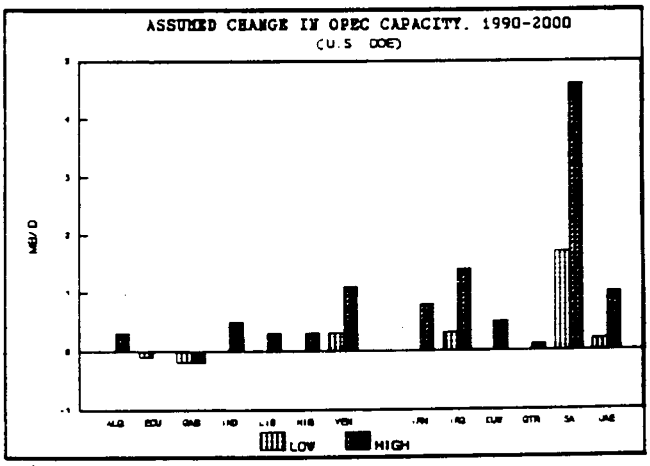

Figure 7-8
Source: [DOE IEO 1991]

Although it is difficult to be precise about where oil will be found, or what areas will produce how much, the reorientation of many oil companies towards overseas investment and the desire of producing governments to increase foreign investment implies that Third World oil production will continue to increase, and probably total non-OPEC will as well, the U.S. being the primary exception.

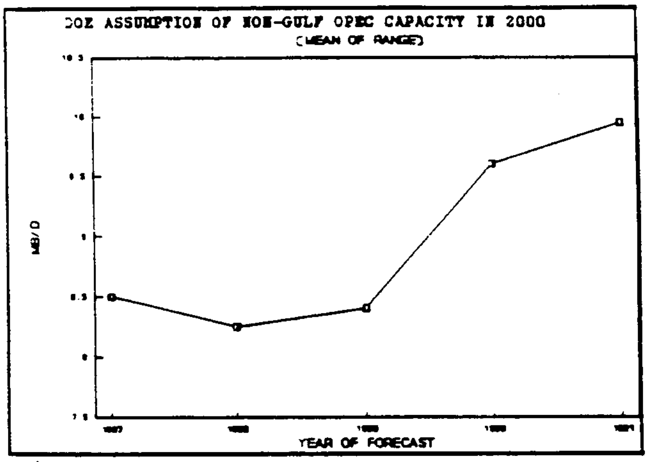

Figure 7-9
Source: [DOE IEO]

Certainly, the supply of oil is finite, but there is clearly no reason to be concerned about availability for at least the next half-century, by which time technological improvements will should have vastly changed the costs and availability of global energy. People did not switch from coal to oil because of scarcity, except inasmuch as the newer fuel proved better and cheaper. And yet, coal and even wood remain important energy sources today, eons after the first use in the case of the latter fuel, and it is likely that our grandchildren will still rely on petroleum as a major raw material if not fuel.

VIII. THE DETERMINANTS OF PRICE

Having rejected the theory that the "Hotelling Principle" explains prove movements, and the argument that costs are driving prices, how can long-term prices be forecast? Recalling Figure 1-2, assuming a price of $10/bbl would appear to be the best predictor over the history of the industry, at least until 1970. However, this is hardly satisfying, since it ignores changing economic, political, and market conditions, to say nothing of rather drastic deviations from the mean during the past two decades. While a flat price might be the best estimator in the long-term, the deviations from it have been significant enough in both magnitude and duration to render it of low utility, at least in terms of corporate planning horizons. An oil company might paraphrase Keynes by saying, "In the long run, we are all bankrupt."

VII.A. Inability to Explain Price Forecasts

Bearing in mind that the price of oil is set in the short-term, and the long-term price is merely the short-term reiterated, there are nonetheless various factors that one would expect to influence if not determine the price over extended periods. Primarily, these are the level of oil demand, which indicates the necessary intensity of exploitation or the intersection with the supply curve, and the level of OPEC sales, or exports, which demonstrates, in the crudest form, the power of the cartel.

Yet these do not appear to affect most oil price forecasts. In Figures 8-1 to 8-4, the IEW forecasts are reviewed to demonstrate the correlation (actually, the lack thereof) between these variables and expected prices. In Figure 8-1, a comparison of demand versus price forecasts for 2000 is made; Figure 8-2 shows the expected level of OPEC exports in 2000 as opposed to prices for each forecast. Figures 8-3 and 8-4 show the rates of growth from 1990 to 2000 for oil demand and OPEC exports, respectively, compared to the rate of growth for price, to test whether the rate of change, as opposed to the absolute level, is determining.[59]

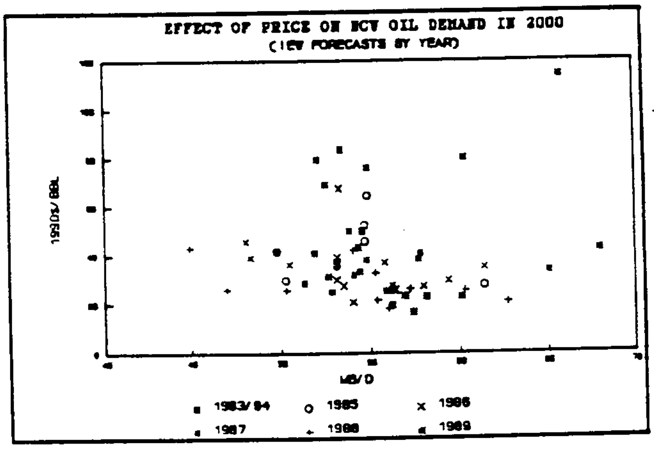

Figure 8-1
Source: [IEW]

[59] Note that the IEW forecast surveys do not include base year data, but rather predictions or estimates for 1980, 1990, and 2000, and so forth, such that the rate of growth

What is immediately obvious from each of these graphs is the near-total lack of correlation between either oil demand and OPEC sales and the expected level of and rate of change in price. The figures resemble nothing so much as scatter-plot diagrams. And in the regression results presented in Appendix A, the highest R^2 in any case is only 0.07, indicating that there is, indeed, virtually no correlation between expectations for price (either absolute or growth rate) and either demand or OPEC exports (absolute or growth rate).

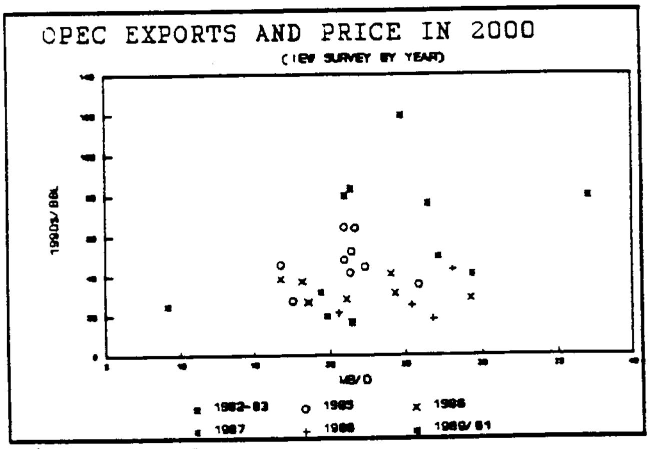

Figure 8-2
Source: [IEW]

And indeed, formal models typically employ an explicit algorithm which equates annual price changes to changes in OPEC capacity utilization. But is this algorithm endogenous, or merely an entry point for bias?

VII.A. 'Scientific' Price Forecasting: OPEC Capacity Utilization

Given that supply and demand do not seem to be driving oil price forecasts, the next step is to consider what is, at least for the computer models, where explicit formulas are presented. [Beider 1980] The typical equation is a simple one, price as a function of OPEC capacity utilization, and is sometimes cited to demonstrate that oil price forecasts are endogenous. ([Gately, Kyle, and Fischer 1977] first noted the correlation.)

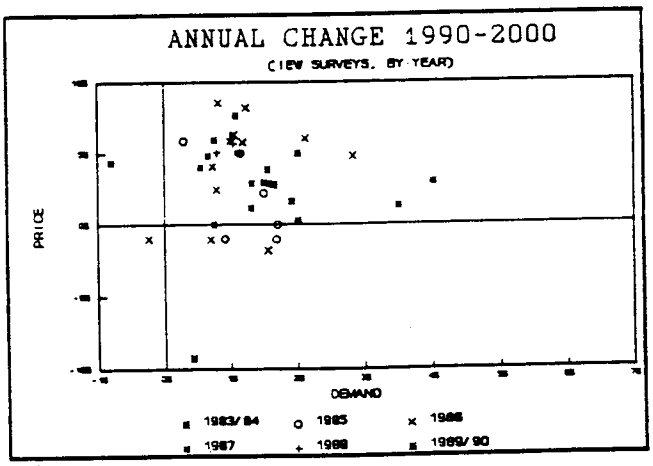

Figure 8-3
Source: [IEW]

VII.A.1. The Benefits of the Formula

This algorithm is appealing for many reasons, including the fact that capacity utilization is frequently

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from the initial period to the terminal year cannot be calculated. For this reason, the rate of change from 1990-2000 was used to indicate the projected long-term rate of change in these figures.

employed to predict inflation, both at the macroeconomic, or economy-wide level, and at the microeconomic, or industry (or commodity) level. And in the oil market, it also appears to have some validity, as can be seen in Figure 8-5, which DOE published annually in its energy outlook. That the various observations fall close to the line suggests a high correlation.

Clearly, the basic concept, that prices rise when OPEC capacity utilization is high and fall when it is low (with stability at the 80% level) makes some sense: when capacity utilization is high, producers wanting lower prices cannot increase production to prevent price increases, since, by definition, they have little spare capacity. Similarly, when capacity utilization is low, it makes little sense for price "hawks" to cut production to bolster prices, since there are large amounts of spare capacity to replace any reductions they make.

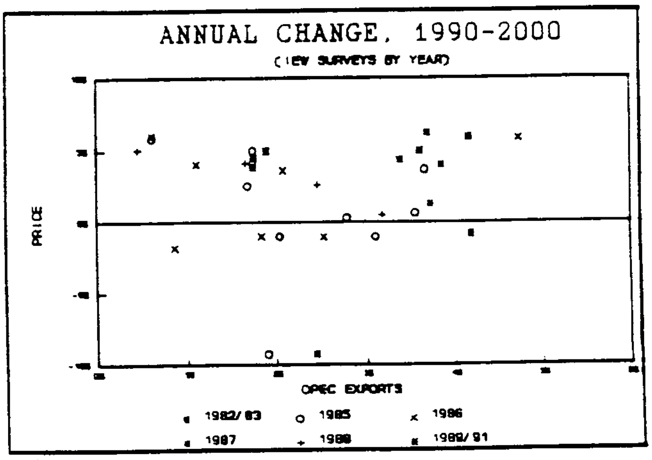

Figure 8-4
Source: [IEW]

VII.A.2. The Shortcomings[60]

But the algorithm has a number of practical and theoretical shortcomings. The most obvious are the data problems, including the fact that OPEC governments rarely if ever allow outside analysis of their production capacity. Such estimates as are made often suffer from a lack of timeliness, consistency, and, possibly, objectivity. For example, the CIA publishes regular estimates of capacity in its monthly International Energy Statistical Review, but for years defined "maximum available capacity" as that which a producer was willing, not able, to produce. Thus, the figure did not represent true capacity, especially for Saudi Arabia. The primary alternative source of capacity estimates, Petroleum Intelligence Weekly, published them regularly from 1975 to 1986, but only irregularly afterwards.

Additionally, prices do not move on an annual basis, but daily and even hourly, such that a disruption (like the Gulf War) could result in very high capacity utilization, and price increases, for a brief period, but averaged over the year, neither price nor utilization would be particularly meaningful. As it happens, the only period of high capacity utilization and rapid price increases covered by DOE's figure, the 1979/80

[60] Some of the arguments in this section can also be found in [Powell 1990].

OPEC Pricing Behavior, 1975-1987

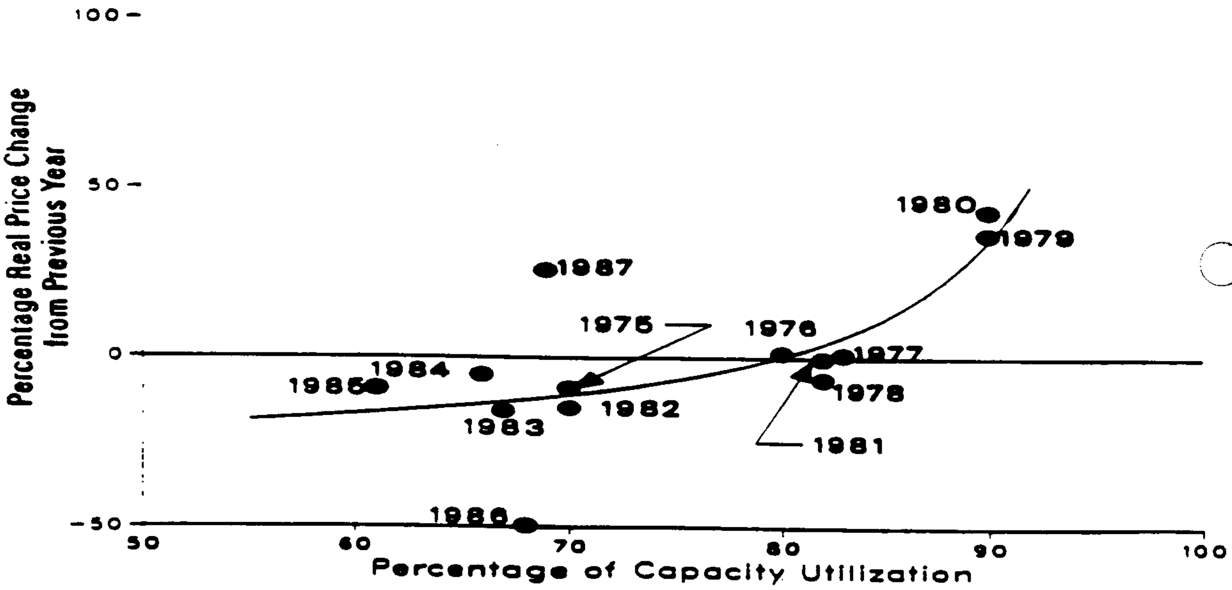

Figure 8-5
Source: [DOE IEO 1987]

oil crisis (which included not only the effect on capacity of the Iranian Revolution, but the Iran/Iraq War) lasted for years, not months.

There are also theoretical shortcomings. Capacity utilization is normally used to describe price movements only for the short-term because of feedback effects. At the microeconomic level, high capacity utilization raises prices, which encourages new investment that increases capacity and moderates prices. At the macroeconomic level, if the nation's industrial sector experiences from high capacity utilization, inflation does indeed rise, but typically results in slower economic growth, lower demand and, therefore, reduced capacity utilization.

But the oil models consistently rely on this formula, and little effort is made to address the shortcomings. Indeed, OPEC capacity is rarely modeled endogenously, (the IPE model being one of the few that does). [Beider 1980, p. 120] DOE explicitly lists its OPEC capacity projections under assumptions, for example.

But also, note that Figure 8-5 only covers the years 1975-1987. Prior to that time (and throughout much of the post-war era), capacity utilization would have been on the order of 90%, but with falling prices. And after 1985, prices have not only varied wildly, but the points have not fallen anywhere near the curve, which is presumably why DOE ceased to publish it after 1987 in its annual forecast. Recently, an updated version of the figure was presented (Figure 8-6) with the argument that "[t]here is no fundamental serious economics driving this curve. However, it works, and that is it's saving grace." [STEF 1991 p. 158.] But even a casual observation suggests that since 1985, none of the years provides a good fit.

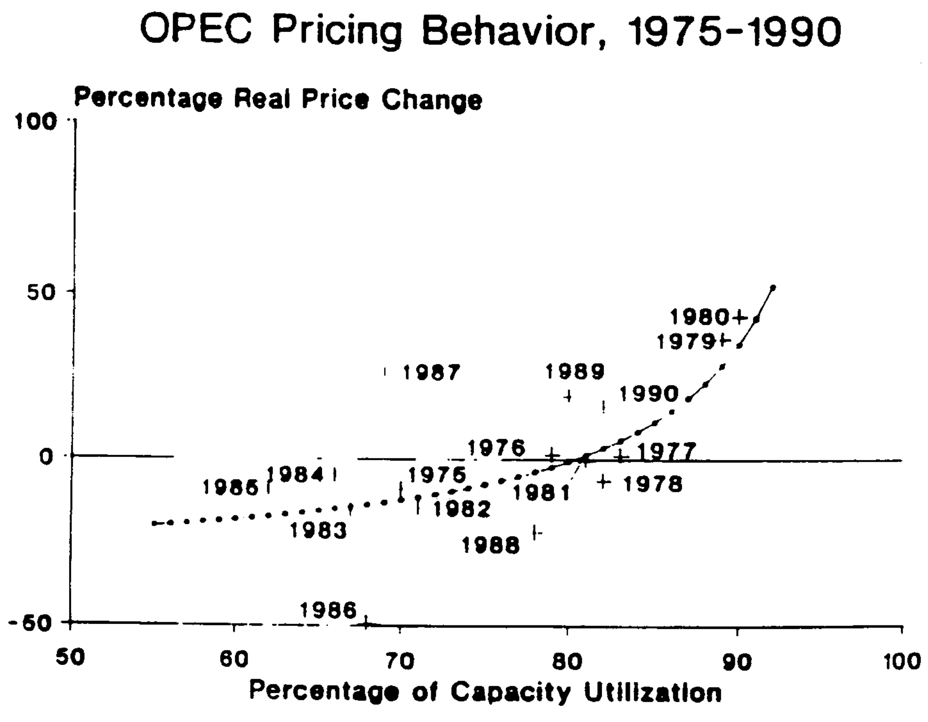

Figure 8-6
Source: [STEF 1991]

Arguably, oil market structure was different during 1975-1985, when it could be said that OPEC was a effectively dominant-firm cartel, with the Saudis usually acting as swing producer. However, this only supports the argument that the capacity utilization algorithm was a good predictor of price for that specific period, and it clearly needs to be modified or updated given its failure since.[61]

VII.B.3 The Exogenous Nature of the Endogenous Algorithm

Finally, the fact remains that while the use of such an equation may suggest an element of objectivity to the forecast, the reality is that the algorithm is, by nature, exogenous. Capacity utilization is, after all, only production divided by capacity, and as mentioned capacity forecasts are almost always exogenous.[62] As a result, the forecaster need only alter expected capacity to produce the desired price projection.

And capacity expectations do change, partly reflecting the simple fact that investment is a policy decision, and the larger OPEC producers are effectively capable of generating whatever capacity they desire, whether it is an amount sufficient to balance the market or to provide them with bargaining power within OPEC, given their minimal exploitation rates. But additionally, capacity forecasts have suffered from a Malthusian bias, as was seen in the previous section, where capacity projections for the smaller OPEC members changed dramatically, largely responding to current levels of production.

Total OPEC capacity forecasts/assumptions follow the same pattern, albeit to a lesser extent, as can be seen in Figure 8-7, where the assumed capacity for a given point in the future (in this case 1995) is constantly adjusted in line with current production and the expected demand for OPEC oil. Thus, as demand for OPEC oil plummeted in the early 1980s, expected demand fell, and assumed capacity was reduced to the level that would still result in continued price increases of several percent per year. When demand for OPEC oil began growing in the late 1980s, projections for demand naturally increased accordingly, and capacity followed suit.

Without these revisions in capacity assumptions, the forecast in the early 1980s would have called for much weaker prices, and in the late 1980s, for much higher ones. Again, most forecasters appear to be trying to predict a certain rate of price increase and so must become more optimistic about OPEC capacity.

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[61] See [Lynch 1987] and [Lynch 1989] for alternative theories of factors which affect price behavior.

[62] See [DOE IEO 1991], p. 13 for one example. The IPE model uses endogenous investment by producers to increase their capacity in line with expected demand for their oil.

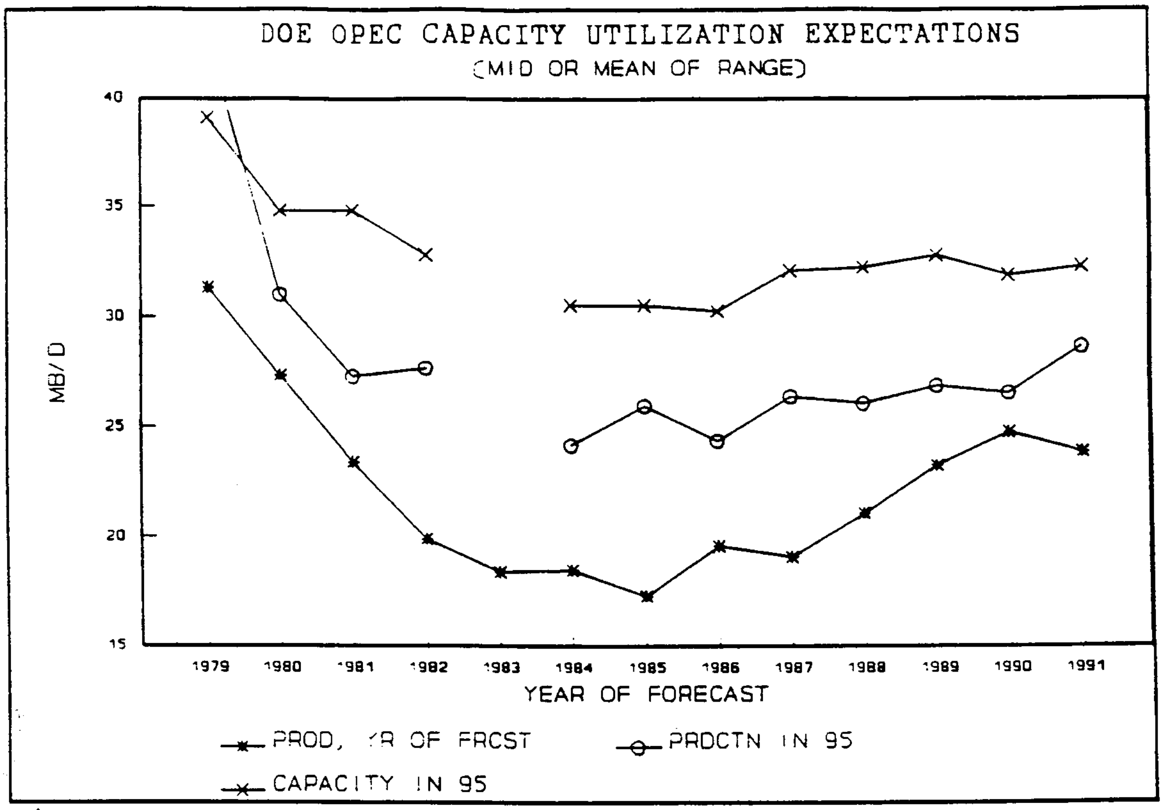

Figure 8-7
Source: [DOE IEO]

VII.C. Conclusion: The Maelzaelian Machine at Work

Thus, the only reasonable conclusion is that the use of an OPEC capacity algorithm with exogenous capacity assumptions, renders price forecasts as another example of a Maelzaelian Machine. Given an expected level of demand for OPEC oil, the level of capacity assumed (or forecast) is exogenously adjusted to provide the assumed price path, namely, real growth of several percent per year.

VIII. CONCLUSIONS

A number of specific and general lessons have emerged from this study of the history (and failure) of oil price forecasting, applicable not only to the oil market and energy policy, but to a many aspects of policy-making.

The Dominance and Failure of Assumptions

In a number of cases, it has been seen that nearly all forecasts can be condensed to a single assumption. In effect, if one wants to know what oil price forecasts will be, assume that they will increase by 3% per year. (For U.S. natural gas prices, assume 5% per year growth; for CPE exports, assume that they will decline to zero; for short-term oil supply and demand, assume moderate change). All other variables and factors appear to be irrelevant. Nearly identical price increases are predicted when the initial price is $45/barrel as at $15/barrel, when OPEC production is 20 mb/d or 30 mb/d. Demand for OPEC oil is predicted to grow slowly after sharp price increases, as well as after a price collapse. CPE exports will decline to zero, regardless of oil price, energy policies in the Soviet Union (and its successors), etc.

Malthusian Bias

Additionally, concerns about resource constraints appear to be nothing more than a Malthusian bias, that is, a belief since resources are finite, society must now be facing higher costs and scarcity. While depletion is a concern, and costs can be a constraint, particularly in the U.S., the indiscriminate application of pessimism to virtually every country in the world, including areas like Russia where enormous discoveries continue to be made, demonstrates that pessimism represents an exogenous assumption, rather than an analytical result. Indeed, the steady growth in the estimate of the world's total oil resources, and the repeated upward revisions even in the U.S., the most mature and intensively studied petroleum province, undermines the use of such estimates as measures of scarcity or production potential.

Not Extrapolation, Not Conservatism, Not Wishful Thinking

But the bias and the errors were not due to conservative planners extrapolating past behavior, nor to wishful thinking on the part of the analysts. Consuming and producing nations alike, oil companies and environmentalists, academics and consultants, all accepted a paradigm which represented a severe departure from historical experience. That the underlying ideas appeared to be logical may explain why the paradigm has been so hard to overturn.

And indeed, the repeated failure of the paradigm appears to be finally converting some, in keeping with Kuhn's theories of paradigm shift. Increasingly, forecasts calling for price stability are appearing, and the International Energy Agency has at least accepted flat prices as a scenario. [IEA 1991] However, the process is not yet complete, as seen by [EMF11 1991], [DOE 1991] and even many others. That so many are willing to at least question the consensus, must be considered a healthy sign.

Beyond Satisficing

But how can decisions be made? Given that a complex system like the world oil market is difficult to forecast at all, let alone by an individual analyst, or a small planning department, relying on the consensus is the obviously the easiest method. Yet it is important to realize that not only is the consensus insufficient, but a track record of correct forecasting is not necessarily proof of awareness. Recall that the Ptolemaic system was actually capable of fairly accurate predictions of planetary movement, despite the bankruptcy of the underlying theory. Similarly, Malthusian oil market predictions in the late 1970s performed very well for a few years, even though the oil market was not responding to the scarcity underlying the expectations.

The current consensus forecast, which calls for rising long-term oil prices, with all of its attendant implications, needs to be discarded. The fact of consensus is shown to be relatively meaningless, and appears, in this case, to be the result of psychological and institutional factors rather than common acceptance of a theoretical model with high explanatory power.

That so many have been capable of embracing concepts which have not only proven incorrect, but have repeatedly failed to provide any significant explanatory power, says much about the degree to which economic activity is not understood, hidden, one might say, in a fog of commerce.

APPENDIX A
Regression Results:
Effect of Supply and Demand on Price
Oil Market Forecasting
(from IEW Surveys)

A. Price in 2000 (1990$/barrel), as effected by non-Communist consumption and OPEC exports (mb/d).

(1) $Price_{2000}$ = 56.8 + (-0.34)* (NCW Consumption) (R^2=0.023)
(3.61) (-1.24)

(2) $Price_{2000}$ = 25.75+ (0.44) * (OPEC Exports) (R^2=0.031)
(2.23) (0.89)

B. Rate of change in price from 1990-2000, as affected by rate of change in non-Communist consumption and OPEC exports (all in percent per year).

(3) Price Change = 4.54 + (-0.8) * (Change in NCW Consumption) (R^2=0.070)
(7.70) (-2.23)

(4) Price Change = 2.72 + (-.40) * (Change in OPEC Exports) (R^2=0.047)
(3.14) (-1.25)

T-statistics in parentheses.

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