Limits to oil pricing

Scenario planning as a device to understand oil price developments

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The bad record of oil price forecasting indicates that conventional oil market models should be critically reassessed. Scenario planning may be one alternative approach. This approach does not contradict other theories of the market. But it claims that no single discipline is able to tell the whole truth about the market. The SP approach stresses and clarifies the role of uncertainty. It argues that without a cross-disciplinary approach, with an adequate choice of parameters, at the right level of in depth discussion, the analysis may either lose essential imput or drown in detail. As an example of the methodology, an analysis of the oil market in the 1990s is presented. This shows how upper and lower limits for the price can be constructed, and which actual price development can be expected, in a combination of economic and political reasoning.

Keywords: Oil price; Scenario technique; OPEC

There is still no general agreement about how to analyse the oil market, oil producing countries' behaviour, oil demand and the future of oil prices. On the supply side, the views can be roughly divided into two groups; wealth maximizing theories and 'others', with all shades in between. 'Others' often include theories of political and target revenue types. On the demand side, analyses address factors such as economic growth in various regions of the world, income and price elasticities for energy demand in general and oil in particular, the existence and price of alternative energies and technological development. The perception of the market mechanism ranges between competition to monopoly in various forms both on the demand and the supply side. The market outcome is seen as a result of economic or political factors in force, sometimes as an interplay between the two.

In spite of the great number of approaches, oil price forecasting has tended to be quite uniform over the last two decades. Furthermore, it has a rather bad record.[1] Conventional price forecasting has usually extrapolated past trends into the future, and only to a very limited extent incorporated the possibility of major shifts in the market environment. When major shifts actually have taken place, they have been perceived as shocks and unexpected events bringing discontinuity and surprise in the smooth expectations of future developments.

The political and economic implications of choosing a wrong price expectation eg when formulating a nation's macroeconomic policy or a company's strategy is that the outcome will be other than the expected one. A theory need not be correct to have direct impact on decision making, but it will lead to a suboptimal solution in comparison with a situation where a right theory or expectation had been chosen. The impact of the belief of continuous rising prices of the begining of the 1980s, when they already were at a historic height, has obviously been rather costly not least for an oil exporting country like Norway. The benefit of implementing a better understanding of the market mechanism can be expected to be significant for the countries and companies involved, whether sellers or buyers.

The scenario planning (SP) methodology, which is the focus of this paper, is an alternative to conventional oil market models. This approach does not overthrow any competing methods for understanding oil price movements. However, it stresses that no one-disciplinary model, being economic or political, is able to tell the *whole* truth about the market. Over the longer term, SP analysis stresses that more than

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0301-4215/92/0111097-09

one academic discipline must be applied in order to understand major changes in the market.[2]

However, in periods with stability, one-disciplinary approaches may have significant explanatory power. Their periodic success contributes to making such forecasts dangerous. As they often are based on an assumption that the future will look much like today, they rarely incorporate the possibility of major shifts in the market environment.

Thus, in comparison with the often used economic, political or other models, the scenario planning approach is first of all an extension in the way it increases *understanding* of the functioning of the market by integrating disciplines rather than giving exact predictions of price movements. By analysing important factors for development and translating them into quantitative and behavioural effects on market mechanisms, disciplines are combined in a comprehensive assessment.

The procedure attempts to clarify the uncertainty inherent to the complexity of the oil market and gives perhaps more an indication of what *cannot* happen than what actually *will* happen. In that sense, SP has a lower level of ambition than many more deterministic models. SP analysis argues that companies and governments should accept uncertainty as an integral part of the analytical environment, instead of extrapolating trends. Depending on what kind of uncertainty we are facing, ways of dealing with this uncertainty must be developed.

In this paper, in making an attempt to narrow and clarify the range of the unknown, I will split uncertainty into three types: trivial, systemic and structural.[3]

UNCERTAINTY AND THE PRICE OF OIL

Trivial uncertainty, can be reduced by providing more information to support the model in use and to refine the model.

Systemic uncertainty, however, arises from inadequacy of understanding rather than a lack of knowledge of more facts and lack of refinement. Such a type of uncertainty may be dealt with by extending disciplinary boundaries in multi- or interdisciplinary approaches.[4] How economies and politics interact in the Middle East and world markets is an example of such insight. In principle, it is possible to arrive at a consistent understanding of such relationships and dimensions. In a system of equations linked with each other, the value of one variable can be determined endogenously as a result of changes in other variable(s). Then, if the model still involves degrees of freedom, the importance of choices and strategies of various actors can be underlined.

Structural uncertainty is inherent in the type of phenomena being studied. Structural uncertainty represents exogenous fluctuations in important variables and relationships, uncertainty in the choice of model and situations where a model gives results with wide variations.

The two first types of uncertainty can (theoretically) be dealt with, while the third kind cannot be fully eliminated. The actors can only learn to live with structural uncertainty and to find ways of reducing sensitivity and vulnerability to it.[5]

An essential subgoal in the SP approach is to distinguish predetermined from genuinely uncertain events.[6] The predetermined elements should include trivial and systemic uncertainty. These uncertainties depend on whether enough and adequate information is provided, and whether the understanding of the functioning of the market is sufficient. The trivial uncertainty can be reduced by good disciplinary work. The systemic uncertainty can be reduced by multi- or interdisciplinary work providing a more comprehensive understanding. Methods must be found to deal with the structural uncertainty, rather than to try to eliminate it. The process of clarifying the kind and magnitude of structural uncertainty may, however, be an important input into the process of adaptation to it.

There are always some elements in an analysis that can be characterized as predetermined. In an SP analysis for the oil market, these events set frames for future development and outline the bounds of possible price paths. These should be rather insensitive to possible and significant changes in the parameters. But as in fact 'anything can happen in the future', it is also useful to discuss which extreme events would push the price outside these bounds. The sensitivity analysis needed for this is first of all of pedagogical value, as it illustrates and gives some background for evaluating how robust the results from the analysis can be expected to be.

Then, in a perfectly performed scenario analysis a number of more or less likely outcomes based on structural uncertainty are left within the probability window. According to various opinions of the likelihood of the occurrence of such specific events, a probability analysis can indicate where within the frame the result will most probably be. Such an analysis must necessarily include both technical, economic and political considerations. To assess the impact of changes in technological and political factors on the price of oil, they must be translated

into the effect they may have on economic factors important for the market, on market structure, and on possible behavioural changes by the main actors, in a multidisciplinary procedure.

The identification and measurement of parameters are crucial to the analysis. Even if an analysis is brilliantly performed, this brilliance cannot outweigh mistakes created by poor choice of data, low quality statistical input or choice of an irrelevant model, unless the purpose is a drill of the chosen model and the relevance to the problem at hand is of a more minor concern. Obviously, there are no limits as to what could be included in the assessment. But the logic of scenario planning requires an adequate choice of parameters at the right level of in depth discussions. If we go too deeply into the material or choose too many parameters, the overall process can be paralysed by details. On the other hand, if we take too few parameters into consideration on a too superficial level, we can lose important input. It is important to keep in mind the purpose when designing a SP analysis.

THE PREDETERMINED FRAMES

This analysis will argue that there are probably upper and lower limits for the price of oil for a combination of economic, political and strategic reasons. Whether the price in the long run will be closer to the one or the other limit will depend on the fit between demand and supply, the degree of monopoly in the market, the way the actors behave etc. I will denote the long-term lower limit for the price the lower (L) limit as opposed to the upper (U) limit. Possible future prices discussed must be read as examples rather than absolute predictions.

The lower limit

The technical lower limit for the price of oil is fixed by the marginal cost of the development of new oil fields. Adelman argues that this will be the price of oil in the long run.[7] But as the marginal cost of oil production in the Middle East has always been far below any price prevailing in the market, even before the first oil shock, we must ask whether something else is preventing the price from dropping to this technical–economic floor. Is something or somebody stopping the price from dropping to the marginal cost of new oil fields? What interests do producing and consuming countries have in not letting the price drop too low?

Consuming countries' interests

Importing countries want to reduce dependence on Middle East oil in case of new crises in that region. Some level of non-OPEC production should be maintained, and the investment necessary for this requires a higher price than does Middle East oil ie the marginal cost of developing new oil fields if politics are disregarded.

If dependence on such imports were not a problem consumers' lower limit should fall to the economic marginal cost for developing new oil fields, because all gates for imports of oil could then be opened, including oil from the Middle East. Importing countries would desire a free competitive market and prices be fixed at the point where the demand curve intersected the global marginal cost curve.

But as long as such a dependence is considered a problem, consumers' desired lower limit may perhaps lie in the range of US$ 10–25 per barrel; this level may vary with the perception of how risky dependence on Middle East oil and what the cost is of non-Middle East oil.

Producing countries interests

Obviously, producers are not interested in a low oil price. On the other hand, from time to time, they may desire to maintain or gain market share for political reasons.[8] However, there are reasons for not letting the price drop *too* low, even with such a goal. We shall divide producers' (ie OPEC countries') possible reasons for maintaining a minimum price above the marginal cost of new oil fields into three: the inelasticity of demand; fear of increased excise taxes; and the cost and inelasticity of non-OPEC production.

In the short run, demand elasticities have tended to be rather low. In the long run, however, history has shown that demand is elastic with respect to price changes. Furthermore, when oil has a large share of a consumer's budget, demand may be more elastic with respect to price changes than when oil has a small budgetary share. With low budgetary shares, or low prices, price changes may not necessarily impose significant changes in demand, or at least they may take a lot of time. There is thus a threshold at which the benefits of increased demand from lower prices are overtaken by the loss of income for main producers in the short and/or in the longer term. Therefore, in the interest of gaining market share the optimal price from a producer's point of view should be determined from the point at which a marginal decrease in price is met by a marginal increase in demand after some (determined) time.

The lower the price of oil, the easier it will be for the governments of importing countries to introduce

excise taxes on crude oil or petroleum products. The optimal lower level of oil price from the viewpoint of producing countries, when market shares are to be gained in the long run, should, from a tax fear argument point of view, be determined in such a way that tax risks are balanced against anticipated economic growth and income and price elasticities in consuming countries in order to raise demand for oil. Fiscal measures in consuming countries can become a pure transfer of surplus from exporting to importing countries.[9]

The drop in prices in 1985–86 proved that the most marginal non-OPEC oil fields were in the USA, with a cost per barrel in the stripper wells in the range of US$15–20 per barrel. Much North Sea oil is produced at a cost of around US$5 per barrel.[10] Thus, prices much below the cost of marginal US production would, to a large extent, only transfer wealth from producing to consuming countries rather than close more non-OPEC production. The US$15–20 per barrel level in the second half of the 1980s did not significantly encourage new (US) production, and there should be no need to stay much below this price level in order to discourage non-OPEC production in any significant manner.

From the point of view of producers wanting to gain market share, the lower limit should be some sort of weighted sum of the aspects discussed. Given the current political situation, resource basis, cost figures for non-OPEC production, availability of alternative energies, demand and supply elasticities and taxing policies, a reasonable estimate today seems to indicate a lower limit, from the producer's point of view, in the range of US$15–20 per barrel in order not to increase non-OPEC production too much, to avoid significant new taxes and encourage demand sufficiently.[11] The way producers (ie OPEC) have managed to keep such a minimum price is through price and/or production administration.[12]

The upper limit

The upper limit for the long-term price of oil is expected to be determined by what the importing countries will 'submit' to paying, without experiencing economic setback and large substitution to other energies which reduce demand over time. The backstop price, as discussed in the economic theory of non-renewables, will be a technico–economic ceiling for the price, even though prices may exceed this limit for a period of time. Thus, the upper limit level is the level exporting countries want, based on long-term market considerations, to keep below. When a marginal price increase leads to such a large marginal decline in demand that the net effects will be a loss of income for exporters, they will obviously lose in the long run by raising prices above this level.

A price of US$35-40 (nominally) at the beginning of the 1980s proved not to be sustainable in the long run. A price of US$35 per barrel in 1981 corresponds to almost US$60 in 1992 value. Thus, the upper limit should be somewhere below the top level of 1981, but above the level of US$15–20 of the last years in order to keep consumption stable. Because flexibility in switching between fuels during the 1980s has increased, we may expect the upper limit to be lower today than ten years' earlier, with today's portfolio of consumption by different sectors. In the 1980s consumption stopped declining when prices reached US$27–30 (nominally). A price of US$28 in 1981 corresponds to a price of some US$45 per barrel in 1992. Thus, a fixing of the upper limit in the 1990s today may possibly be in the range of US$30–40 in 1990 money.

A PRICE WINDOW FOR THE 1990S

Figure 1 shows the price development from 1968–1991/92 (adjusted for inflation). For the expectations for the next decade (1992–2002), the upper and lower levels are shown as predetermined constraints for price development. They are formed by events in the past, of political, technological and economic factors as well as reasoning and strategies among various actors involved. This window limits the possible variety of future prices to a still wide, but, nevertheless, narrower range as compared to the view that 'anything' can happen in the future.

By determining these limits, trivial and systemic uncertainty in price development is reduced by constructing tracks that the price should stay within. As the fixing of the limits combines both economic, political and strategic reasoning, and explicitly outlines an area of structural uncertainty, the approach is different from more (partial and) deterministic models for the oil market, telling us that the price will follow one or another specific path.

Alternative price developments are drawn (a) and (b) to illustrate two rather extreme possible outcomes. The (a) path illustrates a situation where a new dramatic event occurs, while much of Kuwait and Iraqi oil facilities are still out of order and additional capacity has not been built in Saudi Arabia (so far, disregarding the existence of the Strategic Petroleum Reserves (SPR)). With little free capacity in the world, such a dramatic event may

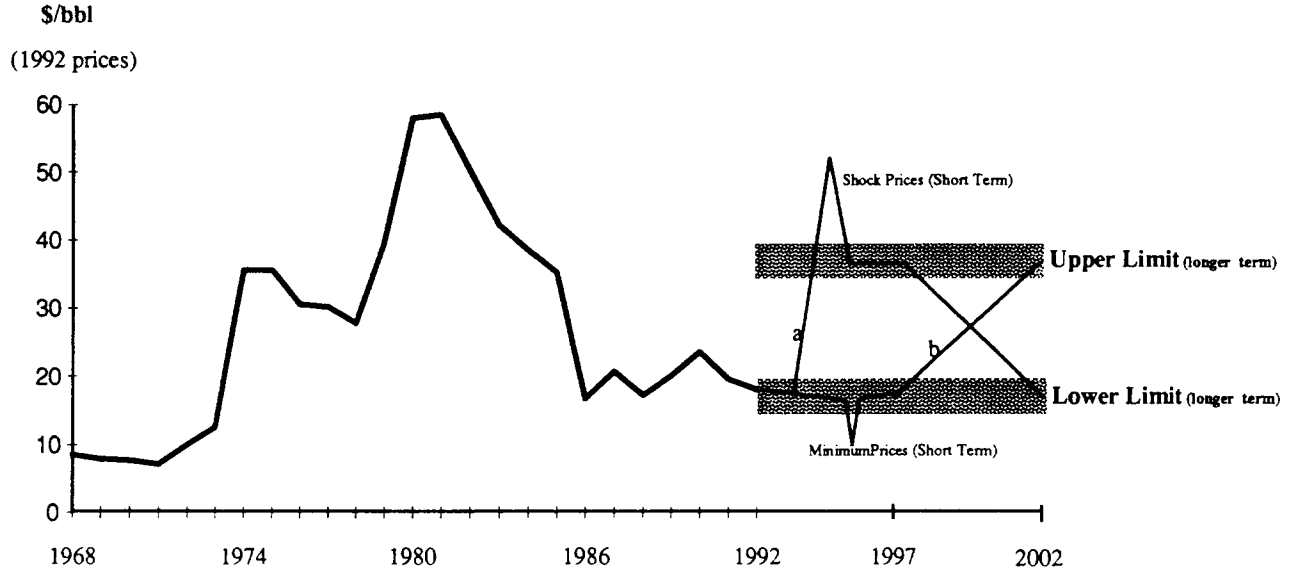

Figure 1. A window for oil prices in the 1990s (constant 1992 prices).

cause prices to shoot higher than they did during autumn 1990. The tightness in the market (92–100% capacity utilization in worldwide oil production) indicates that such a high price level could be sustained for some time if damages or shortfalls are severe enough. But the consequence of such a price hike, for example to US$60, would be lower demand and produce a later drop in prices, perhaps much below the upper limit. This illustrates the intertemporal relationship between prices arising from mechanisms of supply and demand and their time lags.

The (b) path illustrates a stable situation with steadily increasing demand. Prices are kept at the lower limit as capacity (in Middle East countries) is continuously increased (beyond previous historic levels). At some point in time this increase in capacity will meet a ceiling and the growth in demand will lead to higher prices.[13] After the war, with this development, such a ceiling is illustrated as being reached in the mid-late 1990s.

Nobody can claim to know all factors influencing the price to develop along the (a) or (b) path or some other trend. Only with strict assumptions can conditional expectations be formed. In fact, over the next decade, and given our assumptions, the only thing we know with reasonable certainty is that prices will remain at or between the upper and lower limits.

Main features of the price window

The main assumptions to be made about oil prices in the 1990s, according to the discussion above, can be summarized as:

- Prices are not in the long run sustainable below the lower limit (illustrated as 1992 US$15–20 per barrel). Nor can they sustain a level above the upper limit (illustrated as 1992 US$30–40). The levels of the limits may change with significant changes in important relations determining them (see the sensitivity test below).
- Our most likely scenario today will be that prices may well remain on the lower limit for several years if no new instability in the oil market occurs, if production capacity in Saudi Arabia is expanded and Kuwait and Iraqi oil comes back into the market. Prices may increase later in the decade if consumption continues to increase and available capacity at some point in time is absorbed.
- The potential magnitude of a sudden price shock depends on its severity. Prices in the range of 1990 US$50–55 may last up to a couple of years before demand decreases, alternative energies supplement oil, and oil production is increased elsewhere with a following drop in prices. Prices above US$60 should be expected to be sustainable only for a shorter period of time. If prices stay outside the L and U limits respectively, the consequence will be a reaction in the opposite direction after some time. The more extreme the oscillations and the longer they last, the larger will be the reaction and the market becomes more unstable.
- With the strategic reserves SPR at hand, (short-term) price shocks above the upper limit are less likely. The existence of the SPRs may

also dampen smaller shocks, below the U limit, if they are used in a subtrigger system.[14]

- With a functioning OPEC organization, or some other supply side regulator, prices below the lower limit do not seem very likely. The supply-side regulator must be expected to restore prices at the lower level rather quickly to avoid increased petroleum taxes and transfer of wealth with no gain in market share. If this perception establishes itself in the market, actors may discount future OPEC reactions and prices will be limited downwards by the lower limit also in the short term.
- The scenarios discussed share the opinion that the oil market has many similarities to other markets where supply must balance demand and the price is determined endogenously. The special feature of the oil market seems to be that changes in prices, demand and supply take much more time and that they are much more politicized. The inelasticities with respect to prices in the short run and the larger elasticities in the longer run for both supply and demand are characteristic for the market for crude oil.
- Hotelling's theory of non-renewable resources is perhaps the theory most frequently applied to oil markets, developed to take account of various types of uncertainty and shifting assumptions. But it does not analyse why, when or at what magnitude such shifts take place. To a longer extent these are taken as exogenous parameters in the analysis. Therefore, an SP approach comprises a qualitatively wider spectrum of variables than economic theory. But SP analysis does not contradict this, or any other, theory of the oil market. It suggests that the market and its actors are not performing fully according to its principles. The expectation that future oil prices will be based on economic theory can, with SP analysis, be viewed as *one* out of many possible market outcomes.[15]

HOW ROBUST ARE THE RESULTS?

In the oil market, business as usual is often that something unusual happens. Therefore, a crucial element of this analysis is to test the results for some of these not very likely, but nevertheless not impossible, changes.

Energy security policy, as well as economic strategies for both oil exporting and importing countries and oil companies, must be targeted towards unlikely, but if they happen costly, events. This problem may concern whether the U and L limits are determined correctly (describing trivial and systemic uncertainty) and whether our most likely scenario will occur between or at these limits. A sensitivity analysis reexamines the parameters chosen. This is important in order to be aware of the effects if the grounds for the analysis should be dramatically changed; it also gives some perspective on how robust projections can be expected to be and when they should be changed.

The purpose of identifying the predetermined frames for price development is first of all to suggest some principles for understanding what can and what cannot happen. I will not go into depth on all sensitivity tests that could be performed against the analysis; I will merely list some of the most important ones. The reader can modify the results according to his or her beliefs.

Of course, some factors by their very nature influence both the predetermined frames and the actual paths the price can be expected to follow in the future. A factor can influence price changes between the limits up to a certain magnitude of alteration. When alterations become larger the factor may also influence the predetermined frames as well.[16] This is implicit in the assumptions underlying the analysis, as the predetermined frames should be much more robust to changes in the environment than prices between the frames. We shall first suggest some tests for the sensitivity of the level of the lower and upper limits respectively, and afterwards for the conditional price expectations between the limits.

What could change the lower and upper limits?

In the future both the lower and upper limits may, in principle, be changed to higher or lower levels. The discussion below is about unusual events which might cause them both to drop. Obviously, a change in parameters in the opposite direction would move the limits upwards.

The lower limit

The following are examples of extreme, but not totally impossible, events and situations that could lead to a drop in the lower limit (below the indicated US$15–20 per barrel):

- The Middle East is seen as a less dangerous source of oil, so that dependence can increase without increasing sensitivity and/or vulnerability. For consuming countries, this would indicate that it was less important to maintain

expensive non-Middle East production. For example, such a perceived reduction in sensitivity could occur if consuming countries gained physical control over oil reserves by political or military force (direct or indirect change of property rights). An interesting question is whether this is already to some extent taking place in the aftermath of the Gulf war in 1991.[17]

- OPEC breaks down, no other supply regulator emerges and the market becomes more competitive. Prices could fall below the lower limit and consuming countries could use the opportunity to take power in the market by fiscal means to regulate demand, and transfer wealth from producers to consumers on a more permanent basis. This chance was to a large extent spoiled in 1986. If fiscal means are not introduced after a collapse of OPEC, demand can be expected to increase over time, and prices with it.[18]
- Demand for oil becomes much more elastic to price changes also at low prices.
- Substantial amounts of new low cost oil are found outside the Persian Gulf. This seems to be the main Adelman scenario.[19] He finds that the price of oil will fluctuate with political–military movements and cycles with OPEC meetings, quota and pricing decisions within OPEC, followed by cheating, threats and promises. But because of the (according to him) abundance of oil, other energy sources and more efficient technologies will be developed. Therefore, over time, prices will decline slowly towards a 'long-run equilibrium price of US$5 per barrel'. Adelman argues that OPEC output may reach some 60 million barrels per day (mbbl/d) and estimates the monopoly ceiling of the price to be in the range of US$25.[20]
- The possibility of introducing excise taxes on petroleum is, for some reason, seen as a politically impossible measure in consuming countries (although it might happen in the USA).

If parameters change in the opposite direction the lower limit may rise, ie if the Middle East is seen as an even more dangerous source of oil; if OPEC, or the concentration of 'hawkish' pricing countries' power is strengthened; if demand becomes much more inelastic; if a substantial amount of oil from outside the Middle East disappears; if consuming countries tend to introduce more petroleum taxes ie as a result of environmental concern.

The upper limit

The following are examples of events that could lead to a drop in the upper limit:

- Backstop energies and/or technologies are introduced in large scale at a lower cost than today. At high prices this is a continuous process. At low prices such innovation processes usually take much more time.
- A drop in the upper limit may also lead to a drop in the lower limit as well. The more easily one can substitute other forms of energy for oil, the more acceptable it is to have high imports of crude oil. Thus, low prices and great dependence on imports will be less of a problem the lower the upper limit, implying that lower non-OPEC production is more acceptable from the viewpoint of an importing country's security of supply.

On the other hand, if these factors changed in the opposite direction, the upper limit could rise; if backstop energies and/or technologies become more expensive; if the income elasticity of demand for oil becomes higher (again). If prices increase, there will be sector by a sector switch to other energies. The highest substitute price today is in transport. If oil is mostly used for transport purposes in the future and no cheaper substitute is found in this sector, the upper limit may rise to the price of these substitutes, which perhaps lies in the range of US$50–60 per barrel.[21]

What will the price of oil actually be?

Modest oil prices

The following examples of events that would reinforce our assumption of a modest price development in the medium term (the (b) path in the graph), perhaps prolonging the period of low of low prices (within the frames of the L limit):

- A stock exchange crisis would lead to lower demand growth (or even decline) in demand.
- If oil countries increasingly become major investors in world industry.
- If technology should significantly improve automotive and/or industrial efficiency in the use of oil.
- If a substitute becomes more easily commercially available, for example superefficient natural gas for cars.
- If a reasonable amount of new oil is found.
- If gasoline taxes are introduced in the USA (or increased other places).[22]
- If significant amounts of new technology are

transferred to Russia so it can improve its efficiency in oil production. A 10% increase in Russian oil production represents 1.0 mbbl/d. Alternatively, the Russians could transfer their own energy consumption towards natural gas (of which they have ample reserves and production) to increase oil exports.

If any of the factors mentioned above should occur to a sufficient extent, prices should not be expected to go below the lower limit (except for a shorter period) unless the changes are very significant, as listed in the example of the sensitivity test of the L limit above.

High oil prices

On the other hand, the following could lead to high prices in the 1990s:

- The changing political environment in Russia may lead to a decline in oil production as the government emphasizes shifts from the industrial to the consuming sector and labour unrest rises. Environmental problems in Siberia (where 70% of Russian oil production takes place) may cause a decline in oil production.
- A new war in the Gulf, or other places in the world, where further production facilities are destroyed.
- Economic growth induces demand to increase in the range of 2–3 mbbl/d annually instead of 1.5–2.0 mbbl/d (path between (a) and (b)).
- US oil production is significantly curbed eg because of large new accidents in Alaska.
- Accidents in nuclear power plants occur to an extent that substantial atomic energy production is closed down.
- Oil tankers collapse because of high age. Radetzki argues that if one or two of the old supertankers, fully loaded, break down because of corrosion and age, causing huge environmental damage, decisions may be taken to eliminate many of these tankers from operation.[23] This will make transport a bottleneck in the market for some years.
- Power in OPEC changes from Saudi Arabia to the more 'hawkish' pricing thinkers in Iran, Algeria and Libya (also Iraq before the war).[24]

The list, both for the more modest and the more dramatic price development, and for the changes in the level of the L and U limits, can be made longer. Our purpose in listing them is to illustrate how scenario planning focuses less on predicting the outcome and more on understanding the forces making the result. There are therefore fewer figures in such an analysis than in forecasting generally. The result will be found in the sum of all factors important for price development. The intention of the SP technique is to provide more insight. It is a way of thinking, to see forces in relation to each other and be aware of which events can create discontinuity in the future. It says as much about what cannot happen as what will actually happen. A price forecast within a SP framework should therefore be understood as a conditional prediction.

CONCLUDING REMARKS

The methodological approach to understanding the development of oil prices presented in this paper, may have some intuitive appeal as a summary of an obviously more complicated process. The advantages of the *ad hoc* reasoning in the various elements of the technique must be balanced against its limitations. The procedure illustrates how important the way of thinking about market mechanisms is, or how important it is to reduce what we have called systemic uncertainty. It stresses the importance of making sensitivity tests (risk analyses) of the *de facto* subjective judgments made about the assumptions for any scenario (or say forecast). Finally, the method argues that, even with a brilliantly performed analysis, uncertainty must be accepted as a structural element of the assessment.

Wack describes the real world as a macrocosm and the mental model of researchers, analysts, politicians or managers as microcosms.[26] The SP technique has a consequence for the *way of matching* forces and testing whether microcosms match macrocosms or not. Thus, leaving forecasting and turning to scenarios, because SP seems to match macrocosms better, some change of microcosm may be required in order for it to be useful. Therefore, if a scenario technique is applied to the assessment of future oil prices, this may have, in and by itself, consequences for the conclusions, and strategies that should be taken, on the basis of its results as compared to the use of more deterministic models. This may turn out to be a rather difficult issue, perhaps even more difficult than changing perceptions of market mechanisms. But that is outside the scope of this paper.

[1]Shown in A.S. Manne, and L. Schrattenholzer, *International Energy Workshop: Overview of Poll Reponses*, Energy Modelling Forum, Stanford University July 1987.
[2]Royal Dutch Shell was the only party acknowledging that a

major price shock for oil would come in the beginning of the 1970s (OPEC I), using a scenario planning methodology. See Pierre Wack, 'Scenarios: uncharted waters ahead', *Harvard Business Review*, September–October 1985, and 'Scenarios: shooting the rapids', *Harvard Business Review*, November–December 1985. Scenario planning has its parallel in linear programming in mathematics. For a more general and comprehensive introduction to scenario management see M. Godet, *Scenarios and Strategic Management*, Butterworth Scientific Ltd, 1987.

[3]Norwegian Research Council for Science and the Humanities (NAVF), *Conference on Sustainable Development, Science and Policy: Final Statement*, Bergen, 8–12 May 1990.

[4]Multidisciplinarity combines disciplines by aggregation. Two disciplines may include various aspects of an object and the integration is done by combining the two partial studies, or by taking conclusions from one discipline to serve as input into research within the other. It is to some extent possible to translate the consequences of, for example, a political event to a change in economic variables. A new war in the Middle East must primarily be dealt with through political analyses. The effects on economic factors such as production capacity and production strategies can be translated from how tense the situation is and possible actions of war. These effects can then, in their turn, be dealt with within the field of economics. Interdisciplinarity combines disciplines in a common core of concepts and methods. How actors' qualitatively different values and motivations can be combined in a common core of concepts is not always clear. Interdisciplinarity is therefore a more demanding approach than multidisciplinarity. In the SP approach presented in this paper, the disciplines are combined by multidisciplinarity, first of all by combining economic and political factors and translating a change in the one into the consequence for the other.

[5]Obviously, the distinction between these three types of uncertainty is not always clear. Sometimes, trivial uncertainty may be perceived as a part of a rather systemic problem. Similarly, systemic uncertainty may sometimes be regarded as a structural problem. But the concepts demonstrate one way of splitting up an issue in order to make it more easy to work with.

[6]When all factors influencing an outcome are known, the outcome is predetermined. For example, if it rains heavily in the mountains, we know that this results in a lot of water in the river down along the valley below the mountains (unless an earth-crack occurs and changes the track of the river). The flood in the river can be said to be a predetermined event, if you have already observed the heavy rain falling. However, we cannot with the same degree of certainty say whether it really will rain heavily or not, even with all weather forecasts in the world at hand. The event heavy rain is an uncertain event, to which you can assign certain probabilities for occurrence (*op cit*, Ref 2, Wack).

[7]M.A. Adelman, 'Comments on D. Gately', and D. Gately, 'Lessons from the 1986 oil price collapse', *Brookings Papers in Economic Activity*, No 2, 1986.

[8]See O.G. Austvik, 'Krigen om oljeprisen. Oljepolitiske argumenter for krigen ved Den persike gulfen', (The war over the price of oil: the role of oil in the war in the Persian Gulf), *Internasjonal Politikk*, No 3, August 1992, for a discussion of economic–political arguments between Iraq and Kuwait on the pricing of oil as a prelude to the 1990/91 conflict.

[9]It is the portfolio of taxes in consuming countries that is important for OPEC. See T. Schelling, *Global Environmental Forces*, Discussion Paper, Energy and Environmental Policy Center, Kennedy School of Government, Harvard University for a discussion of the importance of international cooperation in introducing excise taxes for the purpose of reducing oil consumption in order to reduce CO_2 emissions. This parallels the interest of oil consuming countries in reducing overall world demand for oil in order to keep prices down (see O.G. Austvik, 'Oil prices and the dollar dilemma', *OPEC Review*, Winter 1987, and 'De strategiske petroleumsreservene (SPR) som oljepolitisk kriséredskap' (The SPRs as instrument for managing oil crises), *Sosialøkonomen*, No. 1.

[10]See O.G. Austvik, 'Introduction' and 'Market considerations in Norwegian oil policy', in O.G. Austvik, ed, *Norwegian Oil and Foreign Policy*, Norwegian Foreign Policy Studies No 68, NUPI/Vett and Viten, Sandvika, Oslo, 1989.

[11]The price of oil in the period 1986–90 was in the range of 1990 US$16–19 per barrel. This price led to an annual increase in world demand of 1.5–2.0 mbbl/d, rather modest excise taxes were introduced and decisions of (world scale) significant investments in non-OPEC production were not made except in the North Sea.

[12]See the discussion in the sensitivity test at the end of the article about what would change if OPEC or some other grouping of producers would be unable to influence prices by decision making and cooperation.

[13]Today, it seems unlikely that Saudi Arabia will increase capacity beyond some 14 mbbl/d by the turn of the century given the country's existing economic and political framework. See O.G. Austvik, *En vurdering av produksjonskapasiteten for råolje i fem land ved Den persiske gulf* (Assessing Oil Production Capacity in Five Persian Gulf Countries), Report to the Norwegian Treasury, published as NUPI-report No. 150, October 1990. Before the 1990 conflict in the Gulf growth in demand was already producing higher prices. See W.W. Hogan, *Oil Demand and OPEC's Recovery*, Discussion Paper, Energy and Environmental Policy Center, John F. Kennedy School of Government, Harvard University, 1990, for a discussion of the relationship between prices and capacity utilization.

[14]See eg R.G. Hubbard and R. Weiner, *The 'Sub-Trigger' system: An Economic Analysis of Flexible Stock Policies*, Discussion Paper H82–07. Energy and Environmental Policy Center, John F. Kennedy School of Government, Harvard University, 1982.

[15]A forecast based on the assumption that prices really *will* develop along a path making producers indifferent when to produce (as many forecasts do), indicates an oil price rising up to some US$35 per barrel in year 2002 assuming a 7% discount rate and price of US$20 in 1991, not too different from the (b) path.

[16]Accordingly, the distinction between trivial, systemic and structural uncertainty is made first of all in order to clarify the concepts of uncertainty.

[17]*Op cit*, Ref 8.

[18]M.A. Adelman, 'The oil supply and price horizon', *Energy Policy*, October 1989, argues that the 'rewards of monopolizing the world oil industry have been so great that the nations cannot give up the effort. If the cartel collapses, it will be put together again, with a partly different membership.' See also R.S. Pindyck, 'Gains to producers from the cartelization of exhaustible resources', *Review of Economics and Statistics*, Vol 60, 1978.

[19]*Ibid*.

[20]The opposite (a sudden drop in reserves) has in fact occurred. The field Cerro Azul Number 4 in Mexico after producing 260 000 barrels per day and a total extraction of 60 million barrels began producing only salt water in 1916 (F. Banks 'Economic theory and the price of oil', *OPEC Review*, Autumn 1986). If such an event happened on a larger scale, reserves and production quite immediately could take a substantial cut back.

[21]This indicates that with gradually higher prices and demand switching to other fuels in a growing number of sectors, the upper limit may also rise up to the substitute price in the sector where it is the highest.

[21]See O.G. Austvik, *Strategies for Reducing US Oil Dependency*, Department of Economics, Harvard University, NUPI Report No 130, July 1980.

[23]M. Radetzki, 'Shocks: plausible shocks in world energy in the 1990s', *Energy Policy*, August 1989.

[24]See eg B.R. Scott, *Saudi Arabia: You Can Hear it on the Radio*, Case Paper, Harvard Business School, 1987, and *Saudi Arabia: Emergence As a World Paper*, Case Paper, Harvard Business School, for a discussion of the evolution of Saudi oil policies over the last decades.

[25]*Op cit*, Ref 2, Wack.