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SEPARATING STATIC AND DYNAMIC EFFECTS IN AN OIL PRICE MODEL

by

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ABSTRACT

A static and a dynamic model of the oil market are compared. Three major differences appear in forecasts. The dynamic model fluctuates around the static model equilibrium price. The dynamic model shows greater uncertainty in trend development. The dynamic model forecast overshoots the cost level of synthetic oil.

1. INTRODUCTION

In this paper I examine behaviour of a static and a dynamic version of the same oil price model. The purpose of separating static and dynamic effects is to understand model behaviour and to assess the importance of dynamic formulations. Starting with a static model also helps communicating the results.

The static model produces an equilibrium oil price forecast. The structure of this model is explained in Chapter 2; its behaviour is explained in Chapter 3. In Chapter 4 the static model is extended into a dynamic model. (This dynamic model is a very simple version of the OILTANK model, Endress & Ervik, Moxnes (1982), and Moxnes (1983)). Lags are introduced in both supply and demand. This reflects high capital intensity and long construction delays in oil production and capital-imbedded technologies for consumption of oil. Instead of requiring that the oil price equilibrates supply and demand at each point in time, a price theory is formulated. The chosen price formulation aims at an equilibrium situation, which is never quite reached. In Chapter 5 the behaviour of the dynamic model is examined. A forecast made by the dynamic model is compared to the static model forecast. Three major differences appear. The dynamic model fluctuates around the static model equilibrium price. The dynamic model shows greater uncertainty in trend development. The dynamic model forecast overshoots the cost level of synthetic oil.

All prices are assumed to be in real 1984 USD.

2. A STATIC OIL MARKET MODEL

Figure 1 shows the static oil market model in terms of long-term supply and demand curves. The long-term equilibrium price is given by the intersection of the supply and the demand curve. Four actors are represented in the diagram: consumers, OPEC producers, non-OPEC producers and producers of synthetic oil.

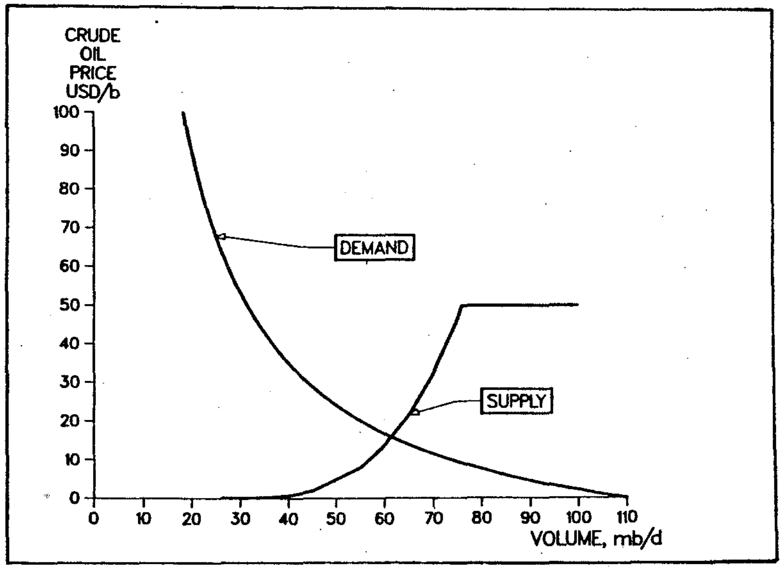

Figure 1. Long-term supply and demand curves for the static oil market model.

Consumers conserve oil or substitute it with other types of energy when the oil price increases, and consumption increases in step with economic activity. These effects can be expressed formally by the equation:

$$q_D = q_{ED} \left(\frac{y}{y_0}\right)^v \left(\frac{p+c}{p_0+c}\right)^e \qquad (1)$$

q_D - demand for oil (mb/d)

q_{ED} = 44 mb/d - equilibrium demand for oil in initial year (1984)

y - index for economic activity

y_0 = 100 - index for economic activity in initial year

v = 0.75 - income elasticity

p - crude oil price (USD/b)

p_0 = 30 USD/b - oil price in initial year (1984)

c = 20 USD/b - additive taxes plus costs of refining and distribution

e = -1.0 - oil product price elasticity

The sum of crude oil price, p, and additive taxes and costs, c, make up oil product prices. Consumers react to product prices relative to initial product prices through a product price elasticity, e. This elasticity combines the effects of conservation and substitution. Because crude oil prices are buffered by additive taxes and costs, the resulting crude oil price elasticity always stays below the product price elasticity. When crude oil price equals zero, demand is only limited by additive taxes and costs. This explains the interception between the demand curve and the quantity axis in Figure 1. A constant price elasticity is a very crude assumption on how demand reacts to price changes. However, it is sufficient for the purpose of this paper.

Expected growth in economic activity is set to 3 percent per year. The effect of economic growth in Figure 1 is shown by a rightwards shift of the demand curve.

Non-OPEC producers invest in exploration and development of oil fields according to current crude oil prices. The success of these investments depends on the availability of oil. Availability declines as remaining resources are depleted. A formal expression for total oil supply is given by the equation:

$$q_S = \begin{cases} q_N + q_{op} & , \quad 0 < p < p_S \\ q_D & , \quad p = p_S \end{cases} \qquad (2)$$

$$q_N = q_{EN} \cdot \left(\frac{p}{p_0}\right)^a \cdot \left(\frac{R}{R_0}\right)$$

q_S		- total supply of oil (mb/d)
q_N		- supply of non-OPEC oil (mb/d)
q_{EN}	= 43 mb/d	- initial equilibrium non-OPEC oil production
a	= 0.3	- non-OPEC supply elasticity
R		- remaining resources (mb)
R_0	= 600000 mb	- remaining resources initially (1984)
q_{op}	= 26 mb/d	- OPEC production
q_D		- demand for oil (mb/d)
p_S	= 50 USD/b	- cost of synthetic oil

A long term supply elasticity as low as 0.3 indicates limited access to oil fields for oil companies. Limits are imposed by governments in order to stretch out oil production and income generation in time.

Non-OPEC supplies are assumed to be a function of current prices only, no weight is put on expectations about future prices. This simplification needs some justification.

First, current prices determine current incomes, which put certain financial restrictions on investments.

Secondly, "perfect foresight" has to be implemented through the application of uncertain forecasts. According to Morecroft (1983) (p. 6) decision makers tend to put less emphasis on uncertain information from distant sources than on certain information from close sources. Morecroft seeks support for this view from representatives of "the behavioural school of economics": Cyert, March and Simon. In this context, today's oil price represents the certain information.

Thirdly, it is argued that price forecasts for the long-term are influenced by current prices.

Fourthly, to the extent that oil companies have other goals than maximization of profits, the importance of "perfect foresight" is diminished. Such goals, for example, may be company growth or stability of operations.

The effect of resource depletion on non-OPEC supply is given by the linear expression R/R_0. Since R equals R_0 initially, the effect on supply is at first neutral. As remaining resources are depleted, non-OPEC supply is reduced; the supply curve shifts leftwards. Remaining resources are monitored by the equation:

$$\dot{R} = - q_N \cdot 365 \qquad (3)$$

OPEC-producers are assumed to maintain a given production, q_{0p}, throughout the forecasting period independent of oil price. This assumption is motivated by the stress on criteria other than profit maximation by OPEC members. The assumption becomes more realistic the more insensitive OPEC considers its profit to be to its own supply strategies. Ervik (1981) has found that OPEC's profits are fairly immune to its choice of production capacity.

Producers of synthetic oil are assumed able to supply any demanded volume, q_D, at an oil price equal to costs of synthetic oil, p_S. This explains the horizontal part of the supply curve.

It is important to note that synthetic oil is defined as a liquid fuel which can be used by consumers of ordinary oil, without major adjustments in energy consuming equipment. Thus, gas, coal, and electricity are not classified as synthetic oil. Market shares for oil are lost to gas, coal, and electricity according to oil prices and the assumed price elasticity.

3. BEHAVIOUR OF THE STATIC MODEL

Figure 2 shows a prediction from the static model. As the demand curve moves rightwards because of economic growth, and as the supply curve moves leftwards because of resource depletion, the oil price grows until the cost level for synthetic oil is reached. From then on, demand is met by a mixture of oil and synthetic oil at a fixed price of 50 USD/b. (The static model behaviour is calculated using DYNAMO. In order to do so the equilibrium price is given by the equation $\dot{p} = p(K \cdot (q_d/q_s - 1)))$.

Figure 2 also shows the behaviour of the dynamic model. In the following, I shall describe how the structure of the static model is extended to yield a dynamic model.

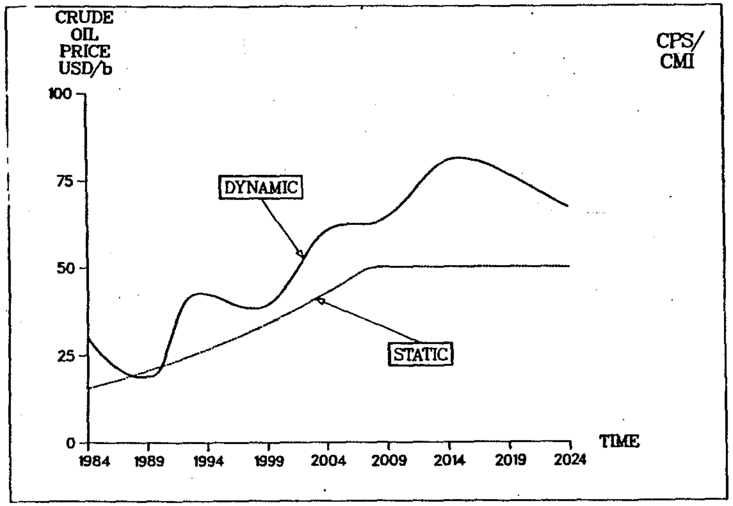

Figure 2. Deterministic oil price forecasts made by the static and the dynamic oil market model.

4. A DYNAMIC OIL MARKET MODEL

<u>Consumers</u> need time to adjust to new price signals. Some conservation measures can be implemented immediately, while others result from slow changes in production processes and infrastructures. In the dynamic model, adjustments in consumption, lag behind price changes by on average eight years. About 63 percent of the adjustments take place before the eight years have elapsed, and 37 percent take place afterwards. This means that in the short-run consumers are less flexible than in the long run; the short-term demand curve is steeper than the long-term demand curve in Figure 1.

The delayed response to oil price is modelled by introducing a delayed version of the crude oil price, P_D, in Equation 1. (It makes no difference whether the lag is introduced in the oil price or in the actual demand equation). The demand equation becomes:

$$Q_D = q_{E0} \left(\frac{Y}{Y_0}\right)^v \left(\frac{P_D + c}{P_0 + c}\right)^e \quad (4)$$

$$q_{E0} = q_{D0} / \left(\frac{P_{D0} + c}{P_0 + c}\right)^e \quad (5)$$

P_D - delayed crude oil price for demand

Q_{D0} = 58 mb/d - demand for oil in initial year (1984)

P_{D0} = 18 USD/b - initial level of delayed crude oil price

The constant q_{E0} is calculated in the initial year <u>before</u> the model starts simulating. q_{E0} denotes equilibrium demand in the initial year, where equilibrium is given by delayed oil price equal to initial oil price, $P_D = P_0$. Equation 5 ensures that initial demand, q_D in equation 4, equals measured initial demand, q_{D0}, for any choice of price elasticity, e, and initial level of delayed crude oil price, P_{D0}. With chosen values for q_{D0}, P_{D0}, e, and c, q_{E0} becomes 44 mb/d. This is the value used in the static model.

The delayed crude oil price, P_D is given by a first order delay corresponding to a simple one parameter Koyck lag:

$$\dot{P}_D = (P - P_D)/T_D \qquad (6)$$

T_D = 8 years - average time delay for demand adjustments.

<u>Total supply</u> is given as the sum of non-OPEC, OPEC, and synthetic supply

$$q_S = q_N + q_{op} + q_A$$

<u>Non-OPEC producers</u> need time to adjust production capacity when the oil price changes. It takes time to make plans, to explore, and to develop new fields. In this respect oil production is similar to oil consumption: The supply curve, like the demand curve, is steeper in the short-term than in the long-term. Non-OPEC production is assumed for equal non-OPEC production capacity; non-OPEC producers maintain full capacity utilization.

As with demand, supply is delayed by the introduction of a delayed crude oil price, P_N. Non-OPEC production is given by the formula:

$$q_N = q_{EN} \cdot \left(\frac{P_N}{P_0}\right)^a \cdot \frac{R}{R_0} \qquad (7)$$

$$q_{EN} = q_{N0}/\left(\frac{P_{N0}}{P_0}\right)^a \qquad (8)$$

P_N - delay crude oil price for non-OPEC supply

q_{N0} = 38 mb/d - initial non-OPEC supply

P_{N0} = 20.4 USD/b - initial level of delayed crude oil price for non-OPEC supply

As in equation 5 for demand, equation 8 for non-OPEC supply ensures that initial non-OPEC supply, q_N in equation 7, equals measured initial supply, q_{N0}. Initial equilibrium non-OPEC supply, q_{EN}, equals 43 mb/d with the chosen values for q_{N0}, P_{N0}, P_0, and a.

Delayed crude oil price for non-OPEC supply is given by the equation:

$$\dot{P}_N = (P - P_N)/T_N \qquad (9)$$

T_N = 6 years - averge time delay for non-OPEC supply adjustments.

The delay time in this simple model is an average of the average time needed to increase and to decrease production.

<u>OPEC</u> acts as a "swing producer". When total supply increases above demand, OPEC cuts back on production to maintain a desired price level. Since OPEC capacity is given exogenously, cutbacks result in lower capacity utilization. OPEC production is given by the equation

$$q_{0p} = q_D - q_N - q_A \qquad (10)$$

Capacity utilization is given by:

$$U_{0p} = q_{0p}/C_{0p} \qquad (11)$$

U_{0p} - OPEC capacity utilization

C_{0p} = 32.5 mb/d - OPEC capacity

OPEC's desired price level is influenced by current market conditions. The best information about the market is given by OPEC's own capacity utilization. Since nobody knows exactly the best price level for OPEC to choose, practical OPEC policies must, to a large extent, be based on today's price and on current market conditions. In the dynamic model, OPEC lowers its desired price from today's level if capacity utilization falls below 80 percent. When capacity utilization approaches 100 percent, OPEC is no longer in control of the oil price, and a rapid price escalation occurs. This means that the model does not calculate an equilibrium price. Rather, the model constantly produces exploratory price changes in order to restore an equilibrium characterized by 80 percent capacity utilization.

Ignoring short-term spot market fluctuations, outside the control of OPEC, the crude oil price equals OPEC's desired price. The crude oil price is given by the equation:

$$\dot{p} = p \cdot f(U_{0p}) \qquad (12)$$

$f(U_{op})$ - growth rate (fractional change per year)

The chosen functional relationship between OPEC capacity utilization, U_{0p}, and fractional change in oil price, $f(U_{0p})$, is shown in Figure 3. Historical observations give an indication of the quality of this assumption.

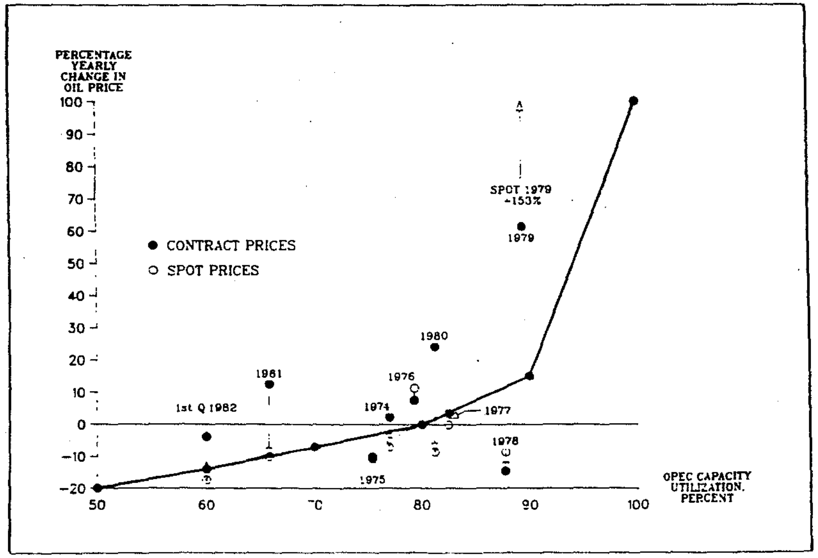

Figure 3. Fractional yearly change in oil price from OPEC capacity utilization.

At the desired 80 percent capacity utilization OPEC production is 26 mb/d, which is the production rate in the static model.

<u>Producers of synthetic oil</u> also need time to increase production. This is because planning, construction etc. take time. Furthermore, absolute growth in production of synthetic oil is limited by lack of resources in an infant industry. For example, lack of trained manpower slows down growth directly or through wage and cost escalations. Supply of synthetic oil, q_A, is given by the equation:

$$\dot{q}_A = q_A \cdot g(p/P_s) \qquad (12)$$

p_s = 50 USD/bbl - cost of synthetic oil
$g(p/p_s)$ - growth rate (fractional change per year)
q_{A0} = 0.5 mb/d - initial synthetic oil production

Figure 4 shows the assumed relationship between return on investments in synthetic oil, p/p_s, and the yearly growth rate for this industry. At low return, capacity is slowly depreciated because of long lifetimes of capital equipment. Factories tend to operate as long as prices are higher than operating costs, which are much lower than the total costs of synthetic oil, p_s. The higher the return, the faster the growth. As return becomes very high, physical constraints become more and more dominant. This explains why growth is limited at very high returns.

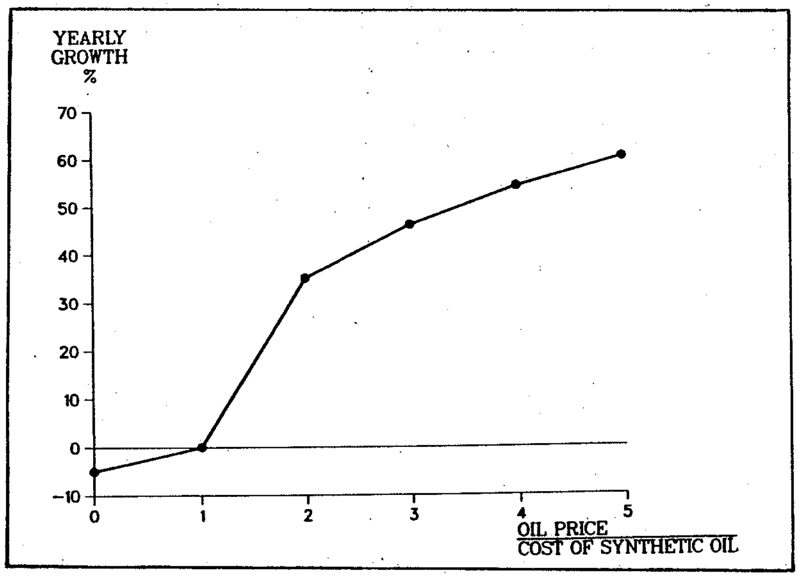

Figure 4. Relationship between return on investments and synthetic oil production growth.

Initial synthetic oil production, q_{A0}, reflects the initial status of synthetic oil producton with respect to capital equipment and experienced manpower. As this is the resource base the industry will be built on, its size is of great importance with regard to the market penetration of synthetic oil.

5. BEHAVIOUR OF THE DYNAMIC MODEL

The static model is characterized by static equations for supply and demand, and an oil price which equilibrates supply and demand. In the dynamic model, both supply and demand are delayed reactions to oil price, and the oil price is given by an explicit price theory. Figure 2 shows the different forecasts resulting from the two models. There are three important differences:

- The dynamic model produces price cycles
- Uncertainty in the long term trend is greater in the dynamic than in the static model
- The dynamic model forecast overshoots the cost level of synthetic oil

Price cycles

The structure of the oil market has changed remarkably since 1973. Prior to the 1973 oil embargo, oil prices were well controlled by a few large oil companies. Instabilities appeared only in volumes. During the years 1973 to 1976 oil companies operating in OPEC countries were progressively nationalized. For example, the Saudi-Arabian government had acquired a 100 percent interest in Aramco's crude oil concessions in mid-1976, OPEC (1983) p. 115. The number of actors in the oil market increased. "During 1979-80 the very long terms of many contracts were reduced. Total volumes traded to former concessionary companies fell to around 50% of the total. Direct trade to Government-importing agents increased and the volume traded at spot prices expanded from 5-10% to perhaps 10-15%", Mitchell (1982) p. 89. These latter changes broke up the old market structure even more. By the beginning of the 1980s the structure of the oil market had become much like the structure of other raw material markets. Thus it has become more likely that traditional commodity price cycles will appear in the oil market. The two price hikes in 1973 and in 1979 will in fact be viewed as two such fluctuations around an increasing long-term trend.

The Cobweb theory, Henderson & Quant p. 142, gives an explanation of the commodity cycle in the case of supply only lagging behind price. A high price in one period means that supply will be high in the next period, with the result that price falls. A low price means low supply in the next period and so forth. In general, the Cobweb theory states that fluctuations increase in magnitude over time when supply is more flexible than demand, and decrease in magnitude when demand is more flexible than supply.

The Cobweb theory can easily be formulated in a dynamic model if one assumption is altered, Meadows (1970) p. 15. Instead of assuming that supply changes in steps exactly one period after each price change, assume that the supply response is distributed in time. This seems to be a realistic assumption since supply can be changed by different means, for example, capacity utilization, employment, and investments. In addition, the possibilities for production enhancements differ among producers. When the distribution is as wide as that implied by the delay-function in equation 9, cycles will no longer appear in the Cobweb model. Thus the Cobweb theory is not sufficient to explain fully the cycles in the presented dynamic oil market model.

The price formulation is also of importance for the cyclical tendency. This is most easily explained by going through one period of a typical cycle. (An analytical analysis of instability is very difficult.). Assume that exports from one oil producing country is suddenly cut off. This is the event that makes the model reveal its dynamic properties. Excess demand and very high OPEC capacity utilization leads to a rapid price escalation more or less outside the control of OPEC. As both demand and supply is inelastic in the short run, the price has to rise very high to balance the market. The new price becomes the desired price level that OPEC wants to maintain. However, after a few years, the high price level has brought about reductions in demand and increases in production. OPEC's capacity utilization drops. OPEC still desires a high price, but the low capacity utilization forces OPEC to lower the real oil price. This reduction comes about both through nominal reductions

and general price inflation. Reduced prices stimulate demand and discourage investments in marginal oil fields. The major results of these incentives appear after a few more years. As demand approaches total supply capacity, no small force can change the direction of this movement. OPEC capacity utilization grows towards one hundred percent, while the oil price escalates rapidly. This situation is similar to the starting point. This time there is no exogenous event that begins the cycle. Rather, instability is passed on from the previous period.

This is how the oil price cycle works in the model. Another deviation from the Cobweb theory worth mentioning, is the delayed response in demand. Because of this delay, the short-term price elasticity is very low. According to the Cobweb theory, this destabilizes the price cycle.

As the purpose of this paper is to discuss the behaviour of one particular dynamic model compared to a static version of this model, I will not discuss sensitivity to different model formulations in detail. I only mention a few possible extentions:

- The price formulation is no doubt a great simplification of reality. The rationale for the formulation is not that it is the best policy OPEC can adopt. Rather, it is chosen because I believe that it is a politically feasible policy. In Moxnes (1982) p. 53, it is shown that oil price development can be stabilized, if OPEC reacts to changes in its own capacity utilization as well as in the level of the capacity utilization. A policy where capacity utilization influences price directly in addition to the effect on fractional change in price, also stabilizes price development. Well-founded expectations about future supply and demand should also be expected to stabilize price development. However, policies that prove to work in a deterministic model are not necessarily acceptable policies in an environment characterized by much uncertainty.

- Adding random disturbances to supply and demand, serves to propagate the price cycle. This point is well explained by Frisch (1933) p. 171: "In many cases they (economic oscillations) seem to be produced by the fact that certain exterior impulses hit the economic mechanism and thereby initiate more or less regular oscillations".

- Adding inventories in the model, also seems to destabilize the price cycle, Moxnes (1982) p. 49. This is the case if inventory holders tend to build-up security stocks when it is revealed that supply is short of demand. This effect works to maintain price cycles. Release of governmental strategic petroleum reserves in cases of short supply, counteracts the effect of private inventory build-ups.

Because of random disturbances and limited knowledge about parameters and structure, it is very difficult to predict the timing of oil price fluctuations beyond one future cycle. A cyclical tendency can be predicted for a longer period, however. Thus, price cycles increase total uncertainty in oil price forecasts. Knowledge about cycles also helps to sort out short and long-term trends from recent historical developments.

Greater uncertainty in long-term trend

If a smooth line is drawn through the price prediction from the dynamic model in Figure 2, one can see that the dynamic model gives a higher trend development than the static model. The reason for this is delay in supply and demand. At each point in time supply and demand are given by the oil price of a few years ago. Given that the price trend is increasing, supply and demand are always determined by a price lower than the current price. This means that demand will exceed supply persistently, compared to the static case where supply and demand react to current prices. To obtain the same balance between supply and demand as in the static case, the oil price must increase ahead of time. This is in fact what happens to a large extent in the model. The price formulation accumulates the pressure on price from market imbalances and the result is a higher price trend than in the static model.

In a scenario producing s a declining long-term trend in the oil price, the dynamic model also produces a price prediction which is ahead of the static model prediction. This means that in the declining scenario, dynamics lower the price prediction. Altogether this means that the dynamic model portrays greater uncertainty in price predictions than the corresponding static model.

Price overshoot

In scenarios where synthetic oil is demanded, the oil price prediction from the dynamic model overshoots the cost level of synthetic oil. Figure 2 illustrates this point. The explanation is that synthetic oil is not brought quickly enough on to the market to prevent a supply shortage when non-OPEC oil production tapers off as demand grows. Figure 4 shows how the growth rate is influenced by oil price and costs. Because the synthetic oil industry is in its infant stage as the oil price passes the cost level for synthetic oil, absolute growth is low in the early years. This is in contrast to the static model where the implicit growth rate is enormous in the first few years of operation.

The price overshoot means that forecasts made by the dynamic model portray greater uncertainty than forecasts made by the static model. The uncertainty only extends upwards.

6. CONCLUSION

This paper has demonstrated that there are important differences between a static and a dynamic model of the oil market. The explicit investigation of a static and a dynamic version of the same oil price model has been a very useful approach to understand and explain the importance of dynamic formulations.

First, the dynamic model produces fluctuations in the smooth trend of the static model's equilibrium price prediction. Understanding such fluctuations is imperative for those who want to extract short and long-term trends from recent history. Also, price fluctuations call for further policies by oil companies and oil producing countries, than do smooth trend-developments.

Secondly, when model parameters are chosen to give an increasing trend in predictions, the trend development of the dynamic model is higher than the trend development of the static model. In the example used in this paper, the difference is about 12 USD/b. When parameters are chosen to give a downward price trend, the dynamic model gives a lower trend development than the static model. Thus, the dynamic model portrays greater uncertainty in price forecasts than the static model when input parameters are uncertain.

Thirdly, the dynamic model forecast overshoots the cost level of synthetic oil. This happens while synthetic oil production is going through the first part of its s-shaped growth curve. As demand for synthetic oil grows faster than supply, the oil price rises above the cost level of synthetic oil. This effect introduces upwards uncertainty in oil price predictions.

The latter two differences between the two models are relatively easy to understand. Thus, they need less justification than the first and more complicated difference, namely the cycles. It is clear from model experiments that the fluctuations are sensitive to model formulations. It is the "second best" OPEC policy that leads to the strongest fluctuations. Therefore, the current model version is based on the assumption that the best OPEC policy is politically

infeasible. Furthermore, several important variables are left out of the model, for example inventories. Thus, the cycles in the dynamic model predictions should not be judged by their relation to future development. Rather, the purpose of the model and its presented behaviour, is to gain an understanding of a complicated phenomenon. As reasonable assumptions about the market produce fluctuations, the phenomenon is likely to occur.

That "commodity cycles" in the oil price are likely to occur, can also be concluded from the recent development of the structure of the real oil market. The structure is more like a regular raw material commodity market today than ten years ago. Regular raw material commodity markets are characterized by price fluctuations.

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