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Industry restructuring, OPEC response – and oil price formation

Abstract:
Increased focus on shareholder returns, capital discipline and return on capital employed (RoACE) caused a slowdown in investment rates and production growth among international oil companies around the turn of the century. Focusing on supply side dynamics of the oil market, we explore a hypothesis that the restructuring in the international oil industry towards the end of the 1990s had long-lived effects on OPEC strategies – and on oil price formation. Based on a partial equilibrium model for the global oil market, we examine the effects of the industry restructuring on oil supply and oil prices, compared with a counterfactual reference scenario characterised by industrial stability and unchanged price ambitions within OPEC. A key result is that important factors behind the currently high oil price can be traced back to the industrial restructuring and to the Asian economic crisis. This suggests that temporary economic and financial shocks may have a long-term impact on oil price formation.

Keywords: Oil market, investment behaviour, market power, equilibrium model

JEL classification: G31, L13, Q41

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1. Introduction

Oil plays a crucial role for the prospects of the world economy. Security of supply at acceptable prices is vital for political stability and for continued economic growth – in developing countries as well as in the industrialised part of the world. Accordingly, general public interest in the factors behind oil price formation has increased.

Based on a partial equilibrium model for the global oil market, we present new insights and explanations for oil market developments over the last few years. Our key hypothesis is that the increased focus on shareholder returns, capital discipline and return on capital employed (RoACE) caused (a temporary) slowdown in investment rates and production growth among international oil companies (Antill and Arnott 2002; Osmundsen et al. 2006). Focusing on supply side dynamics of the oil market, we explore a hypothesis that the strategic redirection of the international oil industry towards the end of the 1990s had long-lived effects on OPEC strategies – and on oil price formation. Coupled with strong growth in oil demand, the new supply situation in the competitive fringe allowed OPEC to raise their price ambitions significantly at the turn of the century. Using an equilibrium model for the global oil market, we examine the effects of the industry restructuring on oil supply and oil prices, compared with a counterfactual trajectory; industrial stability among the international oil companies and unchanged price ambitions within OPEC.

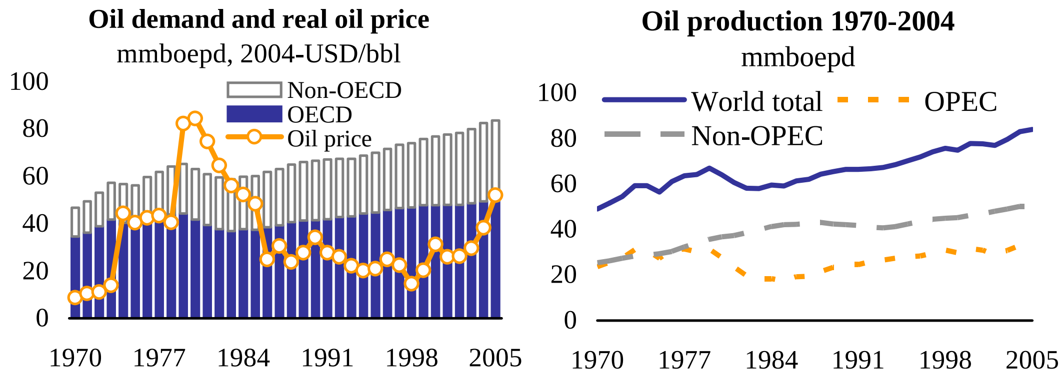
Grasping the process of capital formation in the international oil and gas industry is vital in order to understand supply-side dynamics in the oil market, and therefore also an important factor behind the formation of oil prices. Regular warnings are heard about investment shortage in the oil industry (e.g., IEA 2005), the "Peak Oil" idea is making its way into the public debate,1 and policies are adjusted, not only to reduce the dependency of oil, but also to meet the issue of global warming (IPCC 2007).

Moreover, the role of the oil price in business cycles and macroeconomic performance has intrigued macroeconomic researchers for decades (Barsky and Killian 2004). Following the substantial boom in the oil price over the last few years, researchers have studied the potential adverse effects on the global economy. Empirical studies suggest that the macroeconomic effects of oil price changes are non-linear; the effect may be modest (or even negligible) up to a certain point. However, price increases

[1] The idea stems from the geophysical approach initiated by Hubbert (1962), who argued that oil production can be described in terms of logistic growth, with subsequent bell-shaped trajectories for reserves and production. Today "Peak Oil" refers to the popular discussion of when world oil production will actually peak.

above some threshold level will have contractionary effects on global economic activity (e.g., Jiménez-Rodriguez and Sánchez 2004; Jones, Leiby and Paik 2004; IMF 2005). In addition to the effects on economic activity, distributional effects are also involved; the rewards of an increase in the oil price are reaped by oil-exporting nations, whereas the costs tend to be carried by less wealthy oil-dependent countries.[2]

Figure 1. Oil market trends



Source: US Energy Information Administration (EIA).

Oil demand is generally perceived as quite inelastic to oil price changes, and tightly linked to GDP growth (e.g., Gately and Huntington 2002). The growth in world demand for crude oil has also been fairly steady over the last three decades, as illustrated in Figure 1. On the other hand, crude oil supply is less straightforward. The degree of concentration among the most important oil producers is significant (e.g., Smith 2005). As illustrated in Figure 1, total oil supply is comprised by production from two groups of players. One is the group of OPEC countries, with their national oil companies located in the most resource-rich regions of the world (e.g., Hertzmark and Jaffe 2005). The other is the group of international oil companies (IOCs). Most of these companies have their origin in the western hemisphere, they have private shareholders, and their shares are traded on stock exchanges in London and New York. Osmundsen et al. (2007) illustrate how changes in the interaction between listed oil companies and their shareholders have suppressed investment behaviour and production growth among these companies over the last 10 years.

[2] See Krugman (1980) and Golub (1983) for early theoretical foundations of this point. A recent cross-country comparison of links between oil demand, oil price and income is offered by Gately and Huntington (2002), whereas the World Bank (2005) gives an updated, applied analysis.

An integrated model framework is required to study more carefully how changes in IOC investment behaviour impact the market, and to evaluate the impact on oil price formation. To this end, we apply the FRISBEE[3] model, developed by the Research Department at Statistics Norway (see Aune et al. 2005). This framework allows an assessment of investment and supply side dynamics following the period of strategic redirection and restructuring, coupled with financial and operational improvement efforts among the IOCs towards the end of the 1990s. Our results provide firm support for the key hypothesis that increased focus on shareholder returns, capital discipline and return on capital employed (RoACE) caused a temporary slowdown in investment and production growth among international oil companies. Global exploration activities, investment expenditures and oil production growth have been suppressed, providing an extra upward push on the oil price. Our results suggest that the industrial restructuring of the late 1990s caused a lift of approximately 10 per cent in the long-term oil price. Both OPEC and non-OPEC producers gain from this development, whereas the cost is carried by oil-importers and consumers.

The paper is organised as follows. Section 2 provides a brief retrospect on oil market developments over the last few years. Focusing explicitly on OPEC behaviour and industrial restructuring among the IOCs, we provide suggestions on how to implement our hypotheses about changes in supply side behaviour. In Section 3, we introduce the FRISBEE model, and discuss two different scenarios for the oil market – to isolate the effects on exploration activities, investments, oil production growth and price formation. Concluding remarks and directions for future research are presented in Section 4.

2. Oil market development, industry dynamics and OPEC behaviour

2.1 General oil market trends

In recent years, energy demand has been fuelled by rapid economic growth, both in the OECD area and in emerging economies – like China. According to EIA (2006), global demand growth has averaged 1.7 per cent since 1970. OECD countries remain important in terms of substantial levels of absorption. However, the link between oil demand and economic growth weakens when countries reach a mature phase in the industrialisation process (Gately and Huntington 2002), and oil demand has stagnated among OECD countries. However, the slowdown in oil demand from industrialised countries has been compensated by increased demand from the fast-growing countries outside the

[3] Framework of International Strategic Behaviour in Energy and Environment.

OECD. Examples include the so-called tiger economies in South-east Asia, China[4] – and more recently also India. Thus, newly industrialized countries have gradually taken a more important role in global oil demand.

The last serious oil demand shock was experienced in 1998-1999, when the Asian economic crisis reduced anticipated demand growth rates by some 2 percentage points (EIA 2006). The result was a dramatic drop in oil prices – to their lowest levels since the early 1970s. The temporary collapse in earnings across the international oil and gas industry encouraged the emerging pressures from financial markets and shareholders for improved efficiency and increased shareholder returns (cf. Figure 2). One result was a change in investment behaviour among the IOCs. On the other hand, the Asian economic crisis had the effect of pulling the OPEC countries together. Consolidation was supported by renewed commitment and dedication among the member countries. OPEC regained market power and oil price ambitions were raised. We explore the behavioural changes among the IOCs and within OPEC in greater detail below.

2.2 Industry restructuring - increased required rate of return

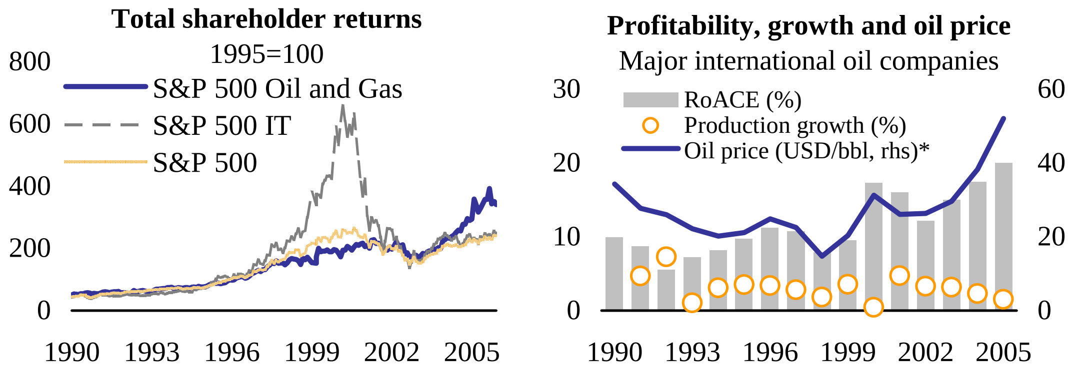
The oil price is probably the single most important indicator for oil companies' financial performance and success in the short to medium term. However, for a full understanding of the industrial dynamics of the oil and gas industry over the last 10 years, a more extensive consideration of the broader historical, political and economic context is well-advised. By the end of the 1990s, deregulation and privatisation caused a stronger focus on financial and operational efficiency in all industries – including oil and gas (Osmundsen et al. 2006). National oil companies were privatised all over the world, and embarked on new strategies of aggressive international business development. Consequently, the competition among IOCs – for increasingly scarce oil and gas resources – became more fierce than ever (Weston, Johnson and Siu 1999).

Against this background, both the oil market and the financial market turned against the oil and gas industry in the late 1990s. First, the "New Economy" euphoria made investors shift their investments from oil and gas to IT stocks (cf. Figure 2). Oil and gas companies were generally perceived as old-fashioned and inefficient, with limited exposure to the exuberance of the IT sector. Second, the Asian economic crisis caused a sharp slowdown in global oil demand, and in 1998 the oil price touched record lows of 10 USD/bbl., increasing the uncertainty and anxiety also with respect to oil price expectations. The result was not only a severe pressure on current oil company cash-flows, but also an

[4] For an updated review of the outlook for Chinese oil demand, see Skeer and Wang (2006).

increasing scepticism with respect to future earnings. In consequence, oil and gas companies failed to deliver competitive returns to their shareholders.

Figure 2. IOC investment indicators



* in real terms (at 2004-prices).

Source: http://www.ecowin.com (stock market data), Deutsche Bank (2004; oil industry data).

At the same time, analysts and investors had become aware of a potential for value-enhancement and stock price appreciation among listed oil and gas companies. The massive restructuring and improvement programmes that materialised in the late 1990s were indeed the result of financial market pressures. The focus turned from development of reserves and production in the longer term to operational efficiency and capital discipline in the short to medium term. Companies were benchmarked and rated according to a specific set of financial and operational performance indicators. The most important of these indicators was Return on Capital Employed (RoACE).[5] This simple accounting measure of capital return became a vital input to valuation analyses among stock market analysts and investors (Antill and Arnott 2002, Osmundsen et al. 2007). With its direct link to net income, RoACE is significantly influenced by the oil price. However, as indicated in the right-hand panel of Figure 2, the increase in reported RoACE from 1998 to 2000 was more pronounced than the oil price increase would suggest. One explanation is that this development coincided with a slowdown in investment, which again is a reflection of the underlying increase in the required rate of return.

According to Deutsche Bank (2004), total investment expenditures among the major international oil and gas companies were cut by more than 15 per cent from 1998 to 2000, with a 33 per cent reduction in exploration expenditures over the same period (see Reiss 1990). One important reason for this

[5] RoACE is defined as net income adjusted for minority interests and net financial items (after tax) as a percentage ratio of average capital employed, where capital employed is the sum of shareholders' funds and net interest-bearing debt.

supply-side suppression was an increase in the required rate of return on new investments among international oil companies, to secure competitive shareholder returns. Due to conservative valuation procedures inherent in the accounting system, RoACE temporarily improves when investment rates decline, providing an additional argument for IOCs to curb their investments.[6] Ceteris paribus, this would dampen the propensity to invest, and eventually also production growth. Financial analysts – who are familiar with accounting systems – should therefore not be surprised that the single-dimensional focus on RoACE would challenge the sustainability of activity and long-term production (i. e. reserve replacement) among international oil and gas companies.[7]

Pressures for improved operational and financial performance now reduced the former mistrust between oil companies and the capital markets. With curbed investment rates, substantial cash-flows were building when the oil price started increasing at the turn of the century. A large share of these funds was returned to shareholders, through comprehensive share buyback programmes and extraordinary dividends.

Over the last couple of years, the tide has turned. Both investors and companies seem to have realised that reserve growth is required to sustain long-term production and activity growth. Accordingly, the pressure for short-term financial returns is relaxed. Spurred by advancing depletion of legacy fields of the past and limited access to new exploration acreage, management focus has shifted back to exploration and business development to access new oil and gas reserves. Our model scenarios are designed to capture both the rise and the fall of the RoACE era in the international oil and gas industry.

2.3 OPEC behaviour – increased price target

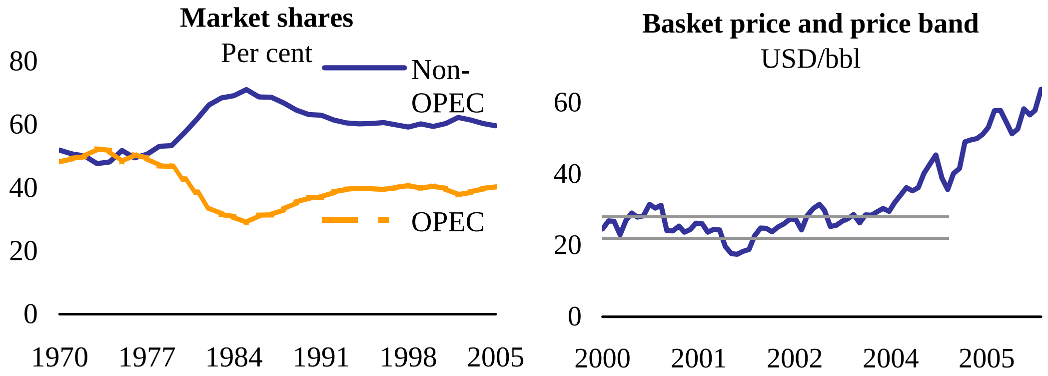
Empirical studies of OPEC's role in the oil market have generally failed to establish firm evidence of stable cartel behaviour. However, recent studies do acknowledge that some sort of collusion is taking place. The current discussion is more about which model of imperfect competition the oil price formation adheres to, and to stability issues of OPEC's market power. Böckem (2004) combines theories of new empirical industrial organisation (NEIO) literature with modern econometric techniques, and argues that a price-leader model provides the best description of OPEC behaviour and

[6] This improvement in RoACE generated simply by reducing activity levels is mainly due to the system of depreciation (production unit method) and the most common way of treating exploration expenses (full cost method).

[7] In spite of differences in terms of definition, there is a close economic relationship between the *ex ante* required rate of return (RRoR) measure and the *ex post* return on average capital employed (RoACE) indicator. See Antill and Arnott (2002) for a more comprehensive discussion of accounting standards, financial market behaviour and corporate investment strategies.

oil price formation. Hansen and Lindholt (2004) obtain similar results in an econometric study of monthly oil price data over the period 1973-2001. Smith (2005) provides a critical overview of recent empirical studies of OPEC behaviour, and concludes his own assessment with weak support for a "bureaucratic syndicate" model.

Figure 3. OPEC decision variables



Source: EIA, http://www.ecowin.com.

Traditionally, OPEC has collected data for a "basket" of different crude oil qualities, and the global oil market has been monitored through a reference price based on this basket (cf. Figure 3). In March 2000, OPEC established a price band mechanism to respond more automatically to changes in oil market conditions. According to this mechanism, production would be adjusted at price levels below 22 USD/bbl and above 28 USD/bbl. The mechanism was later adjusted to allow production adjustments at OPEC's discretion, and by 2004 the price band mechanism had been activated only once.[8] The price band mechanism was suspended in January 2005. Combining these observations with the oil price development (cf. Figure 3), there are clear indications that OPEC's oil price ambitions have increased since the turn of the century.

A variety of developments may shed light on this increased confidence on OPEC's behalf. First, the outlook for non-OPEC supply was curbed by financial market pressures and strict capital discipline. Second, the oil price outlook was uncertain, and did not provide sufficient incentive for massive private oil and gas investment. Third, the domestic provinces of the IOCs were maturing rapidly,[9] with deteriorating exploration results and stagnating reserve development. Fourth, in terms of demand, the global economy was recovering swiftly, with especially high growth in GDP and energy demand in

[8] OPEC activated the mechanism in October 2000, to increase total OPEC production by 500,000 barrels per day.
[9] USA, Canada, United Kingdom Continental Shelf and the Norwegian Continental Shelf.

non-OECD countries. Recent econometric evidence also indicates that current oil demand is less responsive to oil price changes than in the 1980s (e.g., Liu 2004). Finally, the Asian economic crisis had demonstrated the importance of internal discipline when demand is insufficient to meet every cartel member's production ambitions. All in all, OPEC regained strength, and entered the new century with increased market power – and a willingness to exploit it.

We now turn to a detailed and model-based analysis of these developments, to reveal more precise implications in terms of investments, production growth and oil price formation.

3. Model scenarios

3.1 Overview of FRISBEE

The FRISBEE model is a recursive, dynamic partial equilibrium model of the global oil market, developed by the Research Department of Statistics Norway.[10] The model accounts explicitly for discoveries, reserves, field development and production in four field categories across 13 global regions (including two OPEC regions). The model is calibrated based on market data for the base year 2000, as well as other relevant data and estimated parameters from the literature (e.g. demand elasticities, production costs, oil resources etc.).

In each region oil is demanded for transport and stationary purposes in three sectors of the economy: Manufacturing industries, Power generation, and Others (including household demand). Oil demand depends on user prices of oil products, and to some degree on other energy prices. In the end-user sectors the direct price elasticities are on average around -0.3 in the long run, and around -0.1 in the short run. Income growth is particularly important in the longer term, with (per capita) income elasticities on average around 0.6. Population growth and exogenous energy efficiency are also affecting energy demand. In the power sector oil competes with other fuels on a cost basis. The global oil market is assumed to clear in each period (year). Regional supply, demand and trade flows are among the outputs of the model.

The development of non-OPEC production is influenced by initial production capacity and investments – in exploration, field development and efforts to increase oil recovery (IOR). Production

[10] A more extensive presentation of the FRISBEE model system is offered by Aune et al. (2005): http://www.ssb.no/publikasjoner/DP/pdf/dp416.pdf. More recently, the model has been extended to include international gas and coal markets (see Rosendahl and Sagen 2007).

volumes from developed fields are determined by the equalisation of marginal producer costs to producer prices in each region. Investments are driven by expected returns, and net present values are calculated for the four field categories in the 11 non-OPEC regions (i.e., 44 field groups), based on adaptive price expectations and a pre-specified required rate of return. The investment horizon is quite different for the three types of investment. IOR investment typically produce returns with a time lag of 0-2 years, field developments have a perspective of 2-5 years before start-up, whereas exploration projects are for the long term. Different investment activities will therefore respond differently to oil price changes.[11] We capture this variation in terms of activity-specific price expectations, whereby recent price history dominates in the evaluation of short-term IOR projects, whereas a longer historical memory is applied in oil price expectations formation for exploration projects. More specifically, we apply adaptive oil price expectations that differ across investment activities in the following way:

[1] $$E_t\left[P_{ij}\right] = \alpha_i P_{ijt-1} + \left(1-\alpha_i\right) E_{t-1}\left[P_{ij}\right],$$

where $E_t[P_{ij}]$ is the expected (real) oil price applied for evaluation of investment activity i in field group j, P_{jt-1} is the corresponding observed (real) price last year, and α_i are parameters that determine the speed of expectations adjustment for each of the three investment categories. The values of α_i are assumed to be respectively 0.60, 0.35 and 0.10 for IOR activities (I), field development (D) and exploration activity (E). Neglecting footscript t for simplicity of exposition, investments in field development and IOR activities in non-OPEC are derived from the following maximisation problem (see Appendix B for details):

[2] $$Max_{R_{ij}} \Pi\left(R_{ij},\ E\left[P_{ij}\right],\ r,\ CO_j,\ CC_{ij}, GT_j,\ NT_j, \vec{F}_j\right),$$

where Π is expected discounted profits, R_{ij} denotes investment in new reserves (new field developments or IOR) in field group j, r is the required rate of return, CO_j and CC_{ij} operating and capital costs, respectively, GT_j and NT_j gross and net tax rates on oil production, respectively, and $\vec{F}_j$ is a vector of field characteristics that differ across field groups (notably production profile and time lags). Note that capital costs are increasing in investment activity, decreasing in undeveloped reserves (new fields), and increasing in the recovery rate (IOR). A simpler approach is applied for exploration

[11] When the oil price started rising around the turn of the century, volatility was high, and the longer term outlook was very uncertain. The company response was a redirection of investment toward activities with a short-term horizon, like IOR and (satellite) field developments, at the expense of longer term exploration investments (Osmundsen et al. 2007).

investments, where we assume that the process for discovered reserves (R_{Ej}) is captured by the following function (cf. Appendix B):

$$[3] \qquad R_{Ej} = R_{Ej}\left(E\left[P_{Ej}\right],\ r,\ U_j,\ \vec{F}_j\right),$$

where $E[P_{Ej}]$ is the expected oil price applied for evaluation of exploration activities, U_j denotes (expected) remaining undiscovered reserves, and footscript t is still subdued. A higher expected price and/or a lower required rate of return will increase the investments in new fields and IOR activities, and increase the level of discoveries. The required rate of return is most important for exploration, and least important for IOR activities, since the time lag between capital outlays and revenues is highest for exploration and lowest for IOR.

As discussed above, production behaviour within OPEC seems to be driven by ambitions to reach pre-determined price targets. FRISBEE therefore assumes that OPEC searches for the price path that maximises its net present value of oil production until 2030 at a discount rate of 7 per cent, and chooses a production profile consisten with this price path. However, we restrict the analysis to price paths on the following form:

$$[4] \qquad P_{t+1}^{OPEC} = P_t^{OPEC} + \gamma^{t-t_0}\psi,$$

where P_t^{OPEC} is the average producer price for OPEC, and ψ and γ are parameters that determine the price path from an exogenous base year level (t_0 = 2000). The concave price trajectory illustrated in Figure 5 is the result of a calibration with $\gamma = 0.9$, which is also applied in our further simulations.[12] The model now searches for the value of ψ that maximises the net present value of OPEC's profit flow. Note that the expectation formation is different for OPEC and non-OPEC. Whereas non-OPEC producers have adaptive expectations about the future oil price, OPEC has (implicitly) rational expectations about the future market.

Figure 4 provides a stylised overview of oil price formation in the FRISBEE model. Total demand and non-OPEC supply are based on neo-classical behavioural equations for oil and gas producers, other

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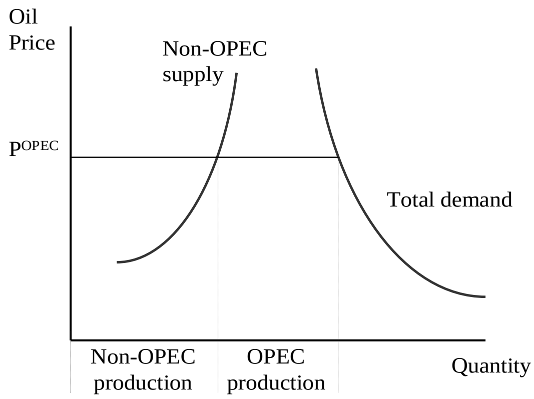
[12] Our choice of γ is of course a significant restriction of all the possible price paths OPEC can choose between in reality. However, for the purpose of exploring the impacts of industry restructuring this restriction is of minor importance since γ only determines the curvature of the price path. Simulations with other values of γ (including γ 1, i.e., linear and strictly convex price paths) indicate that the price differential in the long run (i.e., 2020-2030) is very quite similar in relative terms.

industrial companies and households in 13 regions across the world. The price set by OPEC (P^{OPEC}) clears the market, and implicitly determines both total oil production and the market shares for OPEC and non-OPEC. For a given price chosen by OPEC, oil demand and non-OPEC production are determined independently, and OPEC supply is simply closing the gap. A credible defence of the price target will require surplus capacity. In our model, we therefore assume that OPEC will always invest sufficiently in new fields and IOR activities to maintain a capacity surplus of 10 per cent. OPEC's distribution of investments between IOR and new fields, and between OPEC field groups, is exogenous to the model.

Figure 4. Oil Price Formation in the FRISBEE Model



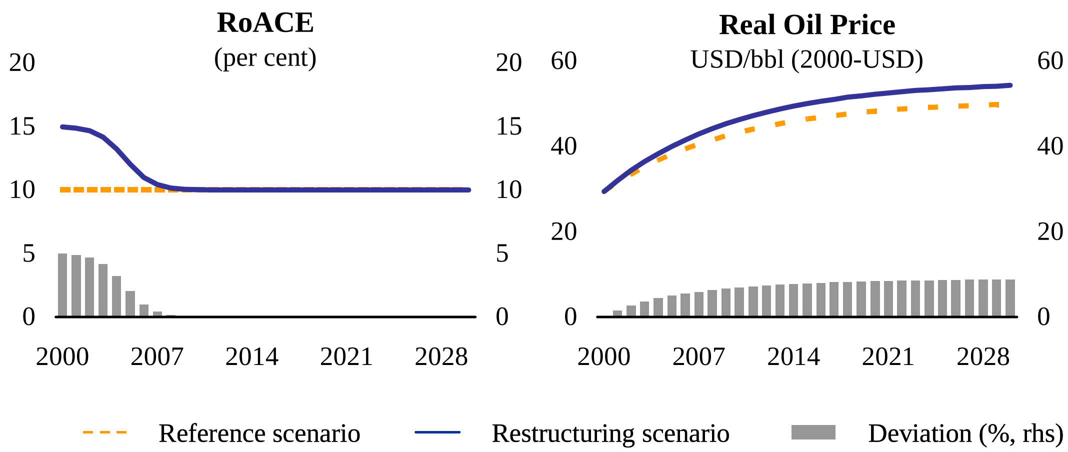
In summary, oil companies invest in exploration for new reserves, field developments and in efforts to increase oil recovery from producing fields. Non-OPEC production is profit-driven, whereas OPEC meets the residual "call on OPEC" at a pre-specified oil price path which is determined through an NVP maximisation process, subject to total demand expectations and conjectures for non-OPEC supply behaviour. A higher oil price path (compared to a reference path) will gradually increase non-OPEC production. Extraction from existing capacities is fairly fixed, but the profitability of IOR investments is increased, leading to higher production capacity in the short to medium term. In the medium to long term more fields will be developed, and in the longer term new fields are discovered and appraised for development. A higher oil price path will also gradually reduce oil demand. The model scenarios below illustrate how the interaction between financial markets and oil and gas companies may affect the supply side of the oil market.

3.2. Assumptions and calibration of two scenarios

Following the discussion in Section 2, we want to explore the market effects of the industry restructuring observed in the oil market at the end of the last century. As explained in Section 2.2, RoACE increased substantially among the IOCs in the 1990s, from 8.9 per cent in 1990-1997 to 16.0 per cent in 1998-2005. This indicates that the required rate of return on new investments was significantly raised in this period.

We will consider two different scenarios using the FRISBEE model. The first scenario, called the 'Reference scenario', assumes that the non-OPEC producers follow the attitude of the IOCs from the first half of the 1990s. That is, their required rate of return is assumed to be 10 per cent. The second scenario, called the 'Restructuring scenario', assumes that the non-OPEC producers require a higher rate of return, i.e., 15 per cent, at the beginning of the new century. However, as discussed above, we have seen a gradual change among the IOCs over the last couple of years, with a gradual redirection of attention (and investment) from short-term profitability to long-term reserve and production growth. Accordingly, we allow the required rate of return to fall gradually from 15 to 10 percent towards 2010, as illustrated in Figure 5. In all other respects, the scenario assumptions are identical.[13]

Figure 5. RoACE and Oil Price Scenarios



Source: Exogenous assumptions (RoACE) and *FRISBEE* Model (oil price).

[13] We assume that OPEC has perfect expectations about the required rate of return in non-OPEC. Alternatively, we could assume that OPEC has adaptive expectations about the rate of return. In this case OPEC would choose a higher initial growth in the oil price in the Restructuring scenario, assuming that non-OPEC producers would stick to a high required rate of return also in the future. Simulations indicate that this would lead to a significantly higher oil price level also in the long run.

A higher rate of return in the 'Restructuring scenario' will lead to less investment among non-OPEC producers compared to the 'Reference scenario'. On the other hand, when the rate of return is gradually reduced in the former scenario, investment activities should pick up again. In fact, with more unexploited projects and possibly higher oil price, investment activities may surpass the activity level in the 'Reference scenario' after some years. In the next subsection we will investigate how this may have affected the oil market since 2000, and what impacts it may have on the future market.

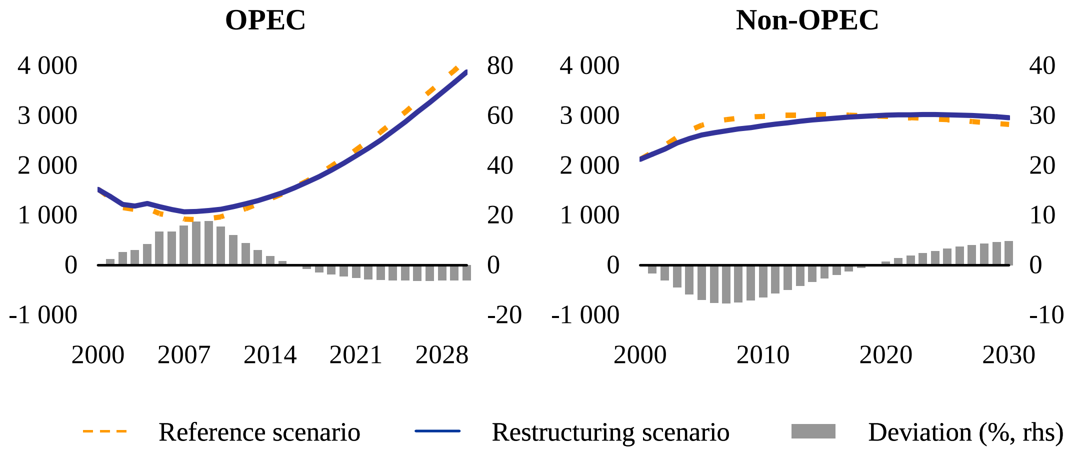
3.3 Model results

In the ‘Reference scenario’, the oil price increases from 29 USD/bbl 2000 to 50 USD/bbl in 2030. Hence, it is clearly profitable for OPEC to settle on an increasing oil price path from the level in 2000. Reduced investment activities among non-OPEC producers in the 'Restructuring scenario' gradually reduce the supply outside OPEC compared to the ‘Reference scenario’, at least temporarily. This makes it profitable for OPEC to choose a higher oil price than in the latter scenario, cf. Figure 5. The short-term investment effect of the IOC strategy redirection is significant. Still, the long-term oil price difference between the scenarios is not big (4.4 USD/bbl, or 8 per cent), since the difference in attitude for non-OPEC producers is fairly short-lived.

Between 2005 and 2010 investment levels in the 'Restructuring scenario' surpass the levels in the 'Reference scenario' for all three investment activities. After 2005 the required rate of return is almost the same, whereas the oil price is higher in the former scenario. Moreover, the recovery rate in existing fields is lower, which means that there are more profitable IOR projects left. In addition, there are more undeveloped fields (despite fewer discoveries), which means that there are more profitable fields to develop. The (expected) amount of undiscovered oil reserves is also higher.

From Figure 6 we see that non-OPEC supply is somewhat reduced in the 'Restructuring scenario' compared to the 'Reference scenario' in the first 18 years. Less investment gradually affects production levels. In the first couple of years this is driven by fewer IOR projects. After 5-10 years the effects of less development projects are perceptible, too. Gradually fewer discoveries also affect supply. However, before 2010 investment activity in non-OPEC shifts back when the required rate of return is reduced. A higher oil price and more unexploited projects then lead to higher investments in the 'Restructuring scenario' (see below). Thus, production levels outside OPEC gradually catch up with the 'Reference scenario'. From around 2020 the supply outside OPEC is highest in the 'Restructuring scenario'.[14]

Figure 6. OPEC and non-OPEC Oil Supply (Mtoe per year)



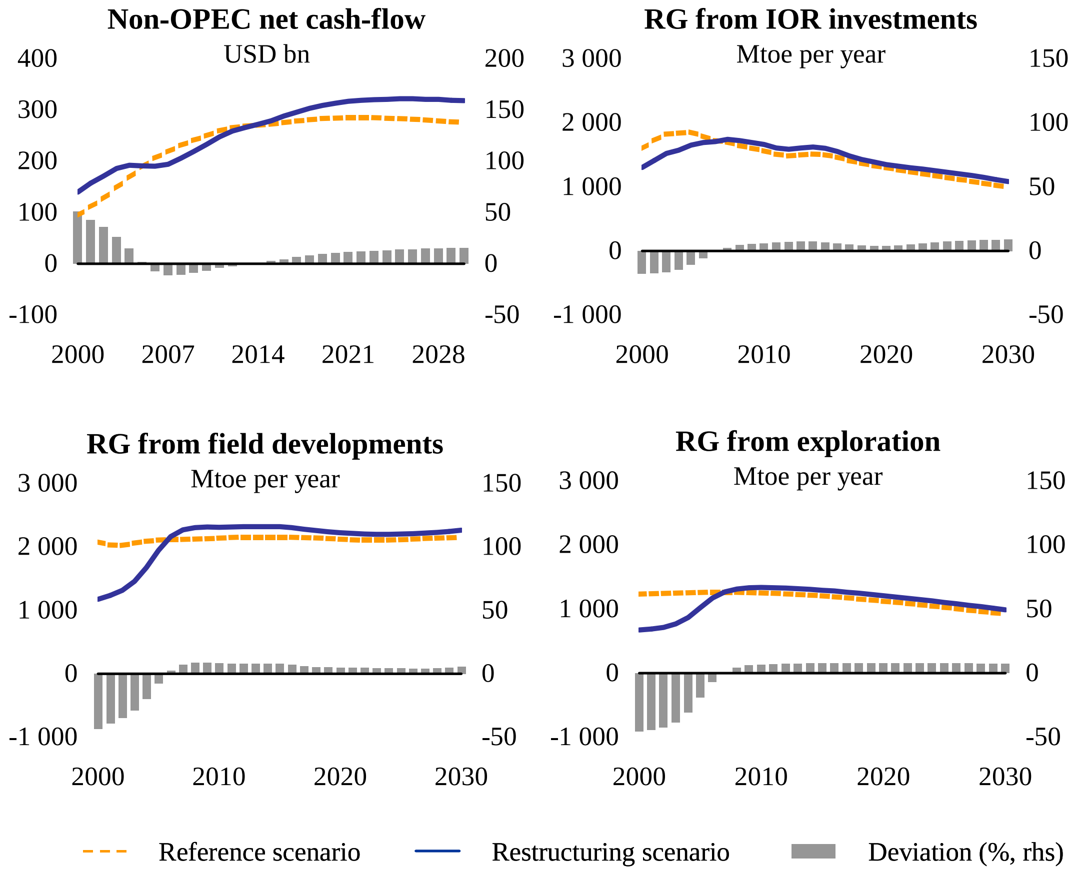
Source: *FRISBEE* Model.

As explained in Subsection 3.1, a higher required rate of return will affect new discoveries most and IOR projects least. This is because the time lag between investment expenditures and expected revenues are lowest for IOR activities and highest for exploration activities. Figure 7 shows how the different investment activities develop in the two scenarios. We see that IOR investments are least affected, as expected. They are reduced by up to 18 per cent in the 'Restructuring scenario'. New field developments are almost halved in the first couple of years, and so too are new discoveries.

Which scenario is most profitable for non-OPEC producers? Figure 7 shows how the net cash flow evolves, i.e., net revenues from oil production minus investment expenditures. We see that the 'Industry restructuring' scenario is clearly the most profitable one, whatever discount rate we apply. In the short run, non-OPEC producers gain from reducing their capital outlays. In the medium term, they gain from a slightly higher oil price, and lose from a slightly lower supply. Investment expenditures are about the same. In the longer term, both the oil price and non-OPEC production are higher, and these effects dominate the effect of higher capital expenditures. That is, non-OPEC's temporary restraint in investment activities is beneficial for both non-OPEC and OPEC producers, whereas the consumers stand to lose from higher prices.

[14] If the oil price path was unchanged in the 'Restructuring scenario', the investment levels would still surpass the levels in the 'Reference scenario' before 2010. However, the investment levels in the two scenarios would be more similar towards 2030, and Non-OPEC supply would be highest in the 'Reference scenario' over the entire time horizon.

Figure 7. Non-OPEC Net Cash-Flow and Reserve-Generation (RG) by Investment Type[15]



Source: *FRISBEE* Model.

4. Conclusion

The process of capital formation in the oil and gas industry is an important part of the supply side dynamics in the oil market. Understanding how oil and gas companies think in terms of investment is therefore essential in order to develop and maintain the required insights for meaningful analyses of oil price formation. Over the last 15 years, international oil and gas companies have gone through a period of escalating market turbulence, restructuring and redirection of investment strategy. From the beginning of the 1990s, the focus on short-term accounting returns increased, at the expense of reserve replacement. We explore the impact of this strategy redirection on oil price formation.

[15] Unconventional oil (i.e., tar sands in Canada) is included in all graphs except for new discoveries. Within our time horizon, conventional oil discoveries are much more important for new field developments than unconventional discoveries, as reserves of tar sand are already huge and not really constraining field development in Canada. If we subtract unconventional oil also in the graph for new field developments, we will see a gradual but distinct decline after 2010 in both scenarios. In 2030 unconventional oil constitutes almost half of new field developments outside OPEC, according to our scenarios.

The temporary one-dimensional focus on RoACE forced the international oil companies to cut back on investments, thus generating higher oil prices. This change in strategy has clearly proved profitable for the international oil industry. Through the capital market analysts' RoACE-benchmarking of companies, an implicit coordination on lower investment levels was achieved. In retrospect, it can easily be demonstrated that deviation from the common strategy of low investment would have been profitable for any individual oil company. By maintaining its standard investment policy (e. g., a constant reinvestment ratio), it could have reaped the joint benefit of high oil prices and high production. However, tight co-operative capital discipline was maintained, as managers feared that a lower RoACE than the industry average would harm share prices in the short run, thus making it harder to raise capital and increasing the takeover probability.

Based on a partial equilibrium model for the global oil market, we present new insights and explanations for oil market developments over the last few years. Our results provide firm support for the key hypothesis that increased focus on shareholder returns, capital discipline and return on capital employed (RoACE) caused a temporary slowdown in investment and production growth among international oil companies. We find that the strategic redirection of the international oil industry towards the end of the 1990s had long-lasting effects on OPEC behaviour – and on oil price formation. Our scenarios suggest that the industrial restructuring of the late 1990s caused a lift of approximately 10 per cent in the long-term oil price. Both OPEC and non-OPEC producers gain from this development, whereas the cost is carried by oil-importers and consumers.

Industrial leaders and their companies do not operate in a vacuum. Rather, they respond continuously to changing political and market environments. Their models and ways of thinking may be stable for periods. However, their mindset will also be challenged by external forces from time to time. And sometimes these pressures even bring about deeper changes. This study demonstrates that such a change took place in the oil and gas industry in the 1ate 1990s, that had persistent effects on the oil market. Today, competition among international oil companies is more aggressive than ever (Weston, Johnson and Siu 1999). Easily accessible oil and gas reserves in market-oriented economies like USA, Canada and United Kingdom are faced with depletion. Oil and gas investments are now gradually redirected in a rat race for increasingly scarce oil and gas resources. On this background it should come as no surprise that investment behaviour among international oil and gas companies changed gears.

From the perspective of the investors, an adequate question is if strategies now have shifted too far away from accounting returns. The international oil industry has a history of over-investment at high oil prices (e.g., Jensen 1986). However, there are signs that the current situation is different from the traditional high price cycle scenario: The lack of adequate investment projects actually put an effective curb on investments, and reserve replacement levels are low. On the other hand, some of the current investment projects in the oil industry have break-even prices considerable above historic oil prices. Company managers thus face some tough decisions. Traditional counter-cyclical asset trading (selling reserves at top of the oil price cycle) may not seem so tempting when the company is not replacing its reserves. On the other hand, buying reserves in the current market sentiment may seem risky. Assets are traded at prices that entail a considerable downside risk. Part of this picture is the fact that the IOCs are competing for new reserves against NOCs that are not subject to the same capital market scrutiny.

An interesting direction for future research would be to study the stability of the investment process in the oil and gas industry in greater detail, preferably with micro-econometric studies of company data. Modern econometric techniques may reveal more exact information on how the process of capital formation in the oil and gas industry was altered in the late 1990s.

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Appedix A

List of regions and field categories in the FRISBEE model

Regions	Field categories 1	2	3	4
Africa	Onshore All	Offshore deep < 400 Mboe	Offshore deep > 400 Mboe	Offhore shallow All
Canada	Onshore All	Unconventional All	Offshore < 400 Mboe	Offshore > 400 Mboe
Caspian region	Onshore < 400 Mboe	Onshore > 400 Mboe	Offshore < 400 Mboe	Offshore > 400 Mboe
China	Onshore < 100 Mboe	Onshore >100; < 1000 Mboe	Onshore > 1000 Mboe	Offshore All
Eastern Europe	Onshore < 100 Mboe	Onshore > 100 Mboe	Offshore < 100 Mboe	Offshore > 100 Mboe
Latin America	Onshore All	Offshore deep < 1000 Mboe	Offshore deep > 1000 Mboe	Offhore shallow All
OECD Pacific	Onshore All	Offshore deep All	Offshore shallow < 100 Mboe	Offshore shallow > 100 Mboe
OPEC core*	Onshore < 400 Mboe	Onshore >400; < 1000 Mboe	Onshore > 1000 Mboe	Offshore All
Rest-Asia	Onshore < 400 Mboe	Onshore > 400 Mboe	Offshore < 400 Mboe	Offshore > 400 Mboe
Rest-OPEC	Onshore < 400 Mboe	Onshore > 400 Mboe	Offshore deep All	Offhore shallow All
Russia/Ukraine/Belarus	Onshore < 400 Mboe	Onshore > 400 Mboe	Arctic < 400 Mboe	Arctic > 400 Mboe
USA	Onshore All	Alaska All	Offshore deep All	Offhore shallow All
Western Europe	Offshore deep < 400 Mboe	Offshore deep > 400 Mboe	Offshore shallow < 100 Mboe + Onshore	Offshore shallow > 100 Mboe

* OPEC core consists of Saudi Arabia, Iran, Iraq, Kuwait, UAE and Venezuela, whereas Rest-OPEC consists of the remaining OPEC member countries.

Appendix B

A more detailed outline of the modelling of investment behaviour for non-OPEC producers in the FRISBEE model is presented below. For the complete formal structure of FRISBEE, see Aune et al (2005). With access to all non-OPEC regions and field categories, oil companies maximise expected discounted profits from investments. Choice variables are given by reserve additions (R_{ij}) from field development (footscript $i = D$) and IOR activities (footscript $i = I$) in the various regions of origin (footscript j). Expanding the profit function of Equation [2] according to the FRISBEE specification yields (footscript t is dropped for simplicity of exposition:

[B1]

$$Max_{R_{ij}} \Pi\left(R_{ij},\ E\left[P_{ij}\right],\ r,\ CO_j,\ CC_{ij}, GT_j,\ NT_j, \vec{F}_j\right) =$$

$$\sum_j \left[\left(\eta_j \cdot E\left[P_{Dj}\right](1-GT_j) - \frac{CO_j}{R_{Dj}T_j} \right) \cdot (1-NT_j) \cdot h_j - \frac{CC_{Dj}}{R_{Dj}} \left(1 - \frac{1}{6} NT_j \cdot e^{-r} \frac{1-e^{-6r}}{1-e^{-r}} \right) - RISK_j \right] \cdot R_{Dj}$$

$$+ \sum_j \left[\frac{E\left[P_{Ij}\right](1-GT_j)\alpha_j}{r+\alpha_j} (1-NT_j) - \frac{CC_{Ij}}{R_{Ij}} \left(1 - \frac{1}{6} NT_j \cdot e^{-r} \frac{1-e^{-6r}}{1-e^{-r}} \right) \right] \cdot R_{Ij},$$

where $E[P_{ij}]$ is the expected (real) oil price applied for evaluation of investment activity i (= $[D, I]$) in region j, r is the required rate of return, and CO_j and $CCij$ are operating costs and capital costs, respectively. GT_j and NT_j are gross and net tax rates on oil production, and $\vec{F}_j$ is a vector of field-specific characteristics. $RISK_j$ is a parameter that reflects other important non-cost factors such as political risk, contract terms etc. The first part of Equation [B1] represents expected revenues and costs of developing new fields (footscript $i = D$), whereas the second part relates to improved oil recovery projects (IOR, footscript $i = I$). The production profile varies across field groups, affects both discounted income and operating costs, and is determined by η_j (peak production level as a fraction of initial reserves), α_j (decline rate in the decline phase) and the length of each production phase (t_{kj}). These characteristics of the production profile are embedded by a compound discount factor for production revenues (h_j) in the following way:

[B2]

$$h_j = e^{-rt_{1j}/3} \left(0.5 \frac{1-e^{-rt_{2j}}}{1-e^{-r}} + e^{-rt_{2j}} \frac{1-e^{-rt_{3j}}}{1-e^{-r}} + e^{-r(t_{2j}+t_{3j})} \frac{1-e^{-(r+\alpha_j)(T_j-t_{2j}-t_{3j})}}{1-e^{-(r+\alpha_j)}} \right).$$

t_{1j}, t_{2j} and t_{3j} denote the length of the investment phase, the building up phase, and the peak phase, whereas T_j denotes the (expected) total lifetime of the field (including the decline phase). Operating costs (CO_j) for fields in production are further given by the following expression:

[B3] $$CO_j = CO0_j R_{Dj} \left[1 - \gamma_{Dj} \ln \left(\frac{UR_j}{ADRR_j} \right) \right] e^{-\tau_O t},$$

where $CO0_j$ is calibrated based on operating cost data, UR_j and $ADDR_j$ denote remaining undeveloped reserves and accumulated discoveries, respectively, and τ_O is exogenous technological progress (γ_{Dj} is a calibrated parameter). The investment costs (CC_{Dj}) for new field developments depend on the current supply from the respective field group (S_j) and region (S_{reg}), as well as undeveloped reserves:

[B4] $$CC_{Dj} = CCC_{Dj} \cdot R_{Dj} \left(0.5 + c_{C,UR} \frac{R_{Dj}}{UR_j} + c_{C,S1} \frac{R_{Dj}}{S_j} + c_{C,S2} \frac{R_{Dj}}{S_{reg}} \right).$$

$c_{C,i}$ are calibrated parameters. CCC_{Dj} depends on undeveloped reserves in the following way:

[B5] $$CCC_{Dj} = CCC0_{Dj} \left[1 - \gamma_{Dj} \ln \left(\frac{UR_j}{ADRR_j} \right) \right] e^{-\tau_D t},$$

where $CCC0_{Dj}$ is calibrated based on capital cost data, and τ_D is exogenous technological progress. Similarly, the costs of IOR projects (CC_{Ij}), which only can occur in the decline phase, are given by the following expression:

[B6] $$CC_{Ij} = CCC_{Ij} \cdot R_{Ij} \left(0.5 + IOR0_j \left(\frac{R_{Ij}}{\frac{\alpha_j}{\eta_j} RD_j + 0.01} \right)^2 \right) \left(\frac{\frac{REC_j}{(1 - REC_j)}}{\frac{REC0_j}{(1 - REC0_j)}} \right)^{\gamma_{Ij}} e^{-\tau_I t},$$

where CCC_{Ij} is calibrated based on cost data, RD_j is remaining reserves in fields that are in the decline phase, $REC0_j$ is initial (average) recovery rate, τ_I is exogenous technological progress, and $IOR0_j$ and γ_{Ij} are calibrated parameters based on IOR potential.

Following Equation [3], the expanded specification of discoveries (R_{Ej}) is given by:

[B7] $$R_{Ej} = R_{Ej}\left(E\left[P_{Ej}\right],\ r,\ U_j,\ \vec{F}_j\right) = \gamma_{Ej} U_j E\left[P_{Ej}\right]^{0.5} e^{-r(t_{0j}+2t_{1j}/3)} \eta_j h_j,$$

where t_0 is the length between exploration activity and development decision, U_j is expected undiscovered reserves, and γ_{Ej} is a calibrated parameter.