THE FUTURE OF THE OIL INDUSTRY IN A "WELL BELOW 2 DEGREE" WORLD: A COMPANY-LEVEL AGENT-BASED SIMULATION

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Overview

The future of the global oil industry is highly uncertain, given the tension between climate targets and oil companies' business models.[1] Potential pathways for the industry are not often discussed in mainstream modelling of climate scenarios, even though its future has significant implications for society at large. This study explores how individual oil companies, and the oil sector, are affected if the Paris Agreement goal of "well below 2 degrees" of global warming is met. We introduce a new simple model of the upstream oil market and demonstrate its use through example scenarios. The model combines an idealised market model of oilfield investment and operation with an agent-based decision-making framework at the level of individual companies. This model framework is used to explore how investments decision under imperfect foresight influence the outcomes for firms in the crude oil market from 2020 to 2040. Our results contribute to a broader understanding of possible oil industry futures providing additional insight to optimisation modelling. We find that in a scenario with oil demand decreasing over time, oil prices decrease substantially, meaning the success of companies operating in the crude oil space is largely dependent on the production costs of their reserves. There is much scope for further developing and applying the model introduced in this paper.

Methods

This study provides an agent-based model of the global crude oil market in which individual companies are represented as decision-making agents that operate and invest in production assets. The purpose of the model is to provide insights into the potential financial outcomes faced by companies in a scenario in which long-term oil demand declines in a way that is compatible with the climate targets of the Paris Agreement.

The model consists of two modules, the operations module and the investment decision module, as shown in figure 1.

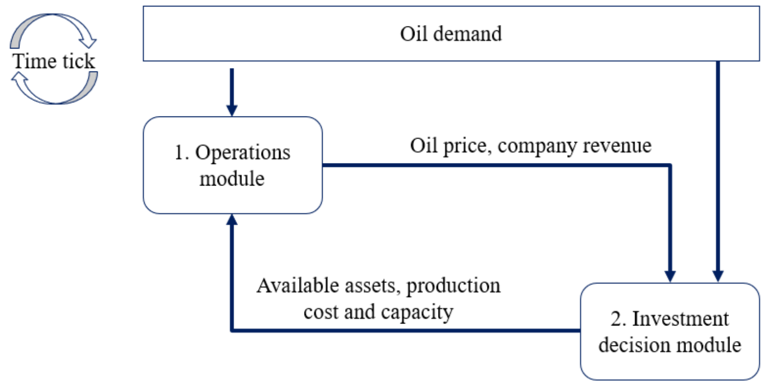

Figure 1. Illustration of the agent-based model of the global oil market which consists of an economically optimising operations module, an agent-based investment decision module, and exogenous oil demand.

The operations module constructs a global supply curve for oil production based on the currently-available assets, and deploys these in order of increasing marginal price to satisfy the exogenous demand. Fields with low production costs will always be dispatched at full capacity before any fields with higher production costs are called upon. The module therefore minimises global operating costs, and through the intersection of supply and demand it yields the price of oil and profits for each company, based upon the assets they own. It follows a number of oil market models in literature by implicitly assuming perfect competition [2], [3], and neglects inter-temporal constraints (such as the time taken to begin or cease operation of a specific well). The module is run on a monthly resolution in order to capture high-level price and production trends rather than inter-daily fluctuations.

In the investment decision module, oil company agents decide how much of their capital to allocate to the development of oil reserves based on information about the current state of the market and beliefs about future price and demand. The decision rules for each company consider the oil price trend, types of assets at their disposal, and the risk appetite or beliefs about future oil price trends. The investment decision module uses annual time steps and determines the oil supply curve for the following year. Within the model, oil companies may therefore differ based on their starting position (what assets they own and where these sit within the supply curve), and their organisational philosophy regarding risk and diversification. For the model runs presented in this paper, the parameters determining likelihood of investment under different scenarios are assumed to be the same for all companies.

The model requires data on asset-level reserves, production levels and production costs for the starting year, and the ownership of each asset. Such datasets are typically available from specialist consultancies at inaccessible prices, or directly from oil companies [3], so here a dataset is constructed by combining and cross-validating data points from a range of public sources. As complete data cannot be found in the open literature, some assets are allocated stochastically between company agents reflecting the real dynamics of oil markets between international oil companies (IOCs) and national oil companies (NOCs) - i.e. Mexican oil fields to Pemex, those in Saudi Arabia to Aramco.

Due to incomplete data coverage, the resulting oil supply curves are validated against those published by oil industry data providers. While validation at the level of individual countries and assets is not possible, this process was found to give good high-level agreement at the global level. To study the difference between futures that “business-as-usual” (BAU) and consistent with a 2-degree pathway (2D), exogenous oil demand scenarios from the International Energy Agency (IEA) were inserted into the model. [4]

The model, and particularly the parameter values in the investment decision module, are calibrated by comparing the price projections of the model under business-as-usual and decarbonisation scenarios to the price projections given by the IEA for comparable scenarios. [5]

Results

The annual oil price given by the oil model fluctuates over time in both the BAU and 2D scenarios. However, the BAU scenario leads to relatively steady average price level in the period from 2020 to 2040, whereas the low-demand scenario shows a clear declining trend over the long run.

The key result of running the model is the difference between the BAU and 2D scenarios. A preliminary results in the form of annual price difference between the scenarios, as absolute dollars per barrel, is shown in figure 2. The BAU scenario leads to overall higher price levels throughout the model run.

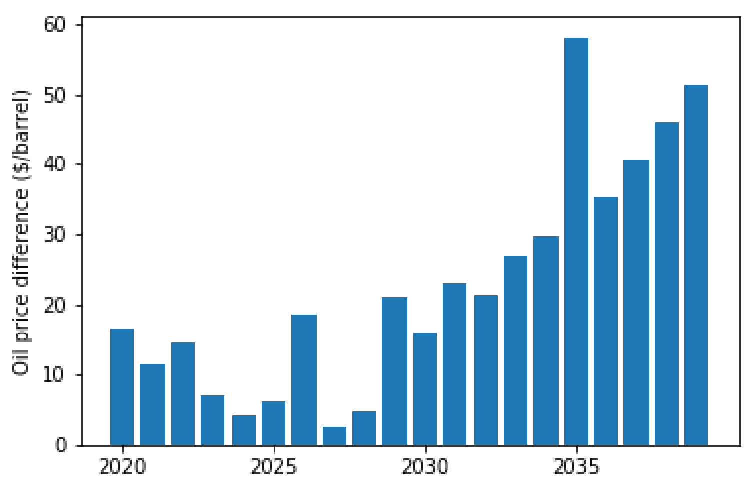

Figure 2. Preliminary result: Price differential in dollars per barrel between the two scenario outputs of the oil model, calculated by subtracting the annual average prices of the low-demand scenario from those of the business-as-usual scenario.

Figure 8 shows the differences in annual profit (top row) and upstream oil investments (bottom row) of NOCs and IOCs, respectively, across the two scenarios. Both NOCs and IOCs lose earnings in the 2D scenario compared to the BAU scenario. The levels of these losses (as shares of earnings in the BAU scenario) are reasonably similar for both types of companies, although the losses of earnings ramp up faster for IOCs. Investment does not decline as rapidly as profits when compared between the two scenarios. In other words, the investments companies make in the 2D scenario are higher compared to the profits they are receive than in the BAU scenario, indicating lower returns on investment.

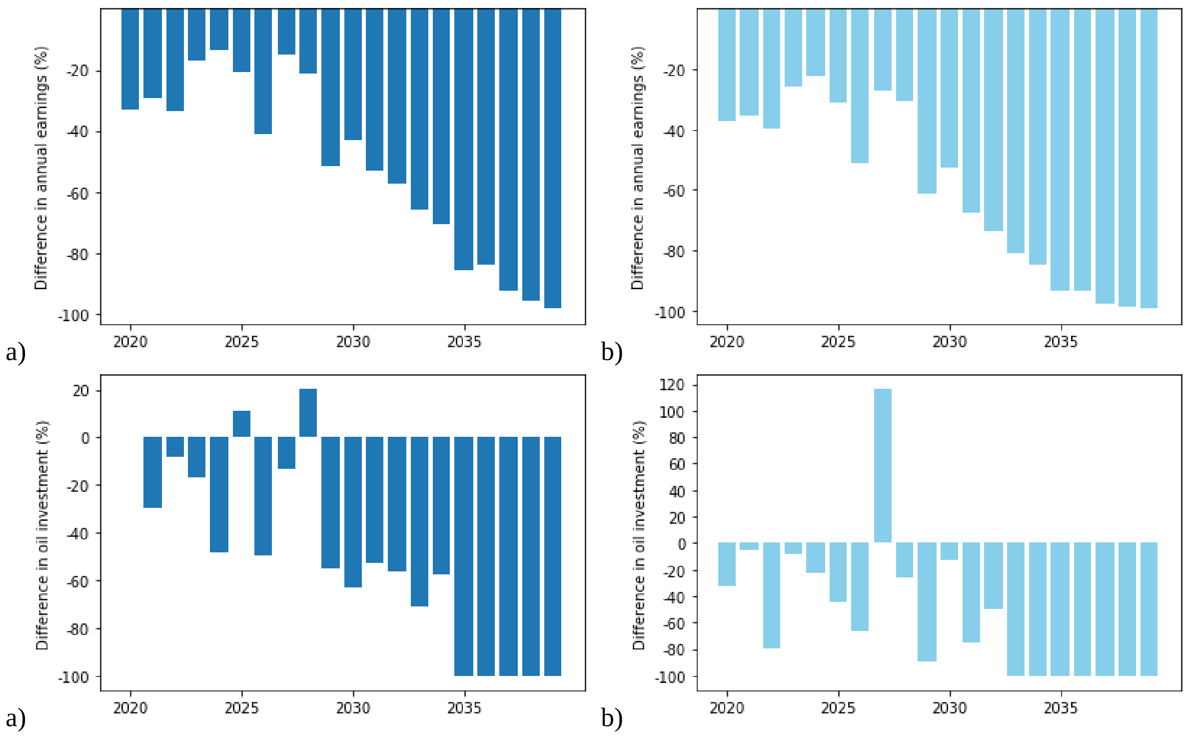

Figure 3. Preliminary result: Difference in the annual profit (top row) and investments (bottom row) of a) NOCs and b) IOCs across the two scenarios. The difference is calculated as the percentage by which the earnings in each year of the 2D scenario differ from those of the corresponding years in the BAU scenario.

Conclusions

The most important takeaway from the preliminary results of running the model is that long-term oil demand, and the extent to which oil companies anticipate future developments in oil demand, greatly affect the companies' ability to compete in the market and the risk of asset stranding. The investment strategies that work reasonably well under a BAU scenario lead to less desirable outcomes when paired with a "well below 2 degrees" scenario. However, these impacts are not evenly distributed in the upstream oil sector, as international oil companies with higher average production costs are likely to struggle to maintain market share in under low-demand scenarios.

The scope for future work on this topic is broad, for by using more granular input data, and testing the effects of a wider range of scenarios and decision rules. It would also be interesting to study in more detail e.g. the alternative capital allocation options of companies which choose not to invest all their capital on oil, and the implications of these for their potential financial performance.

References

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