OFF-SHORE ENHANCED OIL RECOVERY IN THE NORTH SEA: THE IMPACT OF PRICE UNCERTAINTY ON THE INVESTMENT DECISIONS

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Overview

CO_2 enhanced oil recovery (CO_2-EOR) entails the injection of CO_2 in mature oil fields in order to mobilize the oil. In particular, the injected CO_2 reduces the oil's viscosity and acts as a propellant, resulting in an increased oil extraction rate (Leach et al. 2011). CO_2-EOR is considered to play a significant role in stimulating subsequent CCS deployment (Scott 2013). Most studies that evaluate CO_2-EOR economically give evidence of oil and CO_2 price uncertainties, but only address this issue by a sensitivity analysis (Fleten et al. 2010; Klokk et al. 2010). From the 1980s on however, it is increasingly being recognized that the net present value (NPV) and discounted cash ow methods are inadequate to deal with issues like uncertainty, the irreversibility of an investment decision, and the exibility of the decision process (Dixit and Pindyck 1994). Furthermore, most of these studies consider the CO_2-EOR project as one investment decision and implicitly assume that a CO_2 stream will be readily available.

Methods

We first develop two real options models to evaluate the investment in a CO_2 capture unit and the investment in enhanced oil recovery separately. We consider the investment decisions to be made by the electricity producer and the oil company as two separate decisions. To analyse the investment decision of the electricity producer who has to invest in a CO_2 capture unit, we present a real options model that considers the avoided payment of CO_2 emission allowances as an uncertain revenue stream. Based on this model we determine the critical CO_2 price level at which the firm is willing to invest in the CO_2 capture unit. As regards the enhanced oil recovery, CO_2 is input to the production process and hence a cost to the oil producer. For the investment decision in the enhanced oil recovery we present a second real options model that considers the oil price and the cost of CO_2 as uncertain. After the two separate investment analyses, we analyze the investment decision of the electricity producer again, considering the revenue stream as the sum of the avoided payment of CO_2 emission allowances and the revenue from selling the caputered CO_2 to the oil company. Based on this analysis we define the CO_2 and oil price regions in which a trade in CO_2 can take place between the electricity producer and the oil producer.

We apply the model to a hypothetical but realistic case study. We consider an electricity producer located in the Antwerp harbor region (Belgium) that will build a new coal fired power plant and has to decide whether or not to invest in a CO_2 capture unit as well. The oil company, located in the UK, exploits an ff-shore oil field in the North Sea Basin and has to decide whether or not to invest in CO_2-EOR and in a 250 km pipeline to transport the CO_2.

Results

When uncertainty is integrated in the decision analysis, oil price threshold levels are higher than the threshold level determined using an NPV approach. Klokk et al. (2010) only applied an NPV approach and find for their base case example that for an oil price of 50 USD/bbl (± 45 €/bbl) and a CO_2 price of 27 USD/tonne CO_2 (±24 €/tonne CO_2) the NPV of CO_2-EOR is positive. We show that when uncertainty is integrated in the investment analysis, for a CO_2 cost of 24 €/tonne, the oil price needs to be at least 124 €/bbl. For an oil price of 45 €/bbl the CO_2 cost needs to be negative before an investment in CO_2-EOR is justified. Also Kemp and Kasim (2013) study EOR investments for different oil fields in the UK Continental Shelf and calculate NPVs for different oil fields. They do not determine investment threshold values but conclude that for low carbon prices with an average of 5 GBP/tonne CO_2 and an average oil price of 80 GBP/bbl (± 113 €/bbl) EOR is economically feasible. If we project the result of Kemp and Kasim (2013) on our results, not only the NPV result is positive, but also the threshold level determined by the real options analysis is reached. Comparing our results to those of Mendelevitch, we come to a similar conclusion. Like Mendelevitch (2014) we show that for the given CO_2 and oil price levels, the NPV is positive. However, when uncertainty is integrated, for a CO2 cost of 83 €/tonne, the oil price level needs to be 168 €/bbl. Different from Klokk et al. (2010), Kemp and Kasim (2013), and Mendelevitch (2014) we do not address uncertainty by a sensitivity analysis. Although a Monte Carlo sensitivity analysis highlights the several substantial risks involved, it only provides a range in NPV. Making a decision based on a range of NPVs is still difficult. We show how the integration of uncertainty in the economic model shows the impact of uncertainty more effectively.

Most of the existing studies that consider CO_2-EOR do not take into account that a transaction of CO_2 will take place between the electricity producer and the oil company and that a CO_2 selling price needs to be established between these two parties. Mendelevitch (2014) integrates a CO_2 transport system operator, but the transaction values are not determined based on the investment threshold levels of the firms considered. If the electricity producer can sell the captured CO_2 to the oil company, then the revenue that the power plant receives is twofold: the price it receives from selling the CO_2 to the oil company and the avoided payment of emission allowance.

The higher the CO_2 emission permit price, the lower the CO_2 selling price and the lower the critical oil price threshold level. Considering the real options approach, for CO_2 emission permit prices equal to 40 €/tonne, the minimum CO_2 selling price is zero and at that cost, the oil company will only invest in CO_2-EOR if the oil price is at least 107 €/bbl. At zero CO_2 emission permit prices, a trade in CO_2 will only take place if oil prices are higher than 136 €/bbl.

Conclusions

Building further on existing studies regarding CO_2 enhanced oil recovery, this study analyses for the first time the deployment of CO_2-EOR as two separate investment decisions and defines the minimum CO_2 and oil price levels at which a trade in CO_2 can take place between a carbon emitting source and an oil company. Furthermore, contrary to previous studies, we do not apply an NPV approach but integrate uncertainty in the decision analysis by applying a real options approach. It is shown how to determine the minimum revenue per tonne CO_2 captured necessary for the investment in a CO_2 capture unit to become economically feasible, taking into account CO_2 price uncertainty. This revenue includes both the avoided cost of CO_2 emission allowances and the payment the electricity producer receives from the oil company. If permit prices are high, the electricity producer might be willing to pay the oil company to store the CO_2 in the oil reservoir.

By extending the real options analysis with a game theoretical approach, further research can determine which selling price will be established between the two profit maximizing firms and how the option of the CO_2 supplier to temporary suspend the operation of the CO_2 capture unit affects the decision to invest in enhanced oil recovery. Also the decision to provide CO_2 transportation infrastructure publicly can be made part of a real option game and is subject to further study. Furthermore, it should be studied whether experience in CO_2-EOR will reduce the cost of CCS deployment and how it aligns with policy objectives regarding the reduction in CO_2 emissions and investments in renewable energy. Using an oil reservoir after EOR as a CO_2 storage project, making use of the existing EOR infrastructure, may be economic and it is therefore desirable to include it in an real options scheme for further research. Although EOR projects, if linked to ETS driven capture projects, will normally produce less carbon intense oil than standard production from the same field, they would also increase the net oil reserves. This could lead to a prolonged use of fossil fuels and a delayed introduction renewables. Other low carbon technologies such as CCS, woul likely benefit from technology developments that CO_2-EOR would bring. Evaluation of such hidden effects is necessary to ensure that EOR would lead to a substantial reduction in CO_2 emissions in the long term. Such type of analysis should also balance issues as energy security, job security and social welfare in general.

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