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A real options model to evaluate the effect of environmental policies on the oil sands rate of expansion

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ABSTRACT

Canadian oil sands hold the third largest recognized oil deposit in the world. While the rapidly expanding oil sands industry in western Canada has driven economic growth, the extraction of the oil comes at a significant environmental cost. It is believed that the government policies have failed to keep up with the rapid oil sands expansion, creating serious challenges in managing the environmental impacts. This paper presents a practical, yet financially sound, real options model to evaluate the rate of oil sands expansion, under different environmental cost scenarios resulting from governmental policies, while accounting for oil price uncertainty and managerial flexibilities. Our model considers a multi-plant/multi-agent setting, in which labor costs increase for all agents and impact their optimal strategies, as new plants come online. Our results show that a stricter environmental cost scenario delays investment, but leads to a higher rate of expansion once investment begins. Once constructed, a plant is highly unlikely to shut down. Our model can be used by government policy makers, to gauge the impact of policy strategies on the oil sands expansion rate, and by oil companies, to evaluate expansion strategies based on assumptions regarding market and taxation costs.

1. Introduction

Oil sands, also referred to as extra heavy oil or bituminous sands, are naturally occurring mixtures of clay or sand, water, and bitumen, a viscous and extremely dense form of petroleum. The Canadian oil sands hold the third largest recognized oil deposit in the world, after Saudi Arabia and Venezuela, covering an area of approximately 140,000 km^2 (Government of Alberta, 2010). While the rapidly expanding oil sands industry has driven economic growth in western Canada and the province of Alberta, it has brought with it many new challenges and concerns, including environmental pollution and manpower shortages. It is believed that the government policies and regulations have failed to keep up with the rapid expansion, creating serious challenges in managing the environmental impacts (Winfield, 2009). This paper aims to provide a real options framework that estimates the rate of oil sands expansion, under different environmental cost (tax) scenarios, while accounting for oil price uncertainty and managerial flexibilities, in a multi-agent[1] setting. We believe that our model can be used by oil companies and government policy makers to gauge the impact of policy strategies on the oil sands expansion rate, based on market and taxation assumptions.

Since GHG emission is one of the most important environmental impacts of the oil sands industry (see for example Bramley et al. (2011)), we use it as a proxy for the environmental damage of this industry. We investigate the consequences of two hypothetical emission cost/tax policies. The first scenario, namely the Increasing Environmental Cost (IEC) scenario, is based on the current government tax policy, where environmental tax is expected to increase over time, in order to better account for the true cost of the environmental damage. In this scenario, we assume that the environmental cost increases based on the projected emission compliance costs reported by the Millington et al. (2012). The second environmental cost scenario, namely the

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[1] By agent we mean an independent oil company.

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Decreasing Environmental Cost (DEC) scenario, is based on a government tax policy where the true cost of environmental damage is captured at all times, with the assumption that this cost will decrease as technology improves. In this scenario, we assume that the environmental damage cost decreases by the same rate that it has been historically decreasing as a result of technology improvements.

In a different classification, we categorize an emission tax policy as full or marginal, where a full emission tax policy charges a CO_2 compliance cost for the total emissions, and a marginal emission tax policy provides tax exemptions at emissions above some specified levels, namely the baseline. The tax exemptions may offer an incentive to the agents to improve their extraction technology or to run their plants at a reduced capacity. Alberta's government currently charges oil sands producers an emission compliance cost of $\$15/tCO_2e$, through the Specified Gas Emitters Regulation (SGER), which is an example of a marginal emission tax policy.[2] Here, we consider a simplified marginal emission tax policy, and investigate the effects of the tax exemptions on the optimal operating strategies of an agent. Because of the importance of the oil price dynamics on the expansion rate, we perform a sensitivity analysis on the volatility of the oil price. Finally, we investigate the implications of a flat oil price market on the rate of expansion.

The remainder of this paper is organized as follows: Section 2 presents a literature review on natural resource valuation models and real options analysis in the petroleum industry. Section 3 presents our oil sands valuation model. Section 4 presents the results through an illustrative numerical example. Section 5 summarizes the findings of the paper.

2. Literature review

According to Brennan and Trigeorgis (2000), the development of valuation techniques can be categorized into three groups: static, dynamic, and option game models. In a *static* model, an investment project can be completely described by a stream of expected cash flows, while the managerial flexibilities are ignored. The "Discounted Cash Flow" (DCF) model is a well-known static approach. DCF techniques are known to be fundamental tools for engineering and financial analysis in the petroleum industry, and are well understood by managers; however, they systematically undervalue proven undeveloped reserves, may encourage premature development of certain reserves, and fail to identify important risk management opportunities (McCormack and Sick, 2001).

In contrast with static valuation techniques, dynamic valuation techniques account for managerial flexibilities in responding to future events as uncertainty is resolved (Trigeorgis, 1993). Arguably, there are two main approaches for modeling the value associated with managerial flexibility: Decision Tree Analysis (DTA) and Real Options Analysis (ROA). As discussed in Trigeorgis (1996), real options models often incorporate dynamic programming and stochastic programming techniques and are considered to be consistent with economic theory. The author points out that DTA, on the other hand, while relatively simple to apply to real world problems, has one specific drawback: it does not provide a mechanism to adjust the discount rate for more risky, or less risky scenarios. As such, we utilize ROA in this work.

The third valuation approach includes *option game* models, which combine ROA and game-theoretic models. In an option game model, firms can condition their decisions not only on the resolution of exogenous uncertainties, but also on the (re)actions of outside parties (e.g., competitors) (Chevalier-Roignant et al., 2011). In an option game analysis, future cash flows can be understood as the payoffs of a game involving several decision makers; and the trade-off between managerial flexibility and commitment in dynamic competitive settings, under uncertainty, is then examined. A firm can effectively make an early strategic investment that alters the later game structure by inducing asymmetry among all firms. In deterministic settings, the sign of the strategic effect depends on the intent of the commitment and the type of competitive reaction. Research contributions addressing the intersection of investment under uncertainty and industrial organization have been progressing in recent years, specifically in R&D and new technology investment project valuation (see for example, Trigeorgis (1991), Huisman and Kort (2004) Mason and Weeds (2010), and Chevalier-Roignant et al, (2011)).

Although the theory has been improving to incorporate many real-world features, the explicit consideration of strategic interactions is often ignored in available ROA models (Del Sol and Ghemawat, 1999). For example, Bjerksund and Ekern (1990), Laughton (1998) management, and Almansour and Insley (2011) all employed ROA to evaluate natural resource investments under uncertainty, while ignoring the interactions between multiple agents. In our model, we evaluate oil sands projects in a multi-agent setting. As the oil sands industry expands, a significant labor shortage is anticipated, which will increase the associated cost implications for new projects (Millington et al., 2012). As new agents come online, labor costs will increase for all agents; thus, the optimal actions of the leaders and followers are interwoven. To determine whether an agent would delay investment or not, it is necessary to understand the strategic interactions in a multi-agent setting. This is a competitive oligopoly. Note that we do not account for the embedded competitive game and resulting Cournot–Nash and/or Bertrand equilibria, which are beyond the scope of this work. The following section describes our valuation technique.

3. Methodology

In this section we develop our methodology, and highlight the models used to estimate the key components of a cash flow. We also explain the project valuation process for operating flexibility, construction flexibility, and a combination of both.

3.1. Basic assumptions

We assume a fixed and finite number of agents, *N*, each with the ability to construct a single oil sands plant. All plants have an identical maximum production capacity. Each agent has a lease contract for an equal and finite term, where the duration of the lease contract is shorter than the life of the site, therefore the site would not run out of oil and cash flows can be realized during the *entire* term of the study. Agents can forecast the future cash flows one time step into the future.[3] However, the plant may continue to operate, while receiving negative cash flows, since the expected future cash flows may be large enough to offset the immediate negative cash flow. An agent can lock into fixed labor costs for one time step.

As stated above, as new agents come online, labor costs will increase for all agents; thus, the optimal actions of the leaders and the followers are interwoven. Note that there is a subtle but important difference between the effects of strategic interactions and the expiration of an oil lease, in our model. Contractual expiration occurs on a specific date which is known in advance and is unaffected by the actions of the lease holder. The loss of investment opportunity due to the actions of

[2] According to the SGER, the emissions intensity reduction obligations of new facilities – i.e., facilities that completed their first year of commercial operation after year 2000 and have completed less than eight years of commercial operation – are phased in over a 6-year period at rate of 2% per year beginning in the fourth year of commercial operations. The first partial year, first calendar year, and second year are assumed to allow commissioning and start up of the facility. The third year forms the start of the baseline period. In the fourth year of commercial operations, the baseline emissions intensity is calculated using the facility's third year of commercial operations. In the fifth year, the baseline is calculated based on the third and fourth years. In the sixth year and beyond, the baseline is calculated based on the third, fourth and fifth years.

[3] As will be discussed further, the numerical model requires the desensitization of time into arbitrarily small steps. Sine the time steps are arbitrarily small, the assumption is realistic.