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Uncertainty and preferences in a joint E&P development program analyzed in a game-theoretic framework

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ABSTRACT

Decision making in the capital-intensive upstream oil and gas industry is complex for several reasons. One is the uncertainty of the investment opportunities. Another is that many projects are developed in joint ventures, in which stakeholders with potentially contrasting preferences must reach mutual agreements on the decisions at hand. In order for players to be successful in a joint venture, each player should understand the preferences, the positions, and the exposure of all other players.

This study provides insight into the type of strategic interactions to be expected in typical joint-development programs in the upstream oil and gas industry. The decision situation considered involves a joint venture of three oil fields connected by a shared infrastructure used to export the produced hydrocarbons. A game-theoretic framework has been applied to analyze the relationships among players' preferences, uncertainties resolution, and commercial drivers. An improved understanding of the evolution of the players' project perspectives during the project development period will enable decision makers to be much more effective in influencing the project to their advantage. Understanding the preferences and tradeoffs of all of the joint venture participants will lead to improvements in selecting investment alternatives, timing and order of the investments, and the mitigation project upsides and downsides.

1. Introduction

1.1. Investment in hydrocarbon exploration and production projects

Typical exploration and production (E&P) projects in the energy industry are capital intensive and have high failure rates and long lead times. Analysts at Barclays Capital Global estimated that about $439 billion will be spent globally in 2010 on oil and gas exploration and production.[3] Information Handling Services (IHS) reported that the E&P industry success rate for wildcat wells was about 40% in the period 2001–2003.[4]

Project development in the E&P industry typically spans many years. The development of the 13 billion-barrel Majnoon oil field in Iraq is expected to last seven years.[5] Major liquefied natural gas (LNG) projects in Australia are similar. For example, the reserves associated with the LNG Pluto project were discovered in 2005, and the first LNG is expected to be exported in 2011.[6] Another example is the development of the "pre-salt" fields in the Santos Basin off the coast of Brazil. The discovery of that region's Tupi field, which is estimated to hold recoverable reserves of between 5 billion and 8 billion barrels of oil equivalent, was announced by Petrobras in 2007. The field's pilot production is expected to start in December 2010.[7] In some cases, the development times are staggering. The Clair field, located west of the Shetland Isles in the UK, was discovered in 1977 but was not brought online until 2005, after the technology for developing the field had been introduced and hydrocarbon prices were high enough to justify the investment.[8]

1.2. Joint ventures, uncertainty modeling and game theory

The E&P community is acutely aware of the riskiness of their operations and the importance of risk modeling has been recognized within the industry (Bickel and Bratvold, 2007). Newendorp and Schuyler (2000) and Bratvold and Begg (2010) illustrate and discuss

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the application of risk analysis to E&P. Tversky and Kahneman (1974, 1981) discussed judgment under uncertainty and the framing of decisions.

Although the relationship between uncertainty and the interaction between stakeholders has been discussed by several authors (Fudenberg and Tirole, 1991; Dixit and Skeath, 1999; Rasmusen, 2001; Hausken, 2002), this dynamic has rarely been assessed in the development of upstream oil and gas projects. All projects listed at the start of this introduction are examples of joint ventures in which individual stakeholders potentially have conflicting preferences on how much to invest, in which sequence to make decisions, and stakeholders also decide on whether to make decisions before or after the other stakeholders. An understanding is required of the relationships among expected values, player preferences, and choices made by the players, which evolve as uncertainty is resolved during project development. This knowledge can enable a player to influence the selection of investment alternatives, optimize the timing of capital expenditures and evaluate the commercial attractiveness of a joint venture.

Joint ventures have been investigated using uncertainty models embedded in a game-theoretic analysis. These models created insight into the alignment of decisions and incentives during a new product development (Bhaskaran and Krishnan, 2009), the competitive dynamics between partners (Grenadier, 2002; Li et al., 2008), the bargaining power of players (Yan and Gray, 2001), acquisition and divesture opportunities (Chi, 2000) and the management and exploitation of uncertainty (Kogut, 1991; Chi and McGuire, 1996; Reuer and Leiblein, 2000).

A joint venture of an E&P project offers participants the ability to diversify their exposure to technical and geological risks and to participate in projects too expensive to be undertaken by a single player. Key issues of this type of decision problems relate to the resolution of technical and geological risks and the phasing of capital investment during project development as opposed to the management of production innovation (Kogut, 1991; Bhaskaran and Krishnan, 2009), manufacturing output (Grenadier, 2002) or competition for market share (Li et al., 2008).

1.3. The economic dependency between hydrocarbon fields

A complexity that is specific to many E&P projects relates to the economic dependencies between different hydrocarbon fields (Willigers et al., 2010). Hydrocarbons from a catchment area are typically processed and transported through shared facilities (Fig. 1). Shared facilities include hubs, pipelines and oil-and-gas receiving terminals. The infrastructure costs are covered by the revenue generated by all connected fields. Hubs are typically producing fields themselves and might therefore be liable to payment to other parts of the infrastructure. The profitability of an infrastructure system is a function of the performance of all connected fields. The connected fields rely on the existence of the infrastructure and also depend on the performance of its fellow fields connected to the infrastructure (Willigers et al., 2010). The dependencies that exist in the system of hydrocarbon fields and infrastructure the uncertainty of recoverable reserves of an individual field affect all parts of the system. A joint venture, as defined in this study, relates to all stakeholders of the system of fields and infrastructure elements. Willigers et al. (2009) analyzed an E&P example of a joint venture and considered players' preferences as a function of different outcomes in terms of hydrocarbon reserves, but no probabilistic assessments could be made because the likelihoods of the various outcomes were not considered.

Table 1
The equity position e_{ij} of player i, $i = A, B$, in oil field j, $j = 1, 2, 3$.

Player	Equity in field 1	Equity in field 2	Equity in field 3
A	1	0	0.5
B	0	1	0.5

1.4. The studied decision situation

This study uses a game-theoretic approach to analyze a typical upstream oil and gas investment problem. An important aspect of the study relates to the externalization of uncertainties, how uncertainty affects the preference of one player and how its resolution could affect the outcome of the entire game. Van Binsbergen and Marx (2007) studied these types of dynamics in a more general setting. The decision situation involves a development project in which players have equity stakes in some but not all oil fields. The project has uncertain payoffs and requires agreement among the players for project execution. As with real-life E&P project developments, the uncertainties associated with the project are gradually resolved during the game. Different aspects of the game are investigated in several simplified versions of the game, before the complete game is solved and discussed. The contribution of this paper is threefold. First, we show how a typical joint venture project considering all of the partners can be structured and modeled to generate useful insights for decision makers. Second, we illustrate the use of the game-theoretic approach to analyze the impact of key uncertainties, their resolution and the impact they bear on player's preferences. Third, we show how an improved understanding of typical real-world tradeoffs that exist in a system of dependent hydrocarbon fields can be used to improve decision making in a E&P joint venture.

The remainder of this paper is structured as follows. Section 2 outlines the decision situation and develops the model. Section 3 solves the deterministic game without and with a dominant player. Section 4 solves the simple and full probabilistic games. Section 5 discusses the results, with a focus on risk attitude and upfront investments. Section 6 concludes this paper.

2. Outline of the decision situation and development of the model

The investigated decision situation relates to the development of three oil fields by two players. Each player owns one field and has full

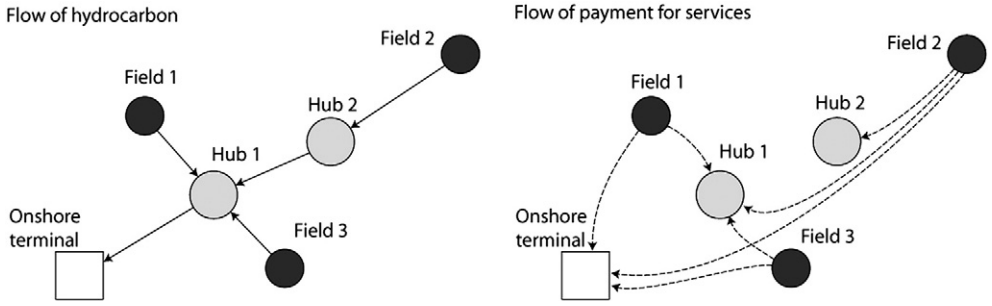

Fig. 1. Hydrocarbons produced in a region are often exported by a shared infrastructure. The fields connected to the infrastructure pay for the services provided by the infrastructure owners.