Creating Value from Uncertainty and Flexibility

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Background

One of the most important responsibilities of corporate managers in the petroleum business is to evaluate and choose among major investment projects. The role of analysis in this decision-making is to help identify the alternatives that managers should consider and to support high-quality conversations, using information from throughout the organization, that lead to the best choices possible.

Two concerns are often voiced in the context of these strategic investments. First, there is concern that the analyses and decision-making process frequently do not capture some of the flexibilities associated with projects. Commonly used decision models typically assume that management makes an initial investment decision, and then the project uncertainties are resolved and cash flows are determined. In reality, the firm makes a series of investment decisions as the uncertainties resolve over time. For example, when considering the development of a new oil field, if oil prices, production rates, or reserves exceed their expectations, or if production technology improves, the firm might be able to develop more aggressively or expand to nearby fields. Similarly, if prices, rates, or reserves are below expectations, the firm might be able to scale back planned investments and limit their downside exposure.

A second issue that has long concerned many decision makers and analysts in the petroleum industry is the way cash flows are discounted. Many investments have time horizons as long as 30 or 40 years, and the Net Present Values (NPV) for these investments are extremely sensitive to the discount rate used. Companies calculate NPVs for these projects using a discount rate that reflects their cost of capital and desired rate of return. This discount rate is well above the rate for risk-free borrowing and lending and hence can be viewed as a "risk-adjusted" discount rate. There is concern, particularly among decision-makers in the exploration and new ventures parts of the business, that the blanket use of such a risk-adjusted discount rate causes them to undervalue projects with long time horizons.

With these issues in mind, recent theoretical developments in how to value flexibilities, or options, should be considered. In this approach, one views projects as analogous to put or call options on a stock and values them using augmented versions of techniques like those developed by Black, Scholes, and Merton in 1973, to value put and call options on stocks. These methods explicitly model and value the decision maker's ability to make decisions (e.g., "exercise the option") after some uncertainties are resolved and do not require the use of a risk-adjusted discount rate. Thus, these new techniques appear to have the potential to address both of the concerns voiced above.

Modeling Flexibility

Some companies already routinely use a limited form of decision-tree analysis (DTA) to analyze a few select types of flexibility. Unfortunately, this type of DTA often has a focus on "making a decision now" which may lead decision-makers to overlook future options in the analysis. To incorporate options, we need to put them on the table in the early phases of the analysis in order to consider both current and future decisions. Being creative in thinking about and generating future options will, in most cases, increase value creation.

Consider the development decision for a large offshore project as an example. Assume that a significant amount of exploratory drilling has been conducted resulting in the identification of substantial reserves. However, there is still large uncertainty about the extent of the field and the total reserves. A common model for such a project is shown in a simple decision tree in Figure 1.

The only decision considered in this model is the current decision of whether to proceed with the project. Three uncertainties are included: reserves, prices, and costs. Each price scenario represents a sequence of annual oil prices, going out for approximately 30 years. Frequently in discounted cash-flow (DCF) valuations, "conservative" assumptions about the price variables are used to generate information about what "value" could look like if things proceed poorly. The resulting corporate planning price is sometimes

Figure 1: Decision tree for "Decide Now" decision

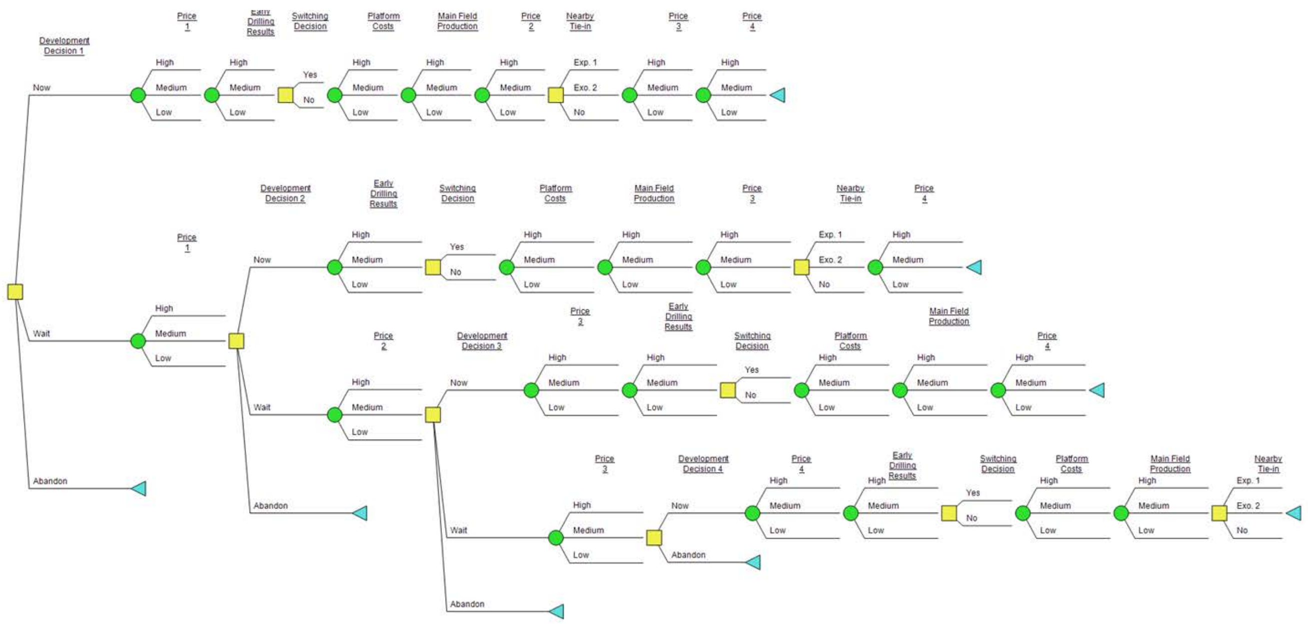

Figure 2: Decision tree with downstream decisions

called the "expected"[1] price, and the investment is also "valued" using a high and a low price.[2] This is sensitivity analysis or stress testing, not a means of incorporating price uncertainty into the valuation.
Similarly, the cost and reserve uncertainties represent a sequence of costs and production rates (and associated drilling expenditures) for each year, going out about 30 years. The distribution for reserves is usually calculated using a complex model that considered uncertainty about reserves in the as yet unexplored areas, the uncertainty in production rates, as well as many other factors. The values at the end of the tree represent NPVs of cash flows determined using an economic model that includes complex tax calculations. The result of the analysis in this example is a project with a positive expected NPV but a significant chance of having a negative NPV. The project is viewed as marginal because its expected NPV is small compared to the amount of capital required.

In such investment opportunities there are significant flexibilities that are not captured in the original analysis. Because the project in our example is marginal and its value is very sensitive to oil prices, it can be viewed as being like a call option: Although the project is marginal at current prices, it could have considerable value if prices were to rise at some point in the future. There are also several expansion options in that one can use the platform and facilities constructed for this project to develop (or "tie in") other nearby fields when production at the main field declines. There are also gas reserves in the reservoir that provides an option to switch from oil to gas production when the cashflows from the oil production become marginal. Finally, there is an abandonment option in that the field could be abandoned at any time if continued production appears to be uneconomic. The "decide now" decision tree shown in Figure 1 is typical in its lack of delayed (or "downstream") decisions.

The first step in analyzing the options associated with the project is to construct a new decision tree (Figure 2) for the project that incorporates these previously unmodeled options as well as the key uncertainties in our model. The result is a decision tree that is significantly "richer" than the "decide now" tree depicted in Figure 1.

This tree has more than 50,000 endpoints and includes a rich spreadsheet-based cashflow model. This tree includes significantly more uncertainties and decisions than a typical tree. Even so, the model takes only a few minutes to run on a PC.

An alternative approach to evaluating these flexible decision models is to use dynamic programming techniques such as Least-Squares Monte Carlo (LSM). In this approach for valuing options, we build a Monte Carlo simulation model that takes into account all of the uncertainties in the problem, which can then be used to calculate expected NPVs for any given exercise policy. To calculate an optimal exercise policy, at each decision point, we need to examine the expected future NPV for each alternative, conditioned on the resolution of all uncertainties up to that time. The optimal policy is found by selecting the alternative which maximizes the future NPV in a given information state. Using the LSM approach, the max future NPV is obtained by comparing the exercise values with the continuation value. The continuation values are estimated using least squares regression.

The LSM method is very general. However, although the complexity of the procedure is relatively insensitive to the number of uncertainties in the problem, its complexity grows with the number of decisions and alternatives in the problem in the same way as decision trees. In general, we need to perform regression analysis to estimate conditional expectations for each alternative of each decision in the model, working backwards from the last decision towards the first.

<u>Benefits of Modeling Flexibilities</u>

To create value from uncertainty and flexibility, we must assess and solve more complex decision models. Incorporating flexibilities can only increase the project values because one could always choose the base case alternative assumed in the model without flexibilities. In practice, project managers do respond to the resolution of uncertainties over time and make decisions accordingly. In general, these kinds of options are difficult to value intuitively. Without explicitly modeling the uncertainties we cannot put a value on the flexibilities and without being able to put a

[1]For most firms, the price curves used are not actually expected prices; rather, companies decide to control expenditures by using "conservative" prices. In fact, many companies have boasted of their conservativeness in this regard. The expressed logic is that by using conservative price forecasts, they can be sure the projects are robust and that only the best projects will be funded. This second reason requires an assumption that the company is capital constrained to be even internally consistent, much less to be correct. The fact that the price curves are not expected prices but are risked is critical to valuation, both to the absolute valuation and the relative valuation of the alternatives. Thus, firms mix expected costs with risked revenues to generate a set of cashflows that are neither explicitly risked nor expected.
[2]Companies often refer to the low and high price values as the P10 and P90 value, respectively, although, clearly, they are not P10 and P90 values drawn from the underlying distribution.

value on the flexibilities, we tend not to worry about them.

A second and more important benefit is that in modeling flexibilities we often identify new options and strategies. While some options might be discovered in due course (in which case the benefit of identifying them now is through the improved measurement of the value of the project), some of them might be lost if they are not identified up front and steps are taken to preserve the flexibilities.

A final benefit from modeling flexibilities is the set of optimal policies generated by the analysis. While the traditional analysis (the "decide now" focus) generates an initial decision and value, the models that incorporate these downstream decisions generate an optimal policy that specifies, for example, when the project should be developed, when production should be shifted to nearby fields and when the production should be switched from oil to gas. Such a policy might say, for example, "Initiate the development when oil prices reach $115 per barrel" or "If oil prices are below $80 per barrel, gas prices are above $3.80 per million BTU and oil production is below 1,000 barrels a day, then switch to gas production." These kinds of results provide decision-makers with "signposts" that suggest changes to (or at least a re-evaluation of) their operating procedures under certain conditions.

Valuing Risky Cash Flows

In the classical discounted cash flow (DCF) approach to valuation, the net present value (NPV) of a project is calculated by discounting the future expected values using a discount rate that reflects the cost of capital and desired rate of return. This discount rate is markedly higher than the prevailing risk-free interest rate and hence can be viewed as a risk-adjusted discount rate. Furthermore, most corporations use a single discount rate in the analysis of all projects or, at best, establish different discount rates for only a few large classes (e.g., political, pipeline installation vs. new field development) of investment decisions. This one-size-fits-all approach to dealing with projects mimics the risks of the overall firm, but it fails to reflect the variety of projects that feature different types and levels of uncertainty. Furthermore, using risk- adjusted discount rates often leads to an undervaluation of oil and gas projects with long-time horizons.

While the classical DCF approach may, in some sense, be right "on average" for the company, it can lead to trouble when applied to projects that are significantly different from the firm as a whole. If we want to use risk-adjusted discount rates, we should use different discount rates for different projects, evaluating each on the basis of their own cost of capital. To do this, we need to somehow estimate the correlation between the project returns and the market as a whole, either by identifying betas for firms that are "similar in risk" to the project or by making a difficult, subjective estimate of the beta.[3] Given a flexible project, we might need to go one step further and use different discount rates for different time periods and different scenarios as the risks of a project may change over time, depending on how uncertainties unfold and decision-makers react. For our project example, the risks associated with the later cash flows are very different in the case where we choose to expand development as compared to the cases where we abandon the project after the main field declines. While, in principle, we could use time- and state-varying discount rates to value flexible projects, it becomes very difficult to determine the appropriate discount rates to be used in this framework.

Rather than risk-adjusting discount rates to capture risk premiums, the market-based approach use a fully risk-neutral approach where we construct a single, coherent risk-neutral model and use it to estimate the value of the project. In this approach, we would risk-adjust the probabilities or processes associated with the uncertainties or stochastic factors in the model (e.g., oil prices and the production) and calculate the value of any investment by determining its expected NPV using these risk-neutral probabilities or processes and discounting at the risk-free rate. Due to space limitations, we will not get into further details of why this makes sense other than to say that using the fully risk-neutral approach in situations where the project cannot be perfectly replicated by trading securities can be justified in two different ways: by (1) using an equilibrium model of asset prices and (2) using a decision-analytic valuation procedure.

In the market-based approach, the probabilities or processes associated with the uncertainties or stochastic factors in the model (e.g., oil prices or production) are risk-adjusted. The value of the investment is then calculated by determining its expected NPV using the risk-adjusted probabilities or processes for market risks and subject-matter-experts[4] (SME) probabilities for private risks—all discounted at the risk-free rate. Risks that fall somewhere between market and private (e.g., rig-rate risks) are assessed as SME probabilities conditional on the concurrent market state.

To value general options, we need to use models that consider the evolution of the underlying uncertainties directly. In our example, such a direct model would consider uncertainty in both oil & gas prices and production over time.[5] For market based uncertainties the value of each security should be equal to its expected future value, where expectations are calculated using risk-adjusted probabilities and discounting is done at the risk-free rate. For example, if we use a mean-reverting price model for the oil price, we select the parameters to minimize the squared errors in futures and options prices, where the errors are the differences between the discounted expected values calculated by the model and the prices listed on the relevant stock exchange. In this approach, the futures prices should be equal to the expected (risk-adjusted) oil price. In Figure 3 we see that the expected values of the mean-reverting process provide a very good fit to the futures prices. The option prices provide information about the uncertainty in these risk-adjusted price forecasts. To place the option prices back on the same scale as the futures prices, we use the listed options prices to estimate confidence bands (10th and 90th percentiles) for the risk-adjusted distribution for oil prices in the month of expiration, using the current price for options expiring in that month. Comparing these implied confidence bands to those from the mean-reverting model, we see that the estimated put and call prices generated by the mean-reverting model are very close to their true prices.

One challenge in using the futures and options markets to generate the risk-adjusted oil price forecasts is that the maturities of the exchange-traded futures and options contracts are much shorter than the time horizons of the projects we are interested in evaluating. While the projects may last 30 or 40 years, the futures contracts go out about 8 years and the options contracts only a few months.[6] Thus, we need to somehow extrapolate from these shorter term risk-adjusted forecasts. In performing this extrapolation, it is important to remember that we are not attempting to forecast what oil prices will be in the future. Instead, we are asking what an oil futures or option contract maturing in say, 2020, would trade for today: it is not the firm's projections of future oil prices that matters, so much as the current market assessment. Here, we extrapolate using our mean-reverting price model, estimating its parameters with the near-term market data and assuming these estimates hold going forward.

The market-based approach is used without questions when valuing derivative securities. It has, however, been tough to sell in corporate contexts. Its use can make a big difference in values and strategies particularly for projects with long time horizons and significant uncertainties and flexibilities. The approach has

[3]"Beta" comes from the Capital Asset Pricing Model (CAPM) and is a measure of the risk arising from exposure to general market movements as opposed to idiosyncratic factors.
[4]The firm's geoscientists, engineers, economists, lawyers, etc.
[5]Note that the goal is not to try to predict the actual future price or production. Trying to predict the actual future values is an exercise in futility and, luckily, we don't need them for valuation and decision-making. The goal is to describe the possible price and production levels and their probabilities; i.e., the uncertainty in these values.
[6]Longer maturity futures and options are currently traded over-the-counter, though prices for such contracts are not readily available to those not active in those markets.

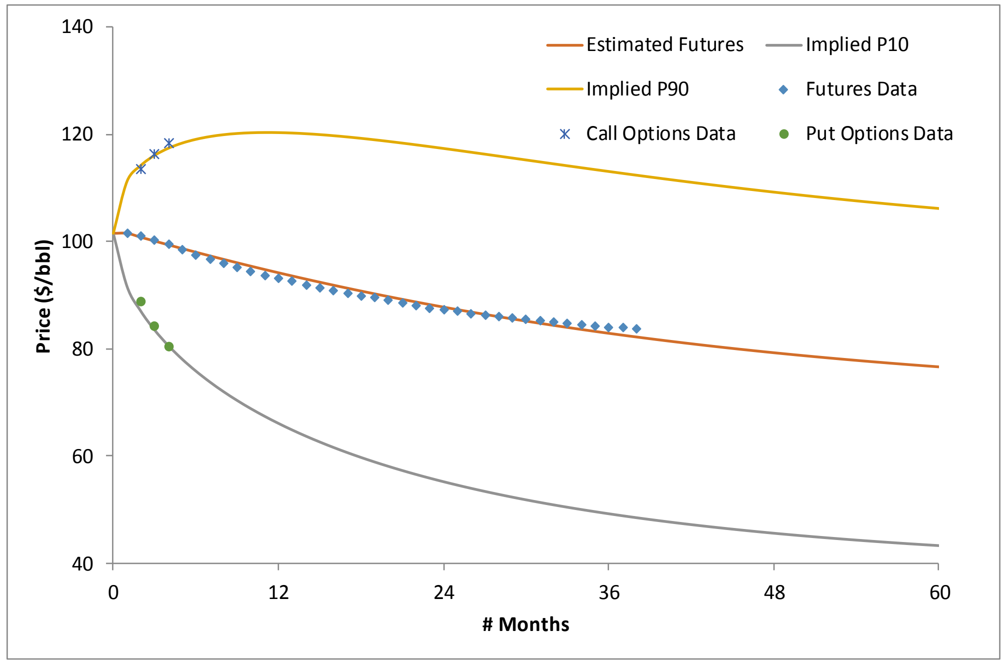

Figure 3: Price-process calibrated to futures and options

broad applicability is logically correct and no more difficult to implement than the conventional risk-adjusted discount rate approach. It provides the benefit of highlighting the interaction between market and private risks. Using market-based valuation requires a shift away from the risk-adjusted discount rate mindset. An obvious benefit of this shift is the lack of need to choose, sometimes seemingly arbitrary, a risk-adjusted discount rate.

Summary

Despite the ubiquity of options in business and everyday life, in practice we find that embedded options are often overlooked in the formulation and evaluation of decision problems, even when uncertainties are explicitly modeled. One possible reason for this is the difficulty of evaluating decision problems that include many downstream decisions. To properly evaluate these downstream decisions, we must model not only the downstream decisions, but also the information available at the time these decisions are made. While decision analysts have developed techniques for assessing probabilities for simple random variables, with flexible decision models, we need to consider some complex conditional probability or stochastic process assessments representing key uncertainties. As shown in Figure 4, significant value can be created by including downstream options in the early analysis.

The real options approach recognizes the value-creation potential resulting from decision-makers' active management of their investments over time. My goal has been to help the readers better understand methods for modeling and creating value from uncertainty and flexibility. Although some of the methods discussed here—risk-neutral valuation and Monte Carlo methods for dynamic programming—may be unfamiliar to many of the readers, these tools can be quite useful for modeling project dynamics and options. The tools that many oil & gas professionals know well—including decision trees and probability assessment methods—are also quite helpful for modeling project dynamics and options.

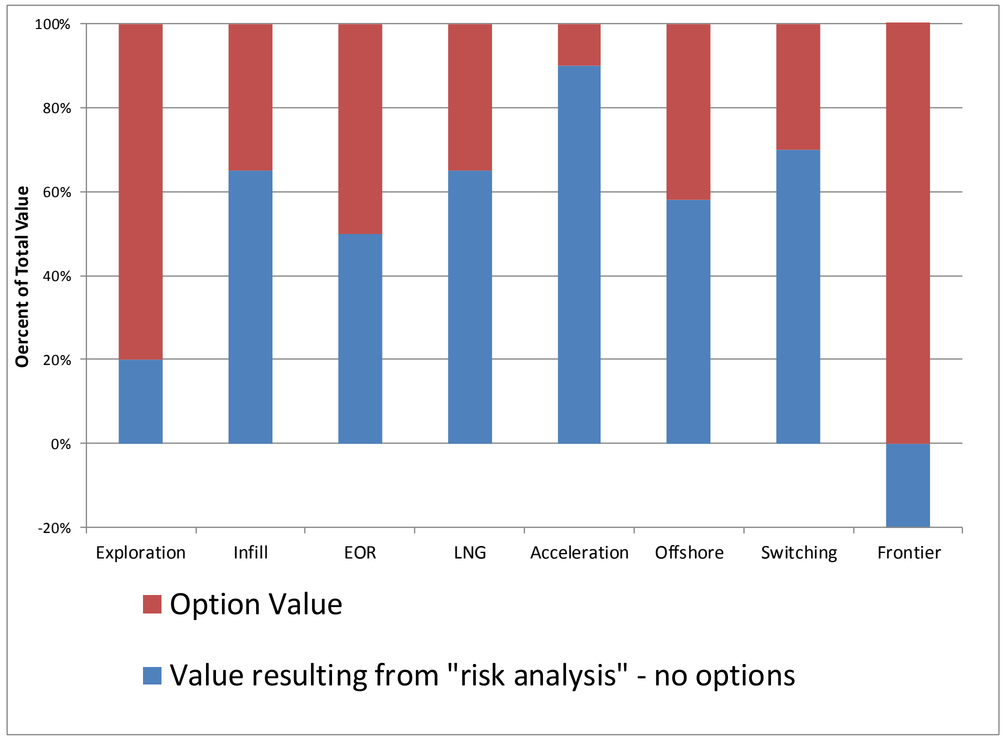

Figure 4: Option values

Acknowledgement

In writing this article, I have borrowed liberally from the writings of several of the leading researchers and practitioners in real option valuation including Jim Smith, Luiz Brandao, Jim Dyer, Joe Hahn and David Laughton.