Development as the continuation of appraisal by other means[1]

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"War is the continuation of policy by other means."
- Carl von Clausewitz in "On War" (1832)

"All diplomacy is a continuation of war by other means."
- Chou En Lai (1954)

Abstract

The upstream petroleum asset life cycle is usually divided into discrete phases. However, the actual situation is more fluid. For example, information arrives, and can be collected, throughout the life of the asset. In this sense, appraisal never stops, and, in principle, development and production activities should be tuned to take into account the value of the information that can be collected as a result of these activities.

We begin to explore this by examining, in an integrated fashion, the appraisal and development phases of the asset life cycle, using a model of an offshore oil-field development lease as an example.

We presume that drilling and facilities construction are the only two activities during this part of the life cycle.

Drilling can give information about the asset ("appraisal drilling") or provide production capability ("production drilling") or both.

Investment in production facilities begins at sanction, which can occur in any year until the end of the lease.

In our initial exploration of this issue, we have found situations where an asset manager can add value by considering the option to have mixed appraisal and production drilling programmes before and after sanction.

The overall programme

This paper is the first report on a programme to investigate how to distill the massive amounts of technical information that are generated in the analysis of any upstream petroleum asset into suitable formats for use in "complete" decision tree analyses of the design, management and value of that asset. A complete decision tree analyses future flexibility in response to all dynamic uncertain variables, including prices, throughout the life cycle of the asset.

It is part of an overall effort to develop valuation methods, based on insights gained from financial markets over the last 30 years, for use in the asset selection, design and management process in the upstream petroleum industry. One such insight (Laughton 2005) is the desirability of basing valuations on complete decision tree analysis where future design or management choices are at issue. Another is the desirability of valuing the effects of uncertainties on asset value at the source of the uncertainties using market-based valuation methods (Laughton 2005). The valuation methods to use are outlined in Laughton (2005), and described in detail in the papers in Laughton (1998a), especially Laughton (1998b), and in Laughton, Sagi and Samis (2000).

The issues considered

Appraisal in the upstream petroleum industry is undertaken because, with more technical information, better decisions can be made about the timing, location and design of further appraisal activities and ultimately of the wells and facilities put in place to extract the petroleum. This is done to increase value by managing the production profile to increase the value of revenues and/or by reducing the effective costs of production. There is trade-off between the value of this information and both its cash cost and its cost, if any, in time.

In previous work (Laughton, Frimpong and Whiting 1993) that set up a simple taxonomy of appraisal activities, we found the direct effects on value of reducing uncertainty were typically less important than the indirect effects of increasing the effective production from the asset or decreasing the effective unit costs of production through more informed design and management. Therefore we decided to explore first a model in which the only effect of appraisal is that the productivity of production drilling increases deterministically with the amount of information available about the field, and the amount of information increases deterministically with the amount of appraisal drilling.

Previous work (Laughton, Frimpong and Whiting 1993) has also shown that if the value of the potential project at sanction is high enough (e.g., if the price forecast is high enough), the cost of delaying the capture of that value by delaying development to continue with appraisal can overcome the value of the decreased costs or more effective production profile management that would result from the extra appraisal effort.

Therefore we wanted to explore whether it would ever materially add value to an asset to have the option to continue with some appraisal after sanction.

In other words, just as von Clausewitz considered "War [to be] the continuation of policy by other means", and Chou En Lai considered "All diplomacy [to be] a continuation of war by other means", we wish to examine, as our title states, whether it is useful to consider "development to be the continuation of appraisal by other means".

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1 This is a revised version of a paper (SPE 91055) with the same title presented at the SPE (Society of Petroleum Engineers) Annual Technical meeting on 29 Sept 2004.

The model structure

We have examined offshore oilfield development leases in an economic environment where the only material uncertainty is in the oil price, modelled, as described in Salahor (1998), so that:

1) the oil price forecasts follow a single-factor time-independent diffusion process with volatilities exponentially decaying in the term of the forecast; and
2) risk-discounting in the forward oil prices in any period proportional is to the relevant forecast volatilities for that period.

In this model, the contemporaneous price is a sufficient state variable.

We use a very simple model of the production and decommissioning phases of the asset.

If undertaken, production would increase at a constant rate over a ramp-up time to capacity production for a plateau period if possible, followed by an exponential decline. The plateau period is determined by the constraint that if production were to continue indefinitely, all the recoverable oil would indeed be recovered.

There would be a constant unit variable cost of production and a constant period cost that depends on the production capacity put in place.

Abandonment is possible at any annual point and would result in a capacity-dependent decommissioning cost.

Our focus is on the appraisal and development phases of the life cycle. The key is the treatment of the information that might arise from appraisal drilling and its effect on the productivity of production wells.

This is mediated by an information index that changes in each period proportionally to the product of:

1) a power (between zero and one) of the amount of appraisal drilling for the period, so that there are on-increasing returns to scale to drilling in any period; and
2) a non-positive power of the information index at the beginning of the period, so that, as the amount of information increases, as much or less new information is gained from any given amount of drilling.

We model the productivity for production drilling in any given year as proportional to a product of:

1) a power (between zero and minus one) in the amount of production drilling in that period, so that there are decreasing returns to scale of drilling in any period;
2) an increasing non-convex function in the information index, so that more information results in greater well productivity but at a non-increasing rate; and
3) a decreasing function in the well production capacity at the beginning of the period, so that adding capacity becomes more difficult the more there is already in place.

Decisions about the amount of appraisal and production drilling can be made annually until the production facilities are completed

This brings us to the last feature of the model. Sanction for developing the asset must occur within a fixed period of time. The decision is revisited annually until sanction occurs or that deadline arrives. If development is not undertaken, a decommissioning cost is incurred. Upon sanction, a choice of facilities production capacity is made and a fixed period of facilities construction begins with a profile of costs that, in each year, is a linear function of the capacity chosen. In each year the option exits to decrease the planned investment in facilities and the resulting facilities production capacity.

The example considered

The oil price model we use has the following parameters.

1) If the current price is $20 per bbl, the term structure of real price medians is constant at that price.
2) The short-term forecast volatility is constant at 10% in annual terms (0.5% in daily terms).
3) The term structure of the forecast volatilities is exponentially decaying at each time, at 10% per year.

With these features the process of the logarithm of price itself features a 10% volatility in annual terms and linear restoring force with a strength of 10% per year.

The valuation is based on time discounting at 3% per year, and on risk discounting in oil forward prices such that each 10% of annual forecast volatility results in a 4% per year rate of risk discounting.

Figures 1-3 show some relevant details of these models.

Figure 1 shows the term structure of 80% confidence intervals of the real oil price, if the current price at different levels. We can see the reversion effect and the stationarity of the long-term price distribution.

Fig. 1 Real oil price medians, 80% intervals current price = 10 20 30 ($/bbl)

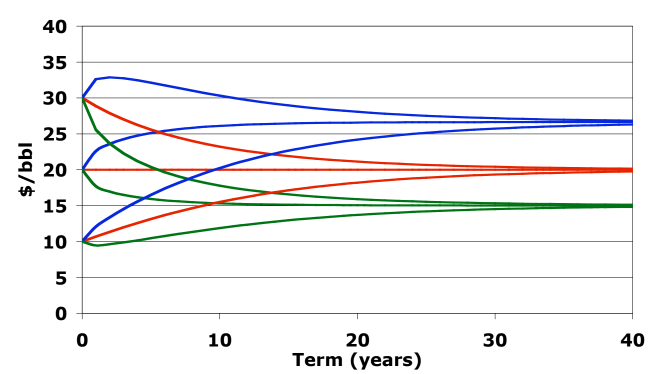


Figure 2 shows the term structure of forward prices, for the current price at different levels. We can see the saturation of the long-term risk discounting that is a feature of the MBV approach with this type of price model.

Fig. 2 Real oil forward prices
current price = 10 20 30 ($/bbl)

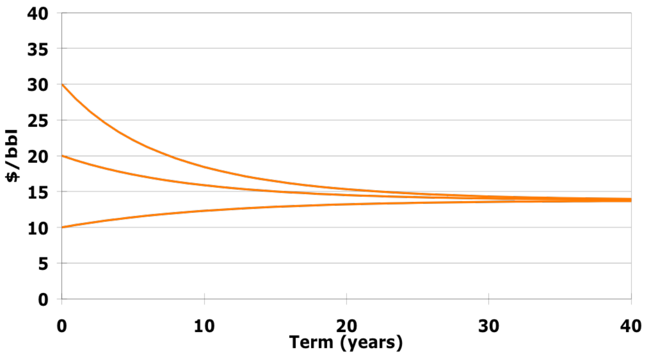
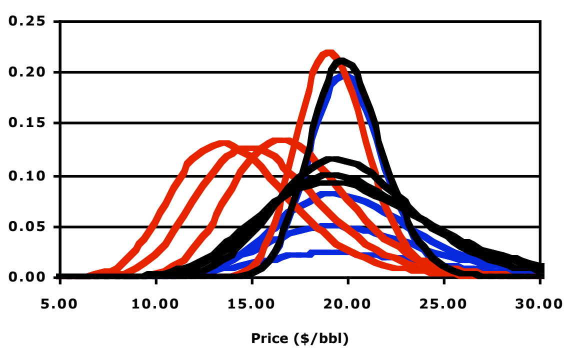


Figure 3 shows the true, risk-discounted and risk-adjusted probability distribution of the oil price states for prices at various times in the future.

Fig. 3 True (black), risk adjusted (red) and risk discounted (blue) probabilities



The amount of recoverable oil is 200Mbbl. The ramp-time in the production phase is 1 year, the decline is 20% per year and the unit variable operating cost is $2/bbl. The fixed period operating cost and the decommissioning cost are the same at $1.5M for every 1000bbl/day of facilities production capacity.

The development lease has three years to run and facilities will take 3 years to build at a cost of $3M in each of the first two years and $5M in the third for each 1000bbl/day production capacity. We consider four possible facilities capacity levels: 25, 30, 35 and 40Kbbl/day.

One or two wells may be drilled per year until the facilities are constructed at cost of $10M per well. The pre-sanction decommissioning cost is also $10M. Each annual drilling programme may have the following pattern of focus on appraisal and production:

1) 100% appraisal and 0% production
2) 80% appraisal and 10% production
3) 30% appraisal and 50% production; or
4) 0% appraisal and 100% production.

Therefore, there are diseconomies of scope for drilling: mixed drilling programmes are less effective than pure programmes.

The information index begins at 1.00, and will increase, in any given year independent of its current level, by 0.2, if the equivalent of 2 appraisal wells are drilled. The power in the dependency on equivalent number of appraisal wells drilled is 0.3. Therefore

information index_0 = 1.0; and
information index_{t+1} = information index_t
+ 0.2 * (appraisal focus_t* number of wells_t/2)^0.3.

The power in the dependence of the production well productivity in any year on the equivalent number of production wells drilled in that year is -0.15. The decline in well productivity with capacity already in place is exponential and is halved if a capacity of 69.3Kbbl/day has already been put in place.

We look at two examples of the dependence of the productivity of the equivalent of one production well, in the absence of any well production capacity already in place, on the information index. In both cases the dependence is linear, beginning at the initial information index of 1 at 2.0 and 5.0 Kbbl/day respectively, and increasing by 16.5 and 15.0 Kbbl/day respectively for each unit increase in the index. Therefore:

production drilling productivity_t
= (initial productivity + a*(information index_t-1))
* 0.5^(production capacity_t/69.3Kbbl/year)
* (production focus_t * number of wells_t)^(-0.15)

where:

initial productivity = 2 or 5 Kbbl/day/production well
a = 16.5 or 15.0 Kbbl/day/production well

The results

Table 1 gives the value at various current oil prices of each of the two assets with and without the option to have appraisal wells post sanction and production wells pre sanction, and lists the initial action taken.

We can see that the option to have mixed drilling programmes, before and after sanction. has value for these two assets at various levels of the current oil price.

1) At low prices and low initial productivity, there is no change in the initial decision to drill 1 appraisal well. However, there is a different pattern of optimal decisions for one year later, with the developer going to sanction at lower prices (with some continuing appraisal) than it would without the option to appraise after sanction.
2) At low prices and high initial productivity, it permits an accelerated beginning for facilities construction.
3) At moderate and higher prices and low initial productivity, it permits the addition of some well production capacity

pre sanction

4) At moderate and higher prices and high initial productivity, it permits some post sanction appraisal.

Table 1

Initial productivity (Kbbl/day)	Option	Value ($M)	Initial Action
		Initial Price = $15.00/bbl	
2.00	With	536.23	one 100% app'l
	Without	524.91	one 100% app'l
	Difference	11.32	
5.00	With	569.32	one 100% app'l, 25kbbl/day cap
	Without	556.67	one 100% app'l
	Difference	12.65	
		Initial Price = $20.00/bbl	
2.00	With	692.89	two 80% app'l
	Without	678.96	two 100% app'l
	Difference	13.93	
5.00	With	753.68	two 50% prod'n, 25kbbl/day cap
	Without	724.16	two 100% prod'n, 25kbbl/day cap
	Difference	29.52	
		Initial Price = $25.00/bbl	
2.00	With	833.43	two 80% app'l
	Without	817.39	two 100% app'l
	Difference	16.04	
5.00	With	914.69	two 50% prod'n, 25kbbl/day cap
	Without	881.08	two 100% prod'n, 25kbbl/day cap
	Difference	33.61	

Conclusions and future work

These results suggest that asset management is best undertaken by integrated multidisciplinary teams that can make judgments about tradeoffs involved among a broader set of design alternatives than might otherwise be considered. To support these teams, we need to develop more powerful evaluation tools that can facilitate more detailed analysis of this broader set of decision alternatives in more complex settings of long-term dynamic uncertainty resolution.

Finally, it may be useful to explore systematically the use of the concept of an information index to distill the complex information that is generated about any particular asset, adding explicit uncertainty to its evolution as well as to the realised well productivity and the amount of recoverable oil.

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