Volatility estimation in Real Options with application to the oil and gas industry[i]

by Jenifer Piesse and Alexander Van de Putte

Estimating volatility for use in financial options is a pretty straight forward process as the underlying is actually a traded security. When applying financial options theory for purposes of project valuation an estimate of volatility is also required. This can be a daunting task as a project is usually not traded, making the volatility not observable in financial markets.

The financial option analogy

Real options rests upon an analogy between real option value levers and financial option value levers. Luehrman [1994] established a mapping between project characteristics and financial option value drivers as depicted in figure 1.

Figure 1: Mapping between project and financial option drivers

Financial option value levers	Variable	Real options value levers
Exercise price	X	Investment cost
Stock price	S	Present value of expected cash flows
Time to expiry	t	Time to expiry
Risk-free interest rate	r_f	Risk-free interest rate
Uncertainty of stock price movements	σ	Volatility of expected cash flows

- The investment cost is equivalent to the exercise price (X). When keeping the other real options levers constant, an increase in X will decrease the value of the project as X represents a negative cash flow.
- The present value of the expected cash flows is analogous to the stock price (S). The higher the stock price the higher the value of the option. As a result, an increase in the present value of the expected cash flows will increase the overall value of the project.
- The time to expiry is analogous to the time to maturity of a financial option (t). It is the maximum time period – expressed in years – that an investment can be

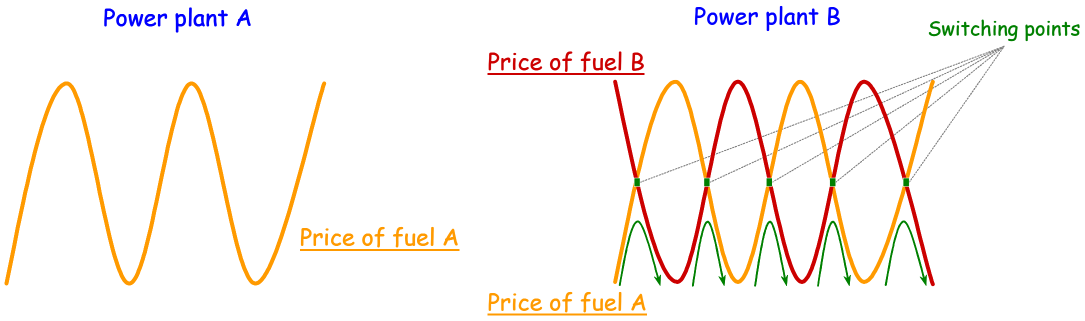
deferred without losing the option to investment in the project. In an uncertain environment, the more time there is to learn about the uncertainty then the more insight will be gained of how to appropriately address the uncertainty. As a result, a longer time to expiry will increase the value of the project.

- The risk-free rate (r_f) will increase (decrease) the value of a call (put) option because it will reduce the present value of the stock price (S). It will have the same effect when applied to a real options situation.
- The volatility of expected cash flows (σ) is analogous to the volatility of stock price movements. Thus, a higher volatility will increase the value of the option.

This call option analogy must, however, be applied with caution. In financial options, the volatility of stock price movements is a function of the uncertainty of stock price movements, because flexibility is built into the financial instrument. In real options, however, the volatility of expected cash flows is a function of the uncertainty of expected cash flows and the ability of management to respond to the resolution of this uncertainty.

Consider two power generating assets A and B of identical capacities. The only differences between the two assets is that power plant A can only burn one type of fuel, while power plant B can burn two types of fuel. Assume also that the price of both fuels are volatile and that they are negatively correlated over time. Finally assume that there is no storage capacity for the fuels. Figure 2 provides a graphical representation of this example.

Figure 2: Volatility as a function of both uncertainty and flexibility

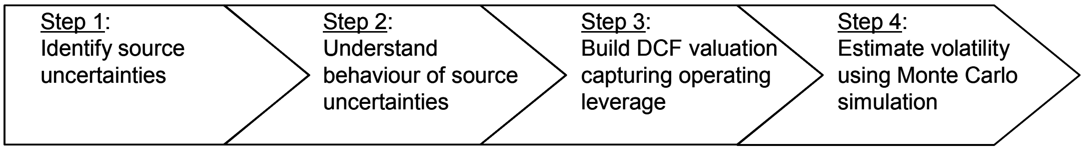


In order to preserve the integrity of the analogy between real options and financial options, we are not per se interested in the volatility of the cost of input fuels, but in the volatility of the resulting cash flows. To be precise, we are interested in the annual volatility (i.e., the natural logarithm of the growth rate) of the present value of the project excluding investments. This is because operating leverage – the extent to which a project cost structure consists of fixed and variable costs – will tend to amplify the volatility of the source uncertainties (the fuel prices in our example). For additional examples see Copeland and Antikarov [2001].

An application to the oil and gas industry

Consider an oil and gas project in North America. Management has the flexibility to temporarily shutdown and restart the production of the proven developed reserves in the reservoir. Management will decide to temporarily shut down the field if prices fall below a certain level and will restart operations once prices are high enough to pocket a profit. To estimate the annual volatility of the present value of cash flows of this project, we will follow a four-step process (see Figure 3).

Figure 3: A 4-step process for volatility estimation



Step 1: To identify the source uncertainties to be modelled, we use three straightforward criteria. First, the source uncertainties in question must be noticeably uncertain. US oil and gas prices meet this criteria as they had a historical 12 year annual volatility of 29.9% and 74.1% respectively.[1] Secondly, the source uncertainties must be significant to the valuation. Again, the US oil and gas prices meet this criteria as they will influence the amount of revenues – and as a result the cash flows – that will be generated by the project. Finally, the project must have embedded flexibility in order to mitigate the negative effect of the source uncertainties. Again, the US oil and

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[1] 12 years was choosen as the time period over which we conducted the analysis as Henry Hub prices are available since January 1991.

gas prices meet this criteria as management can decide to temporarily shutdown and restart the project depending on the oil and gas prices.

Step 2: Now that the source uncertainties have been identified, it is imperative to understand their behaviour. In fact, we need to understand the distribution (normal, lognormal etc.) of the oil and gas price data, the mean value, the standard deviation and finally whether the data is mean reverting or not.

The US oil price has experienced very high levels over the last 2.5 years with a mean of \$27.74/bbl and an annual volatility of 64.5%. These levels are likely to return to the long-term historical levels (mean of \$21.5 and an annual volatility of 29.9%) in the medium term once political stability returns in the Gulf region and regular Iraqi oil production begins.

During the period January 1991 till December 1995, the average US gas price was \$1.8/MMBtu, while the period January 1996 till December 1998 experienced slightly higher average gas prices of \$2.3/MMBtu. In contrast, Henry Hub prices started climbing steadily from January 2000, resulting in the highest average gas prices over a 2.5 year period of \$4.2/MMBtu, with an annual volatility of over 100%. The recent steep increases in gas prices are a reflection of a supply/demand imbalance and the depletion of the cheaper US gas reserves. In addition, according to Cambridge Energy Research Associates, the US electric power sector has consumed about 40% more natural gas in absolute terms over the last decade. This is due to the fact that utilities have favoured gas-fired power plants over other generating technologies. As a result, it is expected that the mean gas price going forward will be similar to the one we have experienced since January 1999 (i.e., \$4.2/MMBtu). On the other hand, it is expected that the US gas price volatility will reflect more its long-term historical level of about 70% as opposed to the current levels exceeding 100%. Figure 4 below provides a tabular overview of historical oil and gas prices in the US.

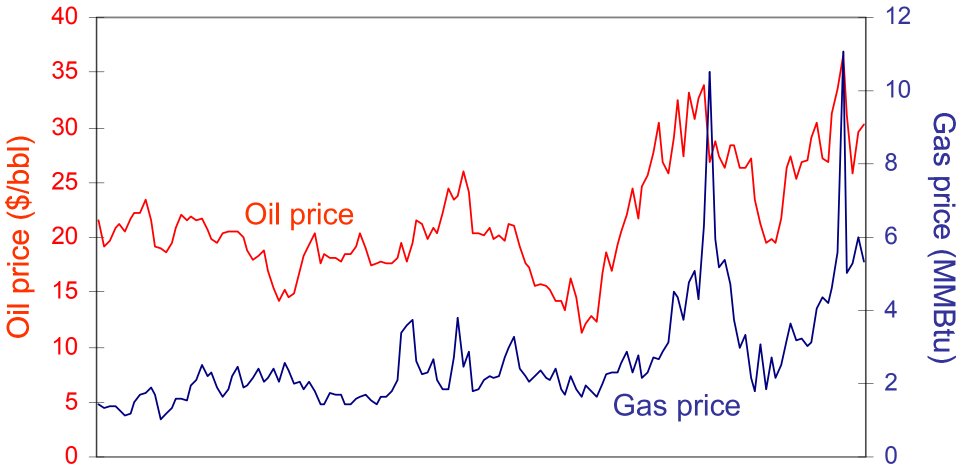
Figure 4: Historical oil and gas prices in the US

		Jan 91	**Dec 95**	**Jan 96**	**Dec 99**	**Jan 00**	**Dec 03**
OIL prices	**Mean**	\$19.20/bbl		\$19.08/bbl		\$27.74/bbl	
	Std dev.	19.7%		34.1%		64.5%	
	Mean	\$21.5/bbl					

	Std dev	29.9%		
Gas prices	**Mean**	$1.8/MMBtu	$2.3/MMBtu	$4.2/MMBtu
	Std dev.	53.0%	62.4%	106.8%
	Mean	$2.6/MMBtu		
	Std dev.	74.1%		

From the historical oil and gas price plots we can already observe the mean reverting tendency of both (see figure 5 below). Visually, we can already observe that the gas price reverts much faster to its long term average than the oil price.

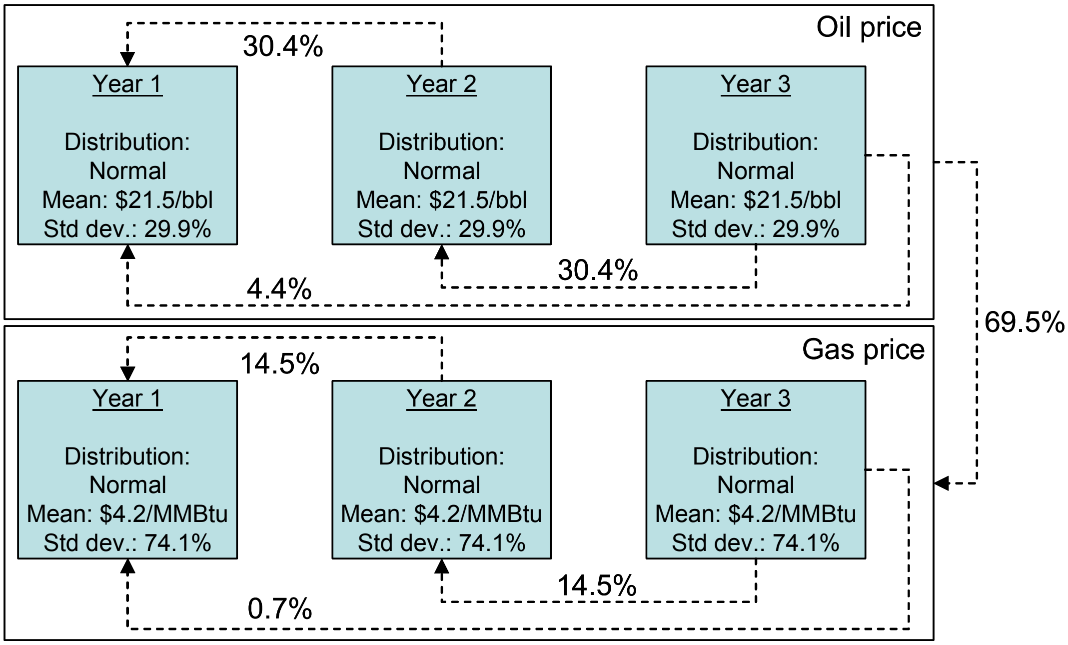
Figure 5: Historical oil and gas prices (1991-2003).



Source: Bloomberg Professional

To quantify the mean reverting tendency for simulation purposes, we de-trend the oil and gas data and run a regression analysis. For each data set two regressions were run: X_t versus X_{t+1}, and X_t versus X_{t+2}. In addition, a regression was run to understand to what extend the historical oil and gas prices are correlated. We also looked at the distribution of historical oil and gas prices and found that the prices were normally distributed. This concludes the second step of the volatility estimation process. We can summarise the results of our analysis as depicted in figure 6

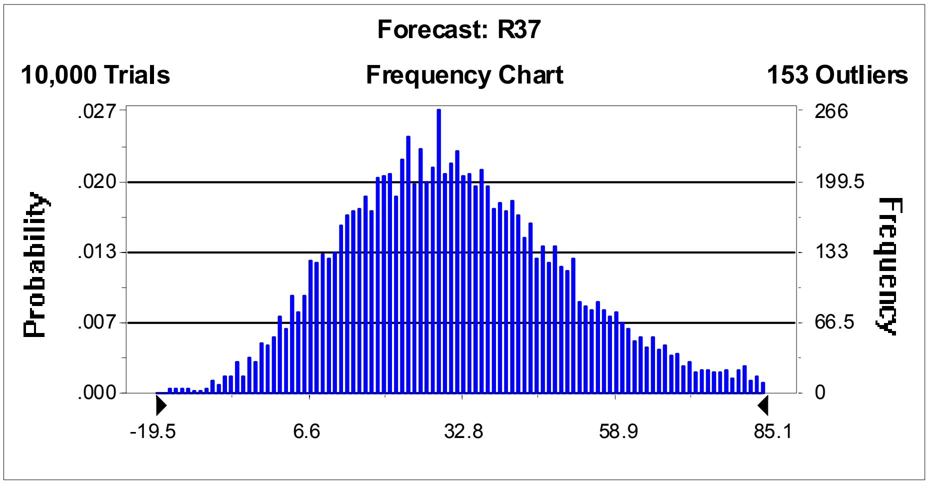
Figure 6: Behaviour of source uncertainties



<u>Step 3</u> in our four step process to estimate volatility for use in real options is to build a DCF valuation spreadsheet. While we will not detail the mechanics of building the DCF spreadsheet, it is important to emphasise that it needs to accurately capture the operating leverage of the project. This will be crucial when executing step 4.

<u>Step 4</u> is the final step in estimating volatility at the project level. As Monte Carlo simulation is used, an Excel plug-in software such as Crystal Ball from Decisioneering or @Risk from Palisade facilitates the task in transforming the behaviour of the source uncertainties into an estimate of volatility for use in real options. Using Monte Carlo simulation, we take into account the mean prices and annual volatility of both the oil and gas prices, their mean reverting tendency, the oil/gas correlation and the operating leverage of the project. It is our experience that few people have developed an intuitive feel of the volatility at the project level without having gone through this four step systematic process. Having completed step 4, we obtain an estimate of volatility at the project level of 62.9%. This estimate can now be used in the real options model to complete the real options valuation. Figure 7 below shows the output as obtained when using Crystal Ball.

Figure 7: Monte Carlo simulation output of volatility estimation at project level



Conclusion

Estimating volatility for use in real options can be a daunting task. Fortunately, in the oil and gas industry we have historical source uncertainty data (historical oil and gas prices). Using a four-step process we have demonstrated how the volatility of these source uncertainties can be transformed into a volatility estimate of the present value of the project using Monte Carlo simulation.

References

Copeland, Tom and Vladimir Antikarov, Real Options (Texere, 2001)

Luehrman, Timothy A., Capital Projects as Real Options: An Introduction (Harvard Business School Technical Note, 1994)

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[i] An earlier version of this articles was presented at the 8th Annual International Conference on Real Options of the Real Options Group on June 16-17, 2004 in Montréal.