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BEYOND DCF: CAPTURING THE VALUE OF-MANAGEMENT FLEXIBILITY

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Beyond DCF: Capturing the Value of Management Flexibility

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Summary

I Summary

Managers often retain flexibility to respond to changing circumstances. Depending on market conditions, they can defer investment, expand production activities, or shut down activities altogether. This flexibility creates economic value by enabling parties to capture upside when conditions are favorable and avoiding or limiting downside when they are not.

In arbitration settings, practitioners routinely estimate damages using the discounted cash flow (DCF) method. However, DCF analyses often assume a single forecast with a fixed management strategy – overlooking the value of management flexibility. While ignoring management flexibility may not be critical in some circumstances, it can lead to systematic and materially understated valuations in others.

This chapter discusses alternatives to the DCF approach adopted by practitioners outside of arbitration to assess the value of management flexibility. We discuss practical considerations that determine whether and when such valuations can be credible and useful. We consider the potential use of such approaches in dispute settings and how tribunals might respond to them in practice. We highlight several examples from sectors where flexibility plays a central role.

II Limitations of DCF in capturing flexibility

The DCF method has become the dominant approach for valuing lost profits and investments in the context of disputes.[1] A DCF analysis involves two steps.[2] First, a practitioner develops a forecast of cash flows from an investment. Practitioners commonly develop an 'average expectation' forecast, effectively identifying likely average price, cost and cash flow outcomes. In a second step, the DCF method accounts for risk – the potential for price, cost, cash flow and value outcomes to fluctuate and almost certainly deviate from the average expectation forecast. Practitioners adjust downward, or 'discount', forecast cash flows to account for the risk that outcomes can differ from expectations.[3]

A straightforward DCF works best when management strategy and the resulting cash flows are highly predictable and well-defined. One example is a wind or solar power plant selling electricity under a power purchase agreement. The plant will generate energy when the wind blows or the sun shines. The resulting production depends on well-defined engineering parameters, such as plant capacity and the 'power curve'. Sales prices are likely to be predefined and even fixed by contract. Correctly performed, a straightforward DCF will accurately capture the value of the plant.[4]

However, the application of DCF becomes more difficult where a firm's activities can significantly alter in response to changing circumstances. For example, management might be able to expand production activities if it is profitable to do so, or shut down existing activities if not. Management might be able to extend a contract if it is attractive, or exit early. This management flexibility is often analogous to financial options that give owners the right but not the obligation to buy or sell an underlying asset at a predetermined price. 'Real options' involves the application of valuation techniques for financial options to assessments of management flexibility.

A simple example illustrates. Suppose a firm can spend €11 to expand production activities a year from now. Suppose also that market prices are currently €10, but that they could rise to €12 or fall to €8. Management can wait and see if market prices rise or fall over the next year and then expand or not accordingly. If market prices were to rise to €12, management would likely respond by incurring €11 to expand production and thereby earn an extra €1 of profit. In contrast, management would not incur the €11 needed to expand activities if market prices fell to €8. Management's ability to expand when favourable to do so is analogous to a financial call option with a strike price of €11, reflecting the costs of expansion.[5]

Management's ability to expand would be worth €0.50 if prices were equally likely to rise or fall over the next year. The value of the option represents the probability-weighted average profits from expanding when market conditions turn out to be favourable and sticking with the current production level when they are not. Figure 1, below, illustrates.

Figure 1: Option to expand.
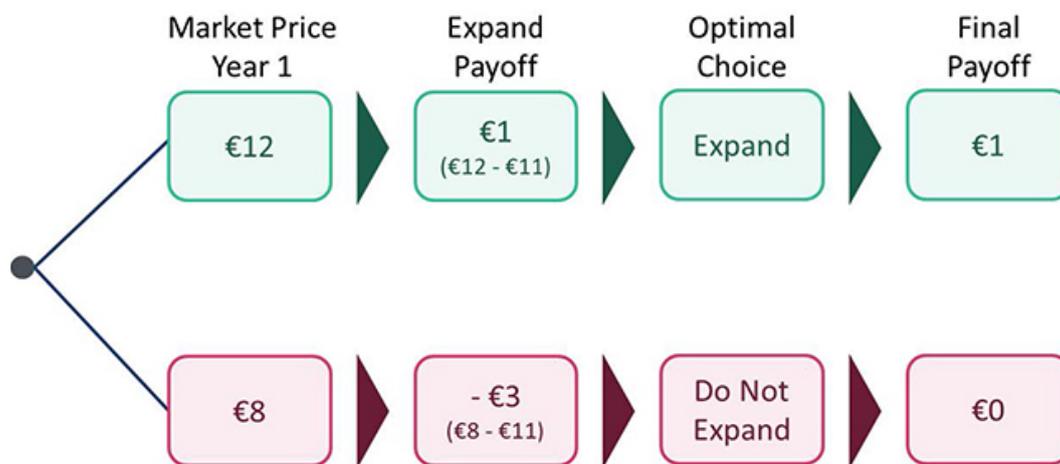
Three key insights emerge from this simple example. First, real-world options arise at discrete decision points that give management defined opportunities to act (or refrain from acting) based on how circumstances unfold. In our example, the option to expand matures at a specific point in time, one year from now, and allows management to expand only if market conditions were to improve. No option would exist if management had to commit today to expansion, come what may. Identifying discrete decision points and the associated flexibility is essential to the recognition and valuation of real options.

Second, the value of management flexibility generally increases with uncertainty. The more market prices can move, the more valuable it becomes for management to wait and decide later. Suppose prices could rise to €14 or fall to €6 instead of to €12 or €8. Expansion would generate a €3 profit if prices rose to €14, while the downside would remain limited to zero if prices fell to €6, since management would not expand in that event. The option to expand would increase in value to €1.5 (assuming prices were equally likely to rise or fall over the next year), triple the €0.50 assuming less uncertainty.[6] Increased uncertainty increases the value of flexibility, since flexibility allows management to capture greater upside potential while continuing to avoid downsides.

Third, a DCF focused on average expectations would ignore the value of management's ability to expand. In Figure 1, the average price expectation would be €10, reflecting the

average of €12 or €8. With an average price forecast of €10 and expansion costs of €11, simplistic modelling might assume that expansion was unattractive and, as a result, exclude the potential for expansion in the cash flow forecast. The DCF result would reflect only the value of existing production and entirely ignore the value of management's ability to expand if and when attractive.

The issue with such simplistic DCF modelling is that it implicitly assumes management remains static and a firm's activities fixed, rather than adaptive to changes in market circumstances over time. The static assumption may be more or less reasonable in many circumstances. The expansion option in our example is worth only €0.50 (compared to a market price of €10), and option values may not be material in many cases. Omitting this option value might even be reasonable and err on the low side for damages. Nevertheless, option values can sometimes become significant and their omission material to overall valuations. Practitioners will need to turn to option valuation techniques in such circumstances to supplement common and more simplistic DCF applications.

III Option valuation techniques

The following sections outline three general and well-established approaches to the challenge of valuing management flexibility: scenario analysis, option valuation and Monte Carlo simulation.

Scenario analysis requires practitioners to define a set of discrete outcomes, assign probabilities to each, and then compute the average payoff across the defined outcomes. Option valuation models involve closed-form or formulaic solutions for the value of discrete management decisions. The Monte Carlo method involves computer simulation of potential price outcomes and management responses.

Scenario analysis

Scenario analysis identifies a set of future outcomes and then evaluates how management can respond differently in each particular outcome. Practitioners will typically specify a number of possible scenarios (for example, different price, demand or cost levels), assess likely management responses in each and then calculate the resulting value payoffs. Practitioners will then assign probabilities to the value payoffs in each scenario and compute a probability-weighted average value across the full set of scenarios.

Scenario analysis often utilises a DCF approach to assess scenario outcomes and their present value. It nevertheless differs from a more simplistic DCF in that it accommodates the ability of management to respond to a defined set of alternative forecast conditions, represented in the set of scenarios.

To pick up the expansion example again, scenario analysis might focus on assessing performance in a 'low price' scenario that assumes that market prices fall to €8 and separately in a 'high price' scenario that assumes market prices rise to €12. Scenario analysis would then use the DCF approach to calculate value payoffs in each of these two scenarios. Scenario analysis then requires the assignment of probabilities to each scenario and the computation of a probability-weighted average.

Working through distinct scenarios offers a clear theoretical improvement over a simplistic DCF that focuses only on a single average price forecast of €10 and that, as a result, fails to consider the possibility of alternative management responses to different price outcomes. However, scenario analysis can be practically difficult and attract allegations of subjectivity. In our experience, scenario forecasting works best when there is a reasonable and objective basis to determine the relevant scenarios and corresponding probabilities. It becomes more difficult, particularly in a dispute context, where the choices of scenarios and probabilities are largely subjective.[7]

Many international institutions undertake and publish 'official' scenario forecasts periodically, which can form the basis for an 'objective' scenario analysis in the context of a dispute. For example, the International Energy Agency publishes a World Energy Outlook (WEO) each year. The latest WEO develops three forecast scenarios representing different visions about the evolution of the energy industry out to 2050. In Table 1, we highlight a sample of other institutions that routinely develop and publish scenario forecasts. These scenario forecasts relate to a range of economic sectors.

Table 1: Examples of scenario forecasting.

Institution	Sector	Scenarios	Time Horizon	Frequency	Geography
EIA (U.S. Energy Information Administration)	Energy	Reference; Alternative electricity, Alternative Transportation; High/Low Oil Price; High/Low Oil and Gas Supply; High/Low Zero-Carbon Technology Cost; High/Low Economic Growth	2050	Annual	USA
OECD - FAO (Organisation for Economic Co-operation and Development - Food and Agriculture Organization)	Agriculture	Baseline; Policy variations	10 years	Annual	Global
IEA (International Energy Agency)	Energy	STEPS (Stated Policies); APS (Announced Pledges); NZE (Net Zero Emissions by 2050)	2050+	Annual	Global
IMF (International Monetary Fund)	Macroeconomics	Various Policy and Market scenarios	5 to 10 years	Biannual	Global
IRENA (International Renewable Energy Agency)	Energy	Planned Energy, 1.5°C Pathway	2050	Annual	Global
OECD - ITF (Organisation for Economic Co-operation and Development - International Transport Forum)	Transport	Current Ambition; High Ambition	2050	Biennial	Global
OECD (Organisation for Economic Co-operation and Development)	Digital Economy	Various Technology Adoption and Regulatory scenarios	2030	Every 2-3 years	OECD countries
WHO (World Health Organization)	Health	Historical-based projection; Target-based projection; Outperformance projection	2030	Annual	Global
World Bank	Mining & Energy	Baseline; Sharper slowdown	1-2 years	Biannual	Global
UN-Habitat (United Nations Human Settlements Programme)	Urbanization	Various emission level scenarios	2040-2050	Biannual	Global

Such institutions not only develop distinct forecast scenarios but sometimes include commentary about the likelihood of different forecast scenarios. This commentary can form the basis for probability assignments. Other formal research techniques, such as Cooke's method, determine scenario probability weights in an objective way from available sets of expert scenario forecasts and probability assessments.[8] In some circumstances,

we have been able to calibrate forecast scenarios and weights against available market evidence, such as transaction prices.

A good rule of thumb is for practitioners to use available public sources and objective analytical techniques to minimise subjectivity in scenario choices and probability assessments as far as possible. A high degree of subjectivity can undermine the usefulness of forecast scenarios for purposes of estimating valuation and damages in arbitration.

Option valuation models

Like scenario analysis, formal option-pricing models aim to capture the value of decisions that depend on uncertain events. The difference lies in their treatment of uncertainty. Instead of defining discrete scenarios, option pricing models assume a continuous range of possibilities, typically modeling market prices as following a random walk[9] and using mathematical methods to assess the extent of potential price variation over time.

One key input is a measure of price volatility, meaning the extent of price variation typical over a defined period of time. Practitioners can measure price volatility using historical pricing data. For example, we could measure the extent of daily price movements for a particular stock or futures contract. The alternative is to infer forward-looking price volatility based on the market prices of publicly traded options and the assumption that option pricing models can produce the observed market prices.[10] A volatility measure allows the construction of a distribution of potential outcomes for a future date. The distribution matches each price outcome with a corresponding probability of occurrence.

To illustrate, we return to our expansion example. In previous sections, we allowed for two possible price outcomes in one year: a rise to €12 or a fall to €8.[11] Market prices typically move all the time and can follow a fluctuating, random path throughout the year. In theory, the number of possible scenarios should expand to encompass the full range of potential price outcomes after one year, rather than just the two defined scenarios considered previously. For example, we would envisage over 1 million possible price paths across a calendar year if prices were to move up or down once at the end of each day. The number of possible paths grows even further if we were to account for continuous price changes.

Figure 2 shows a distribution of potential price outcomes after one year, aligning with our prior example of prices rising to €12 or falling to €8 but reflecting the possibility for prices to continuously develop across the year in accordance with an annualised price volatility of 20 per cent (equivalent to daily volatility of 1.3 per cent). The height of the line indicates the probability of each price outcome. The spread of the distribution depends on the extent of volatility. More volatility would result in a wider, flatter distribution and vice versa.[12]

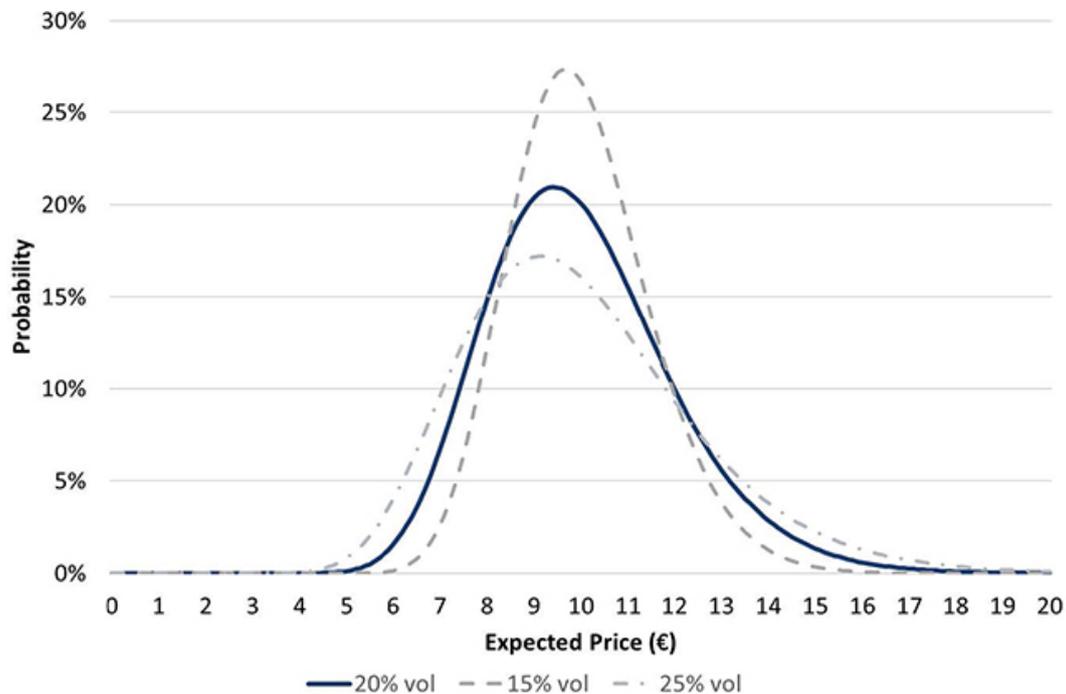Figure 2: Year-ahead price distribution (assuming continuous price movements)

Figure 3 builds on Figure 2 above and, in Panel A, illustrates the range of price outcomes where expansion makes sense, and in Panel B, the resulting payoffs to expansion. The light blue vertical line represents the average price of €10; the red vertical line represents the expansion break-even price of €11. The value of the option to expand corresponds to the red area in Panel B, weighted by the probability associated with each potential outcome. The greater the extent of the Panel A price distribution exceeding €11, the more likely that management pursues expansion and the more valuable the option to expand.[13] The ability to expand is analogous to a financial call option with a strike price of €11.[14]

Figure 3: Log Normal Distribution with Mean and Strike Price[15]
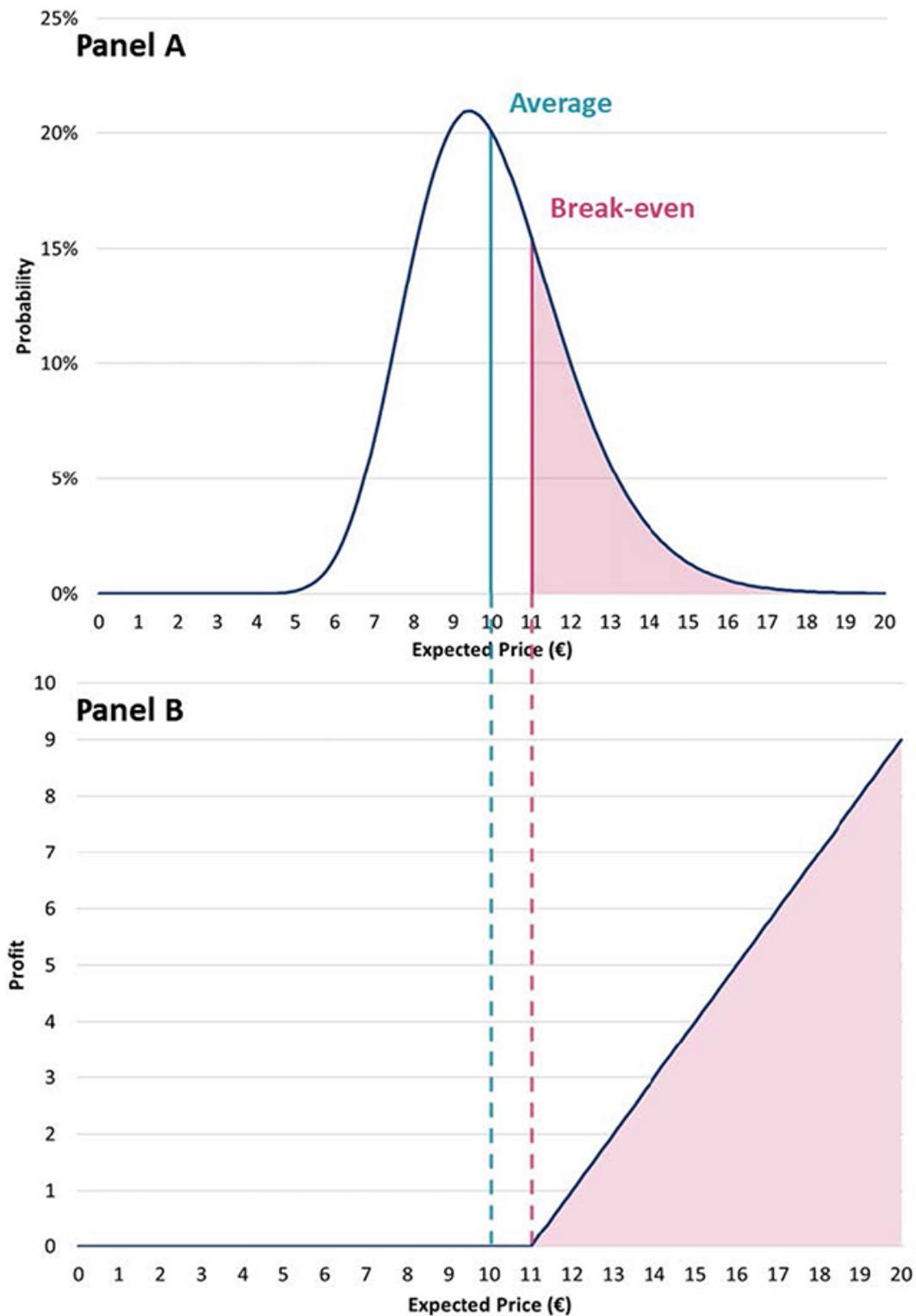
There are established option-pricing models to measure the value embedded in the shaded area. The famous Black-Scholes-Merton model is used for share options and assumes a payoff based on the distribution of likely market prices at exercise. The Black model is similar but applies to options written on commodities.

Both the Black-Scholes-Merton and the Black models relate to standard European options that assume a single exercise date. American options permit exercise at any time up to maturity; Asian options compute payoffs based on average prices through to maturity.

'Exotic' options are also valued routinely and traded, involving a host of non-standard features such as 'look-back' (optimal historical price), 'barrier' (activated within a price range), 'compound' (option on an option) and 'binary' (all or nothing payout). Many of these different sorts of options introduce further possibilities and complexity as compared to the standard European options assumed in the Black-Scholes-Merton and Black models, in part because the exotic payoffs depend on the path prices take towards a given outcome. Standard approximations and formulaic approaches nevertheless exist to estimate the value of many exotic options.[16]

Option-valuation models necessarily make assumptions about the development of price volatility over time and the shape of the distribution of potential prices (and underlying price movements). Standard assumptions are well established and fit reasonably well to many circumstances. However, reality can be more complex and involve significant changes in volatility over time, skewed pricing outcomes (relatively more upside than downside or vice versa), and even discrete price jumps. Experts must therefore take care to ensure that the assumed distributions implicit in option valuation models are reasonable for the actual situations under consideration.

Monte Carlo simulation

Real-world situations can be more complex than captured by closed-form solutions such as the Black-Scholes-Merton and Black models. Management responses may depend on the path of market prices and involve complicated payoff structures, analogous to some of the exotic options highlighted above. For example, a contract might permit month-by-month extensions, early termination if prices drop too far or volume adjustments based on prior usage.[17] The possibility of price volatility varying over time and price outcomes being skewed adds further complexity.

Monte Carlo simulation offers the computational flexibility to accommodate non-standard features, since computer simulation is not constrained by the mathematical assumptions required for closed-form models. Monte Carlo methods involve the simulation of thousands (or millions) of potential price paths for an underlying asset, calculating the value payoff for each path, and then determining the average expected value across all of the simulated price paths.[18] Monte Carlo simulation also allows for the incorporation of non-standard assumptions about volatility and price distributions, which may better reflect actual conditions than standard assumptions. Monte Carlo is, in essence, a numerical engine that can process any set of rules and outputs, and as such is highly adaptable to custom situations that deviate from standard financial instruments.

To illustrate the Monte Carlo method, we build on the earlier example of an expansion option, where management considers increasing production if market prices justify doing so. In our earlier example, the decision to expand was based on a single price one year into the future (termed 'Year 1'). Now, we adapt the example to reflect a more realistic setting in which the expansion decision must be made at the end of Year 1, but depends on market conditions over the following 12 months (termed 'Year 2').

Specifically, the expansion involves a capital outlay of €11 at the end of Year 1 and becomes profitable only if the average market price over Year 2 exceeds €11. This setup resembles an Asian-style call option, where the payoff depends not on the price at a single point in time but on the average price over a future period. Because of this added complexity, closed-form models become impractical and Monte Carlo simulation offers a flexible approach for valuing this flexibility.

To implement the Monte Carlo approach, we simulate a large number of monthly market price paths over a two-year horizon, based on a stochastic process with an assumed annual volatility (for example, 20 per cent). Figure 4 illustrates several of these simulated paths.[19]

Figure 4: Price paths
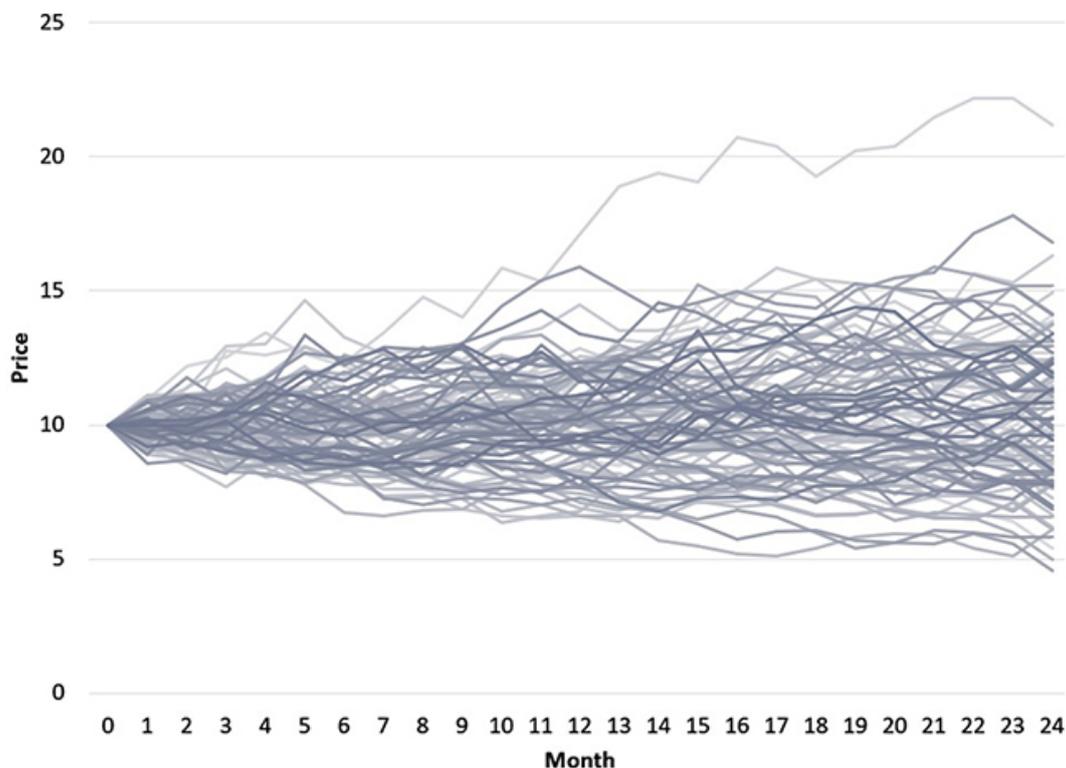
At the end of Year 1, for each simulated path, we calculate the average price over Year 2, that is, over months 13 to 24. If the average price exceeds €11, the expansion is profitable, and the payoff is equal to the average price minus €11. If the average falls below €11, the company foregoes expansion and the payoff is zero.

We then discount this expansion payoff to reflect its value at the time of the decision, using an appropriate discount rate. Repeating this process across all simulated paths yields a distribution of present values. The value of the expansion option is then calculated as the average of these discounted payoffs across all simulations.

Our example assumes that the manager knows the entire sequence of prices over Year 2 at the moment of decision, in Year 1, and can react accordingly. That is, we assume 'perfect foresight'.[20] In reality, managers make decisions based on their expectations of future market conditions at the time of the decision. As a result, simulation approaches that assume full knowledge of future outcomes can overstate the value of flexibility.

Practitioners must take care to ensure that Monte Carlo models reflect only the information that would reasonably be available to decision-makers at the relevant time.

IV Practical challenges

The techniques described above are routinely used to estimate the value of both financial options and management flexibility. Nevertheless, it is important to exercise caution. Clearly defined decision points and payoffs can be difficult to identify in many real-world instances.

Complex commercial arrangements can involve multiple potential decision points, interdependent variables and unclear contractual language. Identifying the possible future courses of action, let alone assigning them reliable payoffs and probabilities, may require a dose of judgment. This is not a flaw of the methodology but a reflection of the complexity of the real world. The challenge can be particularly acute in dispute settings: tribunals and experts are expected to quantify damages, not merely outline a range of potential outcomes, as might be acceptable in strategic or financial planning contexts.

Whether or not to apply option valuation techniques in a particular dispute will likely come down to practical considerations. One consideration is whether the real option in question is likely to be economically meaningful. Minor option value is unlikely to justify the effort required for a robust quantification of option value. Conversely, the presence of important upside potential or downside protections might exist and need to be factored into any reliable valuation exercise.

A second consideration is factual credibility. Valuations are more persuasive when they are consistent with the economic behaviour and expectations of the parties. If internal documents or negotiations indicate that relevant parties assigned no value to a supposed real option, then modelling its value may overstate relevance and over-complicate matters for the tribunal. By contrast, if flexibility were central to negotiations, then it is more plausible for a real option to have substantial value and be material for the overall valuation assessment.

A third consideration is the reliability of inputs. Like any method, tribunals may dismiss options-based valuations if the input parameters are unreliable or poorly documented. The quality and availability of data are thus essential to support a robust option valuation. In addition, some methods such as Monte Carlo can be computationally intensive, especially when an option involves many decision points or interacting uncertainties. The necessary computational complexity only makes sense if data inputs and underlying assumptions are robust and defensible.

A final consideration is tribunal acceptance of the valuation method. Economists and valuation professionals routinely recognise and apply options-based approaches outside of disputes. Valuation guidance, such as the International Valuation Standards (IVS), supports these techniques.[21] However, the methods are relatively less used in arbitration, in part due to their potential complexity and potential need for subjective assumptions. Successful use of options methods in arbitration will depend on transparent application, clear presentation, and a strong connection to the specific commercial and factual context at issue.

When these challenges cannot be satisfactorily overcome, a conservative approach may be to assign no value to the option. This is not to say an option has no theoretical value, but rather that the available evidence may be too thin to support a credible quantification. In some commercial settings, optionality is not explicitly priced but included as a 'sweetener' to make a deal more attractive or to accommodate future uncertainties informally. In such cases, it is plausible that neither party assigned value to the option in the precise sense that valuation models imply.[22]

V Arbitral practice

When supported by the factual record and grounded in commercial logic, option valuation techniques can provide a reliable basis for quantifying loss. The following examples illustrate how options-based reasoning has been applied in arbitral practice.

The first is a prominent example from investor-state arbitration, *Tethyan Copper v. Pakistan*.[23] The Tethyan tribunal awarded over €4 billion in damages using an options-based framework to value a large development-stage mining project. Tethyan had contemplated the phased expansion and optimisation of the mine depending on metal prices and other future conditions. These expansion rights, essentially a series of contingent decisions, constituted the real options embedded in the project.

The Tethyan tribunal agreed that a DCF approach based on fixed cash flows would undervalue Tethyan's rights in part by ignoring upside potential in the context of price uncertainty.[24] To address this issue, the claimant's expert applied a 'modern DCF' model, which simulated the claimant's expansion decisions under many future price scenarios, like the Monte Carlo example discussed above. The *Tethyan* tribunal accepted the approach, concluding that it aligned with mining valuation standards.[25] The tribunal also cited case-specific evidence, including detailed feasibility studies and reserve estimates.[26]

A second example is the valuation of dispatchable power plants, such as coal or gas-fired facilities, which possess the operational flexibility to generate electricity when electricity market prices exceed their variable costs. The ability to choose whether to run or remain idle at each dispatch interval is equivalent to holding a series of call options, each representing the option to run during a given period. The value of dispatchability depends on the volatility of electricity prices, fuel prices and the plant's technical characteristics. Practitioners can apply option-based models, including a Monte Carlo simulation, to capture the distribution of expected price-cost differentials and estimate the plant's expected operating profits.[27] Ignoring this flexibility in valuation by assuming static or average dispatch can significantly understate the economic value of dispatchable assets.[28]

The gas sector provides a third example, with buyers frequently requesting various forms of flexibility in supply agreements. One example is nomination flexibility, under which buyers commit to purchasing a minimum annual or daily quantity of gas but retain the right to nominate higher daily volumes up to a maximum. This nomination flexibility allows buyers to arbitrage short-term price movements or respond to changes in customer demand, effectively a type of real option. The value of this optionality can be assessed by simulating nomination strategies across potential modeled price paths. In practice, Monte Carlo analysis often underpins damages claims arising from such contracts, or contract price renegotiations, even if tribunals do not always explicitly refer to it.

A fourth example concerns embedded flexibility in typical development activities. For example, real estate developers often hold rights to defer construction, phase investments or adapt a project's design depending on how regulation and market conditions evolve. These rights are valuable because they allow developers to wait for critical information before committing capital. Option value can account for a sizeable fraction of the value of development pipelines. Practitioners can model alternative development paths to estimate how a rational developer would respond across different scenarios.

Ultimately, flexibility can have significant commercial value, particularly in highly uncertain environments. Ignoring its value risks systematic underestimates of value in these circumstances and even mischaracterisations of parties' commercial expectations. A lack of flexibility can also impose significant costs and, ultimately, reduce value. Practitioners should therefore be alert to situations where flexibility may play a material role and consider whether the DCF method is sufficient. If not, the alternative techniques discussed in this chapter offer ways to incorporate flexibility into damages assessments.

Endnotes

1   A study of 95 publicly available awards (the majority relating to investment treaty arbitration) found that tribunals have increasingly relied on income-based valuation methods, particularly the DCF method, when assessing compensation. Between 2011 and 2015, income-based approaches were used in 69 per cent of cases where compensation was awarded, compared to only 17 per cent of cases decided before 2000. See PwC, International Arbitration Damages Research 2015, p. 3. See also Sergey Ripinsky and Kevin Williams, 'Damages in International Investment Law', British Institute of International and Comparative Law, 2008, pp. 201–212. ^ Back to section

2   The DCF approach falls under the broader 'Income Approach' as defined by the *International Valuation Standards* (IVS). This approach estimates value by converting future cash flows into present value using an appropriate discount rate. The traditional DCF model involves: (1) forecasting a single set of expected cash flows; and (2) applying a single discount rate. There are several variations of the DCF method, including probability-weighted DCF models for situations with multiple scenarios. See International Valuation Standards Council (IVSC), International Valuation Standards (IVS) 2025, IVS 103 Valuation Approaches, Appendix, ¶ A20. London: IVSC. See also Ripinsky and Williams, 'Damages in International Investment Law', pp. 195–201. ^ Back to section

3   Economists distinguish 'systematic' and 'non-systematic' risk. Systematic risk refers to the market-wide fluctuations that affect all investments to varying degrees. Non-systematic risk relates to risks unique to a particular project or firm. To illustrate, an oil exploration project is subject to risks that are common to all oil exploration ventures, such as fluctuations in global oil prices. But the project is also exposed to project-specific risks, such as the chance that our particular drilling site fails to find oil reserves or that logistical issues delay the development of the project. Best practice in corporate finance is to account for systematic risks in the discount rate and to incorporate non-systematic risks directly into the projected cash flows. ^ Back to section

4 In this case, a DCF would forecast the project's cash flows by: (1) projecting the expected electricity output over time (i.e., incorporating project-specific or non-systematic risks in the cash flows, such as variation in wind or solar resources in the specific area of the project); and (2) using a discount rate that reflects systematic risks that cannot be diversified away (i.e., that affect all comparable projects), such as interest rate changes, macroeconomic trends or global policy shifts affecting the sector. ^ Back to section

5 An analogous example would be an option where a project starts with expanded capacity today but has the option to scale down in the future. ^ Back to section

6 If the 'high-price' scenario remained at €12 but the 'low-price' scenario fell to €6, the option value would remain unchanged, as its final payoffs remain the same (€1 in the high-price scenario and €0 in the low-price scenario). ^ Back to section

7 It can also be challenging to determine what discount rate to apply when valuing cash flows across different scenarios. Discount rates in DCF analyses are typically based on market data that reflect a blend of possible outcomes and risks, rather than a single scenario in isolation. But scenario analysis treats each outcome separately, often with different risks in each case. This can create a mismatch because the discount rate may no longer align with the cash flows being valued. ^ Back to section

8 The Cooke's method is complex to administer and requires the availability of different sets of expert scenario forecasts and probability assessments. ^ Back to section

9 A 'random walk' refers to a stochastic process in which prices evolve step by step with unpredictable movements. ^ Back to section

10 In many disputes, especially those involving illiquid assets or bespoke contracts, relevant pricing data (historical or from options) may not exist or may not be reliable. ^ Back to section

11 The price levels of €12 and €8 are not arbitrary. They are consistent with a price series that starts with €10 and has an annual volatility of 20 per cent. The up and down movements follow from assuming a lognormal distribution, often used to summarise the probability of different stock price changes: $up = e^{\sigma \sqrt{t}} - 1$ and $down = $. See Richard A. Brealey, Stewart C. Myers, and Franklin Allen. 2011. *Principles of Corporate Finance*. 10th ed. New York: McGraw-Hill/Irwin, p. 533. ^ Back to section

12 The line tilts to the right, reflecting that prices can rise by a lot, but can only fall to zero. This pattern reflects our assumption that prices follow a lognormal probability distribution, which is widely accepted as a reasonable model for stock prices. This model captures an intuitive feature of stock price changes: it recognises that prices can go up, in theory, without limit, but they cannot fall below zero. That is, you can lose 100 per cent, but you cannot lose more than what you invested. The result is a distribution of potential prices that is skewed to the right, in the sense that it allows for a wide range of high prices but only a limited range of low prices. ^ Back to section

13 All else equal, higher uncertainty means prices can end up in a wider range. This makes it more likely that some prices will fall above the breakeven point, increasing the size of the shaded area, and with it, the value of the option. ⌃ Back to section

14 A 'call option' gives the holder the right to buy an asset at a given price. A contractual right to extend a contract, defer an investment, or increase offtake is not so different from a financial call option, since it gives the holder the ability to wait, see, and then act. See Brealey, Myers, and Allen, *Principles of Corporate Finance*, chapters 21–22. ⌃ Back to section

15 In a lognormal distribution, the average price is higher than the most likely value because the distribution is skewed; prices cannot fall below zero but can rise without limit, so infrequent high outcomes pull the average upward. ⌃ Back to section

16 Economic textbooks provide frameworks to value different types of options. For example, see John C Hull, *Options, Futures, and Other Derivatives*, 10th ed. (Pearson, 2018). ⌃ Back to section

17 While many contractual options have a fixed exercise date, this is not always the case. Some options can be exercised at any time up to expiry. When the timing is flexible, valuation becomes more complex, since it requires modelling both whether the option will be exercised and when. Although not discussed in this chapter, techniques such as Monte Carlo analysis can address this added complexity. ⌃ Back to section

18 See Jonathan Berk and Peter DeMarzo. 2013. *Corporate Finance*. 3rd ed. Boston: Pearson, chapters 21–22. ⌃ Back to section

19 The simulated price paths are generated using a 'geometric Brownian motion', a standard model in financial economics for capturing how prices evolve over time. In our example, we assume an average (or 'drift') of €10 and an annual volatility of 20 per cent. Intuitively, this means that while prices tend to hover around €10, they can fluctuate significantly from month to month, with the degree of fluctuation governed by the volatility. ⌃ Back to section

20 Our example involves forecasted price paths for a single benchmark, but in many cases, forecasted cash flows depend on multiple, potentially correlated price paths. For example, the value of a coal plant depends on both electricity prices (revenue) and coal prices (fuel cost). In such cases, established methods exist to model and forecast correlated price paths. ⌃ Back to section

21 IVSC, *International Valuation Standards (IVS) 2025*, Appendix, ¶¶ A20.16-A.20-17. London: IVSC. ⌃ Back to section

22 Brealey, Myers, and Allen, *Principles of Corporate Finance*, p. 554. ⌃ Back to section

23 *Tethyan Copper Company Pty Limited v. Islamic Republic of Pakistan*. 2019. ICSID Case No. ARB/12/1, Award, July 12. ⌃ Back to section

24 ibid., ¶ 1476.   ^ Back to section

25 ibid., ¶¶ 347, 355. The claimant's expert referred to statements made by the Special Committee of the Canadian Institute of Mining, Metallurgy and Petroleum on Valuation of Mineral Properties (CIMVal).   ^ Back to section

26 The other known case in which a modern DCF approach was presented is *Bear Creek Mining Corporation v. Republic of Peru*. In this case, the tribunal rejected the use of any income-based method and did not express a view on the modern DCF approach. See *Tethyan v. Pakistan*, ¶ 359.   ^ Back to section

27 For an options-based approach to power plant valuation, see, for example, 'Valuation and Management of Nuclear Assets: Nuclear Options Model' (NOM, Version 1.0), EPRI, Palo Alto, CA: 1998. TR-107541.   ^ Back to section

28 One of the authors of this chapter, Richard Caldwell, used a Monte Carlo approach to value a modern Dutch coal-fired power plant in the context of a dispute.   ^ Back to section

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