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Policy-Constrained Valuation of Real Options Using Monte Carlo Simulation: The Role of the Exercise Condition

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Abstract:

Purpose: *This paper investigates how the economic value of managerial flexibility depends on the design of the decision rule governing option execution. It distinguishes between the policy-constrained real option value (ROV), representing the expected, non-negative potential of flexibility and the financial outcome of managerial flexibility (FOMF), which captures the realised economic effect of managerial actions that may be either positive or negative. The study aims to assess how the choice of the decision variable (EBIT, unit margin, FCFE, or sales volume) and the critical threshold (trigger value) influence both ROV and FOMF under conditions of risk and uncertainty.*
Design/Methodology/Approach: *A simulation-based valuation framework is developed and applied to a theoretical manufacturing investment project located in the European Union. Two complementary valuation models are used: (1) the Double Monte Carlo (2MC) procedure, which estimates the realised financial outcome (FOMF) by comparing base and extended project NPVs across 100,000 stochastic iterations; and (2) the Simulation-based Comparative Valuation (SCV) framework, which estimates the policy-constrained real option value (ROV) by truncating negative outcomes to zero. Both approaches are embedded in a discounted cash flow (NPV) model that includes stochastic drivers (unit margin and demand volume), consistent financing assumptions, and rule-based execution logic.*
Findings: *The results indicate that the expansion flexibility, under the assumed risk structure and decision rules, does not generate positive realised value: FOMF remains negative for all tested variables and trigger thresholds, while ROV stays non-negative and peaks at 89.4 thousand EUR for an EBIT trigger of 200 thousand EUR. The analysis demonstrates that option value depends critically on the choice of trigger variable and the definition of the execution condition. Stricter decision rules reduce both ROV and FOMF despite lowering the share of erroneous exercises. The value of flexibility is maximised when exercised frequently, even at the expense of higher error probability. None of the analysed decision variables yields a positive expected FOMF, confirming that the designed flexibility lacks economic justification under current assumptions.*
Practical Implications: *For managers, the study highlights that purchasing flexibility, such as additional land for potential expansion may increase project risk, without improving expected returns unless the trigger condition is well-calibrated. Decision rules should be operationally clear, empirically tested, and defined during the design stage of flexibility creation rather than ex post.*
Originality/Value: *The paper introduces a dual-metric, policy-constrained simulation*

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framework that bridges theoretical real option valuation and practical decision-making. By jointly using ROV and FOMF, it differentiates potential from realised value and offers diagnostic tools, execution frequency, zero-mass share, timing that improve managerial interpretation of investment flexibility.

Keywords: *Real options valuation, Monte Carlo simulation, managerial flexibility, investment decision-making under uncertainty, option exercise condition, investment under uncertainty.*

JEL codes: *C63, D81, G31.*

Paper type: *Research paper.*

1. Introduction

Investment decisions unfold under conditions of uncertainty, where limited financial and organizational resources must be committed while market, technological, and institutional parameters evolve in unpredictable ways. Uncertainty and risk are inherent features of this process, as investors allocate capital amid incomplete information and continuously changing external conditions that directly affect the project's value.

Flexibility, therefore, becomes a critical managerial attribute, an ability embedded in organizational strategy and structure that allows firms to adapt their actions to unfolding realities. In the literature, flexibility has been conceptualised both as an organizational feature, reflecting responsiveness and adaptive capacity and as a contractual right analogous to financial options (Dixit and Pindyck, 1994; Trigeorgis, 1996; Copeland and Antikarov, 2001).

Within this conceptual framework, real options formalise the economic value of flexibility by representing strategic choices such as expansion, deferment, or abandonment as contingent rights. A real option grants management the right, but not the obligation, to act when certain favourable conditions are met. In this sense, real options capture one dimension of flexibility - the quantifiable potential of decision rights under uncertainty.

However, empirical research consistently shows that in practice, such decisions are rarely optimally timed. They are often executed through policy rules linked to observable key performance indicators (KPIs), rather than through continuous-time optimization (Adner and Levinthal, 2004; Driouchi and Bennett, 2011; Posen *et al.,* 2018).

To formalise this policy-constrained perspective, this study defines several key constructs that together establish the analytical framework for simulation-based valuation.

The Real Option Value (ROV) represents the expected economic value of managerial flexibility exercised automatically once a predefined performance threshold is met. In contrast to classical real option models that assume optimally timed exercise under full information, ROV here is policy-constrained: execution follows a specific decision rule linked to a chosen variable, such as EBIT, unit margin, or sales volume.

The ROV thus captures the expected discounted value of all positive differences between the extended and base project scenarios, conditional on the trigger being satisfied. This yields a practical, empirically grounded lower bound of the theoretical option value.

Complementarily, the Financial Outcome of Managerial Flexibility (FOMF) measures the realised financial result of managerial flexibility. It can take either positive or negative values, reflecting the actual consequences, both beneficial and adverse of executing or not executing flexibility under real decision-making conditions.

The FOMF is computed as the expected difference between the extended project (with flexibility) and the base project (without flexibility) across all simulated scenarios, encompassing both favourable and unfavourable outcomes. Unlike the ROV, which assumes rational and loss-free execution, FOMF captures the ex post economic effect of managerial actions under uncertainty, limited information, and behavioural constraints.

The valuation framework further distinguishes between the Base Project Value (NPVbase) - the expected net present value of the investment under fixed assumptions, without any flexibility and the Extended Project Value (NPVext), which incorporates the option to expand, delay, or modify the investment once a predefined condition is met. The key determinant of whether flexibility is activated is the Trigger (or Threshold Variable), an observable parameter such as EBIT, unit margin, or sales volume that defines when a change in project trajectory occurs.

This distinction between potential and realised value, and between theoretical and rule-based execution, motivates two research gaps. First, the policy-constrained nature of execution is underexplored, despite its significant influence on valuation outcomes and decision error rates. Second, there is no established measure that complements the classical, non-negative ROV with the realised financial result of managerial action, one that explicitly accounts for possible losses.

The objective of this research is therefore to quantify how the choice and stringency of trigger conditions (e.g. EBIT, margin, sales volume) affect both potential value

(ROV) and realised performance (FOMF). To achieve this, two complementary simulation-based frameworks are applied within a consistent discounted cash flow (DCF) structure: Double Monte Carlo (2MC), used to estimate FOMF by averaging pathwise differentials between extended and base models across all scenarios, and Simulation-Based Comparative Valuation (SCV), used to determine ROV by truncating negative differentials to zero-consistent with the principle that an option represents a right, but not an obligation, to act.

The contribution of this study is threefold. First, it develops a practical, policy-constrained valuation setting that mirrors managerial decision rules under uncertainty. Second, it introduces a dual-metric perspective - ROV versus FOMF, that differentiates between potential and realised economic value. Third, it emphasises diagnostic measures such as exercise frequency, share of zero outcomes, timing of execution, and sensitivity to decision thresholds, offering managers a richer understanding of when flexibility enhances and when it erodes project value.

2. Literature Review

The decision to exercise a real option remains one of the most analytically complex and practically uncertain aspects of strategic investment management. Classical works conceptualize real options as contingent claims that grant the right, but not the obligation, to undertake, defer, expand, or abandon a project under uncertainty (Dixit and Pindyck, 1994; Trigeorgis, 1996; Copeland and Antikarov, 2001).

This framework quantifies the economic value of managerial flexibility, which arises from the ability to adjust investment timing and scale in response to changing market conditions. Early studies emphasized the analogy between real and financial options, assuming that decision-making could follow rational, optimally timed rules.

However, in practice, the real option exercise process is influenced by strategic, behavioral, and institutional factors that challenge such assumptions (Adner and Levinthal, 2004; Driouchi and Bennett, 2011). Managerial cognition, risk perception, and learning dynamics play a critical role in determining whether and when an option is exercised (Barnett, 2005; Posen *et al.,* 2018).

In strategic projects, flexibility is often designed at the investment's inception, by embedding options to defer, expand, or abandon and later evaluated based on expected cash flow distributions and risk parameters (Pivorienė, 2017). The option to wait or expand has quantifiable value because it preserves decision rights that may yield future benefits even when the current NPV appears unfavorable (Morreale *et al.,* 2020).

Empirical studies confirm that in practice, option exercise is rarely optimal. Managers often delay exercising to preserve flexibility or, conversely, act prematurely, which distorts the expected value of flexibility (Morreale *et al.,* 2020; Ďurica *et al.,* 2018;

Woodward *et al.,* 2011). Moreover, exercising a real option can reduce future adaptability, creating a trade-off between immediate value realization and long-term strategic flexibility (McGrath and Nerkar, 2004).

This distinction highlights two complementary perspectives. Real options represent a structured, non-negative estimate of potential value derived from optimally exercised flexibility (Trigeorgis, 1996; Copeland and Antikarov, 2001), while managerial flexibility reflects the realized financial outcome of decisions under uncertainty, which may be either positive or negative (Barnett, 2005; Posen *et al.,* 2018).

Real options thus quantify the theoretical upper bound of adaptive value, whereas the realized financial outcome of flexibility (FOMF) captures the empirical performance of decisions taken under imperfect information and bounded rationality (Morreale *et al.,* 2020; Ďurica *et al.,* 2018). The value of both real options and managerial flexibility depends critically on how the decision rule is defined and parameterized.

The length of the exercise period shapes temporal value longer horizons preserve adaptability, while shorter ones restrict it (Dixit and Pindyck, 1994; Trigeorgis, 1996; Morreale *et al.,* 2020). Equally important is the choice of the decision variable: simple price triggers, revenue-based measures, or profitability indicators such as EBIT differ in volatility and informational precision, directly affecting valuation outcomes (Pivorienė, 2017; Décaire *et al.,* 2020).

The critical threshold (trigger value) determines when exercise becomes economically justified; if set incorrectly, it can cause premature or delayed exercise, distorting both the theoretical option value and the realized outcome (Sick, 2010; Fernandez, 2023; Kang, 2018).

Recent research emphasizes identifying observable triggers that define when and under what conditions real options should be executed. Theoretical and applied models commonly use measurable financial and operational indicators, such as EBIT, sales margin, or demand as decision triggers (Sick, 2010; Cetinkaya, 2014). For instance, earnout clauses in mergers and acquisitions, which link contingent payments to performance metrics such as EBITDA, effectively mirror real option structures and demonstrate how economic indicators function as exercise thresholds (Knowcraft Analytics, 2025).

Empirical evidence further shows that firms frequently deviate from theoretically optimal triggers due to competitive pressure, market signals, and dynamic feedback effects (Décaire *et al.,* 2020). Fernandez (2023) notes that such deviations often arise from errors in threshold specification or misinterpretation of exercise probabilities.

Kang (2018) argue that static thresholds fail to represent how firms adapt their decision rules under uncertainty. Adaptive, simulation-based frameworks integrating stochastic control and behavioral calibration better capture how exercise policies evolve dynamically. These perspectives align with the behavioral theory of real options (Posen *et al.,* 2018), which views flexibility as an evolving managerial capability rather than a static contractual right.

In summary, contemporary real options research converges on several key insights. First, the value of a real option depends critically on the timing and condition of exercise, influenced by stochastic, strategic, and informational factors (Trigeorgis, 1996; Dixit and Pindyck, 1994; Morreale *et al.,* 2020).

Second, managerial flexibility can generate both positive and negative financial outcomes depending on how effectively it is executed (Barnett, 2005; Posen *et al.,* 2018). Third, simulation-based approaches that analyze individual stochastic paths offer a promising methodological direction for quantifying both the realized financial outcome of flexibility (FOMF) and the expected value of rule-based real options (ROV), bridging the gap between theoretical valuation and real-world decision-making.

These conceptual and empirical insights reveal a methodological gap in existing real option models, which often assume perfect foresight and optimal timing. In practice, decision-making is bounded by predefined investment policies, information asymmetries, and cognitive limitations (Décaire *et al.,* 2020; Fernandez, 2023; Kang, 2018). To address these limitations, the next section introduces a simulation-based comparative valuation framework designed to capture both the realized financial outcomes of managerial flexibility and the policy-constrained expected value of real options.

3. Methodology

This study employs two complementary simulation frameworks: the Double Monte Carlo (2MC) procedure to estimate the Financial Outcome of Managerial Flexibility (FOMF) and the Simulation-Based Comparative Valuation (SCV) approach to estimate the Real Option Value (ROV). Both are grounded in the discounted cash flow (NPV) model which includes stochastic project parameters and decision rules that reflect managerial flexibility.

In both approaches, two internally consistent models are constructed: a base model (NPVbase) without flexibility and an extended model (NPVext) that includes the option to change, expand, or delay investment upon meeting a defined condition. Each model is driven by the same set of input risk factors, e.g., demand volume, unit margin, prices, costs - specified by probability distributions and, where relevant, correlation and autocorrelation structures.

This design consolidates project risk in the spirit of the MAD approach (Copeland, and Antikarov, 2001), while keeping the mapping from observable business drivers to cash flows transparent to practitioners. Cash-flow definitions (FCFF or in most cases

FCFE) and discount rates (WACC or cost of equity) are aligned with valuation perspective and remain constant across the two models to isolate the incremental effect of flexibility.

In the 2MC framework, the simulation is run twice under identical risk structures. The first run produces the distribution of NPVbase, while the second activates the decision rule to produce NPVext. For each simulated path ω, the difference:

$$\Delta(\omega) = \mathrm{NPV}_{\mathrm{ext}}(\omega) - \mathrm{NPV}_{\mathrm{base}}(\omega) \tag{1}$$

represents the financial outcome on option exercise (or not). Averaging these differences across all paths yields the Financial Outcome of Managerial Flexibility (FOMF), which may be positive or negative, reflecting the realized financial consequences of managerial decisions under uncertainty.

The SCV framework, introduced by Pawlak (2021) and based on Wiśniewski's (2008) 2MC structure, extends this analysis by transforming negative path outcomes into zero, consistent with the real option principle that a rational manager will not exercise an option leading to loss. The expected value of the non-negative differences then represents the Real Option Value (ROV):

$$\mathrm{ROV} = \mathbb{E}\left[\max\left(\mathrm{NPV}_{\mathrm{ext}} - \mathrm{NPV}_{\mathrm{base}}, 0\right)\right] \tag{2}$$

This truncation converts empirical decision outcomes into a policy-constrained valuation measure that captures only those scenarios where the predefined trigger condition, such as an EBIT, margin, or demand threshold is met.

Execution as in 2MC and may be specified at a single date (European) or across discrete windows (Bermudan) using a first-hitting convention or other predefined convention. The execution condition is observable and rule-based rather than optimized, meaning that ROV represents a lower bound of the theoretical, optimal option value derived from continuous-time models such as Longstaff–Schwartz (2001).

The 2MC and SCV frameworks together allow simultaneous assessment of (i) the realized financial performance of flexibility (FOMF) and (ii) the potential economic value of the same flexibility treated as a conditional right (ROV).

Both methods maintain the NPV framework's financial discipline: cash flows remain incremental, risk-adjusted discounting reflects time value, and market incompleteness is addressed through stochastic simulation rather than replicating portfolios (Smith, 2005; Mun, 2006). Decision rules are embedded as algorithmic triggers within the model, ensuring that in each simulated path, the project follows either the base or the extended trajectory depending on the observed state variable.

In summary, 2MC (FOMF) captures the empirical, realized financial outcomes of flexibility, including both gains and losses, while SCV (ROV) applies a non-negativity condition to estimate the expected policy-constrained option value. Used jointly, they provide a comprehensive picture of investment flexibility: FOMF as a measure of actual performance under uncertainty, and ROV as a practical lower bound of potential value.

Reported measures include mean and median NPV values, quantiles of the simulated distributions, the share of zero-valued ROV outcomes, and the probability of achieving a positive FOMF (P(FOMF > 0)). These indicators yield actionable insights into how managerial flexibility contributes to, or detracts from project value under real decision-making conditions.

Both the SCV and 2MC frameworks can additionally report the number of executions, the share of paths with zero (non-executed) or negative outcomes, the distribution of exercise dates, and the sensitivity of ROV and FOMF values to execution thresholds, along with many other indicators providing valuable managerial insights.

4. Research Results

4.1 Projects Assumptions

To illustrate the application of real options theory in the valuation of flexible investment projects, a theoretical example of a standard greenfield investment with an average risk profile, located within the European Union, is presented.

The project involves the construction of a small manufacturing facility producing a single type of product for sale on the market. In its baseline version, the investment begins in 2024 with the purchase of land (CAPEX = 0.4 million EUR), the construction of a production hall (0.8 million EUR), and the installation of a production line (1.2 million EUR).

The total capital expenditures incurred by the end of 2024 therefore amount to 2.4 million EUR. The depreciation rate for the production hall is set at 5% per year and for the production line at 15%. The project's time horizon is 10 years, with the sale of the manufacturing facility scheduled for the end of 2034. The terminal cash flow from the sale is assumed to equal 150% of the book value of the fixed assets.

To start operations, the project requires investment in working capital. The assumptions are as follows: inventory turnover of 30 days, accounts receivable turnover of 14 days, and accounts payable turnover of 21 days. At the end of the project, the net working capital is fully recovered, trade payables are settled, inventories are utilized, and receivables collected from customers.

The unit production cost remains constant at 200 EUR per unit, while fixed operating costs amount to 400,000 EUR annually. A markup is applied to unit costs, starting from 50% in the first year and gradually declining to 30% in the final year of the project, yielding the unit selling price. The annual sales volume is assumed constant at 10,000 units. The corporate income tax rate is 19%. This setup allows for an NPV-based evaluation of project efficiency.

Cash flows are modelled as free cash flow to equity (FCFE) and discounted at the cost of equity (re). The cost of equity is estimated using the CAPM model for a typical EU-based investment and equals 9.91%. Based on Kroll data, the risk-free rate (rf) for the euro area is assumed at 2.5% (Kroll, 2025), the average levered beta at 1.35, and the equity risk premium at 5.5%.

Long-term debt initially accounts for 30% of total capital and is gradually repaid over time. The cost of long-term debt, based on European Central Bank statistics, is set at 7.75% (ECB, 2025). In the event of liquidity shortages, the company may draw on short-term credit facilities bearing an interest rate of 9.75%. The revolving credit line is repaid immediately once sufficient cash becomes available.

For completeness of analysis, a full financial model was constructed for this example, comprising all three core financial statements: the income statement, balance sheet, and cash flow statement. Cash flows were prepared from the owner's perspective (Free Cash Flow to Equity – FCFE) and discounted using the cost of equity of 9.91%. In the baseline scenario, the net present value (NPVbase) of the 10-year investment, covering the construction, operation, and final sale of the facility, amounts to 546 thousand EUR (Table 1).

Table 1. *Value of investment in a factory – base case without stochastic variables*

FCFE	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Net Profit	0.0	263.2	268.2	273.3	197.3	202.3	126.3	18.0	120.2	125.2	129.6
Depreciation	0.0	220.0	220.0	220.0	220.0	220.0	220.0	160.0	40.0	40.0	40.0
CAPEX	-2 400.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Changes in net working capital	32.9	-115.1	0.0	0.0	3.8	0.0	3.8	7.7	0.0	0.0	66.8
Investment sale net value											1 200.0
Net borrowing	710.1	-80.0	-80.0	-80.0	-80.0	-80.0	-80.0	-80.0	-80.0	-70.1	0.0
FCFE	-1 657.0	288.2	408.2	413.3	341.1	342.3	270.2	105.6	80.2	95.1	1 436.4
Discounted FCFE	-1 657.0	262.2	337.9	311.3	233.8	213.4	153.3	54.5	37.6	40.6	558.4
NPV base	**546.0**										

Source: *Own elaboration.*

The investment in the manufacturing facility is exposed to risk, which in this example is represented by two stochastic variables - unit margin and sales volume (Table 2). The margin applied to unit production costs is modelled using a normal distribution.

The second stochastic variable, sales volume, is described by a lognormal distribution, with parameters corresponding to the baseline scenario - a mean of 10,000 units sold annually, a lower bound reflecting the minimum expected volume, and a specified standard deviation. The parameters of both random variables are summarized in Table 2.

Table 2. *Stochastic variable parameters describing project risk*

Stochastic variables	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Unit margin - normal distribution											
Base case (mean)	50%	50%	50%	50%	45%	45%	40%	30%	30%	30%	30%
Standard deviation (%)	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Sales volume – lognormal distribution											
Base case (mean)	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000	10 000
Standard deviation (%)	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Location (minimum)	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000	5 000

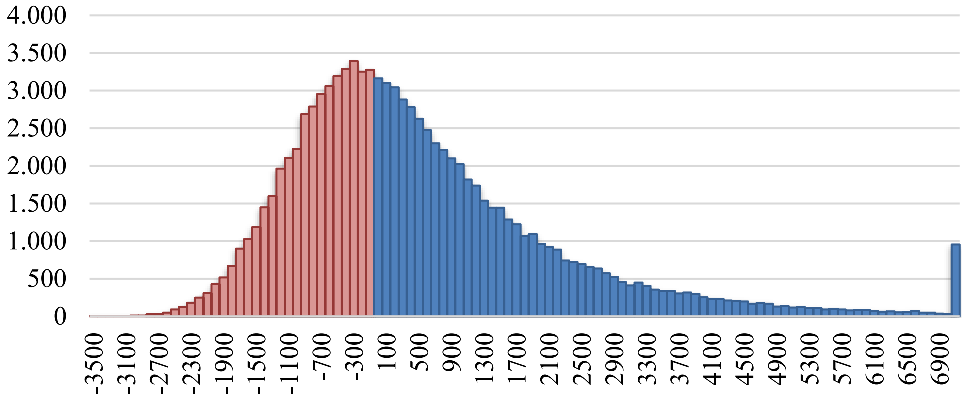
Source: *Own elaboration.*

Using the stochastic characteristics of the random variables (unit margin and sales volume) incorporated into the baseline investment valuation model, a Monte Carlo simulation was performed on the project's financial model. After 100,000 iterations, the mean NPV of base investment amounted to 488.2 thousand EUR, with a median of 122.1 thousand EUR.

The standard deviation, serving as an indicator of risk, reached 1,795.06 thousand EUR. These values differ from the deterministic NPVbase due to the inclusion of parameter uncertainty. The resulting distribution is asymmetric (positively skewed), with a long right tail, indicating a small number of highly favorable scenarios (e.g., exceptionally strong sales) that substantially increase the mean value, even though most outcomes are lower. The simulation results are illustrated in Figure 1.

The simulation makes it possible to generate a probability distribution of the output variable, in this case, the NPV of the baseline investment model, thereby expanding the analytical scope of project risk assessment. As illustrated in Figure 1, scenarios in which the investment yields a negative NPV (46.2% of all observations) are marked in red. This indicates that the probability of achieving at least a break-even or positive return is slightly greater than 50%, suggesting that most outcomes cluster near zero while a smaller number of favorable scenarios drive the mean upward.

Figure 1. *Distribution of NPV values from base model obtained from the Monte Carlo simulation*



Source: *Own elaboration using Oracle Crystal Ball.*

4.2 Acquisition of the Expansion Option

To illustrate the concept of flexibility valuation, this paper presents a strategic decision facing project management after the baseline analysis. Anticipating potential market growth and future profitability, the management considers purchasing a larger plot of land by spending an additional 0.2 million EUR.

This expenditure represents the option premium, the price paid for the right, but not the obligation, to expand production capacity in the future. Economically, this amount also defines the maximum potential loss to the holder of this real call option if the expansion opportunity is not exercised.

The expansion of the production facility may be undertaken within a four-year window, from 2027 to 2030. Once the decision is made, it would require additional capital expenditures amounting to 1 million EUR: 400 thousand EUR for the production hall expansion and 600 thousand EUR for the production line expansion, financed entirely through new long-term debt.

The new fixed assets would be depreciated according to the same accounting rules as in the baseline case and would also increase the project's terminal value upon sale. The expansion is expected to raise production capacity and annual sales by 20%, from 10,000 to 12,000 units, while maintaining the same degree of volatility (standard deviation of sales volume = 50%).

Decision Context. Before the project's implementation, managers must choose between two alternative investment strategies:

1. Proceeding with the baseline project, without acquiring additional land; or

2. Spending 0.2 million EUR to purchase the expansion option, thereby securing the right to scale operations in later years.

If favorable market conditions occur, exercising the option in 2027 would increase production capacity and, consequently, sales volume by 20%, leading to higher expected profits and an increased project value. Under this optimistic scenario, the extended investment yields a net present value (NPVext) of 594.7 thousand EUR, a 48.7 thousand EUR higher than the baseline NPVbase of 546 thousand EUR (Table 3).

Table 3. *NPV of investment in a factory – extended project without stochastic variables*

FCFE	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Net Profit	0.0	259.5	264.5	269.5	187.4	198.7	112.8	-26.7	86.8	98.1	133.7
Depreciation	0.0	220.0	220.0	220.0	330.0	330.0	330.0	270.0	150.0	150.0	120.0
CAPEX	-2 600.0	0.0	0.0	-1 000.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Changes in net working capital	32.9	-115.1	0.0	0.0	-18.4	0.0	4.6	9.2	0.0	0.0	86.8
Investment sale net value											1 890.0
Net borrowing	770.1	-80.0	-80.0	920.0	-180.0	-180.0	-180.0	-180.0	-180.0	-180.0	-150.1
FCFE	-1 797.0	284.4	404.5	409.5	319.0	348.7	267.4	72.5	56.8	68.1	2 080.4
Discounted FCFE	-1 797.0	258.7	334.8	308.4	218.6	217.4	151.7	37.4	26.7	29.1	808.7
NPV extended	**594.7**										

Source: *Own elaboration.*

The obtained results (NPVext > NPVbase) encourage the management team to assume additional risk and purchase the expansion option, that is, to acquire extra land for potential future development. However, given the project's inherent uncertainty, it is necessary to assess the expected value of the expanded investment across a wide range of simulated scenarios. Favorable market conditions may not always occur, and even when they do, their impact on the project's net present value may vary in magnitude.

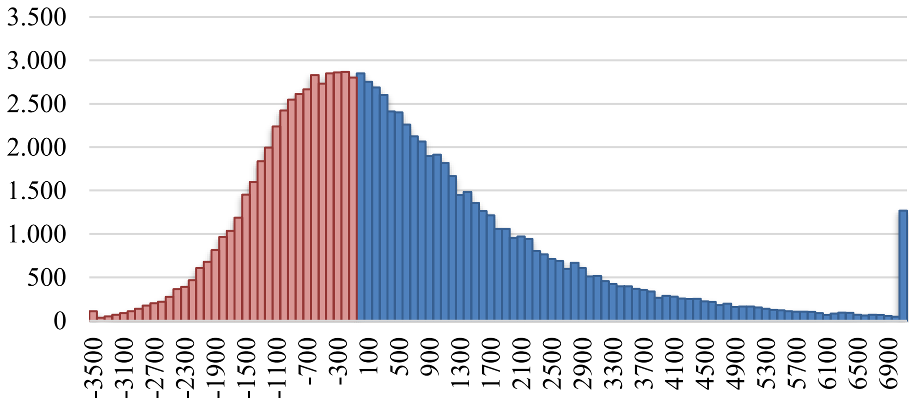
Expansion Option Exercise Condition. When planning the investment, the management links the potential expansion of the factory to the occurrence of favorable future conditions. In practice, such decisions are typically based on the plant's prior economic performance, current forecasts of market development, or key value drivers such as price levels or sales volume.

For the purpose of this example, I exclude cases where decisions to exercise the option were made earlier due to behavioral factors (e.g., anchoring, agency effects, or other economically unjustified motives). Instead, expansion is assumed to occur only if the company's operational performance demonstrates sufficient profitability. Specifically, the management stipulates that the cumulative operating profit (EBIT) over the two preceding years must exceed 200 thousand EUR - this serves as the trigger value for exercising the option.

Accordingly, in order to initiate expansion in 2027, resulting in a 20% increase in sales volume in the following year (2028), the factory must achieve a combined EBIT greater than 200 thousand EUR in 2025 and 2026. If this condition is not met, the option may still be exercised within the subsequent three years (until 2030 inclusive), provided that the same profitability threshold is reached for the two most recent periods. Each time the expansion decision is triggered, new capital expenditures are activated, depreciation on additional assets is recorded, and both production and sales volumes increase.

Project risk, manifested through fluctuations in sales volume and unit margin, implies that the option will not be exercised in every simulation scenario. In cases where the expansion is not undertaken, the project operates at its baseline production capacity, on a slightly larger plot, since the option purchase (additional land acquisition) required an extra CAPEX of 0.2 million EUR. Consequently, when the option remains unexercised, it becomes more difficult to achieve NPVext values higher than NPVbase. The resulting distribution of NPVext values is presented in Figure 2.

Figure 2. *Distribution of NPV values from extended model obtained from the Monte Carlo simulation*



Source: *Own elaboration using Oracle Crystal Ball.*

The distribution of NPVext values is similar in shape to that of the baseline investment (NPVbase, see Figure 1). It is right-skewed, with a noticeable number of extremely favorable outcomes visible on the right side of the graph. At the same time, the left tail contains several highly negative observations, corresponding to scenarios where the plant expansion either did not take place or resulted in financial underperformance. The key parameters of both distributions are comparable: the mean NPVext equals 485.7 thousand EUR, while the mean NPVbase amounts to 488.2 thousand EUR. The median for the expanded project is 104.2 thousand EUR compared with 122.1 thousand EUR for the baseline case.

This indicates that, in most scenarios, the extended investment is less profitable - both its expected and median values are lower than those of the baseline project. In each simulation, NPVext is reduced by the additional CAPEX incurred for purchasing extra land. Unfavorable market conditions, particularly low operating profit (EBIT) prevent expansion, leaving revenues unchanged relative to the baseline scenario, while the initial CAPEX on the additional land lowers overall project value.

Even when expansion occurs, the extra capital outlay for new machinery and production facilities is not always offset by higher sales or increased terminal value. In certain cases, higher production volumes coincide with relatively low profit margins, resulting in limited or even negative net benefits.

These combined effects make the expanded project more exposed to downside and extreme-loss scenarios. However, a smaller subset of simulations also produces highly positive outcomes (Figure 2), representing instances where the expansion generates exceptional profits. This duality results in higher project risk: the standard deviation of NPVext reaches 2,009.1 thousand EUR, compared with 1,795.06 thousand EUR for the baseline investment.

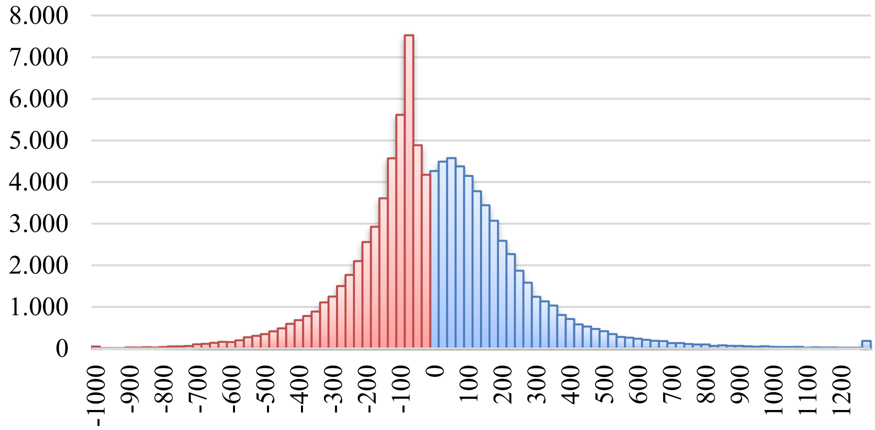
Considering the entire analysis, decision-makers should prefer the baseline investment without purchasing additional land for potential expansion. The expected value and median of NPVext are both lower than NPVbase, while the associated risk is higher. As a complement to this analysis, each simulated scenario can be compared directly by taking the difference between the two project valuations (NPVext – NPVbase). The resulting distribution indicates which alternative, baseline or extended is financially superior in each case.

Positive outcomes reflect scenarios in which the expansion proves beneficial, whereas negative ones show where the baseline project yields greater value. The distribution of these differences is presented in Figure 3.

The chart presented above (Figure 3) consists of two distinct areas. On the left side, representing 50.5% of the 100,000 simulation iterations, the red-colored section shows all paths in which the investment including the expansion option (NPVext) turned out to be less valuable than the baseline project (NPVbase).

These cases correspond to situations where, despite purchasing additional land, the plant was not expanded, or where the option was exercised but the resulting financial outcome proved unsatisfactory. On the right side of the graph, the blue-colored area depicts those simulation paths in which the project with the option, once executed, yielded higher financial efficiency than the baseline investment without additional capital expenditures.

Figure 3. *Distribution of NPV values representing the financial outcome of managerial flexibility (FOMF) related to the project expansion, obtained using 2MC method, from the Monte Carlo simulation*



Source: *Own elaboration using Oracle Crystal Ball.*

The mean of this distribution equals –2.48 thousand EUR, while the median amounts to –21.94 thousand EUR. This indicates that purchasing additional land for potential factory expansion and conditional scaling of operations is, on average, financially disadvantageous compared with the baseline alternative.

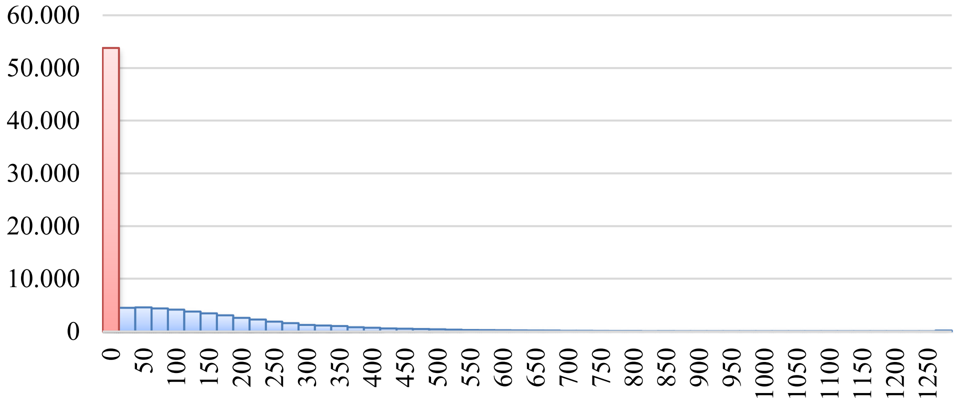
The mean difference between the extended and baseline projects represents the financial outcome of managerial flexibility (FOMF). Unlike the real option value (ROV), this measure can take negative values, as it reflects the realized financial result of decision flexibility rather than its theoretical potential.

In practice, additional investment outlays or operational expansions are not always economically beneficial. Under unfavorable market conditions, the baseline investment may prove more attractive and less risky, offering lower volatility of returns. This comparative, simulation-based approach—assessing the effectiveness of the extended project against the baseline, closely mirrors real-world managerial decision-making, as it directly answers which alternative more effectively contributes to firm value creation.

The real option value (ROV) of the production expansion (Figure 4) was also derived from the simulated financial outcomes of the extended project (NPVext) relative to the baseline (NPVbase). The difference between the distributions of ROV and the financial outcome of managerial flexibility (FOMF) stems from the assumption that an option cannot take negative values.

Theory postulates that the decision-maker always exercises the option optimally; therefore, scenarios producing negative payoffs are treated as non-executed, and their value is set to zero — represented by the high red bar on the left side of Figure 4.

Figure 4. *Distribution of NPV of the real option for project expansion (ROV) obtained using SCV method, from the Monte Carlo simulation*



Source: *Own elaboration using Oracle Crystal Ball.*

The average value of the expansion option amounts to 89.36 thousand EUR, with a median equal to zero — out of 100,000 simulation iterations, 53,794 scenarios resulted in a value of zero. This indicates that the real option to expand the production facility has a positive expected value, reflecting the potential of managerial flexibility to generate additional economic benefits. Nevertheless, the negative NPV outcomes (FOMF) obtained using the 2MC method suggest that, under the assumed levels of project risk and expansion conditions, pursuing the baseline investment remains the more rational and financially sound decision.

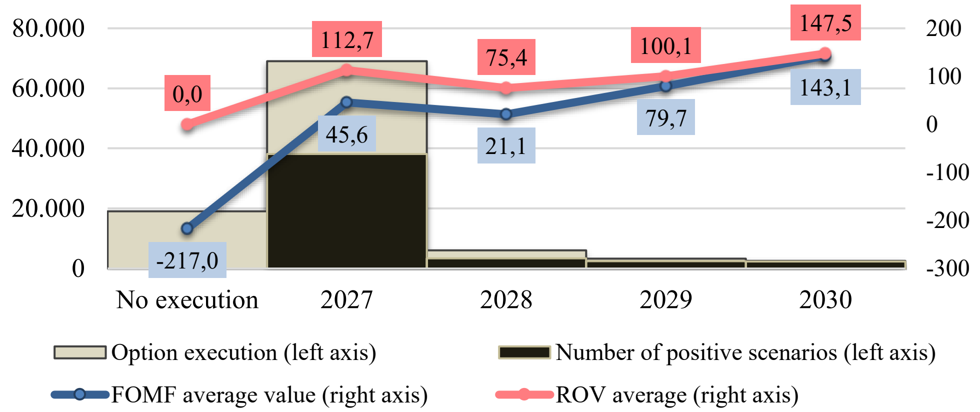
4.3 Searching for the Optimal Exercise Condition

It is important to note that the analysis presented in the previous section remains incomplete without examining how the decision condition the trigger for exercising the expansion option affects the value of the extended investment. Assuming that the plant expansion is initiated when the sum of EBIT from the two preceding periods reaches 200 thousand EUR, the simulation produced an option exercise rate of 80.9% (Figure 5).

As shown in the simulation results, the majority of option exercises 85.4% of the total 80,905 executions occurred in 2027, the first possible year of expansion. This outcome reflects the relatively mild threshold condition that triggered the plant’s extension.

However, only 55% of expansions executed in 2027 and 2028 proved successful, meaning that the extended project value (NPVext) was greater than or equal to the base project value (NPVbase). In subsequent periods, this success rate increased to 73% and 93%, respectively.

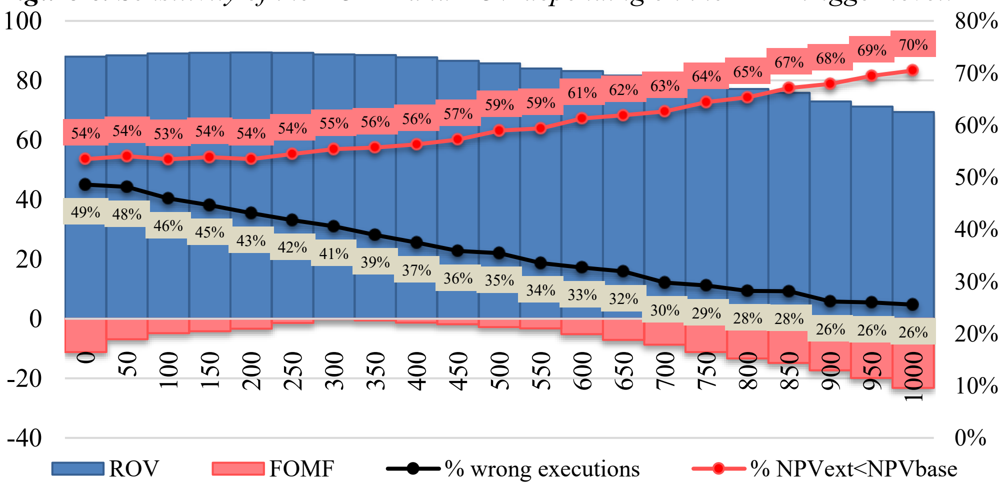
Figure 5. *Option executions in the extended investment model and the ROV and FOMF value*



Source: *Own elaboration using Oracle Crystal Ball.*

This relationship is confirmed by the difference between the values obtained under the SCV (ROV) and 2MC (FOMF) frameworks: the higher the effectiveness of the expansion strategy, the closer the two distributions align. It is therefore reasonable to consider whether adjusting the exercise condition specifically, raising the EBIT trigger threshold could increase both the simulated real option value (ROV) and the realized financial outcome of managerial flexibility (FOMF).

Figure 6. *Sensitivity of the FOMF and ROV depending on the EBIT trigger level.*



Source: *Own elaboration using Oracle Crystal Ball.*

The sensitivity analysis of both the Real Option Value (ROV) and the Financial Outcome of Managerial Flexibility (FOMF) with respect to the decision threshold—defined as the sum of EBIT from the two years preceding the potential expansion decision—leads to several important observations. First, the highest ROV is observed at an EBIT threshold of 200 thousand EUR, amounting to 89.4 thousand EUR. Second, the maximum value of FOMF (a slightly negative result of –0.2 thousand EUR) occurs at an EBIT threshold of 300 thousand EUR.

A further observation is that as the decision condition for executing the expansion becomes more restrictive, both ROV and FOMF tend to decline. This occurs even though managers make fewer incorrect decisions under stricter criteria, as shown by the decreasing black line representing erroneous exercises. These findings indicate that both FOMF and ROV reach their highest values when the expansion option is exercised frequently, even at the cost of a relatively high probability of error.

In other words, flexibility generates the greatest financial potential when decision-makers act proactively rather than overly cautiously. This also justifies the relatively high costs of acquiring flexibility—such as purchasing additional land for potential expansion—which are theoretically expected to be compensated by the financial surpluses generated from scaling up production.

The managerial implication of this analysis is twofold. First, under the current assumptions, the purchase of additional land (the expansion option) is financially inefficient, as reflected in the negative FOMF value. Second, it would be advisable to test alternative decision rules, based on other variables, to determine whether a different trigger condition could yield a positive FOMF and thus justify the expansion option economically.

To assess whether the financial outcome of a potential expansion of the production facility could become positive, an alternative decision variable - unit margin was analyzed. It was assumed that the average unit margin over the two years preceding the expansion decision should exceed a predefined target level, initially set at 50%.

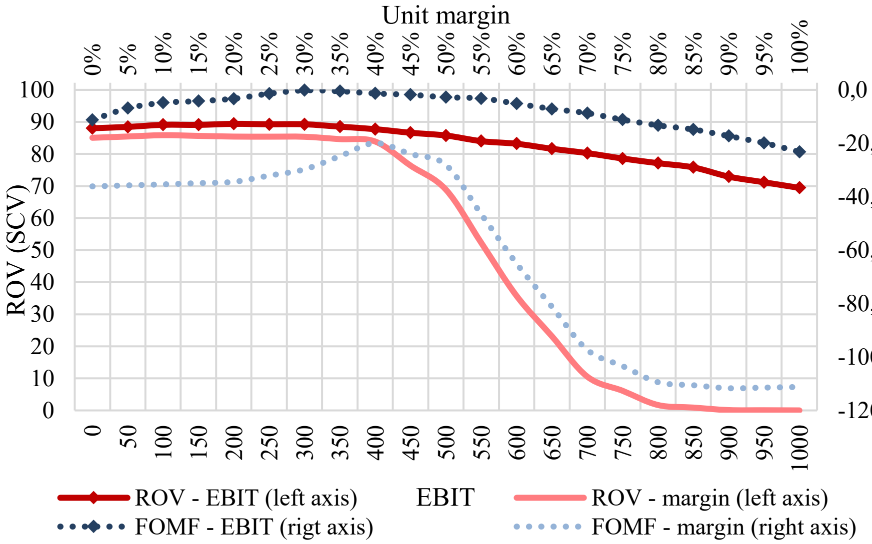
This new variable was then used to conduct a sensitivity analysis of both ROV and FOMF with respect to different trigger thresholds, ranging from 0% to 100% margin. Each threshold value was tested through 20,000 Monte Carlo iterations, and the results are presented in Figure 7.

The obtained results show that the real option values (ROVmargin) remain non-negative only for margin thresholds exceeding approximately 80%, with the maximum ROVmargin reaching 85.9 thousand EUR at a 10% margin threshold.

However, in none of the tested scenarios did the margin-based ROV exceed the value derived from the EBIT-based condition, where the maximum ROVEBIT amounted to 89.4 thousand EUR. From a managerial standpoint, however, the FOMF metric—

representing the realized financial effect of flexibility—provides a more practical basis for evaluating the profitability of expansion decisions. Similarly to the ROV analysis, the FOMF values linked to EBIT-based decision rules were consistently higher than those based on unit margin (see Figure 7).

Figure 7. *Sensitivity of the FOMF and ROV depending on the EBIT and unit margin trigger level.*



Source: *Own elaboration using Oracle Crystal Ball.*

Two additional decision rules were also tested. The first was based on the sum of FCFE (Free Cash Flow to Equity) from the two periods preceding the expansion opportunity.

The second used the average sales volume from the two preceding years as the trigger variable. In the FCFE-based sensitivity analysis, the maximum FOMF(FCFE) reached –2.9 thousand EUR at a 200 thousand EUR trigger.

For the sales volume–based analysis, the maximum FOMF (sales volume) amounted to–3.8 thousand EUR at a threshold of 9,000 units sold. In summary, none of the examined decision variables EBIT, unit margin, FCFE, or sales volume produced a positive expected value of FOMF for any of the tested trigger levels. This result demonstrates that, under the current design and risk assumptions, the proposed managerial flexibility has no positive economic value.

Therefore, managers should focus on implementing the base investment scenario, without acquiring additional land (the expansion option), since the potential benefits of extending the production capacity are not economically justified in the analyzed conditions.

5. Conclusions

5.1 Summary of Findings and Managerial Recommendations for this Project

The conducted simulations demonstrate that, under the assumed risk structure and rule-based decision conditions, the expansion flexibility fails to generate realized economic value. The Financial Outcome of Managerial Flexibility (FOMF) remains negative across all tested variables and thresholds, while the policy-constrained Real Option Value (ROV) remains non-negative, peaking at approximately 89.4 thousand EUR for an EBIT trigger of 200 thousand EUR.

This divergence confirms that, although the expansion right has theoretical potential, its execution as modelled here does not yield positive financial results once option costs and exercise probabilities are incorporated.

Importantly, the value of the option depends critically on both the choice of decision variable and the condition defining its exercise. Each combination of trigger and variable (EBIT, unit margin, FCFE, or sales volume) leads to a different valuation outcome, implying that managing the execution condition is itself a key component of flexibility design. The analysis also reveals that projects bearing the cost of acquiring and maintaining flexibility (e.g., additional land purchase) are exposed to higher variance of outcomes, thereby increasing the project's overall risk profile.

The assumption underpinning real options reasoning—that additional investment outlays should, on average, increase expected NPV—does not hold universally. As demonstrated, the mere availability of flexibility does not guarantee higher efficiency, and the option's utilization is not always optimal. A project that rarely executes its embedded option tends to have a lower expected value than the baseline, despite exhibiting slightly higher success rates when executed.

Conversely, options exercised more frequently show higher expected value but lower precision (more incorrect or loss-making executions). This trade-off highlights the managerial challenge of defining appropriate decision thresholds that balance flexibility with financial discipline.

From a practical standpoint, the exercise condition must be explicitly defined, operationally transparent, and empirically verified. Decision rules should be comprehensible to those executing them and tested for their empirical consequences—specifically, the share and impact of negative or erroneous executions. Establishing such rules at the stage of flexibility design—rather than post hoc—is essential; creating flexibility intuitively, without clearly defined conditions, risks reducing its economic usefulness.

Overall, under the present assumptions, the baseline investment without purchasing additional land remains the financially preferable policy. If expansion remains strategically desirable, flexibility should be redesigned and recalibrated: (i) reduce or make contingent the acquisition cost, (ii) implement staged or conditional CAPEX, and (iii) adopt multi-factor decision rules to raise the probability that option execution contributes positively to value creation.

5.2 Methodological Conclusions, Observations on Use, and Limitations

Methodologically, this study confirms that the combined use of Double Monte Carlo (2MC) and Simulation-Based Comparative Valuation (SCV) yields complementary insights into the dual nature of flexibility. The 2MC framework measures realized performance (FOMF), capturing both positive and negative outcomes, while the SCV framework reports a non-negative, policy-constrained Real Option Value (ROV) by truncating negative differentials to zero.

This two-metric approach allows a clear separation between potential and realized value, which is particularly decision-relevant when exercise follows observable, rule-based rather than optimized conditions.

The findings emphasize that the design and parameterization of the decision rule—particularly the choice of state variable and trigger threshold—constitute first-order determinants of both ROV and FOMF. Tightening the exercise condition (e.g., raising the EBIT threshold) reduces both expected and realized values, even though it lowers the rate of incorrect executions.

This pattern illustrates a central insight: the value of flexibility is maximized when it is used frequently, even at the expense of higher error probability. A model that remains dormant or executes rarely tends to underperform its baseline counterpart in expected terms, despite appearing more conservative.

Furthermore, the research assumes a rational decision-making framework, excluding behavioral effects such as anchoring, agency bias, or escalation of commitment. While this assumption facilitates analytical tractability, it limits realism. In practice, behavioral factors may significantly influence the timing and frequency of option exercise, potentially amplifying deviations from model predictions. Future extensions should thus explicitly test how bounded rationality and cognitive biases affect the empirical relationship between ROV and FOMF.

From an applied perspective, diagnostics beyond simple averages—such as execution frequency, share of zero payoffs, timing of exercises, and P(FOMF>0) should be systematically reported, as they enhance managerial interpretability of simulation-based models.

Nevertheless, several methodological limitations remain. The analysis concerns a stylized, single-product greenfield investment, with fixed capital structure and assumed risk distributions. Sequential or compound flexibilities, competitive behavior, financing frictions, and regulatory constraints were not modeled. The SCV approach represents a lower bound of theoretical option value, and both frameworks remain sensitive to parameter misspecification, trigger measurement errors, and omitted operational frictions (e.g., lead times, capacity ramp-up, financing covenants).

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