

Multi-Partner Research Projects: A Financial Risk Model of Clawback Exposure

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Abstract:

Collaborative research projects with pre-financed funding can expose the project coordinator to repayment risk if final eligible expenditure falls below the minimum level implied by the funding structure. This paper develops a probabilistic framework for estimating that risk. Annual project expenditure is modelled using bounded PERT distributions, and Monte Carlo simulation is used to generate project outcomes. From these simulation runs, the probability of falling below the expenditure threshold and a distribution of potential shortfalls is derived. The analysis further examines how early implementation performance and consortium structure influence financial risk. Based on the simulated results, an early-warning framework is developed that links observed interim expenditure to conditional estimates of remaining clawback risk and associated reserve needs. The proposed approach provides a practical basis for financial monitoring and reserve planning in multi-partner research projects.

Keywords: Monte Carlo simulation, project risk, expenditure threshold, early-warning system

1. INTRODUCTION

Collaborative research projects funded through public programmes may involve advance payments made at the beginning of the project period. Under such arrangements, part of the approved project budget is transferred at project start, before corresponding costs have been reported and verified, for example to support start-up activities. This pre-financing can create financial exposure for the project coordinator: implementation may begin more slowly than planned due to recruitment, procurement, contracting, or organizational delays affecting one or more project partners, while a substantial share of the funding has already been received and must ultimately be justified through eligible expenditure. The exposure is amplified when the payment made at project start significantly exceeds the final retained payment tranche, which is released only after project completion and verification of reported costs.

In such funding structures, the size of the retained final tranche implies a minimum expenditure level that must be reached if previously disbursed funding is to be fully retained; in the illustrative case used in this paper, this corresponds to 90% of the approved project budget. If total eligible expenditure remains at or above this level, the final tranche is paid in full or in proportion to the verified costs. If expenditure falls below it, the retained amount is insufficient to absorb the gap, and part of the funding already disbursed may need to be repaid. In this paper, repayment of previously disbursed funding is referred to as clawback, while the shortfall denotes the gap between realized expenditure and this minimum expenditure level. For the project coordinator, this creates a practical financial management challenge: during project execution, it becomes necessary to estimate the probability of falling below the threshold, the magnitude of any resulting

shortfall, and the point at which corrective measures, project extensions, or additional financial reserves should be considered.

To address this problem, the paper adopts a probabilistic simulation approach, recognizing that project outcomes are shaped by uncertainty and variability that may not be captured well by single-point planning assumptions (Ward & Chapman, 2003; Perminova et al., 2008). Annual project expenditure is modelled using bounded PERT distributions defined by minimum, most-likely, and maximum values. Monte Carlo simulation is then used to generate large numbers of simulation runs representing possible project expenditure outcomes over the project duration. From these simulated outcomes, governance indicators are derived, including the probability that total expenditure falls below the 90% expenditure threshold and the distribution of potential shortfalls.

The contribution of this paper is threefold. First, it introduces a probabilistic modelling framework for estimating expenditure underutilization and clawback risk in pre-financed collaborative research projects. The framework is applied to a simplified three-year project configuration and used to examine how alternative implementation and partner-structure assumptions influence financial risk. Second, it demonstrates how Monte Carlo simulation can translate uncertain project execution dynamics into practical financial risk metrics, including the probability of falling below the 90% expenditure threshold and the distribution of potential shortfalls. Third, the paper proposes a simple operational early-warning system that links observed interim project expenditure to conditional risk estimates and recommended reserve levels. Together, these elements provide a structured framework for translating uncertain project execution into quantitative financial indicators that support proactive financial governance in multi-partner research projects.

2. METHODOLOGY

This section defines a limited set of project parameters used to describe collaborative research projects in a way that supports comparison across different consortia. These parameters are then used to construct an illustrative example project for the subsequent analysis. The purpose of this example is not to reproduce any specific project in detail, but to provide a transparent basis for illustrating the calculations and deriving practical insights related to budget underutilization and end-of-project clawback risk.

2.1. Project parameters used for comparison

The example project used in this paper is described by a small set of parameters capturing aspects of size, duration, partner composition, funding structure, and expenditure behaviour relevant to the present analysis. The set is intentionally limited to quantities that are typically known or can be reasonably estimated during project execution; Table 1 distinguishes between project-level and partner-level parameters.

Table 1: Project parameters.

Parameter	Level	Description	Purpose
Total project budget	Project	Total approved funding volume	Defines the financial scale of possible shortfalls and clawback exposure
Number of partners	Project	Count of consortium partners	Defines the consortium structure used in the partner-level cases
Budget share per partner	Partner	Fraction of total budget allocated to each partner	Captures budget concentration across partners
Project duration	Project	Total duration (years)	Defines the time horizon of the simulation
Number of payout cycles	Project	Number of reporting/payment periods	Defines the timing of interim payment and monitoring points
Yearly budget consumption	Partner	Fraction of yearly budget consumed per partner	Represents expenditure realization in the simulation model

Probabilistic modelling is applied only to parameters that represent recurring uncertainty, most notably yearly budget consumption. Rare but high-impact events, such as partner dropout, are better treated separately as stress scenarios rather than as statistical inputs.

2.2. Estimating project parameters

Parameter values may be derived from internal project data, external reference data, or a transparent illustrative case. Internal data can be taken from comparable past projects; external data can come from published reports or surveys; and illustrative values can be chosen where neither source is available. The present paper uses an illustrative case, described in Section 3.

3. CASE DESCRIPTION

The parameters shown in Table 2 define the illustrative project used for the subsequent analysis. The selected values reflect a plausible project structure consistent with observations from collaborative, externally funded research projects in terms of scale, duration, partner composition, and funding rules, and are presented as an anonymized example rather than a specific identifiable project.

For the present analysis, financial risk is evaluated relative to a 90% expenditure threshold. This level follows directly from the illustrative payment structure, in which 10% of the funding is retained until project completion; if expenditure falls below 90%, the retained amount is insufficient to absorb the shortfall, and previously disbursed funding may need to be repaid.

Table 2: Project and funding parameters used in the simulation model.

<i>Parameter</i>	<i>Value</i>	<i>Description</i>
Total project budget	1 million EUR	Total approved funding volume
Number of partners	5 incl. project coordinator	Count of consortium partners
Budget share per partner	20%	Fraction of total budget allocated to each partner
Project duration	3 years	Total duration (years)
Number of payout cycles	4	Number of reporting/payment periods
Yearly budget consumption	From simulation model	Fraction of yearly budget consumed per partner

The payout schedule is:

- 30% at project start — before any costs are reported
- Up to 30% at the end of Year 1 — based on reported Year-1 expenditure
- Up to 30% at the end of Year 2 — based on reported Year-2 expenditure
- Remaining balance at project completion — nominally 10%

In the illustrative funding structure, the nominal final tranche of 10% implies a minimum expenditure level of 90% if previously disbursed funding is to be fully retained. The final payment may also exceed 10% if the Year-1 or Year-2 payments were reduced and the final verified expenditure is high enough to support payment of the unpaid balance.

4. SIMULATION MODEL

The analysis uses Monte Carlo simulation to estimate the range of possible financial outcomes for the illustrative three-year project (Zio, 2013). Rather than assuming a single expenditure outcome, the model generates many plausible realizations of annual budget consumption and evaluates how often total expenditure falls below the 90% expenditure threshold relevant for clawback risk. This allows financial risk to be assessed in probabilistic terms and supports the derivation of reserve and early-warning indicators.

Annual consumption ratios are modelled using bounded PERT distributions defined by minimum, most-likely, and maximum values. This formulation follows the classical PERT approach for uncertain activity modelling (Malcolm et al., 1959; Clark, 1962). The distribution is implemented as a beta distribution scaled to the corresponding minimum–maximum range, with weighting parameter $\lambda = 4$. This preserves the bounded nature of expenditure ratios while allowing a single most-likely region.

Baseline parameter values are chosen to represent conservative early implementation dynamics and are shown in Table 3.

Table 3: Baseline PERT values.

Project Year	Minimum	Most Likely	Maximum
Year 1	0.50	0.70	0.80
Year 2	0.70	0.85	1.00
Year 3	0.90	1.15	1.30

For the illustrative case, the approved project budget is assumed to be evenly distributed across the three years. Total project consumption ($total_PCR$) in each simulation run is therefore calculated as the mean of the three annual consumption ratios ($Year_1$, $Year_2$ and $Year_3$):

$$total_PCR = \frac{Year_1 + Year_2 + Year_3}{3} \quad (eq. 1)$$

In the present illustrative case, annual ratios are defined relative to the budget of the respective project year, while total project percentages are defined relative to the approved total project budget. This direct aggregation is valid only because the total budget is assumed to be evenly distributed across the three project years.

Shortfall is defined relative to the 90% expenditure threshold introduced in Section 3:

$$shortfall = \max(0, 0.90 - total_PCR) \quad (eq. 2)$$

Project outcomes were generated using 10,000 Monte Carlo simulation runs with a fixed random seed. Increasing the number of runs did not materially change the reported percentiles.

Risk metrics are computed directly from the simulated distribution. These include the probability of falling below the 90% expenditure threshold and the unconditional 90th percentile of the shortfall distribution. Conditional early-warning thresholds are estimated using a nearest-neighbour approach to obtain local estimates of the conditional 90th percentile shortfall as a function of project status. The neighbourhood size is set to approximately 10% of simulation runs; results remain stable for moderate variation in this parameter (5–15%).

For visualization, density histograms (50–60 bins) are used to represent the simulated distributions. Figures emphasize the 90% expenditure threshold and the proportion of outcomes below it in order to align the visual presentation with the decision context.

All calculations were implemented in Python using standard numerical libraries.

5. RESULTS

5.1. Modelling scenarios

The simulation framework is examined using three cases. Case A models expenditure uncertainty at the aggregated project level and serves as the primary operational model. Within Case A, two execution variants are considered: a baseline implementation scenario (A1) and an improved early-execution scenario (A2). Case B models five equal-budget partners independently and serves as a diversification benchmark; under baseline execution assumptions, this case is denoted B1. Case C extends the partner-level framework by introducing unequal partner budget

shares, allowing the effect of budget concentration to be examined; under the same baseline execution assumptions, this case is denoted C1. All cases use the same project parameters and simulation framework described in Sections 3 and 4.

5.2. Case A – project-level results

5.2.1. Baseline PERT

Under baseline assumptions (Year-1 PERT: 0.50 / 0.70 / 0.80), the simulated distribution indicates substantial risk of under-expenditure. Total project consumption falls below the 90% expenditure threshold in 68.5% of simulation runs, while 31.5% reach or exceed the threshold. Severe underperformance, expenditure below 80%, remains rare (1.1%).

The expected shortfall across all simulation runs is 2.55% of the total project budget. Conditional on a shortfall occurring, the mean shortfall is 3.72%, while the P90 shortfall reaches 6.55%. Figure 1 indicates that under baseline assumptions, the distribution is concentrated near but below the 90% expenditure threshold, while severe underperformance (<80%) remains uncommon. Under baseline conditions, the simulated P90 shortfall indicates that a substantial reserve may be needed.

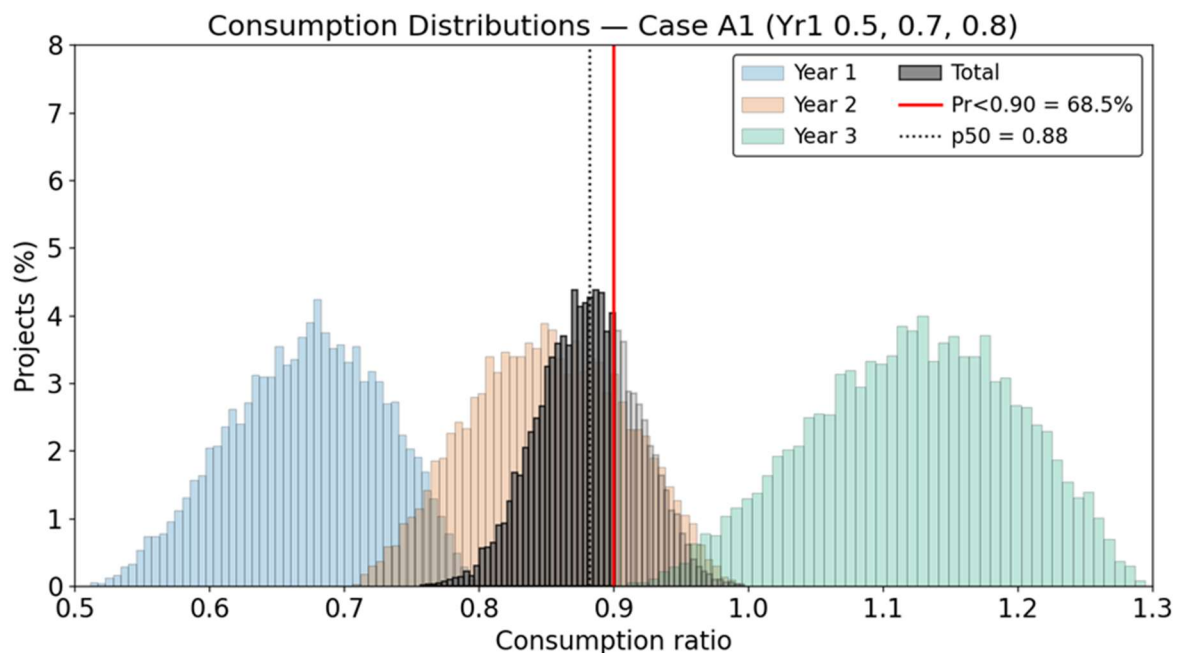


Figure 1: Distribution of simulated total project expenditure, expressed as a consumption ratio, under baseline execution assumptions (A1). The vertical markers indicate the median simulated outcome (P50) and the 90% expenditure threshold, with the latter highlighted in red. No-clawback outcomes (right of the threshold) are muted for clarity.

5.2.2. Improved early-year scenario

To examine sensitivity to early implementation, an alternative scenario shifts the Year-1 PERT parameters upward by 0.10 (0.60 / 0.80 / 0.90), preserving the distribution shape while improving early execution performance.

Under this assumption, the share of projects below the 90% expenditure threshold declines from 68.5% to 34.0%, while 66.0% reach or exceed the threshold. Severe underperformance, expenditure below 80%, becomes negligible (0.1%). The expected shortfall falls to 0.84%, while the conditional mean shortfall declines to 2.46% and the P90 shortfall to 3.22%, approximately half the baseline level.

Figure 2 shows a clear rightward shift in the distribution and a smaller shortfall tail. These results indicate that modest improvements in early execution can substantially reduce both clawback risk and reserve requirements.

A comparison of key risk metrics for Cases A1 and A2 is shown in Table 4.

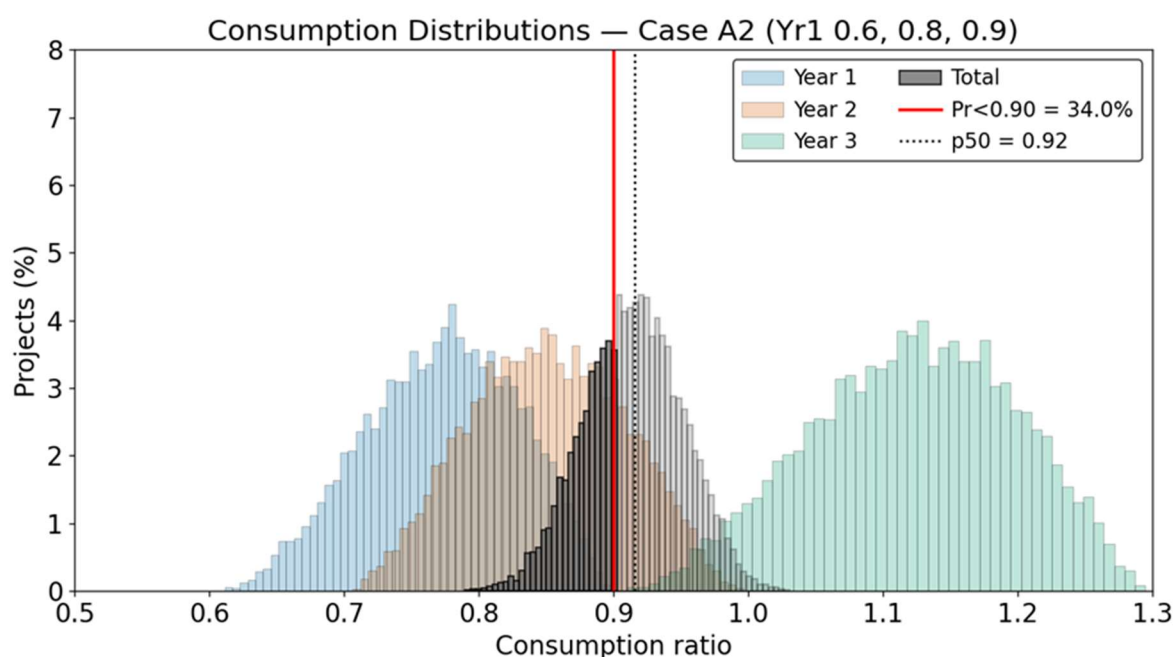


Figure 2: Distribution of simulated total project expenditure, expressed as a consumption ratio, under the improved early-execution scenario (A2). The vertical markers indicate the median simulated outcome (P50) and the 90% expenditure threshold, with the latter highlighted in red. No-clawback outcomes (right of the threshold) are muted for clarity.

Table 4: Comparison of key risk metrics for Cases A1 and A2.

Metric	A1 Baseline	A2 Improved Year 1
Projects below 90% threshold	68.5%	34.0%
Severe underperformance (<80%)	1.1%	0.1%
P90 shortfall	6.55%	3.22%
Mean shortfall (conditional)	3.72%	2.46%

5.3. Case B – independent partners (equal budgets)

Case B introduces partner-level modelling under a simplified equal-share structure in which five partners each receive 20% of the total budget and are simulated independently.

Under this assumption, the probability of falling below the 90% expenditure threshold increases to 87.7%, but the total project distribution becomes markedly narrower. Figure 3 shows that aggregation of independent partner trajectories reduces the severity of extreme shortfalls, even though moderate underutilization becomes more concentrated around the threshold. From a reserve-planning perspective, the main effect is a reduction in tail risk rather than a reduction in the probability of shortfall.

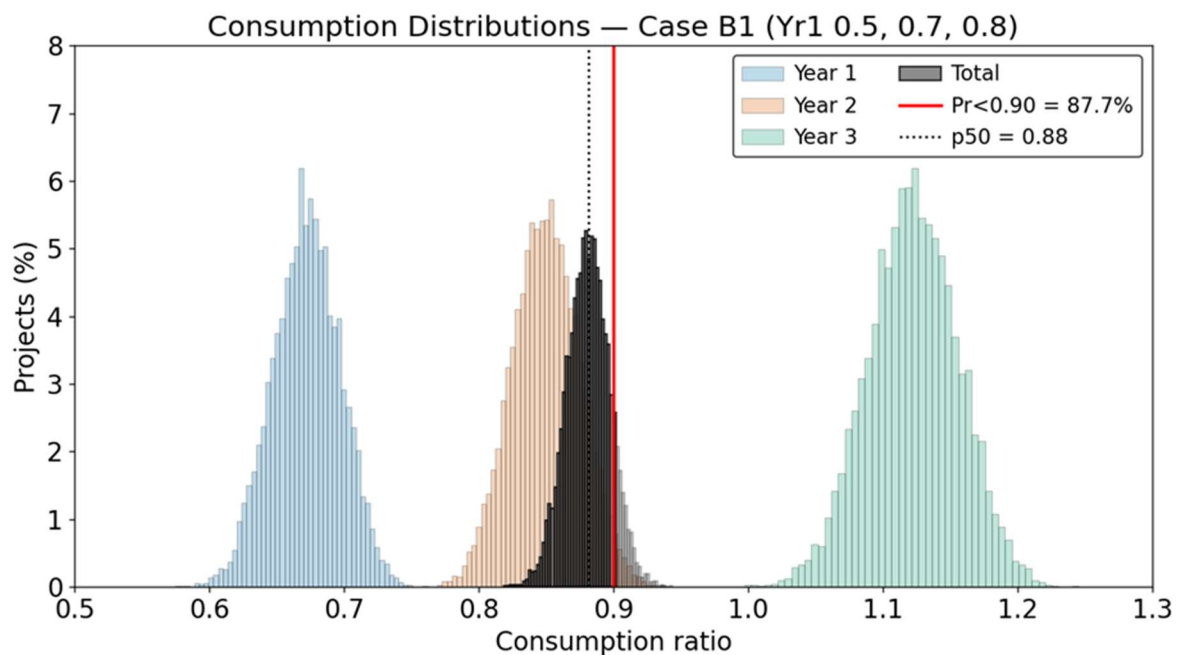


Figure 3: Distribution of simulated total project expenditure, expressed as a consumption ratio, under the independent partner scenario (B1). The vertical markers indicate the median simulated outcome (P50) and the 90% expenditure threshold, with the latter highlighted in red. No-clawback outcomes (right of the threshold) are muted for clarity.

5.4. Case C – unequal partner budgets

Case C extends the partner-level framework by introducing unequal partner budget shares: one partner receives 40% of the total budget and the remaining four partners 15% each.

Under this structure, the probability of falling below the 90% expenditure threshold is 84.9%, while the total project distribution becomes wider than in Case B. Figure 4 shows that budget concentration weakens the diversification effect observed under equal partner shares, increasing the sensitivity of project outcomes to the expenditure behaviour of the largest partner. However, because systemic execution effects may influence multiple partners simultaneously, Case A remains the preferred model for practical risk estimation in this paper.

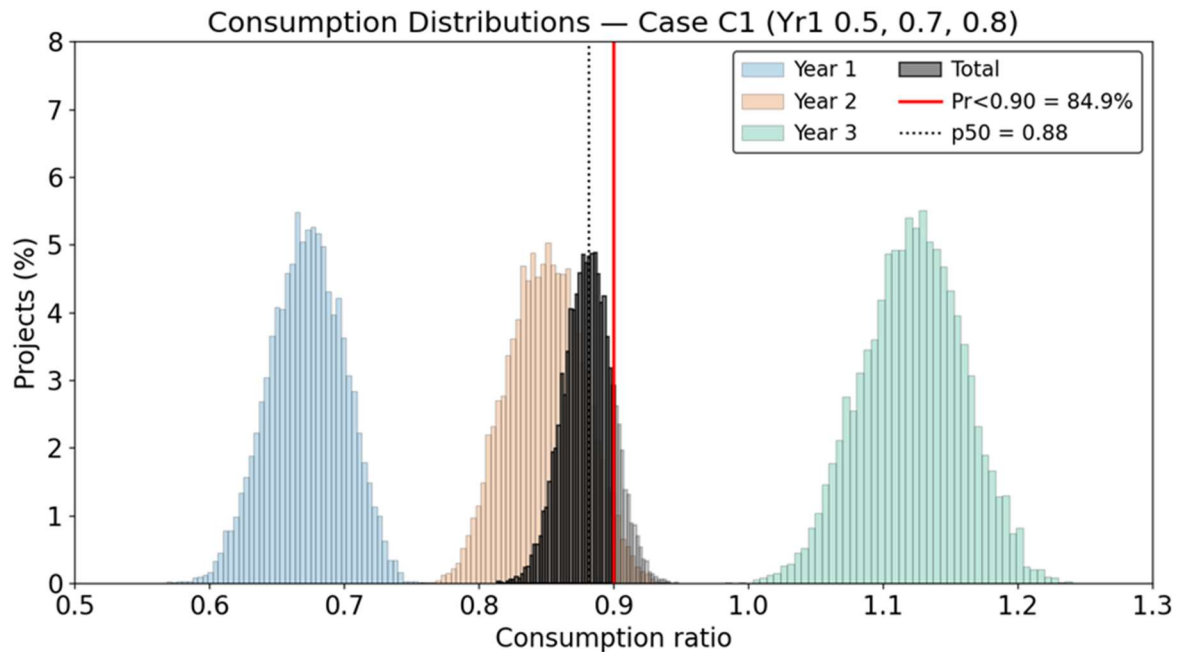


Figure 4: Distribution of simulated total project expenditure, expressed as a consumption ratio, under the unequal partner budget scenario (C1). The vertical markers indicate the median simulated outcome (P50) and the 90% expenditure threshold, with the latter highlighted in red. No-clawback outcomes (right of the threshold) are muted for clarity.

5.5. Early-warning system

The preceding simulations describe how execution dynamics and consortium structure influence the distribution of project outcomes. Building on these results, an operational monitoring framework is derived by conditioning simulated outcomes on observed interim expenditure.

Because the baseline scenario produces a large proportion of high-risk outcomes, the early-warning system is illustrated using the improved Year-1 execution scenario (A2). At the end of Year 1, project status is classified according to the observed expenditure (consumption ratio) into three monitoring zones: Critical, Manage, and On Track. Projects in the Critical zone face a high probability of falling below the expenditure threshold and may require escalation or corrective action. Projects in the Manage zone remain viable but may justify a reserve buffer. Projects classified as On Track exhibit sufficiently strong expenditure performance that clawback risk becomes negligible with high confidence.

Figure 5 shows the Year-1 classification. Under the improved scenario, 38.3% of projects fall into the Critical zone, 56.9% into Manage, and 4.8% into On Track.

For the Year-2 checkpoint, the monitoring indicator is defined as the average of the simulated consumption ratios of the first two project years. Figure 6 shows the corresponding classification at this stage. The share of projects classified as On Track increases to 21.8%, while 45.6% remain in Manage and 32.6% remain Critical.

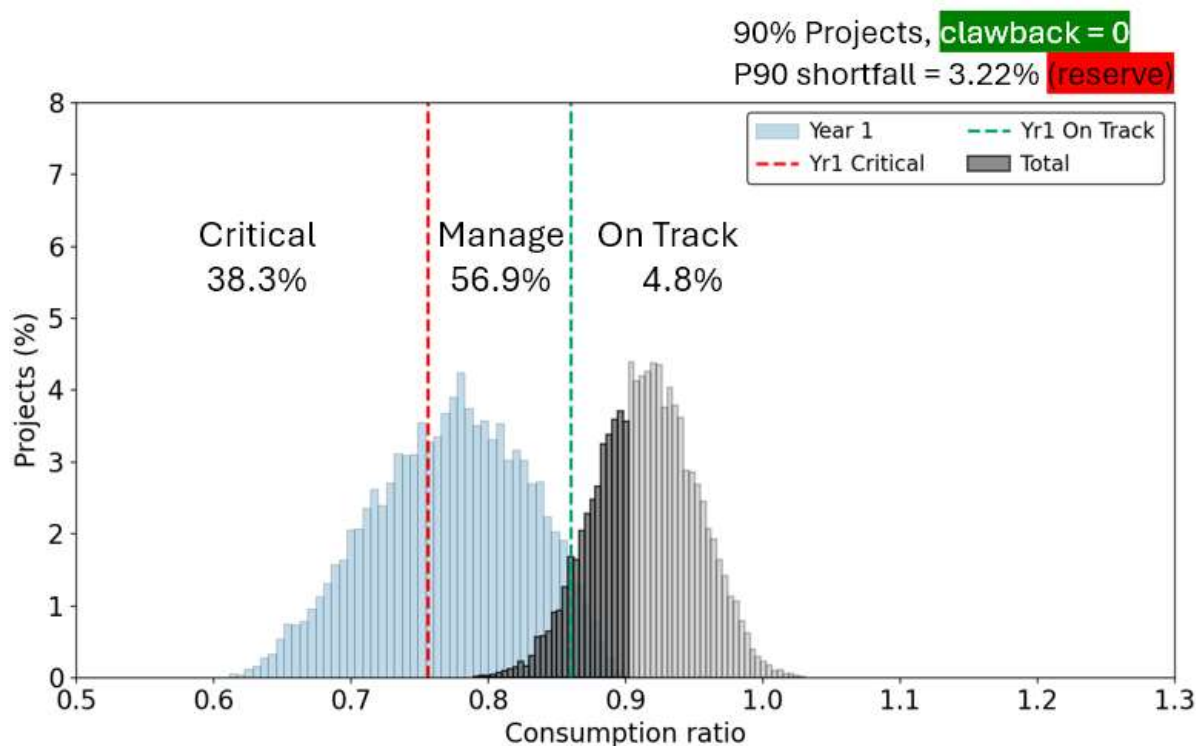


Figure 5: Year-1 early-warning classification under the improved execution scenario. Dashed lines indicate the boundaries between the Critical, Manage, and On-Track zones. No-clawback outcomes (right of the threshold) are muted for clarity.

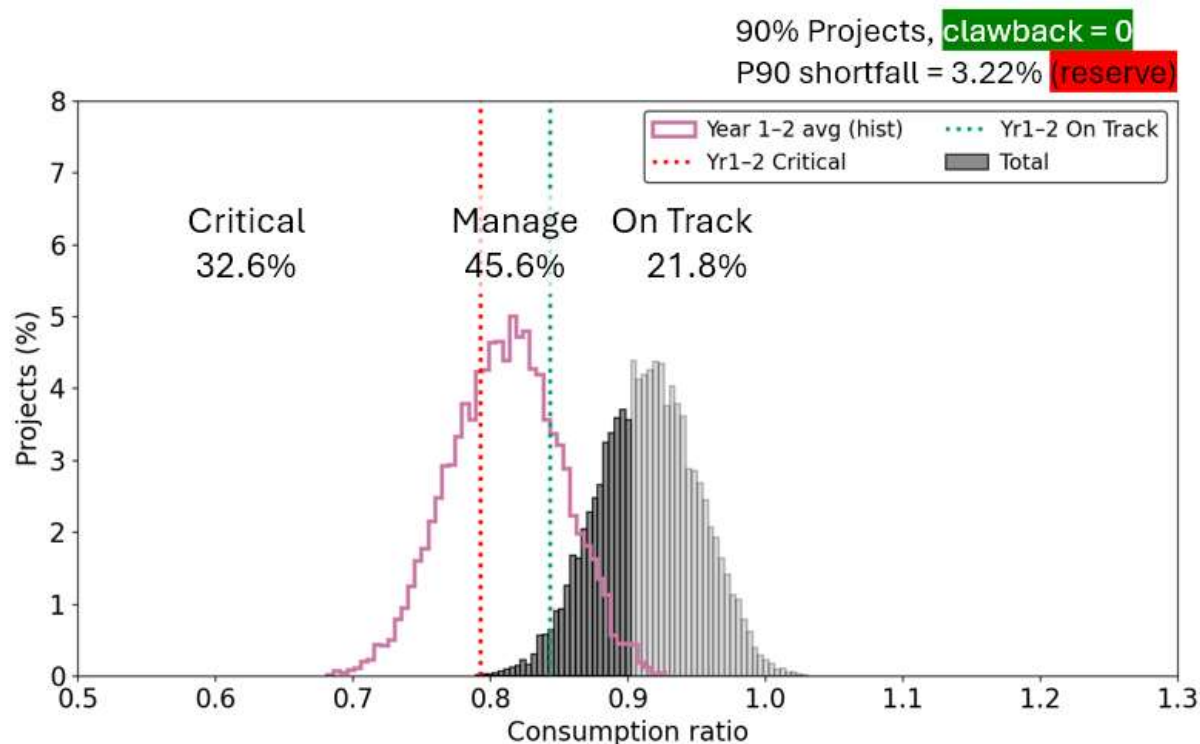


Figure 6: Early-warning classification at the Year-2 checkpoint. Dotted lines indicate the boundaries between the Critical, Manage, and On-Track zones. No-clawback outcomes (right of the threshold) are muted for clarity.

As the project advances, uncertainty about the final outcome decreases and the warning system becomes more decisive. For projects remaining in the Manage zone, the simulation results suggest reserve levels on the order of the conditional P90 shortfall, approximately 3.2% of the total project budget in the improved execution scenario. The operational thresholds are summarized in Table 5.

Table 5: Operational threshold, warning system and respective actions.

Monitoring point	Zone	Consumption ratio	Interpretation	Suggested action
End of Year 1	On Track	≥ 0.861	High confidence of reaching min. expenditure target	No reserve required
	Manage	$0.756 - 0.861$	Moderate risk of shortfall	Build ~2.5% reserve
	Critical	< 0.756	High clawback risk	Escalate; reserve requirement may approach ~3.2%
End of Year 2	On Track	≥ 0.844	High confidence of reaching min. expenditure target	No reserve required
	Manage	$0.793 - 0.844$	Moderate remaining risk	Ensure ~3.2% reserve
	Critical	< 0.793	High clawback risk	Escalate; reserve requirement may exceed ~3.2%

6. DISCUSSION

6.1. Financial reserve planning

The simulation results provide a quantitative basis for estimating reserve levels that may be needed to manage clawback risk in pre-financed research projects. In the illustrative case, the P90 shortfall serves as a practical reference point because it represents a reserve level sufficient to cover the majority of simulated outcomes.

Under the baseline scenario (A1), the P90 shortfall is 6.55% of the total project budget, indicating that slow early implementation can create a substantial contingency requirement. Under the improved early-execution scenario (A2), this value falls to 3.22%, showing that relatively modest improvements in Year-1 implementation can materially reduce reserve needs.

These results also distinguish between two types of financial exposure faced by a project coordinator. If total expenditure remains close to plan but still exceeds the 90% expenditure threshold, the effect may be limited to a reduced final payment. If expenditure falls sufficiently far below the threshold implied by the funding structure, however, part of the funding already disbursed may need to be repaid. In such cases, the project coordinator may temporarily need to absorb the gap until internal reallocations or partner-level adjustments can be made.

Reserve values derived from the simulation should therefore be interpreted as indicative planning ranges rather than fixed requirements. The appropriate reserve policy will depend on the financial strength of the consortium, the availability of corrective measures, the risk tolerance of the

project coordinator, and the financial provisions permitted under the applicable funding programme.

6.2. Operational monitoring and early-warning indicators

While the simulation model estimates end-of-project outcomes, management decisions must be made during project execution when only partial information is available. The proposed early-warning system addresses this problem by translating interim expenditure levels into conditional estimates of remaining clawback risk.

The framework is most informative under improved early execution, where a meaningful On-Track region emerges. It also becomes more informative as additional expenditure information becomes available, with the increase in the On-Track share from the Year-1 to the Year-2 checkpoint reflecting declining uncertainty about final outcomes.

From a governance perspective, the early-warning system links observed project status to management response. Projects in the Manage zone may justify reserve provision, while projects in the Critical zone may require stronger intervention, such as revised work plans, accelerated implementation, or discussions with the funding authority regarding possible adjustments in scope or timing. The framework is therefore not intended to predict final outcomes with certainty, but to support timely and proportionate action.

6.3. Structural risk factors in collaborative projects

In addition to implementation timing, consortium structure can influence project-level financial risk. The alternative modelling scenarios examined in this paper illustrate how aggregation assumptions and budget concentration affect the distribution of possible outcomes.

When partner expenditure is modelled independently with equal budget shares, the aggregation of several partners narrows the distribution of total project expenditure. In this setting, moderate underutilization becomes more concentrated around the threshold, but extreme shortfalls become less severe. This makes the equal-share partner model a useful benchmark for isolating diversification effects, even though it is unlikely to describe operational reality where systemic delays can affect several partners simultaneously.

Introducing unequal budget shares weakens this diversification effect. When one partner accounts for a large fraction of the total budget, project outcomes become more sensitive to that partner's expenditure performance, and the total expenditure distribution becomes wider. This highlights the financial relevance of budget concentration within a consortium and suggests that large budget holders may require closer monitoring.

These findings imply that partner structure should be considered as part of financial risk management during project design and negotiation. In addition, the partner-level formulations used in Cases B and C are also methodologically useful: they provide a flexible basis for future extensions, such as partner-specific expenditure distributions or correlated implementation risks. However, because delays or implementation problems may affect multiple partners simultaneously, Case A remains the preferred model for practical risk estimation in this paper.

7. CONCLUSION

This paper examined clawback risk in pre-financed collaborative research projects when total eligible expenditure falls below the 90% expenditure threshold implied by the funding structure assumed for the illustrative case. Because a substantial share of project funding may be disbursed before corresponding costs are reported, delays in implementation can create a risk that previously paid funds must be returned at project completion.

To analyze this risk, the paper developed a probabilistic framework in which annual expenditure is modelled using bounded PERT distributions and project outcomes are generated by Monte Carlo simulation. Applied to an illustrative three-year project, the model estimates both the probability of falling below the expenditure threshold and the distribution of potential shortfalls.

The results show that early implementation performance is a dominant driver of financial risk. Modest improvements in Year-1 expenditure substantially reduce both the likelihood of falling below the threshold and the reserve levels needed to manage potential clawback. The analysis also shows that consortium structure matters: equal partner shares reduce tail risk through diversification, whereas budget concentration increases sensitivity to the performance of large partners.

Building on these results, the paper proposes an early-warning framework that links observed interim expenditure to conditional estimates of remaining clawback risk. This provides project coordinators with a practical basis for reserve planning, escalation, and corrective action during project execution.

Although the analysis is based on a simplified illustrative case, the framework can be adapted to other project structures and funding rules. Future work could extend it by incorporating partner-specific expenditure distributions, correlated delays, partner withdrawal scenarios, or dynamic management responses.

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