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A rule-based decision analytics approach to sovereign debt restructuring under constrained equal awards and equilibrium restoration

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ABSTRACT

This paper examines sovereign debt restructuring as a decision problem over institutional rules. Creditors choose contractual face values within a borrower-authorized financing environment, the state of nature is realized, and repayment or restructuring follows. The constrained equal awards (CEA) rule is used as a counterfactual allocation benchmark rather than as a literal description of existing sovereign bankruptcy law. The model shows how a good-state repayment cutoff and a kinked recovery rule jointly create discontinuous creditor incentives. We derive explicit sufficient conditions for a repayment-compatible pure-strategy equilibrium and for an equilibrium in which good-state default persists because no single creditor can restore repayment. A proportional scaling clause is then introduced as a prescriptive benchmark. The computational analysis classifies grid equilibria over the (q, Δ) parameter map. Additional one-at-a-time parameter scenarios and grid refinements are evaluated by repeating the same classification procedure The resulting framework contributes to descriptive analytics by mapping claims into recoveries and repayment regimes, to diagnostic analytics by identifying whether instability originates in the repayment cutoff or the allocation rule, to scenario-based predictive analytics by tracing regime changes under parameter shocks, and to prescriptive analytics by comparing institutional modifications. For sovereign debt-management offices, multilateral institutions, restructuring advisers, and institutional investors, the model provides a transparent stress-testing protocol for screening rules that preserve repayment in viable states, limit coordination failures, and reduce avoidable social hardship.

1. Introduction

Sovereign debt repayment depends on incentives, reputation, and continued access to capital markets because ordinary collateral enforcement is limited. The legal and contractual architecture of restructuring therefore affects economic outcomes alongside fiscal capacity and macroeconomic conditions [1]. Dynamic sovereign-debt models explain how maturity, renegotiation, and market access shape default incentives [2]. Recent empirical evidence also shows that restructuring history can prolong speculative-grade rating phases [3], while sovereign credit-risk conditions can spill over to corporate investment [4].

Historical episodes make the institutional problem concrete. Argentina's post-2001 exchanges and holdout litigation illustrate how dispersed claims, secondary-market acquisition, and enforcement strategies can obstruct a widely supported restructuring. The Greek restructuring of 2012 illustrates the importance of collective-action mechanisms and the treatment of different creditor groups. Cross-country evidence confirms that restructuring timing and haircut design vary substantially across episodes [5]. Preemptive and post-default restructurings also generate different resolution paths [6]. More recent litigation and legislative initiatives surrounding Sri Lanka show that domestic enforcement law remains relevant even in the absence of an international sovereign bankruptcy court [7].

These cases also clarify the interpretation of the present model. Sovereign restructuring currently relies on contracts, negotiations, collective-action clauses, official-sector coordination, and domestic enforcement law. CEA is implemented by an abstract rule administrator and is used as a counterfactual allocation benchmark within a single creditor class. Its common-award cap creates a transparent kink in marginal recovery. Comparing this mapping with proportional treatment, contractual aggregation, or statutory scaling reveals how alternative allocation rules affect incentives before restructuring occurs.

The central mechanism is the interaction between a repayment cutoff and the recovery mapping. If aggregate promised claims remain below the cutoff, the debtor repays in the good state. If the cutoff

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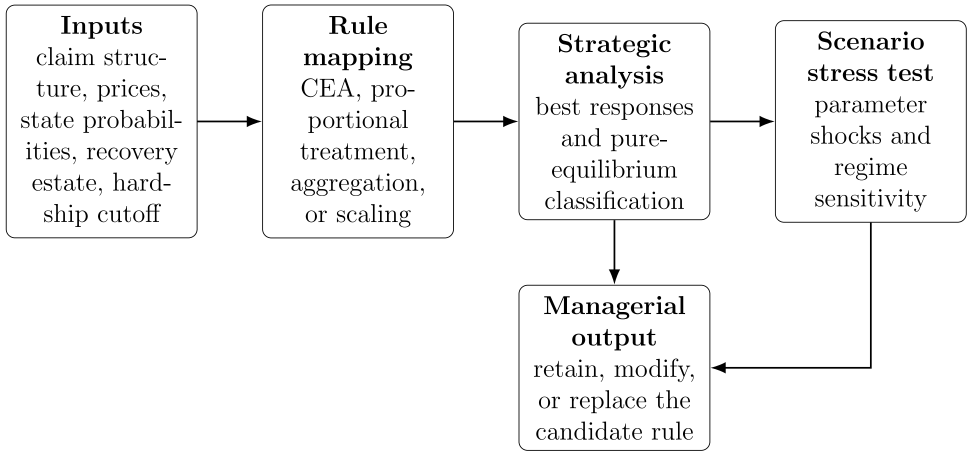

Fig. 1. Decision-analytics workflow for institutional rule screening.

is crossed, the good-state continuation changes discretely. In the restructuring state, CEA compresses the marginal recovery of sufficiently large claims. The combination creates a discontinuous game in which small changes in contractual burdens may alter repayment, default, and hardship outcomes.

Debt-management offices, multilateral institutions, restructuring advisers, creditor committees, and institutional investors must assess how a proposed rule distributes a limited recovery, whether it changes incentives before default, and whether it preserves repayment in economically viable states. The model converts these questions into payment vectors, best responses, equilibrium classifications, and parameter-sensitivity results. Structured decision frameworks have been used to rank financing constraints and possible responses [8], while review work in financial analytics documents the use of explicit risk and optimization models in decision support [9].

The paper contributes in four respects. First, it formulates a tractable sovereign-debt game in which the institutional mapping from claims to payments generates the strategic discontinuity. Second, it derives transparent sufficient conditions for two economically distinct pure-strategy outcomes: repayment at the cutoff and persistent good-state default. Third, it develops a parameter-space screening procedure and an illustrative computational map that distinguishes repayment-compatible, default, and multiplicity regions. Fourth, it translates the formal results into descriptive, diagnostic, scenario-predictive, and prescriptive decision-analytics outputs, summarized in Fig. 1.

The two-period structure is an intentional diagnostic reduction. Reputation, rollover risk, repeated borrowing, and endogenous market access are summarized by the state probabilities, the unit price of face value, and the repayment cutoff. This reduction isolates the incentive effect of the institutional rule within a single restructuring episode. A dynamic extension would make the cutoff depend on continuation values, while the discontinuity mechanism would remain whenever a threshold separates repayment from restructuring. The static model is therefore used as an institutional stress test rather than as a complete quantitative model of sovereign borrowing.

The model also records an avoidable-hardship externality associated with good-state default. The baseline normalization does not imply that a bad macroeconomic state is free of hardship. It isolates the incremental loss caused by default when repayment remains viable. A robustness extension allows positive good-state recovery and state-specific hardship costs, showing that the cutoff and discontinuity survive under less restrictive assumptions.

The remainder of the paper is organized as follows. Section 2 positions the model in the sovereign-default, restructuring-law, claims-division, limited-commitment, and decision-analytics literatures. Section 3 introduces the benchmark environment, its institutional interpretation, and its limitations. Sections 4 and 5 derive the repayment cutoff and the relevant CEA properties. Section 6 defines the equilibrium concepts and discusses mixed strategies. Section 7 presents the repayment and default equilibria and the illustrative parameter-space screen. Section 8 examines avoidable hardship. Section 9 discusses institutional alternatives, and Section 10 develops the managerial implications before Section 11 concludes. Technical proofs are collected in Appendix A.

2. Related literature

This section positions the model in four literatures that bear directly on the paper's mechanism: sovereign default and debt restructuring, bankruptcy rules and claims division, limited-commitment contracting with discontinuous incentives, and decision analytics for institutional rule evaluation. The emphasis is on how contractual promises, legal allocation rules, and repayment thresholds jointly determine creditor incentives before any default actually occurs.

2.1. Sovereign default and debt restructuring

Sovereign default theory treats repayment as an incentive problem shaped by reputation, renegotiation, and continued access to credit markets. Quantitative models formalize this logic by deriving default from the sovereign's optimization problem under stochastic income and limited commitment [2,10,11]. The present model retains the limited-commitment structure and isolates a static repayment cutoff, allowing the institutional rule itself to become the main object of analysis.

The cutoff perspective is related to work on equilibrium selection, debt dilution, and the maturity structure of sovereign liabilities. Unique-equilibrium results in canonical sovereign-debt environments clarify when strategic multiplicity can be ruled out, while debt-dilution models show how outstanding claims alter subsequent borrowing incentives [12,13]. These contributions motivate the paper's focus on the mapping from promised claims to enforceable repayment obligations.

Empirical research on restructuring episodes documents substantial heterogeneity in timing, recovery rates, and creditor losses. Preemptive and post-default restructurings follow different paths in terms of haircut severity and resolution timing, and historical haircut data show large variation across default episodes [5,6]. Broader surveys of sovereign debt and default provide the legal and empirical background for treating restructuring as an institutional problem rather than a purely contractual one [1,14]. Long-run evidence on debt relief further indicates that restructuring affects market access and macroeconomic performance beyond the immediate default episode [15].

The absence of a universal sovereign insolvency forum has generated a long-standing debate between contractual and statutory approaches. Krueger's Sovereign Debt Restructuring Mechanism (SDRM) placed a statutory framework at the center of this debate. In her direct discussion of sovereign debt restructuring, Krueger [16] examines the case for a more orderly restructuring process and considers the statutory SDRM alongside the contractual use of collective-action clauses [cf.17]. The broader legal and economic literature explains why sovereign immunity, dispersed governing laws, and heterogeneous creditor groups prevent a direct transplantation of corporate bankruptcy [1]. Recent comparative work shows that current statutory initiatives operate through domestic limits on enforcement, safe harbors, and anti-holdout legislation rather than through a single global liquidation court [7]. This institutional background motivates the paper's treatment of CEA as a rule-evaluation benchmark rather than as a description of prevailing sovereign practice.

Institutional responses to sovereign distress also shape repayment incentives. Bailout and conditionality arrangements alter the debtor's continuation value and repayment calculus [18]. At the same time, sovereign crises interact with the banking sector through balance-sheet exposure, funding conditions, and crisis spillovers [19,20]. The distinction between systemic and idiosyncratic sovereign crises, together with evidence on European banks during sovereign-debt turmoil, shows why restructuring rules may have consequences outside the bilateral debtor-creditor relation [21,22].

Recent measurement and pricing studies add a market-facing perspective. Restructuring history, nominal relief, and prolonged market exclusion are associated with longer speculative-grade rating cycles [3]. Sovereign CDS spreads and ratings provide different signals of sovereign risk [23]. Recent evidence also links sovereign CDS conditions to corporate investment decisions [4]. These findings reinforce the practical relevance of institutional rule design because restructuring outcomes affect financing conditions beyond the immediate sovereign-creditor relationship.

The welfare and policy dimensions of default are equally relevant for a rule-evaluation model. Empirical work on the costs of default points to contractionary effects operating through credit channels, while crisis-policy studies show that fiscal and monetary responses can shape firm-level outcomes during severe downturns [24,25]. Political-economy accounts of debt management add a distributional channel by linking public debt to social conflict and social peace [26]. These strands motivate the paper's hardship externality and its focus on good-state default as a socially costly outcome.

2.2. Bankruptcy rules and claims division

The claims-division literature provides the formal language for analyzing how a fixed estate should be distributed among competing creditors. The constrained equal awards rule is a central benchmark because it protects small claims up to a common award level and gives the allocation rule a transparent truncation structure [27,28]. In the present model this truncation property matters strategically, since it changes the marginal value of increasing face value once a creditor's claim exceeds the award level.

Fairness constraints in allocation problems also have an efficiency cost. Operations-research work on the price of fairness quantifies the welfare loss that may arise when equal-treatment restrictions are imposed on an otherwise efficient allocation, and algorithmic-fairness research highlights how rule-based systems depend on explicit normative choices [29,30]. This paper uses those insights to read CEA as an institutional design rule with both distributional and incentive effects.

Cost-sharing and cooperative-game foundations supply additional structure. The serial cost-sharing method is relevant because it relies on consistency and monotonicity properties close to those used in claims-division problems [31]. Cooperative market games, in turn, clarify how allocation rules and stability concepts are linked in settings where claims over a common surplus must be reconciled [32].

Financial-network models extend claims division from bilateral contracts to systems of interdependent obligations. Multilayered obligations with physical delivery show how payment cascades can propagate through contractual networks [33]. The sovereign setting studied here is deliberately more stylized, yet the same lesson carries over: an allocation rule affects the burden borne by each creditor and may change incentives before the allocation is ever applied.

2.3. Discontinuous incentives and limited commitment

The discontinuity in the model is generated by the legal-economic environment. Once aggregate face values cross the repayment cutoff, the debtor's continuation regime changes, and creditors' expected payoffs shift discretely. Corporate-finance theory explains why pledgeability, liquidity, and moral-hazard constraints can create sharp contractual margins in financing problems [34,35]. This gives the cutoff mechanism a broader contracting foundation.

State subsidy and moral hazard in corporate financing provide a useful analogue, because subsidy rules can alter private incentives and generate threshold effects in financing choices [36]. In the sovereign model, the bankruptcy rule plays a related institutional role: it changes the payoff consequences of face-value choices and may thereby affect equilibrium existence.

Limited commitment also appears in formal accounts of contract enforcement and debt structure. Work on contract-enforcement efficiency links institutional enforceability to debt maturity, while corporate loan-pricing evidence shows that creditors adjust pricing after credit-market disruptions [37,38]. These results support the paper's modeling choice that creditors respond to the institutional mapping from promised claims to expected recovery.

2.4. Decision analytics and operations research

The paper's decision-analytic contribution lies in using a formal model to compare how legal and contractual rules shape *ex ante* behavior and equilibrium outcomes. Analytical frameworks provide systematic tools for identifying and prioritizing financing constraints [8], while review work synthesizes the principal risk-pricing and optimization approaches used in financial analytics [9]. The present analysis applies these analytical principles to institutional rule comparison. Its object is the equilibrium regime induced by a specified mapping from claims to recoveries, rather than the statistical prediction of an unconditional default probability.

Multiple-criteria decision analysis offers tools for evaluating institutional designs along several dimensions at once. MCDM methods have been applied to financial risk analysis and clustering of risk profiles, while broader surveys of multiple-criteria decision analysis systematize the available methods for ranking and comparing alternatives [39,40]. The analytic hierarchy process supplies a complementary framework for structured evaluation when institutional alternatives must be assessed against several objectives [41].

Decision-support research in finance and operations includes optimization-based planning, network prediction, and efficiency measurement [42–44]. These studies are methodologically adjacent rather than direct foundations of the present model: they illustrate how explicit assumptions, constraints, and decision criteria can be translated into auditable analytical outputs. The substantive foundations of the analysis remain the sovereign-debt, claims-division, and limited-commitment literatures.

3. Model

This section introduces a reduced-form institutional environment. It specifies a borrower-authorized financing program, creditor-side face-value choices, a good-state repayment decision, an automatically triggered restructuring state, and an allocation rule for the effective distributable recovery. The rule administrator represents the contractual, statutory, or negotiated mechanism that applies the selected recovery mapping. Table 1 summarizes the baseline notation.

Table 1
Summary of notations.

Symbol	Meaning
D	The debtor (interpreted as a sovereign or public debtor)
$N = \{1, \dots, n\}$	Set of creditors
$\Omega = \{\omega_G, \omega_B\}$	Finite state space: ω_G (good) and ω_B (bad)
$\pi_G \in (0,1)$	Probability of the good state ω_G
$\pi_B = 1 - \pi_G$	Probability of the bad state ω_B
$F = (F_1, \dots, F_n) \in [0, \overline{F}]^n$	Creditor-side face-value exposures chosen within a borrower-authorized financing program
$q \in (0,1)$	Exogenous price per unit of contractual face value at $t = 0$
$S(F) = \sum_{i=1}^n F_i \geq 0$	Total promised burden (aggregate face value)
$Y(\omega) > 0$	Debtor's gross resources in state ω
$\underline{Y} = Y(\omega_B) > 0$	Resources in the bad state
$\overline{Y} = Y(\omega_G) > \underline{Y}$	Resources in the good state
$a(\omega_G) \in \{R, D\}$	Debtor action in the good state: R (repayment) or D (default/restructuring)
$\Delta > 0$	Poverty/hardship loss if $a(\omega_G) = D$
$E(\omega) \geq 0$	Effective distributable recovery assigned by the institutional rule in state ω
$E(\omega_B) = \underline{Y}$	Estate in bad-state bankruptcy
$E(\omega_G) = 0$	Baseline normalization of unsecured good-state recovery
$\lambda(F, E) \geq 0$	CEA award level satisfying $\sum_i \min\{F_i, \lambda(F,E)\} = \min\{E, S(F)\}$
$p_i(F, E)$	CEA payment to creditor i: $p_i = \min\{F_i, \lambda(F,E)\}$
$U_i(F) \in \mathbb{R}$	Creditor i's expected net payoff
$\mathrm{Pov}(\omega, F) \in \{0, 1\}$	Poverty indicator: $\mathrm{Pov}(\omega, F) = 1$ iff $\omega = \omega_G$ and $a(\omega_G) = D$
$\alpha(F) \in (0, 1]$	Statutory scaling factor applied to good-state face values under SSC

3.1. Agents, timing, and strategies

There is one debtor D and n strategic creditors. The model begins after the debtor has authorized the admissible set of creditor exposures, $[0, \overline{F}]^n$. At time $t = 0$, creditor i chooses the face-value exposure $F_i \in [0, \overline{F}]$ that it is willing to hold and advances qF_i, where $q \in (0, 1)$ is the exogenous price per unit of face value. Aggregate financing, $qS(F)$, is therefore determined by creditors' choices within the debtor-authorized set. The model does not include a separate sovereign issue-size or acceptance decision; introducing such a decision would require an earlier stage of the game.

At time $t = 1$, nature draws $\omega \in \{\omega_G, \omega_B\}$. The state is publicly observed in the complete-information benchmark. In the good state, the debtor chooses repayment or restructuring. In the bad state, the restructuring regime is triggered exogenously, which allows the analysis to focus on the allocation of the effective recovery $E(\omega_B) = \underline{Y}$. The rule administrator then applies CEA or another candidate allocation mapping.

3.2. Resources and the poverty externality

The debtor has state-dependent gross resources $Y(\omega_G) = \overline{Y}$ and $Y(\omega_B) = \underline{Y}$, with $\overline{Y} > \underline{Y} > 0$. The good state represents a situation in which full repayment is technologically feasible for moderate promised burdens. The bad state represents a crisis or restructuring state. Throughout the baseline analysis, $0 < \Delta \leq \overline{Y}$, so the good-state repayment cutoff lies inside the feasible resource region.

The parameter Δ measures the incremental hardship generated by avoidable good-state default. It can represent disrupted public services, an additional credit contraction, emergency fiscal adjustment, or other real losses caused by entering restructuring despite a viable repayment state. Baseline bad-state hardship is treated as common across the candidate institutional rules and is therefore omitted from their comparison. Section 3.5 introduces a separate bad-state hardship term and positive good-state creditor recovery.

3.3. Bankruptcy rule: constrained equal awards (CEA)

When restructuring occurs, a rule administrator allocates an effective distributable recovery $E(\omega)$ across creditors. This administrator is an abstraction for a contractual exchange, creditor committee, statutory enforcement rule, or negotiated restructuring mechanism. CEA gives each creditor the same award up to its claim. The rule is used because its cap creates a transparent marginal-recovery kink; CEA is analyzed as a counterfactual benchmark alongside *pari passu* proportional treatment.

Definition 1 (*Constrained Equal Awards (CEA)*). Fix claims $F = (F_1, \dots, F_n) \in [0, \overline{F}]^n$ and an effective recovery $E \geq 0$. The CEA allocation is $p(F, E) = (p_1, \dots, p_n)$, where

$$p_i(F, E) = \min\{F_i, \lambda(F, E)\}, \tag{1}$$

and $\lambda(F, E)$ is chosen so that

$$\sum_{i=1}^{n} p_i(F, E) = \min\{E, S(F)\}. \tag{2}$$

If $E \geq S(F)$, all claims are paid in full. If $E < S(F)$, the common award exhausts the effective recovery.

The baseline sets $E(\omega_B) = \underline{Y}$ and $E(\omega_G) = 0$. The latter is a normalization of effective unsecured recovery under sovereign immunity, asset sheltering, and incomplete enforcement. The zero-recovery baseline captures limited unsecured enforcement despite positive good-state sovereign resources. Section 3.5 shows that the strategic discontinuity persists when $E(\omega_G) > 0$.

3.4. Payoffs

If the debtor repays in the good state, creditor i receives F_i. If good-state restructuring occurs in the baseline, the creditor receives $p_i(F, 0) = 0$ and society incurs the incremental hardship Δ. In the bad state, the restructuring rule assigns $p_i(F, \underline{Y})$. Creditors are risk neutral, and creditor i's expected net payoff is

$$U_i(F) = \pi_G \mathbf{1}_{\{a(\omega_G)=R\}} F_i + \pi_B p_i(F, \underline{Y}) - qF_i. \tag{3}$$

The cost qF_i is paid *ex ante*. The face-value choice therefore trades off expected recovery against the cost of acquiring the exposure.

3.5. Robustness to positive good-state recovery and state-specific hardship

The baseline normalization can be relaxed without removing the mechanism. Let $E_G \geq 0$ denote effective creditor recovery following good-state restructuring and let $H_G \geq 0$ denote the associated real hardship. The debtor's good-state payoff is $\overline{Y} - S(F)$ under repayment and $\overline{Y} - E_G - H_G$ under restructuring. The generalized repayment cutoff is therefore

$$S(F) \leq \tau_G := E_G + H_G. \tag{4}$$

The baseline is the special case $E_G = 0$ and $H_G = \Delta$. Creditor i's generalized expected payoff is

$$U_i^G(F) = \pi_G \left[\mathbf{1}_{\{S(F)\leq\tau_G\}} F_i + \mathbf{1}_{\{S(F)>\tau_G\}} p_i(F, E_G) \right] + \pi_B p_i(F, \underline{Y}) - qF_i. \tag{5}$$

At the cutoff, the size of the good-state payoff jump is $\pi_G[F_i - p_i(F, E_G)]$. Hence the discontinuity remains whenever restructuring provides less than full good-state recovery. A separate bad-state hardship $H_B > 0$ can be added to social welfare. Since H_B is common to the candidate allocation rules when the bad-state continuation is fixed, it does not alter creditors' best responses in the baseline game.

3.6. Decision-analytic interpretation

Let $\theta = (n, \pi_G, q, \underline{Y}, \overline{Y}, \Delta, \overline{F})$ collect the baseline parameters, and let $\mathcal{E}(\theta, \mathcal{I})$ denote the pure-strategy equilibrium set generated by institutional rule $\mathcal{I}$. The rule-screening output is classified as

$$C(\theta, \mathcal{I}) = \begin{cases} \mathsf{R}, & \mathcal{E} \neq \emptyset \text{ and every } F^* \in \mathcal{E} \text{ satisfies } S(F^*) \leq \Delta, \\ \mathsf{D}, & \mathcal{E} \neq \emptyset \text{ and every } F^* \in \mathcal{E} \text{ satisfies } S(F^*) > \Delta, \\ \mathsf{M}, & \mathcal{E} \text{ contains both repayment-compatible and default equilibria}, \\ \mathsf{N}, & \mathcal{E} = \emptyset. \end{cases} \tag{6}$$

The four labels distinguish a repayment region, a default region, a multiplicity region, and a formal nonexistence region. The analytical results below characterize regions R and D, while the computational illustration identifies R, D, and M cells for the selected parameter grid. Category N is retained for completeness.

For each candidate rule, the analysis reports the induced payment structure, the source of strategic instability, the sensitivity of the equilibrium classification to parameter changes, and the institutional modifications capable of restoring repayment-compatible outcomes.

3.7. Institutional interpretation and scope

CEA is applied to one stylized creditor class with a common unit price and risk attitude. Actual sovereign debt includes bondholders, official bilateral creditors, multilateral institutions, domestic banks, and other claimants. These classes differ in maturity, governing law, seniority, enforcement options, and political objectives. The model also abstracts from holdout acquisition in secondary markets. A heterogeneous extension would replace q by class-specific prices q_{ik}, introduce class-specific recovery mappings, and impose seniority or comparability-of-treatment constraints across classes.

For contractual bondholders, proportional treatment is often the more natural benchmark. If all claims rank pari passu and $E < S(F)$, the proportional allocation is $p_i^P(F, E) = EF_i/S(F)$. CEA intentionally departs from this mapping by protecting smaller claims up to a common award. The purpose of the comparison is to identify the incentive consequences of alternative mappings. CEA is used as a counterfactual comparator to proportional treatment.

CEA is a reasonable benchmark for a single pool of legally comparable unsecured claims, a fixed distributable estate, and an explicit normative objective of protecting smaller claims through a common award. Its interpretation ceases to be valid as a direct description of the restructuring process once priority, collateral, official-sector exemptions, different governing laws, class-specific bargaining power, or strategic holdout enforcement determine recoveries. Such settings require prior segmentation of claims into legally and economically comparable classes. CEA can then be retained as a within-class counterfactual, but not as a representation of the complete sovereign restructuring.

The sovereign's issue-size decision is not modeled. The admissible exposure set $[0, \overline{F}]^n$ is interpreted as having been authorized by the debtor, but aggregate financing $qS(F)$ remains determined by creditors' choices within that set. Endogenous debt demand, issuance acceptance, and bargaining over the total financing amount would require a preceding sovereign decision stage. Such an extension would be necessary for quantitative analysis of borrowing demand, while the present formulation isolates the interaction between creditor choices and the restructuring rule.

The complete-information and static assumptions serve the same isolating purpose. Noisy state signals would make the cutoff belief-dependent, and repeated interaction would introduce reputation, rollover risk, and endogenous market access. These mechanisms can shift the location of the cutoff and alter the price q. They do not eliminate the rule-induced regime switch whenever contractual burdens cross a repayment threshold.

4. Debtor incentives and the repayment cutoff

In this section we derive the debtor's repayment cutoff and show how it turns the strategic environment into a regime-switch problem. The cutoff is the key object: it is a simple inequality in the aggregate debt burden that separates repayment from bankruptcy. Once combined with CEA, the cutoff may induce discontinuous changes in creditors' incentives, which is the key mechanism emphasized in the paper. Since the state is realized only after creditors choose their contractual face values, creditors take expectations at date 0 and cannot condition their lending choices on the realized state.

Lemma 1 (*Repayment Cutoff in the Good State*)**.** *Let us assume repayment in the good state is technologically feasible whenever $S(F) \leq \overline{Y}$. Then in ω_G the debtor chooses R if and only if $S(F) \leq \Delta$, and it chooses D whenever $S(F) > \Delta$. In particular, the debtor's good-state action is a threshold event in the total face value.*

For the proof see Appendix A.1.

The cutoff is a compact representation of limited commitment. The debtor compares the contractual burden of repayment with the combined recovery and hardship cost of restructuring. The generalized expression in (4) shows that positive creditor recovery shifts the threshold without removing it. For decision-makers, the distance $\tau_G - S(F)$ is a directly interpretable resilience margin: small positive values indicate that modest changes in claims or enforcement may trigger a regime switch.

Proposition 1 (*Discontinuity of the Payoff Mapping*)**.** *Let us suppose that the repayment cutoff is given by Lemma 1. Then the creditors' payoff functions are generally discontinuous on the hypersurface*

$$S(F) = \Delta.$$

For the proof see Appendix A.2.

The discontinuity is generated by the institution rather than by an arbitrary non-smooth preference. Immediately below the cutoff, an additional unit of face value can receive good-state repayment. Immediately above it, the same unit is valued only through restructuring recovery. Under positive good-state recovery, the jump narrows to $\pi_G[F_i - p_i(F, E_G)]$ but remains economically relevant whenever recovery is incomplete.

Corollary 1 (*Implication for Equilibrium Analysis*)**.** *Under Proposition 1, continuity-based equilibrium theorems cannot be invoked without additional argument. The discontinuity alone does not prove that a pure-strategy equilibrium fails to exist. Existence, multiplicity, and regime selection must* *be established from the best-response structure for the relevant parameter region.*

5. CEA structure and explicit recoveries in the bad state

The key discontinuity mechanism relies on the fact that CEA compresses marginal incentives in bankruptcy. This section records two elementary properties of CEA that are used in the equilibrium analysis. The first property is existence and monotonicity of the award level, while the second property gives explicit formulas in a region where some creditors are fully paid and a large claimant is partially paid.

Lemma 2 (*Existence and Monotonicity of the CEA Award Level*)**.** *Let us fix $F \in \mathbb{R}^n_+$ and $E \in [0, \sum_i F_i]$. Define the CEA award level by the canonical selection*

$$\lambda(F, E) := \inf \left\{ \lambda \geq 0 : \sum_{i=1}^{n} \min\{F_i, \lambda\} \geq E \right\}.$$

Then $\sum_i \min\{F_i, \lambda(F,E)\} = E$ whenever $E < \sum_i F_i$, and the induced payment vector is uniquely defined by $p_i(F, E) = \min\{F_i, \lambda(F, E)\}$. The map $E \mapsto \lambda(F, E)$ is nondecreasing. Moreover, for each i, holding F_{-i} and E fixed, the payment $p_i(F, E)$ is nondecreasing in F_i.

For the proof see Appendix A.3.

Own-claim monotonicity means that a larger face value cannot reduce the creditor's gross CEA recovery. The marginal gain can nevertheless fall to zero once the claim is capped by the common award. The strategic problem arises from this flat recovery region combined with the positive acquisition cost qF_i.

Lemma 3 (*Explicit CEA Payments for Three Creditors*)**.** *Let $n = 3$ and reorder claims so that $F_1 \leq F_2 \leq F_3$. If $\underline{Y} \in (F_1 + F_2, F_1 + F_2 + F_3)$ and $\lambda(F, \underline{Y}) \geq F_2$, then the award level is $\lambda(F, \underline{Y}) = \underline{Y} - F_1 - F_2$. In that case, the bad-state payments satisfy $p_1 = F_1$, $p_2 = F_2$, and $p_3 = \underline{Y} - F_1 - F_2$.*

For the proof see Appendix A.4.

In the stated region, the two smaller creditors are paid in full and the largest creditor absorbs the residual. Raising the largest face value leaves its gross recovery unchanged while increasing its acquisition cost. This provides a transparent diagnostic of the recovery kink that shapes best responses.

6. Equilibrium concept

We analyze equilibrium in the creditors' face-value game induced by the debtor's cutoff rule. The debtor's date-1 action maps the face-value profile F into repayment or bankruptcy regimes. Since the state space is finite and the debtor's best response is explicit, existence of a pure-strategy subgame perfect equilibrium reduces to existence of a pure-strategy Nash equilibrium in the $t = 0$ game.

The equilibrium analysis can be interpreted as the study of a finite-dimensional discontinuous game. In contrast to standard continuous games, small changes in contractual face values may induce discrete changes in the debtor's repayment regime and therefore in creditors' payoff functions. This feature motivates explicit attention to pure-strategy equilibrium existence.

Definition 2 (*Best-response Correspondence*)**.** For each creditor i and any given F_{-i}, the best-response correspondence is defined as

$$BR_i(F_{-i}) = \operatorname*{argmax}_{F_i \in [0, \overline{F}]} U_i(F_i, F_{-i}), \tag{7}$$

where U_i is given by (3) and the debtor's action is determined by Lemma 1.

Definition 3 (*Pure-strategy Nash Equilibrium*)**.** A profile $F^* \in [0, \overline{F}]^n$ is a pure-strategy Nash equilibrium if, for every creditor i and every alternative $F_i \in [0, \overline{F}]$,

$$U_i(F_i^*, F_{-i}^*) \geq U_i(F_i, F_{-i}^*), \tag{8}$$

where U_i is defined in (3) and the debtor's action $a(\cdot)$ is given by Lemma 1. The equilibrium is noncooperative in the sense that creditors cannot coordinate or sign binding collective-action clauses at $t = 0$.

Definition 4 (*Pure-Strategy Subgame Perfect Equilibrium*)**.** A pure-strategy subgame perfect equilibrium consists of a face-value profile $F^* \in [0, \overline{F}]^n$ and a good-state debtor strategy $a_G^* : [0, \overline{F}]^n \to \{R, D\}$ such that:

(1) for every face-value profile $F \in [0, \overline{F}]^n$, $a_G^*(F)$ maximizes the debtor's good-state payoff given F; and
(2) F^* is a pure-strategy Nash equilibrium of the creditors' date-0 game induced by the continuation strategy a_G^* and the institutional recovery rule.

The bad-state restructuring continuation is fixed exogenously in the baseline model. The bad state is interpreted as a crisis state in which restructuring occurs, and creditors' payments are determined by the institutional recovery rule.

The main analysis uses pure strategies because implemented debt contracts are deterministic objects and the institutional screening exercise seeks a transparent face-value profile and repayment regime. Pure-strategy fragility is therefore a relevant policy outcome even when randomization is mathematically available.

A mixed strategy would be a Borel probability measure over $[0, \overline{F}]$. Opponents' randomization can smooth a creditor's expected payoff, yet it converts the repayment cutoff into an endogenous probability that aggregate claims exceed Δ; it does not remove the underlying institutional threshold. In a continuous-action discontinuous game, mixed-strategy existence and the form of equilibrium distributions require a separate analysis. A full mixed-strategy extension would compare the induced probability of good-state default and expected hardship across CEA, proportional treatment, and scaling rules.

7. Equilibrium implications

The repayment cutoff creates a discontinuity, while the CEA recovery schedule creates piecewise-linear incentives. The following propositions provide explicit sufficient conditions for two distinct pure-strategy outcomes.

7.1. A repayment-compatible threshold equilibrium

Proposition 2 (*Symmetric Repayment-Compatible Equilibrium*)**.** *Consider three creditors and suppose*

$$0 < \underline{Y} \leq \Delta, \qquad 0 < \frac{\Delta}{3} \leq \overline{F}, \qquad q \leq \pi_G. \tag{9}$$

Let $f^* = \Delta/3$. Then the profile $F^* = (f^*, f^*, f^*)$, together with the debtor's cutoff action, is a pure-strategy subgame-perfect equilibrium. The debtor repays in the good state and CEA allocates the bad-state recovery.

For the proof see Appendix A.5.

Each creditor chooses exactly one third of the repayment capacity. A downward deviation sacrifices good-state return. An upward deviation crosses the cutoff and loses good-state repayment, while CEA keeps the bad-state recovery at the common award. The condition $q \leq \pi_G$ makes the repayment-side return sufficiently valuable to sustain the boundary profile. For practitioners, the result identifies a repayment-compatible configuration in which the aggregate contractual burden exactly uses, but does not exceed, the institutional capacity.

7.2. A good-state-default equilibrium

Proposition 3 (*Creditor Lock-In and Good-State Default*). *Consider three creditors and suppose*

$$\underline{Y} \geq 3\overline{F}, \qquad 2\overline{F} > \Delta, \qquad q \leq \pi_B. \tag{10}$$

Then $F^* = (\overline{F}, \overline{F}, \overline{F})$ is a pure-strategy subgame-perfect equilibrium, and the debtor defaults in the good state.

For the proof see Appendix A.6.

The other two creditors already place aggregate claims above the repayment cutoff. A unilateral reduction cannot restore repayment, so each creditor compares only bad-state recovery with acquisition cost. When $q \leq \pi_B$ and bad-state recovery is sufficient for full payment, the maximal exposure is individually optimal. The outcome is a coordination lock-in: collective reduction could restore good-state repayment, while no single creditor has the ability or incentive to do so.

7.3. Discontinuity, multiplicity, and sensitivity

The two propositions show that the same institutional architecture can support economically different equilibria under different parameter values. Near the cutoff, changes in q, π_G, $\underline{Y}$, or Δ can alter the profitability of unilateral deviations. The equilibrium correspondence may therefore move between repayment and default or contain both types of equilibrium. The model's institutional fragility consists in this parameter-driven movement among repayment, default, and multiplicity regimes.

Category N is retained in the general classification, although the analytical and numerical results reported here concern repayment, default, and multiplicity. The policy problem is therefore not inferred from discontinuity alone; it arises when the best-response structure produces creditor lock-in, multiple equilibria, or marked sensitivity near the repayment cutoff.

7.4. Computational implementation, parameter-space map, and sensitivity analysis

For each parameter vector and candidate rule, the analyst computes creditor best responses, identifies the pure-equilibrium set, and assigns the classification in (6). A rule is provisionally acceptable when the relevant scenario lies in R and remains there under plausible perturbations. A D classification calls for coordination or obligation reduction. A M classification calls for an equilibrium-selection mechanism, such as an aggregated collective-action clause, a centralized exchange, or a scaling provision.

Algorithm 1. Grid-based equilibrium classification

1. Specify the parameter vector θ, the institutional rule $\mathcal{I}$, the upper bound $\overline{F}$, and a finite action grid

   $G_h = \{0, h, 2h, \dots, \overline{F}\}.$

2. For every profile $F \in G_h^n$, calculate the aggregate face value $S(F)$ and determine the debtor's good-state action from the repayment cutoff.
3. Apply the institutional recovery rule to calculate $p_i(F, E)$ for every creditor and substitute the resulting payments into the expected-payoff function.
4. For every creditor i and every opponents' profile F_{-i}, evaluate

   $\max_{x \in G_h} U_i(x, F_{-i})$

   and retain all grid actions attaining the maximum.
5. Identify the mutual-best-response set

   $\mathcal{E}_h(\theta, \mathcal{I}) = \left\{ F \in G_h^n : F_i \in BR_{i,h}(F_{-i}) \text{ for every } i \right\}.$

6. Assign the classification R, D, M, or N according to whether the equilibrium set contains repayment-compatible profiles, good-state-default profiles, both types, or no grid equilibrium.
7. Repeat the calculation over the selected parameter scenarios. As a separate robustness check, repeat the computation for successively finer values of h and record changes in the qualitative classification separately from changes in the number or location of grid equilibria.

Table 2
One-at-a-time sensitivity of the grid-equilibrium classification.

Scenario	q	Δ	π_G	$\underline{Y}$	C
Selected baseline	0.40	1.50	0.30	2.50	M
Lower acquisition price	0.25	1.50	0.30	2.50	D
Higher acquisition price	0.80	1.50	0.30	2.50	R
Lower repayment cutoff	0.40	1.00	0.30	2.50	D
Higher repayment cutoff	0.40	2.50	0.30	2.50	R
Lower good-state probability	0.40	1.50	0.20	2.50	D
Higher good-state probability	0.40	1.50	0.65	2.50	R
Lower bad-state recovery estate	0.40	1.50	0.30	1.50	R

In the numerical application reported below, the procedure is implemented for three creditors, $n = 3$, under the constrained equal awards rule, $\mathcal{I} = \text{CEA}$.

Fig. 2 reports the grid-based classification for $n = 3$, $\overline{F} = 1$, $\pi_G = 0.30$, and $\underline{Y} = 2.50$. Each creditor's action set is discretized in increments of $h = 0.025$. For every pair (q, Δ), all grid profiles and all unilateral grid deviations are evaluated. The resulting mutual best responses are classified as repayment-compatible only, good-state-default only, or containing both equilibrium types. The figure is a numerical implementation of the screening procedure; the continuous-game claims remain those established by the analytical propositions.

Table 2 changes one parameter at a time around a baseline multiplicity scenario. A lower acquisition price makes large face-value positions less costly and moves the classification toward good-state default. A higher acquisition price weakens this incentive and produces a repayment-only classification. A higher repayment cutoff enlarges the set of profiles compatible with repayment, while a higher good-state probability increases the expected value of preserving good-state repayment. A smaller bad-state estate reduces the return from claims that rely on restructuring recovery and therefore also discourages excessive face values.

For the reported grid sizes, the selected baseline scenario remains in category M for $h \in 0.10, 0.05, 0.025, 0.0125$. This numerical stability does not imply robustness to parameter changes. Lowering the acquisition price from $q = 0.40$ to $q = 0.25$ changes the classification from M to D and removes the repayment-compatible grid equilibria. The comparison therefore distinguishes stability with respect to grid refinement from sensitivity to economically relevant parameter variation.

The exercise is not calibrated to a particular historical restructuring. Its purpose is to demonstrate implementation, comparative statics, and equilibrium-regime sensitivity under controlled parameter changes. Historical episodes are used below to interpret the institutional mechanisms, not as empirical validation of the numerical parameter values.

8. Avoidable hardship and welfare

The baseline hardship variable measures the incremental social loss caused by good-state restructuring. It does not measure total poverty in the bad state and does not imply that a crisis state is socially costless. Let

$$\text{Pov}(\omega, F) = \mathbf{1}_{\{\omega=\omega_G\}} \mathbf{1}_{\{a(\omega_G)=D\}},$$

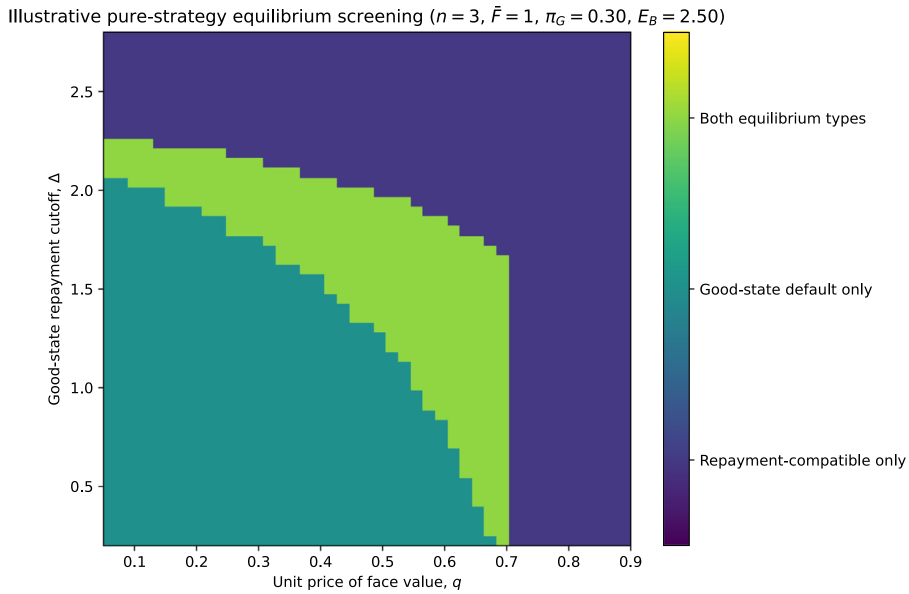

Fig. 2. Equilibrium regions in the Three-Creditor Model.

so that

$$\mathbb{E}[\mathrm{Pov}(\omega, F)] = \pi_G \mathbf{1}_{\{S(F)>\Delta\}}.$$

The indicator records avoidable good-state hardship. A state-specific baseline loss H_B may be added in the bad state, as discussed in Section 3.5. Since H_B occurs under every candidate rule when the bad-state continuation is fixed, it cancels from the comparative rule evaluation.

The hardship indicator inherits the repayment discontinuity. Crossing the cutoff changes expected incremental hardship by π_G. The welfare relevance of the equilibrium analysis is therefore direct: a default equilibrium or a multiplicity region can expose households and public services to an avoidable real loss even when aggregate good-state resources are sufficient for repayment.

Proposition 4 (*Default in the Good State is Socially Costly*)**.** *Suppose that in ω_G aggregate output equals $\overline{Y}$ regardless of whether $a(\omega_G) = R$ or $a(\omega_G) = D$, but hardship Δ is incurred only under D. Then, holding fixed bad-state allocations, any outcome with $a(\omega_G) = D$ is strictly welfare dominated by an outcome with $a(\omega_G) = R$.*

For the proof see Appendix A.7.

Financial transfers between the debtor and creditors redistribute resources, whereas Δ is a real loss. A rule that moves the economy from good-state default to repayment therefore creates a social gain even when creditor and debtor transfers are treated as welfare-neutral.

Corollary 2 (*Poverty and Equilibrium Sensitivity*)**.** *Whenever the model admits multiple pure-strategy equilibrium configurations or no robust pure-strategy prediction for whether $S(F)$ lies below or above Δ, it likewise admits no sharp pure-strategy prediction for* Pov. *This observation persists even though* $\mathrm{Pov} = 1$ *is welfare dominated by Proposition 4.*

9. Policy and institutional discussion

The model evaluates restructuring institutions through their effects on *ex ante* incentives and ex post recoveries. CEA is an egalitarian benchmark with a common award cap. Proportional treatment follows the face value of pari passu claims. Collective-action clauses aggregate creditor votes. Statutory enforcement limits can restrict holdout recovery, while official-sector procedures coordinate bilateral and multilateral claims. Each mechanism changes the mapping from contractual claims to realizable payments and can therefore change the strategic game.

The policy interpretation must respect the absence of a universal sovereign bankruptcy court. Current sovereign restructurings rely on contracts, domestic enforcement law, negotiations, and official-sector coordination [1]. Recent comparative legal analysis identifies several statutory design choices, including safe harbors and restrictions on enforcement against distressed sovereigns [7]. The abstract rule administrator in the model represents these possible mechanisms.

9.1. Relation to prevailing restructuring practice

Prevailing sovereign restructuring practice does not allocate a universal liquidation estate through a single bankruptcy formula. Multilateral support frameworks assess debt sustainability and the financing envelope; official creditor processes coordinate claims among participating governments; bond restructurings use exchange offers and collective-action provisions; and domestic courts determine the enforceability of contractual claims. These arrangements combine macroeconomic assessment, negotiation, voting, and enforcement rather than replacing them with a uniform allocation rule [1,7,16].

Cross-country differences are relevant through both debtor-side capacity and creditor-side coordination. Haq et al. [45] compare OECD and BRICS countries over 2012–2020 and find that intellectual human capital is associated with lower carbon emissions in the OECD sample, whereas the corresponding effect is not statistically significant in the BRICS sample. Renewable-energy use is associated with lower emissions in both groups. These results concern a specific environmental outcome related to SDG 13 and should not be interpreted as a general ranking of the two groups across all Sustainable Development Goals. They nevertheless illustrate that similar human-capital and innovation inputs may translate into different outcomes across institutional settings.

The expanded BRICS+ category is also internally heterogeneous. Using the BRICS-11 analytical sample, Işık et al. [46] report substantial country-level differences in the relationship between environmental, social, and governance factors and SDG outcomes. Environmental factors are negatively associated with the reported SDG measure in Argentina, Ethiopia, and China; social factors have positive effects in South Africa and Argentina; and governance factors have positive effects in Ethiopia, Iran, and Saudi Arabia but a negative effect in the

United Arab Emirates. No statistically significant ESG–SDG relationship is reported for Brazil, Russia, India, or Egypt. These differences caution against treating BRICS+ as a single institutional type. In applying the present framework, fiscal capacity, creditor composition, domestic adjustment costs, and enforcement conditions must therefore be specified at country and instrument level rather than inferred from bloc membership.

Zambia's restructuring under the G20 Common Framework illustrates creditor-side heterogeneity in an actual debt-treatment process. Setser [47] describes delays arising from disagreements among China, traditional bilateral creditors, and market creditors over the perimeter of claims, the form and amount of relief, the treatment of multilateral claims, and comparability between official and private creditors. In the terminology of the present model, these disagreements arise before a within-class allocation rule is applied: they affect which claims enter the restructuring, the size and timing of the recovery envelope, and the conditions under which different creditor groups accept comparable treatment. The homogeneous-creditor benchmark is therefore appropriate only after claims have been separated into legally and economically comparable classes and the principal cross-group coordination issues have been resolved.

The model begins after the effective recovery envelope and the relevant creditor class have been specified. It then examines how a given mapping from claims to recoveries affects creditor incentives and equilibrium selection. CEA is therefore not a substitute for debt-sustainability analysis, financing assurances, comparability-of-treatment requirements, collective voting, or legal-enforcement review. It is a within-class counterfactual used to isolate the incentive effects of an allocation rule.

The historical episodes discussed in the Introduction illustrate these distinctions. Argentina's holdout litigation concerns heterogeneous acquisition prices and enforcement opportunities, features excluded from the single-class benchmark. The Greek restructuring demonstrates how collective-action mechanisms alter the acceptance and coordination process without constituting a CEA allocation. Recent legal developments concerning Sri Lanka illustrate the separate role of domestic enforcement limits. These episodes identify institutional mechanisms that correspond to extensions or alternatives to the model; they are not treated as calibrated applications.

Creditor heterogeneity also affects institutional choice. A single-class CEA or proportional rule cannot by itself settle priority across official bilateral creditors, multilateral institutions, domestic banks, and bondholders. A practical implementation would first segment claims by legal and economic class, apply relevant seniority and comparability constraints, and then evaluate the within-class allocation rule. Holdout and secondary-market incentives should be stress-tested by allowing some creditors to face different acquisition prices, enforcement costs, and recovery mappings.

The appropriate institutional response depends on the source of instability. Aggregated collective-action clauses or centralized exchanges address the unilateral coordination problem identified in Proposition Proposition 3. Replacing CEA with another allocation rule changes the marginal-recovery incentives created by the estate-division formula. Scaling clauses act at an earlier stage by reducing enforceable obligations when aggregate claims would otherwise exceed the repayment cutoff. Table 3 separates ex post estate-division rules from mechanisms that modify coordination or enforceable obligations. CEA, proportional allocation, and constrained equal losses divide a fixed estate. Collective-action mechanisms alter the decision process among creditors. Proportional scaling changes the enforceable burden before the good-state repayment decision.

No rule dominates on every criterion. CEA gives priority to the protection of smaller claims; proportional treatment preserves relative contractual positions; constrained equal losses protects larger claims against disproportionately large nominal losses; collective-action mechanisms address coordination; and scaling prioritizes repayment stability. Institutional choice therefore depends on the legal status of the claims, the accepted distributional objective, the source of the coordination problem, and the expected effect on future financing conditions.

9.2. A stylized scaling clause as an institutional benchmark

Consider a stylized scaling clause that applies to the enforceable good-state obligation. Define

$$\alpha(F) = \begin{cases} 1, & S(F) = 0, \\ \min\left\{1, \dfrac{\Delta}{S(F)}\right\}, & S(F) > 0. \end{cases} \tag{11}$$

The enforceable claim of creditor i becomes $\alpha(F)F_i$. If $S(F) \le \Delta$, the clause is inactive. If $S(F) > \Delta$, aggregate enforceable obligations are reduced to Δ. The clause is a prescriptive benchmark rather than a proposed legal template. It shows how changing enforceability can remove the good-state regime switch while preserving proportional treatment of the contractual claims.

The scaling benchmark relies on verified aggregate claims, a legally effective power to modify obligations, uniform application within the relevant creditor class, and the absence of conflicting priority or collateral rights. Its analytical advantage is the direct removal of the aggregate burden above the repayment cutoff. The corresponding trade-off is an ex post reduction in creditor entitlements, with possible effects on ex ante pricing, market access, and future contracting. The benchmark is not a valid literal design for instruments that cannot be modified collectively, for creditor classes with different seniority, or for settings in which scaling conflicts with governing-law, cross-default, collateral, or official-sector protections. It remains a prescriptive analytical comparator rather than a proposed statutory template.

10. Managerial implications

The framework supports organizational decision-making at sovereign debt-management offices, multilateral institutions, creditor committees, restructuring advisers, and institutional investment organizations. Its practical value lies in converting a legal or contractual proposal into a sequence of auditable analytical steps. The user specifies the claim structure, market price, state probabilities, effective recovery, and repayment cutoff; computes the candidate allocation; solves creditor best responses; classifies the resulting equilibrium set; and stress-tests the classification under alternative scenarios (see Table 4). A practical screening protocol has five stages. First, the debt manager separates creditor classes and records governing law, seniority, maturity, and acquisition-price differences. Second, the analyst calibrates an effective recovery and a range for the good-state cutoff. Third, the organization computes the baseline classification and its sensitivity to small parameter changes. Fourth, candidate clauses are compared using the same scenarios. Fifth, the preferred design is selected only if its repayment-compatible region remains stable under plausible perturbations and its distributional effects satisfy the applicable comparability-of-treatment constraints.

The model is most useful as an early-stage institutional stress test. It can reveal a rule-induced coordination problem before a detailed legal drafting or empirical calibration exercise begins. It cannot replace debt-sustainability analysis, macroeconomic forecasting, legal enforceability review, or bargaining analysis across heterogeneous creditor classes. Its managerial contribution is to make the strategic consequences of a proposed rule explicit and comparable.

Table 3
Comparison of allocation and restructuring mechanisms.

Rule or mechanism	Operational principle	Main advantage	Main limitation or trade-off
Constrained equal awards	$p_i = \min\{F_i, \lambda\}$; creditors receive a common award up to their claims.	Protects smaller claims and makes the distributional objective transparent.	Caps the marginal recovery of large claims and can create flat payoff regions. It is poorly suited to claims with different priority or enforcement status.
Proportional allocation	$p_i^P = EF_i/S(F)$ for an insufficient estate.	Preserves relative claim shares and corresponds closely to pari passu treatment within a homogeneous class.	Larger contractual claims obtain larger recoveries. The rule does not itself resolve coordination failure or prevent aggregate claims from crossing the repayment cutoff.
Constrained equal losses	$p_i^{CEL} = \max\{0, F_i - \mu\}$, where μ equalizes nominal losses subject to estate exhaustion.	Provides a clear alternative fairness criterion based on equal losses rather than equal awards.	Small claims may be exhausted before large claims. The rule shifts, rather than removes, the recovery kink and can concentrate payments among larger creditors.
Collective-action clause or centralized exchange	Aggregates creditor decisions through a voting or coordinated acceptance mechanism.	Can overcome unilateral holdout power and the creditor lock-in identified in Proposition 3.	Effectiveness depends on coverage, voting thresholds, claim aggregation, and the treatment of creditors outside the mechanism. It does not determine the allocation formula by itself.
Proportional scaling	Replaces F_i by $\alpha(F)F_i$ and limits aggregate enforceable obligations to the repayment cutoff.	Preserves relative claim shares and directly prevents the enforceable burden from crossing the cutoff.	Reduces contractual entitlements, may increase ex ante financing costs, and requires a valid legal basis for collective modification.

Table 4
Decision-analytics functions of the framework.

Dimension	Managerial question	Operational output
Descriptive	How do claims and the candidate rule map into payments?	State-contingent recoveries, concentration measures, and distance from the repayment cutoff.
Diagnostic	Why does an undesirable regime arise?	Identification of threshold pressure, CEA truncation, creditor concentration, or unilateral inability to restore repayment.
Predictive	How does the regime change under specified shocks?	Scenario-conditional changes in the equilibrium classification when q, π_G, E, or Δ changes. This is a stress test rather than a statistical forecast.
Prescriptive	Which institutional modification improves the outcome?	Comparison of CEA, proportional treatment, collective-action mechanisms, enforcement limits, and scaling clauses against stability and hardship criteria.

11. Conclusion

This paper develops an institutional decision-analytics model of sovereign debt restructuring under limited commitment. The core mechanism is the interaction between a good-state repayment cutoff and a rule that maps contractual claims into restructuring recoveries. The interaction creates a discontinuity in creditor payoffs and makes equilibrium outcomes sensitive to prices, state probabilities, recovery capacity, and the repayment threshold.

CEA serves as a counterfactual single-class benchmark. Its common award cap exposes the incentive effect of a kinked recovery schedule. The analytical results provide explicit sufficient conditions for a repayment-compatible threshold equilibrium and for a creditor-lock-in equilibrium with good-state default. The computational implementation complements these results by identifying repayment, default, and multiplicity classifications across parameter scenarios and by documenting the qualitative stability of the selected baseline under grid refinement.

For applied screening, the model yields four concrete outputs: state-contingent recoveries, the source of any strategic discontinuity, the equilibrium classification under alternative parameter values, and the effect of modifying the institutional rule. These outputs can support early-stage comparisons by debt offices, multilateral institutions, advisers, creditor committees, and investors. They do not replace case-specific debt-sustainability analysis, macroeconomic forecasting, legal review, or negotiations among heterogeneous creditor groups.

The results establish theoretical mechanisms and a reproducible screening procedure, not an empirical estimate of sovereign default or restructuring outcomes. The model is not calibrated to a particular historical case, and the numerical scenarios do not constitute empirical validation. Aggregate financing is generated by creditor choices within an authorized set, while the sovereign's issue-size and acceptance decisions remain outside the game. The baseline contains one homogeneous creditor class and excludes seniority, collateral, official-sector priority, comparability-of-treatment constraints, secondary-market acquisition, strategic holdouts, and bargaining across creditor groups. Complete information, risk neutrality, exogenous prices, a fixed recovery estate, and a two-period horizon further limit direct quantitative application. These restrictions preserve the identification of the rule-induced discontinuity but prevent the model from replacing debt-sustainability analysis, legal review, case-specific calibration, or negotiation analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Technical proofs

A.1. Proof of Lemma 1

Proof. Fix F in the good state. Under repayment, the debtor obtains $\overline{Y} - S(F)$. Under baseline restructuring, it obtains $\overline{Y} - \Delta$. Repayment is weakly preferred exactly when $\overline{Y} - S(F) \geq \overline{Y} - \Delta$, which is equivalent to $S(F) \leq \Delta$. Since $\Delta \leq \overline{Y}$, every profile satisfying the cutoff is technologically feasible. □

A.2. Proof of Proposition 1

Proof. Fix creditor i and a profile on the cutoff with $F_i > 0$. Approaching the profile from the repayment side, creditor i receives the good-state component $\pi_G F_i$. Approaching from profiles with $S(F) > \Delta$, this component is absent in the baseline. The one-sided payoff difference is therefore $\pi_G F_i > 0$, except at degenerate zero-claim points. Hence the payoff mapping is generally discontinuous on $S(F) = \Delta$. Under the generalized payoff in (5), the jump equals $\pi_G[F_i - p_i(F, E_G)]$ and remains positive whenever good-state restructuring recovery is incomplete. □

A.3. Proof of Lemma 2

Proof. Let $\phi(\lambda) = \sum_{j=1}^{n} \min\{F_j, \lambda\}$. The function is continuous and nondecreasing, with $\phi(0) = 0$ and $\phi(\lambda) = S(F)$ for every $\lambda \geq \max_j F_j$. Therefore, for $E < S(F)$, the canonical selection

$$\lambda(F, E) = \inf\{\lambda \geq 0 : \phi(\lambda) \geq E\}$$

satisfies $\phi(\lambda(F, E)) = E$. If $E \geq S(F)$, the allocation is full payment. Monotonicity of λ in E follows immediately from monotonicity of ϕ.

For own-claim monotonicity, fix F_{-i} and E, and increase F_i from x to $x' > x$. Suppose, contrary to the claim, that the new CEA payment p_i' is smaller than the old payment p_i. Since $x' > x \geq p_i > p_i'$, the new payment must equal the new common award λ', and $\lambda' < p_i \leq \lambda$. Payments to every other creditor are weakly lower at λ' than at λ. Hence

$$p_i' + \sum_{j \neq i} \min\{F_j, \lambda'\} < p_i + \sum_{j \neq i} \min\{F_j, \lambda\} = \min\{E, S(F)\},$$

which contradicts exhaustion of the effective recovery in the non-full-payment case. Thus $p_i(F, E)$ is nondecreasing in F_i. □

A.4. Proof of Lemma 3

Proof. Under the stated ordering and $\lambda \geq F_2$, CEA pays $p_1 = F_1$ and $p_2 = F_2$. Since $\underline{Y} < F_1 + F_2 + F_3$, full payment is impossible, so the largest creditor is capped and receives $p_3 = \lambda$. Exhaustion gives $F_1 + F_2 + \lambda = \underline{Y}$, hence $\lambda = \underline{Y} - F_1 - F_2$. □

A.5. Proof of Proposition 2

Proof. Let $f^* = \Delta/3$. At $F^* = (f^*, f^*, f^*)$, aggregate face value equals Δ, so the debtor repays in the good state. Because $\underline{Y} \leq 3f^*$ and the three claims are equal, each creditor receives $\underline{Y}/3$ under bad-state CEA. The equilibrium payoff is

$$U_i(F^*) = (\pi_G - q)f^* + \pi_B \frac{\underline{Y}}{3}.$$

Consider a downward deviation to $x \in [0, f^*]$. Good-state repayment remains in place. With the other two claims equal to f^* and $\underline{Y} \leq 3f^*$, the deviator's CEA recovery is $\min\{x, \underline{Y}/3\}$. Thus

$$U_i(x, F_{-i}^*) = \begin{cases} (1-q)x, & 0 \leq x \leq \underline{Y}/3, \\ (\pi_G - q)x + \pi_B \underline{Y}/3, & \underline{Y}/3 \leq x \leq f^*. \end{cases}$$

The second expression is nondecreasing because $q \leq \pi_G$. Its value at f^* weakly exceeds the maximum of the first interval because

$$U_i(F^*) - (1-q)\frac{\underline{Y}}{3} = (\pi_G - q)\left(f^* - \frac{\underline{Y}}{3}\right) \geq 0.$$

For an upward deviation $x > f^*$, aggregate claims exceed Δ and good-state repayment disappears. All three claims are at least $\underline{Y}/3$, so CEA pays the deviator $\underline{Y}/3$. The deviation payoff is $\pi_B \underline{Y}/3 - qx$, which is strictly below $\pi_B \underline{Y}/3 - qf^*$. The equilibrium payoff exceeds the latter amount by $\pi_G f^* > 0$. No unilateral deviation is profitable. □

A.6. Proof of Proposition 3

Proof. At $F^* = (\overline{F}, \overline{F}, \overline{F})$, aggregate claims exceed Δ because $2\overline{F} > \Delta$. The debtor therefore defaults in the good state. Since $\underline{Y} \geq 3\overline{F}$, every claim is fully recovered in the bad state. Creditor i obtains $(\pi_B - q)\overline{F}$.

Fix the other two creditors at $\overline{F}$ and let creditor i deviate to any $x \in [0, \overline{F}]$. The other claims alone sum to $2\overline{F} > \Delta$, so the deviation cannot restore good-state repayment. Bad-state recovery remains full because $\underline{Y} \geq 2\overline{F} + x$. The deviation payoff is $(\pi_B - q)x$, which is maximized at $x = \overline{F}$ when $q \leq \pi_B$. Hence no unilateral deviation is profitable. □

A.7. Proof of Proposition 4

Proof. Under good-state repayment, transfers between the debtor and creditors sum to $S(F)$ and cancel in aggregate welfare. Material resources therefore equal $\overline{Y}$. Under baseline good-state restructuring, the effective creditor recovery is zero and aggregate material resources remain $\overline{Y}$, while the real hardship Δ is incurred. Holding bad-state allocations fixed, good-state restructuring lowers welfare by exactly $\Delta > 0$. □

Data availability

No data was used for the research described in the article.

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