

Article

Strategic Decision-Making in Green Financing: A Game-Theoretic Model and Monte Carlo Simulation of Firm, Investor and Bank Interaction

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Highlights

Please indicate how your work links to systems science via your contributions to systems practice, theory, and/or methodology.

- The firm, the bank and the investors are treated as one interacting system: green debt instrument choice is a three-stage extensive-form game whose subgame-perfect equilibrium is a property of the whole, not of any player in isolation, because bank credit enhancement enters the investors' participation condition.
- Analytical backward induction is combined with a 200,000-draw Monte Carlo experiment, variance-based (Sobol) and screening (Morris) global sensitivity analysis and an incomplete-information extension with Bayesian updating, providing a reproducible modeling-and-simulation template for stress-testing strategic financing systems.

What are the main findings and/or the implications of the main findings?

- In the calibrated simulation, the share of parameter configurations yielding a green bond equilibrium falls from 93.4% under high demand and strong issuer credibility to 14.2% when both deteriorate, and the regulatory regime flips the chosen instrument in 19.4% of draws once the bank enhancement channel is active, against 0% when it is switched off.
- Instrument choice switches discontinuously at issuer-specific participation thresholds, so regulatory design should be evaluated at the level of the interacting firm–bank–investor system, and empirical work should track the composition of green debt rather than short-run pricing alone.



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Abstract

Green bonds and green bank loans coexist as instruments for financing the low-carbon transition, yet the strategic mechanism through which issuers select between them remains weakly formalized. This paper models green debt instrument choice as a three-stage extensive-form game with perfect information in which a firm first selects a financing route, a bank then chooses credit enhancement in the bond branch or loan terms in the loan branch, and investors decide whether to subscribe. Because the bank's credit enhancement enters the investors' participation condition, the three players are genuinely

strategically interdependent, and because the bond branch carries only a small standby cost rather than the full loan cost, the regulatory regime affects the choice of instrument and not merely the level of financing cost. The subgame-perfect equilibrium is characterized analytically by backward induction and is then implemented numerically over the eight admissible states of demand, issuer credibility and regulatory regime through a Monte Carlo experiment of 200,000 parameter draws. The share of simulated parameter configurations yielding a green bond equilibrium falls from 93.4% under high demand and strong credibility to 14.2% when both deteriorate; the regulatory regime flips the equilibrium instrument in 19.4% of draws, against 0% in the degenerate special case without the enhancement channel. A variance-based global sensitivity analysis (Sobol and Morris) and an incomplete-information extension with a noisy credibility signal complete the analysis. All reported quantities are numerical solutions of the model under an illustrative calibration, not empirical estimates.

Keywords: green bonds; green bank loans; game theory; subgame-perfect equilibrium; credit enhancement; Monte Carlo simulation; global sensitivity analysis; sustainable finance; regulatory incentives; greenwashing risk

1. Introduction

Green finance has become a central mechanism for mobilizing capital toward environmentally sustainable investment and for accelerating the transition to a low-carbon economy [1,2]. As climate risks intensify, financing decisions increasingly reflect not only expected financial payoffs but also regulatory constraints, reputational considerations and shifting investor preferences toward ESG-aligned assets [3,4]. These forces have altered the firm's financing problem: access to capital is progressively mediated by the credibility of environmental commitments, the quality of disclosure, and the institutional architecture governing sustainable finance markets [2,5].

Among the most widely used green debt instruments, green bonds and green bank loans offer distinct advantages and frictions. Green bonds can broaden market access, enhance visibility and potentially reduce long-term financing costs, particularly when investor appetite for sustainable assets is strong and the issuer's environmental track record is perceived as credible [1,2,5]. However, bond issuance typically entails non-trivial fixed costs, including certification, disclosure and compliance requirements, which may limit its attractiveness for some issuers. Green bank loans, by contrast, are negotiated bilaterally and may offer contractual flexibility and lower upfront transaction costs, making them attractive for firms with constrained capital-market access or shorter-term funding needs [6,7]. Loan-based financing may nonetheless involve higher pricing, tighter monitoring or greater dependence on bank incentives and regulatory regimes, implying that the relative appeal of bonds versus loans is contingent upon market and institutional settings [8].

Despite the rapidly expanding empirical literature on the diffusion and pricing of green debt, the strategic interdependence between issuers, investors and banks remains less explicitly formalized. In practice, firms do not choose instruments in isolation: investor participation determines whether bond financing can be executed at acceptable terms, while banks adjust lending conditions in response to policy incentives, risk assessments and their own competitive positioning. Game-theoretic approaches are particularly well suited to capturing strategic interactions and interdependencies in financial markets [9–12]. Moreover, sustainable finance contexts involve institutional and behavioral frictions, such as information asymmetry, credibility concerns and greenwashing risk, that affect beliefs

and therefore strategic choices [1,13]. Behavioral perspectives further suggest that decision-makers operate under cognitive limitations, and that heuristics, framing and loss aversion can materially influence investment and financing choices [14–16].

This paper addresses the following research question: which strategic conditions determine a firm's choice between green bonds and green bank loans, and how sensitive is that choice to the parameters governing investor participation, issuance cost and institutional design? To answer it, we develop a three-stage sequential game with complete information in the baseline and an incomplete-information extension involving three players: (i) the firm, choosing between green bonds and green loans; (ii) the bank, which in the bond branch chooses whether to provide credit enhancement and in the loan branch sets loan terms (favorable versus standard), shaped by regulatory incentives; and (iii) investors, deciding whether to subscribe to the green bond. Crucially, the bank's credit enhancement enters the investors' participation condition, so the three players interact strategically rather than through independent thresholds.

The equilibrium is derived via backward induction, providing transparent conditions that link investor sentiment, issuance and verification costs, and policy-driven banking incentives to instrument choice outcomes [10,11]. This modeling approach aligns with prior applications of sequential games to corporate financing under strategic interaction and signaling [17,18], as well as with recent work on modeling green financing incentives using game-theoretic frameworks [8,19].

The contribution of this paper is twofold. Analytically, it derives a closed-form characterization of the subgame-perfect equilibrium of the issuer–investor–bank triad, separating the feasibility of market-based green debt from its optimality conditional on feasibility, and identifying a genuine strategic linkage through which the bank's credit enhancement relaxes the investors' participation constraint. Because the bond and loan branches carry economically distinct bank costs, the regulatory regime affects not only the level of financing costs but the choice of instrument itself, so the analytical neutrality of the institutional channel breaks down. Methodologically, and in direct response to the modeling and simulation focus of this Special Issue, the paper does not stop at directional comparative statics. The equilibrium correspondence is implemented numerically and evaluated through a Monte Carlo experiment over the model's parameter space, which quantifies the size of the bond-feasible region, ranks the model primitives by their influence on equilibrium instrument choice through a variance-based global sensitivity analysis (Sobol indices and Morris screening), and characterizes the discontinuity that arises at the investor participation threshold. This numerical layer converts threshold inequalities into a quantitative risk-assessment device: for a given institutional configuration, the model returns the share of parameter configurations for which market-based green financing is attainable, which is precisely the object of interest for issuers, lenders and supervisors concerned with the resilience of sustainable debt markets.

An incomplete-information extension, in which issuer credibility is a private type observed through a noisy signal, gives the notions of belief formation and greenwashing risk an explicit formal representation.

The model yields three core insights. First, green bond financing is optimal when investor confidence is sufficiently strong to compensate for issuance and certification costs and when environmental credibility supports participation [2,5]. Second, green bank loans become optimal when bond-market participation is weak or uncertain, when bond-related fixed costs are high, or when banks, responding to policy incentives, offer concessionary loan terms [6,7]. Third, instrument choice is governed by a genuine strategic interaction rather than by independent thresholds: the bank's credit enhancement can move a marginal issuance from non-participation to participation, so bank incentives and investor confidence

jointly determine whether markets coordinate on bond-based financing or shift towards relationship-based loan financing. A direct consequence is that the regulatory regime is not neutral for instrument choice; in the numerical solution it flips the equilibrium instrument in a non-trivial share of configurations, with direct implications for issuers, financial institutions and regulators designing standards and incentives to improve market functioning [1,13].

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on game theory in corporate finance and its applications in sustainable finance, including behavioral and institutional perspectives. Section 3 presents the model, its assumptions and payoff structure, the equilibrium concept, and the design of the numerical experiment. Section 4 reports the analytical equilibrium and the simulation results. Section 5 discusses implications for firms, investors, banks and policymakers, and delimits the scope of the conclusions. Section 6 concludes.

2. Literature Review

2.1. Game Theory and Corporate Finance

A foundational contribution of game theory to corporate finance is its ability to model strategic interaction under information asymmetry, where financing choices convey signals about firm quality and where investors and intermediaries respond endogenously. Classical work shows that financial contracts and issuance decisions are not merely responses to exogenous prices, but strategic actions shaped by beliefs, incentives and sequencing [20]. The seminal literature on extensive-form games and equilibrium refinement provides the methodological basis for analyzing such problems, including sequential rationality and subgame perfection in multi-stage financing contexts [10,11]. Within this framework, financing instruments can be interpreted as strategic commitments, screening devices or signaling mechanisms, depending on the informational structure and the timing of moves [21].

A prominent strand models capital structure as a signaling game. Under asymmetric information, insiders may prefer debt to equity because issuing equity can reveal adverse information to the market or dilute existing claims; in many signaling environments, the announcement of equity financing is predicted to be interpreted negatively relative to debt [17]. Related analyses discuss circumstances under which debt dominates equity as a strategic financing measure, while equity issuance may generate adverse selection dynamics [18]. These contributions underscore two points relevant to green finance: financing choice is intrinsically informational, and equilibrium outcomes depend not only on fundamentals but on how the market interprets and updates beliefs about issuer type and project quality. At the same time, the broader theoretical literature cautions that informational asymmetries do not universally imply a strict financing hierarchy, suggesting that equilibrium ordering can be sensitive to modeling assumptions, security design and the richness of the contract space [22].

Game theory has also been applied to financial intermediation, including bank monitoring, credit contracting, collateral and risk-shifting incentives [9,23,24]. In these settings the intermediary is not a passive price-taker; banks strategically choose contract terms given borrower incentives and regulatory constraints, and borrowers decide whether to accept bank finance or seek market-based funding. Survey work synthesizing game-theoretic research in finance emphasizes how equilibrium outcomes reflect agency costs, contract design and the strategic behavior of multiple parties [12]. This insight is particularly relevant for green finance because it suggests that the terms of green lending, such as discounts, covenants and KPI-linked pricing, may be endogenously determined by bank incentives,

reputational concerns and regulatory pressures, rather than being simple reflections of project risk.

More recent research extends game-theoretic logic beyond traditional issuance to strategic decision-making in operational and supply-chain contexts, where financing interacts with pricing, production and investment choices under constraints. Stackelberg structures are frequently used to represent leader–follower dynamics among manufacturers, retailers and financiers, including financing modes in capital-constrained supply chains and the influence of external parameters such as carbon prices on financing and operational equilibria [19,25,26]. Although these papers are not primarily about green bonds or green loans, they establish a transferable modeling insight: financing choices often arise as equilibrium objects in broader strategic systems, where the optimal instrument depends on the responses of other strategic agents and on the institutional parameters governing the environment.

2.2. Game Theory in Sustainable Finance

Sustainable finance research indicates that ESG considerations, market design and policy constraints increasingly shape capital allocation. The broad literature argues that sustainable finance can support decarbonization and climate adaptation by reallocating capital towards green technologies and by modifying risk pricing and investment mandates [13,27]. Investor preferences for sustainability may influence expected returns and price dynamics: under certain conditions, assets with lower expected returns can outperform when ESG-related factors experience favorable shocks, indicating that preferences and risk premia are jointly determined [28]. This channel creates a conceptual bridge to strategic modeling. If investors derive utility from impact or face mandate constraints, demand for green instruments becomes endogenous and can shift equilibrium outcomes in corporate financing.

Within green debt markets, two instrument families dominate practice and academic debate. The literature documents that green bonds can improve issuer visibility and potentially lower financing costs, often discussed through the notion of greenium, but that such benefits depend on credibility, standardization and the cost of certification and disclosure [1,2,5]. Green loans, in contrast, are frequently characterized by contractual flexibility and bilateral monitoring, but their pricing advantages and disclosure properties can be less transparent and more heterogeneous, reflecting bespoke KPIs and private contracting [6,7]. These differences suggest that instrument choice is not purely technological; it is institutional and strategic, shaped by how markets and banks reward or penalize disclosure and by how policy frameworks condition the relative attractiveness of each instrument.

Despite the rapid growth of empirical work, explicitly game-theoretic treatments of green financing decisions remain comparatively scarce. Where game theory is applied in sustainability contexts, it often appears in adjacent domains such as green innovation and supply-chain sustainability, typically through evolutionary games or Stackelberg leadership structures. Evolutionary game approaches model how strategies diffuse over time among heterogeneous agents, emphasizing learning, bounded rationality and the possibility of multiple stable outcomes [29]. Related work in platform and supply-chain settings examines how green innovation incentives interact with financing availability, suggesting that policy and financing can jointly determine whether firms choose greener technologies or marketing strategies [8]. Such studies reinforce a critical point for green debt markets: equilibrium outcomes may be path-dependent and sensitive to institutional signals, especially where credibility is costly to establish and where the value of green is partly reputational.

Beyond supply chains, game-theoretic approaches have been applied to renewable energy project financing and to public–private partnership structures. Coopetition models of renewable project financing show how banks’ competitive incentives can be reconciled with cooperative gains under specific payoff structures, highlighting that sustainable investment may require coordination mechanisms rather than simple price incentives [30]. In PPP financing, evolutionary game frameworks are employed to investigate how governments, private capital and financial institutions converge towards cooperative equilibria under suitable incentive design [31]. While these contexts differ from corporate green debt issuance, they provide transferable insights regarding the role of policy-induced payoffs, the emergence of coordination equilibria, and the importance of enforcement and monitoring structures.

A recurring theme across sustainable finance studies is the role of standardization and credibility in supporting market participation. If investors cannot distinguish credible green projects from greenwashing, demand may weaken and equilibrium may shift away from market instruments, favoring intermediate finance where monitoring is stronger but potentially more expensive. The key theoretical gap is therefore not whether green bonds or green loans are better on average, but under what strategic and institutional conditions each becomes dominant.

2.3. Behavioral and Institutional Perspectives

Standard models of corporate finance and asset pricing are built on rational choice under well-defined preferences and complete information. Behavioral finance, however, demonstrates that real-world financial decisions often deviate from strict rationality due to cognitive constraints, biases and social preferences [32,33]. Institutional economics simultaneously emphasizes that those rules, incentives and the credibility of policy shape choices. Both perspectives are especially relevant in green finance because sustainability claims are information-intensive, partially non-verifiable and subject to evolving regulatory standards. Consequently, the willingness of investors and banks to reward green labels depends not only on cash-flow expectations but also on perceived credibility, reputational implications and the likelihood of regulatory enforcement.

A central behavioral concept is bounded rationality, the notion that agents face limits in information processing and optimization [14]. In green finance, bounded rationality can manifest as reliance on heuristics such as ESG ratings and second-party opinions, simplified screening rules, or reputational signals. Rubinstein [16] develops bounded rationality in game-theoretic contexts, supporting the modeling claim that perfect optimization is a stylized benchmark rather than a descriptive assumption. Prospect theory and the broader behavioral literature further emphasize that agents display loss aversion and asymmetric reactions to gains and losses [15]. This is particularly salient for green debt, where payoffs may be long-dated and uncertainty about policy, technology or verification can increase perceived downside risk. Investors may discount green instruments if they fear reputational or performance losses from greenwashing scandals, even if expected returns are comparable [34]. Such asymmetries provide a plausible micro-foundation for why investor demand may collapse discontinuously under credibility shocks.

Institutional economics complements behavioral perspectives by highlighting that financing decisions are embedded in policy and regulatory architectures. Policy affects pay-offs directly through tax incentives, capital relief, subsidies and disclosure standards, and indirectly through credibility and enforcement. Campiglio et al. [13] argue that financial policy and regulation can play a decisive role in steering capital towards sustainability, while the political economy literature highlights how institutional design and policy commitments influence economic incentives and outcomes [35]. In green debt markets, regulatory

clarity can reduce information asymmetry, lower verification costs and strengthen investor confidence, conditions likely to shift the equilibrium toward market-based financing. If regulators encourage sustainability-linked lending, banks may rationally offer favorable terms even when short-term margins are lower, because policy-driven benefits enter the bank's objective function. This institutional channel provides the direct justification for including favorable versus standard terms as a bank strategy in the game.

2.4. Research Gap and Positioning

Two limitations remain salient. First, much of the green debt literature is instrument-centric and primarily empirical, focusing on whether a greenium exists and on cross-sectional correlates of pricing, without fully formalizing the strategic mechanism through which firms select instruments in anticipation of investor and bank responses. While research on green bonds emphasizes disclosure standards, certification and credibility [1,2,5], and work on green loans highlights contractual flexibility and bilateral monitoring [6,7], fewer studies integrate both instruments within a single framework that endogenizes the responses of both capital-market investors and banks.

Second, existing game-theoretic applications in sustainability are often situated in adjacent domains rather than modeling the issuer–investor–bank triad that characterizes corporate green debt choice. Evolutionary games and Stackelberg settings capture diffusion and leader–follower interactions [8,19,29], but they typically do not formalize the trade-off central to corporate treasury practice: market-based bond issuance versus relationship-based bank financing, under disclosure and certification costs, reputational payoffs and regulatory incentives. A third gap is methodological. Theoretical treatments of green instrument choice typically stop at directional comparative statics, leaving unquantified the size of the equilibrium regions, the relative influence of each primitive, and the magnitude of regime-switching effects. Numerical implementation of the equilibrium correspondence closes this gap and is what allows a strategic model to function as a risk-assessment instrument.

Accordingly, this paper positions its contribution as a unifying strategic model that treats green bond issuance and green loan contracting as competing financing instruments. Financing choice is modeled as a sequential game in which the firm anticipates the endogenous reactions of investors and of a bank whose credit enhancement enters the investors' participation condition, so that the issuer–investor–bank triad interacts genuinely rather than through independent thresholds. The model embeds the key sustainable-finance frictions directly into player payoffs and evaluates the resulting equilibrium correspondence numerically over the parameter space, with a variance-based sensitivity analysis and an incomplete-information extension that addresses the credibility and greenwashing concerns identified above.

3. Materials and Methods

3.1. Model Setup: Additional Primitives

The model is specified as a sequential game with three strategic agents, the firm (F), investors (I) and bank (B), whose decisions unfold over ordered stages. The objective is to characterize the conditions under which each financing instrument is optimal once the firm internalizes the anticipated responses of investors and the bank. This is consistent with game-theoretic approaches to financing under interdependence, where equilibrium outcomes reflect not only firm fundamentals but also belief-sensitive participation and contract choices by capital providers and intermediaries [9,12].

At Stage 1, the firm selects the financing instrument, choosing between issuing green bonds (GB) and contracting a green bank loan (GBL):

$$a \in \{\text{GB}, \text{GBL}\} \quad (1)$$

At Stage 2, conditional on $a = \text{GB}$, investors decide whether to subscribe to the green bond issuance:

$$i \in \{\text{Invest}, \text{Not}\} \quad (2)$$

At Stage 3, the bank sets lending conditions, selecting either favorable (F) or standard (S) terms:

$$t \in \{\text{F}, \text{S}\} \quad (3)$$

In the GBL branch, the investor node is absent from construction, reflecting that green loans are negotiated bilaterally between the firm and the bank; investors have no strategic action and no payoff relevance in that branch [11]. The baseline information structure assumes perfect observability of the firm's instrument choice, of the relevant state variables and of prior actions at each stage. This assumption provides a transparent benchmark, enabling a clean characterization of subgame-perfect equilibria via backward induction [10,11]. Real-world green finance decisions are influenced by bounded rationality and credibility frictions; these enter the baseline through reduced-form parameters that capture the informational and reputational environment, while extensions can explicitly relax perfect information or introduce learning [14–16,29,36].

Three primitives organize the economic environment. First, bond-market conditions are captured by an exogenous demand state for green bonds:

$$D \in \{\text{H}, \text{M}\} \quad (4)$$

where H denotes high demand and M denotes moderate demand. High demand typically enables the firm to place more bonds or secure better pricing. This parameter proxies investors' aggregate appetite and the pricing and placement conditions faced by the issuer, consistent with evidence that green bond outcomes are sensitive to market depth and sustainability-oriented flows [2,5]. The relative attractiveness of green bonds further depends on a demand-related benefit scaled by $\alpha > 0$, interpreted as improved pricing, placement success or liquidity advantage when D is high. Stronger demand may translate into a lower required yield and hence a lower cost of debt; it may improve placement success and reduce the need for costly price concessions; and it often correlates with better secondary-market liquidity, which further compresses yields. Because these effects are jointly determined and empirically difficult to disentangle within a stylized model, they are represented parsimoniously by the single demand-driven net-benefit term αD . The scaling parameter α is therefore the issuer's exposure to market conditions: a higher α implies that the firm's net benefit from green bonds is more responsive to changes in green bond demand, consistent with the view that frequent, benchmark-size issuers are better positioned to monetize investor appetites than others.

The second primitive is issuer credibility, represented by an environmental track record state:

$$E \in \{\text{S}, \text{W}\} \quad (5)$$

where S denotes strong credibility and W denotes weak credibility, capturing the degree to which investors perceive the issuer as aligned with sustainability commitments and less exposed to greenwashing concerns [1]. Third, bank incentives are shaped by a regulatory and policy state:

$$R \in \{\text{Strong}, \text{Weak}\} \quad (6)$$

which summarizes policy instruments and supervisory guidance that can make sustainability-linked credit more attractive for banks [13,35].

The model distinguishes between costs and benefits specific to each instrument. Green bond issuance entails an issuance, certification and disclosure cost $CGB > 0$, reflecting reporting, verification and compliance burdens noted in the green bond literature [1,5]. Green bank loans are represented through an effective borrowing cost c_t , where the subscript indicates the contractual terms chosen by the bank, with $c_F < c_S$. Importantly, c_t is not the quoted interest rate alone: it is an all-in measure of the borrower's financing burden, decomposable into the periodic cost of debt service, non-interest charges such as arrangement, commitment, monitoring and verification fees, and the implicit costs created by contractual constraints including covenant tightness, collateral requirements, mandatory reporting and performance-linked pricing grids. Under favorable terms, the bank may reduce the interest margin, lengthen maturity, increase grace periods, relax collateral requirements or adopt more borrower-friendly covenant packages; under standard terms, it prices and structures the loan according to conventional risk–return criteria. The inequality $c_F < c_S$ therefore operationalizes the institutional argument that bank lending conditions are not exogenous but vary endogenously with regulatory incentives, sustainability mandates, reputational considerations and competitive positioning.

An equally important consideration is execution risk in market-based financing. Unlike bilateral bank lending, which can be finalized once terms are agreed, bond issuance is contingent on investor subscription and the successful completion of a placement process. The model captures this vulnerability through a non-negative loss term $L \geq 0$, incurred when the firm chooses green bonds, but investors do not subscribe or subscribe insufficiently. Conceptually, L represents the broader economic consequences of a failed or under-subscribed issuance that are not fully captured by CGB : sunk underwriting and preparation costs beyond formal certification expenses; delays in project implementation and the associated opportunity costs; reputational damage from a visibly weak market reception, which can impair future access to capital markets; and the need to revert rapidly to alternative funding under time pressure, which weakens bargaining power. Introducing L is essential to represent the strategic logic that a firm may rationally avoid green bond issuance *ex ante* when it anticipates weak participation, precisely because the cost of trying and failing is not neutral.

Finally, the baseline operating value of the financed activity is denoted V and is common across instruments. This choice ensures that the analysis focuses on incremental financing incentives rather than on differences in the underlying project's operating cash flows, avoiding any conflation of financing choice with project selection.

Three additional primitives govern the strategic link between the bank and investors in the green bond branch. First, when the firm issues a green bond the bank can provide credit enhancement or standby support of intensity $e \in \{0, \bar{e}\}$, where $\bar{e} > 0$ denotes the enhanced stance and 0 the unenhanced one; enhancement raises investors' willingness to participate through a pass-through parameter $\varphi > 0$, so that the bank's action enters the investors' participation condition directly. Providing enhancement is privately costly for the bank, at cost $k_e \geq 0$, but yields a franchise or fee benefit $\rho \geq 0$ when the placement succeeds, reflecting league-table credit, cross-selling and relationship value from a completed green transaction. Second, because the firm no longer carries the full loan cost when it issues a bond, its residual bank-related cost in the bond branch is a small standby or arrangement cost $b(e)$, equal to b_F under enhancement and b_0 without, with $b_F < b_0$ and both of a smaller order than the full loan cost c_t ; this distinguishes the standby liquidity a bond

issuer retains from the primary loan an issuer contracts, and ensures that the effective borrowing cost does not enter the two branches symmetrically. Third, for the incomplete-information extension developed in Section 4.6, issuer credibility is observed through a noisy signal of precision $q \in (\frac{1}{2}, 1]$, with a prior $\pi_0 = P(E = S)$ on strong credibility. Table 1 summarizes the notation and parameter definitions.

Table 1. Notation and parameter summary.

	Meaning	Role/Expected Effect
F, I, B	Players: firm, investors, bank	Three-player extensive-form game
a	Firm's financing instrument choice, $a \in \{GB, GBL\}$	Decision variable
GB	Green bond financing (market-based)	Requires investor participation
GBL	Green bank loan financing (bilateral)	Investor stage is absent
i	Investor action under GB, $i \in \{\text{Invest, Not}\}$	Participation constraint
t	Bank loan-term choice, $t \in \{F, S\}$	Determines c_t
F/S	Favorable (concessionary)/standard loan terms	Lower/baseline effective cost
D	Green bond demand state, $D \in \{H, M\}$	Higher D $\rightarrow$ higher ERR(D) and αD
E	Issuer environmental credibility, $E \in \{S, W\}$	Strong E $\rightarrow$ higher investor utility via δ
R	Regulatory incentives affecting banks, $R \in \{\text{Strong, Weak}\}$	Strong R $\rightarrow$ more likely $t^* = F$
C_{GB}	Fixed issuance, certification and verification cost, $C_{GB} > 0$	Higher C_{GB} discourages GB
α	Sensitivity of GB net benefit to demand, $\alpha > 0$	Higher α favors GB
L	Execution loss if GB is attempted and not subscribed, $L \geq 0$	Higher L raises the cost of failure
c_t	Firm's effective all-in borrowing cost under terms t	$c_F < c_S$
V	Baseline project value, common to GB and GBL	Normalization
β	Investor sensitivity to expected risk-adjusted return, $\beta > 0$	Higher β favors Invest
δ	Investor weight on issuer credibility, $\delta > 0$	Higher δ favors Invest
θ	Investor perceived participation costs and risks, $\theta > 0$	Higher θ discourages Invest
γ	Bank sensitivity to regulatory incentives, $\gamma > 0$	Higher γ favors F when R is strong
k_F, k_S	Bank cost of offering favorable/standard terms	$k_F \geq k_S \geq 0$
e	Bank credit-enhancement action in the GB branch, $e \in \{0, \bar{e}\}$	Enters the participation condition via φ
φ	Pass-through of enhancement to investor participation, $\varphi > 0$	Higher φ favors subscription
ρ	Bank franchise/fee benefit from a successful placement, $\rho \geq 0$	Higher ρ favors enhancement
k_e	Bank cost of providing enhancement, $k_e \geq 0$	Higher k_e discourages enhancement
b_F, b_0	Firm standby cost in the GB branch with/without enhancement	$b_F < b_0 < c_t$
q	Signal precision on credibility, $q \in (\frac{1}{2}, 1]$	Higher q sharpens beliefs
π_0	Prior probability of strong credibility, $\pi_0 \in (0, 1)$	Sets the posterior μ_s

Notes: The model is an extensive-form sequential game with complete information; the states (D, E, R) summarize market demand conditions, issuer credibility and the regulatory environment affecting bank incentives. Parameters are reduced-form primitives designed to capture key frictions emphasized in the green finance literature. The baseline project value V is held constant across instruments to isolate incremental financing incentives. Source: Authors' elaboration.

3.2. Players and Payoff Functions

The firm is modeled as the initial mover because, in practice, the issuer initiates the financing process and must commit resources to a route before observing the market's final response. Investors are assumed to evaluate subscription decisions based on expected risk-adjusted performance and credibility-related considerations. The emphasis on risk-adjusted return rather than nominal yield reflects the notion that liquidity conditions, uncertainty premium and reputational risks materially affect the attractiveness of labeled bonds. Investor utility is allowed to depend positively on issuer credibility, capturing the fact that ESG preferences, mandate constraints and reputational concerns can create additional value from funding credible green issuers, while greenwashing risk raises perceived participation costs [1,4,5,28]. The bank is modeled as a strategic agent because green lending conditions are not mechanically determined by borrower risk alone; they may respond to institutional incentives and regulatory design [13,35].

The timing is as follows. The firm moves first (Stage 1). In the green bond branch the bank moves next (Stage 2) and chooses a credit-enhancement action $e \in \{0, \bar{e}\}$; investors then decide whether to subscribe (Stage 3). In the green loan branch, the bank sets loan terms $t \in \{F, S\}$. The bank therefore acts as credit enhancer in the bond branch and as primary lender in the loan branch, and it does not make a lending decision after a bond has already been placed.

Under the green bond route, the firm's payoff is contingent on successful placement. When the firm chooses green bonds and investors subscribe:

$$\pi_F(\text{GB} | \text{Invest}, e) = V + \alpha D - C_{\text{GB}} - b(e) \quad (7)$$

This formulation separates the payoff into four economically interpretable components. Term V is the baseline value generated once funding is secured, held constantly across instruments. The term αD captures the demand-driven advantage of issuing green bonds. The term $-C_{\text{GB}}$ formalizes the non-trivial fixed costs of certification, verification, alignment with reporting standards, enhanced disclosure, internal governance and external review; these are incurred regardless of whether the firm obtains a pricing advantage, which is a central reason why green bond issuance is not universally optimal even where investor demand exists. The term $-b(e)$ captures the small standby or arrangement cost the firm retains in the bond branch—a revolving facility, liquidity buffer or bridge line kept alongside a placed bond—equal to b_F when the bank provides enhancement and b_0 otherwise, with $b_F < b_0$. This bond-branch cost is of a smaller order than the full loan cost c_t and is a distinct object, so the effective borrowing cost does not enter the bond and loan branches symmetrically. When the firm selects green bonds, but investors do not subscribe, the relevant payoff is:

$$\pi_F(\text{GB} | \text{Not}, e) = V - C_{\text{GB}} - b(e) - L \quad (8)$$

The first subtraction reflects that a substantial portion of issuance costs is sunk once the transaction is initiated: fees and expenses associated with structuring and documentation, third-party verification, internal reporting and compliance work, and communication costs are incurred mainly before the subscription decision is observed. C_{GB} is therefore best interpreted as the irrecoverable entry cost of attempting green bond financing, and it is precisely this irreversibility that makes the firm's initial choice strategic and forward-looking. The retention of $-b(e)$ reflects that, following non-subscription, the firm still carries the standby or bridge cost arranged around the attempted issuance; the full loan

cost c_t enters only if the firm subsequently switches to the loan route, which is captured by the green loan payoff below.

$$\pi_F(\text{GBL} | t) = V - c_t \quad (9)$$

This reflects two defining characteristics of bank-based green lending. First, the firm avoids the fixed issuance, certification and market preparation costs inherent to bond issuance, which is why C_{CB} does not appear. Second, green bank loans are characterized by execution certainty relative to bonds: once approved and contracted, a loan typically provides predictable access to funds, which is why no term analogous to L appears. The model therefore treats the core risk in green bonds as placement risk, while the core risk in green bank loans is captured indirectly through the pricing and contractual conditions embedded in c_t .

Investors are assumed to evaluate green bonds through an expected risk-adjusted return measure $\text{ERR}(D)$, assumed to be increasing in D in reduced form. Investor utility from subscribing is:

$$\pi_I(\text{Invest}) = \beta \cdot \text{ERR}(D) + \delta \cdot 1\{E = S\} + \varphi \cdot e - \theta \quad (10)$$

The first term captures the financial motive for subscribing, with $\beta > 0$ measuring sensitivity to expected risk-adjusted returns. The second term represents the credibility-related benefit of investing in a green-labeled instrument issued by a firm with a strong environmental track record, with $\delta > 0$ interpretable as a reduced-form representation of non-pecuniary utility, mandate satisfaction and reduced perceived reputational risk. The third term captures participation frictions, with $\theta \geq 0$ representing perceived greenwashing risk, uncertainty about taxonomy alignment, doubts regarding the measurability of environmental outcomes, monitoring and reporting burdens, and uncertainty premia linked to evolving regulation. A fourth term, $+\varphi \cdot e$, is the value the bank's credit enhancement adds to investor participation: enhancement of intensity $e \in \{0, \bar{e}\}$ raises the investor's payoff through the pass-through $\varphi > 0$, so that the investor's best response depends directly on the bank's action. The outside option is normalized to:

$$\pi_I(\text{Not}) = 0 \quad (11)$$

so that payoffs are measured incrementally: $\pi_I(\text{Invest})$ is the net surplus from subscribing to this green bond over and above what the investor could obtain elsewhere with comparable capital and risk capacity, so that, holding demand and credibility fixed, bank enhancement can move a marginal issuance from non-participation to participation. Investors therefore subscribe if and only if:

$$\beta \cdot \text{ERR}(D) + \delta \cdot 1\{E = S\} + \varphi \cdot e \geq \theta \quad (12)$$

The bank's payoffs are specified so that offering favorable terms is privately costly but can be compensated by policy-induced benefits:

$$\pi_B(F) = \gamma \cdot 1\{R = \text{Strong}\} - k_F \quad (13)$$

$$\pi_B(S) = -k_S, \quad \text{with } k_F \geq k_S \geq 0 \quad (14)$$

where $\gamma > 0$ is a reduced-form representation of the channels through which policy increases the net attractiveness of green lending, including explicit financial incentives such as subsidies, guarantees or concessional funding, prudential and supervisory considerations, and reputational or strategic value. This representation does not imply that the bank

incurs losses under standard lending; it normalizes payoffs so that the decision depends on incremental costs and benefits. The bank prefers favorable terms whenever:

$$\gamma \cdot 1\{R = \text{Strong}\} \geq k_F - k_S \quad (15)$$

The right-hand side is the incremental cost of offering favorable rather than standard conditions; the left-hand side is the policy-driven benefit, available only when the incentive regime is strong.

The payoffs in Equations (13)–(15) describe the bank as primary lender in the loan branch. In the bond branch, the bank instead chooses whether to provide enhancement, anticipating its effect on subscription. Providing enhancement costs k_e and yields the franchise or fee benefit ρ when the placement succeeds, together with the policy reward γ under a strong regime. The bank's bond-branch payoffs are therefore

$$\pi_B(GB, \bar{e}) = \rho \cdot 1\{\text{subscribe} \mid \bar{e}\} + \gamma \cdot 1\{R = \text{Strong}\} - k_e, \pi_B(GB, 0) = \rho \cdot 1\{\text{subscribe} \mid 0\} \quad (16)$$

The bank enhances whenever $\pi_B(GB, \bar{e}) \geq \pi_B(GB, 0)$. When enhancement is pivotal for subscription, this reduces to $\rho + \gamma \cdot 1\{R = \text{Strong}\} \geq k_e$, so a marginal issuance is enhanced only where the franchise benefit and, at the margin, the strong-regime reward cover the enhancement cost. This is the channel through which the regulatory regime reaches the firm's instrument choice, not merely the level of its financing cost.

3.3. Equilibrium Concept and Solution Method and Tie-Breaking

The appropriate solution concept is the subgame-perfect Nash equilibrium (SPNE), which refines the Nash equilibrium by requiring that strategies constitute a Nash equilibrium not only for the game but also for every subgame that can arise after any history of play. This requirement matters in sequential financing problems because actors might otherwise be assumed to commit to actions they would have no incentive to carry out when the relevant node is reached: without subgame perfection, the bank could be attributed a threat of offering concessionary terms where doing so would reduce its payoff, or investors could be assumed to subscribe despite negative expected utility. SPNE eliminates such inconsistencies and ensures that equilibrium behavior remains internally coherent across all contingencies [10,11].

The equilibrium is obtained through backward induction. In the green bond branch, the recursion begins at the investors' Stage-3 subscription decision, governed by the participation condition (12), which now depends on the bank's enhancement; it then moves to the bank's Stage-2 enhancement decision, which the bank makes anticipating the investors' response through the payoffs (16). In the green loan branch, the bank's Stage-2 term-setting decision is governed by (13)–(15). The recursion finally returns to the firm's Stage-1 instrument choice, where the firm compares expected payoffs, taking as given the bank's enhancement and term-setting rules and the investors' subscription rule derived in the later stages. Table 2 maps every terminal history of the game to the corresponding payoff expressions, and Figure 1 presents the extensive form. Appendix A provides the corresponding path-coding index of terminal histories.

Because several of these conditions are weak inequalities, agents may be exactly indifferent at boundary configurations, where the equilibrium could fail to be unique. We therefore adopt a conservative tie-breaking rule throughout: an investor who is exactly indifferent does not subscribe; a bank that is exactly indifferent offers standard terms and provides no enhancement; and a firm that is exactly indifferent chooses the green bank loan. Under this rule the subgame-perfect equilibrium is unique for every admissible

parameter configuration, and the boundary points of the equilibrium regions in the figures are assigned to the loan outcome accordingly.

Table 2. Terminal payoff mapping.

Bank Action at Stage 2	Investor: Invest	Investor: Not
Panel A. Firm chooses GB at Stage 1		
Enhancement ($e = \bar{e}$)	Firm: (7); Investor: (10); Bank: (16)	Firm: (8); Investor: (11); Bank: (16)
No enhancement ($e = 0$)	Firm: (7); Investor: (10); Bank: (16)	Firm: (8); Investor: (11); Bank: (16)
Panel B. Firm chooses GBL at Stage 1		
Terminal payoffs		
Favorable	Firm: (9); Bank: (13)	—
Standard	Firm: (9); Bank: (14)	—

Notes: The table links each terminal history of the game to the payoff expressions specified in Section 3.2. In the green bond branch (Panel A), the bank's Stage-2 action is credit enhancement $e \in \{0, \bar{e}\}$ and its payoff is given by (16); investors' payoffs are not reported in the green loan branch because the investor has no decision node there. Source: Authors' elaboration.

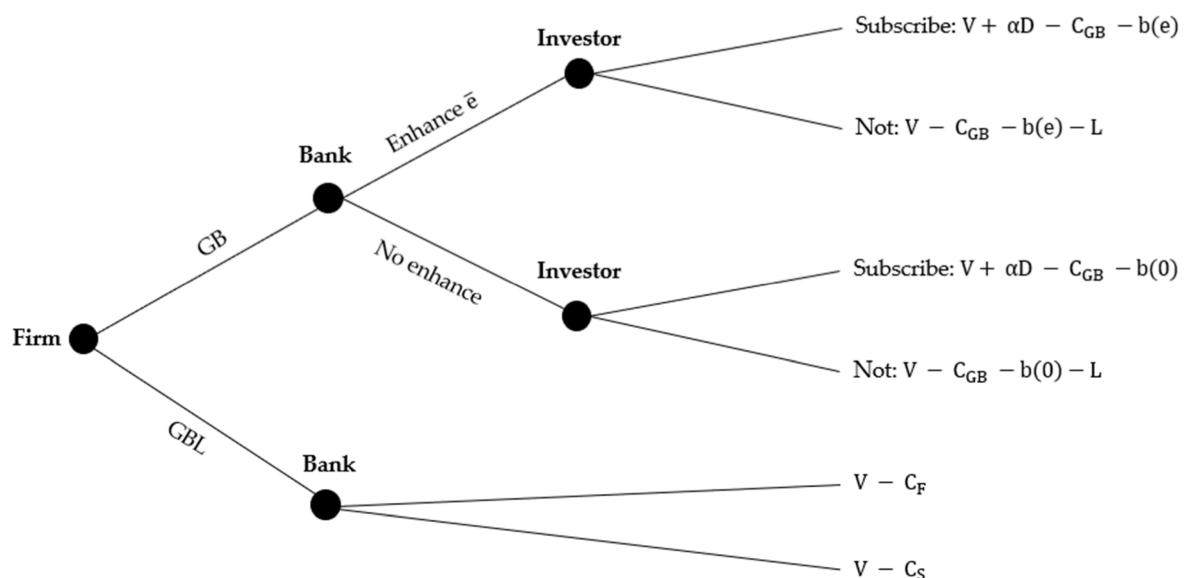


Figure 1. Extensive-form decision tree for green debt instrument choice. Notes: The figure represents the sequential game. The firm's Stage-1 instrument choice determines the branch; in the green bond branch the bank chooses credit enhancement at Stage 2 before investors decide at Stage 3, while in the green loan branch the bank sets loan terms at Stage 2. Terminal payoffs are assigned according to Table 2, by reference to Equations (7)–(9) for the firm, (10) and (11) for investors, (13)–(15) for the bank in the loan branch and (16) for the bank in the bond branch. The equilibrium concept is SPNE, derived by backward induction under the tie-breaking rule stated in the text. Source: Authors' elaboration.

3.4. Numerical Implementation and Simulation Design

The analytical solution delivers threshold inequalities but not magnitudes. To quantify equilibrium regions, rank the influence of the model primitives and characterize regime switching, the equilibrium correspondence is implemented numerically in Python 3.11 (NumPy 2.4, Matplotlib 3.10). The solver implements backward induction for any parameter vector: it evaluates the bank's bond-branch enhancement payoffs (16) and its loan-branch payoffs (13)–(15), then the investors' participation condition (12), and finally the firm's instrument comparison (7)–(11), returning the equilibrium instrument, the bank's enhancement and contractual stance, the subscription outcome and all terminal payoffs. The numerical experiment has three components.

First, a deterministic evaluation solves the game at a baseline parameterization for each of the eight admissible states of (D, E, R), establishing the reference equilibrium. Second, the equilibrium correspondence is mapped over a 400×400 grid in the (θ, CGB) plane for each combination of demand and credibility, partitioning the parameter space into a green bond region, a region in which bonds are feasible but dominated, and a region in which bonds are infeasible because the participation constraint fails. Third, a Monte Carlo experiment draws $N = 200,000$ parameter vectors and solves the game for each draw in every state, yielding, for each state, the share of parameter draws that produce investor subscription, bank enhancement, favorable loan terms and a green bond equilibrium, each reported with its binomial standard error. Global sensitivity is assessed by variance-based methods rather than by simple correlations: Sobol first- and total-order indices [37] are computed by Saltelli sampling [38], and Morris elementary effects [39] by a factorial screening design, for the fraction of states in which a green bond equilibrium obtains as a function of the continuous primitives. Robustness is examined by re-running the experiment under alternative (uniform) distributions, under correlated sampling induced by a Gaussian copula, and under empirically motivated non-equal state weights.

The baseline magnitudes respect the orders of magnitude reported in the cited literature: the fixed issuance and certification burden C_{GB} is set larger than typical demand-driven pricing advantages, consistent with certification and verification costs exceeding the few-to-tens-of-basis-points greenium documented for labeled bonds, and the concessional loan differential $c_S - c_F$ is of the order of the spread reductions reported for policy-supported green lending. Sampling distributions are lognormal for the strictly positive scale parameters $(\alpha, C_{\text{GB}}, L)$ and truncated normal for the remaining continuous primitives, including the enhancement primitives φ, ρ and k_e ; the continuous primitives are drawn independently, an assumption relaxed in the correlated-sampling robustness check. Dispersions are calibrated to span the plausible ordering of magnitudes rather than to reproduce any market. The pseudo-random number generator is seeded (seed = 20,260,820), so all reported figures are exactly reproducible.

Two clarifications on the epistemic status of the numerical results are warranted. The simulation is a numerical solution of the theoretical model, not an estimation exercise: every reported quantity is a deterministic or Monte Carlo evaluation of Equations (7)–(15) and contains no empirical data on green bonds, green loans or issuers. Consequently, every figure reported below is the share of simulated parameter configurations yielding the stated equilibrium outcome—a property of the model under the stated parameterization—and must not be read as an adoption rate or a measured frequency in any real market. What the exercise does deliver is the quantitative shape of the equilibrium correspondence, which is precisely what is required to use the framework as a scenario and risk-assessment device.

4. Results

4.1. Bank's Loan Terms and Credit Enhancement (Stage 2)

At Stage 2, in the loan branch, the bank internalizes a trade-off between the private economic cost of granting concessionary lending conditions and the institutional or strategic benefits arising when the regulatory environment supports sustainable credit expansion. The decision is characterized by the threshold condition (15). The structure clarifies that the bank's choice is governed not by absolute profitability levels but by an incremental comparison: the concessionary stance is selected only if the incremental policy or strategic benefit outweighs the incremental cost of providing those terms. When the regulatory environment does not activate the incentive component, the inequality collapses to a comparison driven purely by private costs, and the bank's best response is the baseline stance whenever concessions are strictly more costly. When incentives are active, the

bank may rationally deviate from baseline pricing because part of its objective function is effectively shifted by institutional design. This is the channel emphasized by the policy-oriented sustainable finance literature: regulation can affect the supply side of green finance not only by shaping disclosure norms or investor demand, but by altering banks' own payoffs so that sustainable lending becomes privately incentive-compatible [13].

Denoting the bank's equilibrium choice by $t^*(R)$, the perfect-information benchmark implies that $t^*(R)$ is uniquely pinned down by (15) for any admissible parameter configuration. Increases in the incentive intensity parameter expand the set of configurations in which the concessionary stance is optimal, while increases in the incremental private cost of concessions shrink that set. This loan-term decision is economically consequential because it determines which effective borrowing cost the firm faces under bank finance, and it therefore constitutes the model's primary institutional transmission channel.

The bank's second decision arises in the green bond branch, where it chooses whether to provide credit enhancement $e \in \{0, \bar{e}\}$ before investors subscribe. From the bond-branch payoffs (16), the bank enhances whenever $\rho \cdot 1\{\text{subscribe} | \bar{e}\} + \gamma \cdot 1\{R = \text{Strong}\} - k_e \geq \rho \cdot 1\{\text{subscribe} | 0\}$. When enhancement is not pivotal—the placement would succeed or fail regardless—this reduces to $\gamma \cdot 1\{R = \text{Strong}\} \geq k_e$, so the bank enhances a non-marginal issuance only if the policy reward alone covers the cost. When enhancement is pivotal—investors subscribe under $\bar{e}$ but not under 0—it reduces to $\rho + \gamma \cdot 1\{R = \text{Strong}\} \geq k_e$, so the bank rescues a marginal issuance only when its franchise benefits and, at the margin, the strong-regime reward jointly clear the enhancement cost. This is the mechanism through which the regulatory regime reaches the firm's instrument choice: by making the bank willing to enhance a marginal bond, a strong regime can render feasible an issuance that would otherwise fail. The bank's loan-term and enhancement rules are both uniquely determined under the tie-breaking convention of Section 3.3.

4.2. Investors' Subscription Decision (Stage 3)

Stage 3 introduces the defining institutional asymmetry between market-based and bank-based green debt: green bond issuance requires voluntary investor participation, whereas green lending is negotiated bilaterally and faces no equivalent subscription stage. Equation (12) makes it explicit that participation depends on four conceptually distinct components. The first is the expected risk-adjusted return, expressed as a reduced-form function of the demand state, reflecting the premise that investors evaluate a labeled bond not solely on headline yield but on risk-adjusted performance incorporating liquidity conditions, uncertainty premia and the broader pricing environment [2,5]. The second is the credibility-dependent term, which formalizes the idea that credibility is an economically relevant determinant of demand because it affects beliefs about whether the green label is informative. Investors may attach additional value to funding credible issuers because many institutions face ESG mandates, because some derive non-pecuniary utility from impact [28], and because credibility mitigates greenwashing concerns and the associated reputational risk [1]. The third is the participation friction, which can also be interpreted through behavioral lenses: when credibility is noisy or scandals are salient, investors may overweight downside outcomes and treat potential reputational losses asymmetrically, increasing the perceived cost of participation even if expected returns are competitive [14–16].

A fourth component, introduced in the revised model, is the bank's credit enhancement $\phi \cdot e$. Because the bank moves before investors in the bond branch, its enhancement enters the participation condition directly, so that a marginal issuance that would fail on demand and credibility alone can be brought to subscription by bank support. Investor participation is therefore no longer a function of demand and credibility only, but also of the bank's Stage-2 action.

The equilibrium relevance of Stage 2 lies in its definition of a binding participation constraint for the issuer. Even if the firm prefers the bond route on its own cost–benefit calculus, that route is not implementable unless (12) holds. In market-based sustainable finance, instrument choice is therefore constrained by beliefs and credibility, not solely by the issuer’s private optimization, and the investor decision acts as the gatekeeping mechanism separating states in which green bond issuance is feasible from states in which it is not—a gate that the bank’s credit enhancement can partly open.

4.3. Firm’s Instrument Choice (Stage 1)

At Stage 1, the firm selects its financing instrument anticipating the continuation strategies derived above. A disciplined way to present the decision is to condition on whether the green bond branch is feasible in the continuation game. Consider first the regime in which (12) holds and investors subscribe. The net payoff difference between green bonds and green loans, evaluated at the bank’s equilibrium stance, is:

$$\Delta\pi_F^{\text{Invest}} = \pi_F(\text{GB} \mid \text{Invest}, e) - \pi_F(\text{GBL} \mid t) \alpha D - C_{\text{GB}} - b(e) + c_t \quad (17)$$

Hence, conditional on subscription, the firm prefers issuing green bonds if and only if:

$$\alpha D \geq C_{\text{GB}} + b(e) - c_t \quad (18)$$

When the bond branch is feasible, the firm chooses the market-based route only if the demand-driven advantage is sufficiently large to offset the fixed issuance, certification and disclosure burden. The result formalizes the intuition that green bond issuance is not automatically optimal even in supportive markets: it must clear an economic threshold once compliance costs are accounted for. Unlike the first-submission specification, the effective borrowing cost does not cancel from this comparison: the green bond branch carries only the small standby cost $b(e)$, whereas the green loan branch carries the full loan cost c_t , so $\partial\Delta\pi_F^{\text{Invest}}/\partial c_t = +1$. The bank’s equilibrium loan terms, and therefore the regulatory regime that shapes them, enter the bond-versus-loan comparison directly. The regulatory channel operates through two routes with opposite signs: a strong regime lowers the loan cost c_t , which favors the loan, and it makes the bank willing to enhance a marginal bond, which favors the bond by relaxing (12). The net effect on instrument choice is therefore state-dependent rather than zero. The neutrality reported in the first submission is recovered only as a degenerate special case, in which the same c_t is placed in both branches and the enhancement channel is switched off; once the two branches carry economically distinct bank costs, regulatory incentives affect the choice of instrument and not merely the level of financing cost. Section 4.6 quantifies how often the regulatory regime flips the equilibrium instrument.

Next, consider the regime in which (12) fails and investors do not subscribe. The net payoff difference becomes:

$$\Delta\pi_F^{\text{Not}} = \pi_F(\text{GB} \mid \text{Not}, e) - \pi_F(\text{GBL} \mid t) = c_t - C_{\text{GB}} - b(e) - L \quad (19)$$

This difference is negative whenever the issuance burden, standby cost and execution loss exceed the avoided loan cost, that is, whenever $C_{\text{GB}} + b(e) + L > c_t$, which holds under any calibration in which the failure loss L is non-trivial. Under this maintained condition, attempting a green bond issuance that is anticipated to fail is strictly dominated by choosing a green bank loan: a failed issuance imposes sunk costs and execution losses without delivering the intended market-based funding benefit. The Stage-1 decision can thus be summarized as an equilibrium selection rule. The firm chooses green bonds if and

only if both conditions hold: feasibility, so that the participation condition (12) is satisfied, and optimality conditional on feasibility, so that the net-benefit condition (18) is satisfied. In all other states the firm chooses green bank loans. This characterization makes clear that market-based green debt can be observed in equilibrium only when the bond branch is both feasible and economically attractive after accounting for issuance burdens, and it identifies the source of potential discontinuities: once investor participation fails, the bond option becomes strictly dominated by the sunk cost and execution loss, yielding a discrete shift towards the loan branch.

4.4. Deterministic Equilibrium Across States

Using the baseline calibration of Table 3, Table 4 reports the equilibrium of the game for each of the eight states of (D, E, R). Three features stand out. First, green bonds emerge in equilibrium in all four high-demand states, where the demand-driven advantage $\alpha D = 6.00$ comfortably exceeds the issuance and standby costs; because the loan cost no longer cancels, the bond advantage now ranges from $\Delta\pi_F = +4.00$ under favorable loan terms to $+5.20$ under standard terms. Second, under moderate demand with strong credibility, the advantage falls but remains positive, at $+0.70$ to $+1.90$, so green bonds are still chosen: with the full loan cost c_t entering the comparison, a moderate-demand issuer that would previously have been pushed to loans can now prefer bonds. Third, under moderate demand with weak credibility, the participation constraint fails without support, and the outcome depends on the regulatory regime: under a strong regime the bank enhances the marginal issuance, which becomes feasible and is chosen ($+0.90$), whereas under a weak regime the bank does not enhance, participation fails, and the comparison (19) yields -4.80 , so the green loan is chosen.

Table 3. Baseline calibration and Monte Carlo sampling distributions.

Parameter	Baseline Value	Sampling Distribution
V (project value)	100.00	fixed
D (high/moderate)	1.00/0.45	fixed
ERR(D) (high/moderate)	0.90/0.40	fixed
α (demand sensitivity)	6.00	lognormal($\ln 6.00, 0.35$)
C_{GB} (issuance cost)	3.50	lognormal($\ln 3.50, 0.45$)
L (execution loss)	4.00	lognormal($\ln 4.00, 0.40$)
β (return sensitivity)	1.00	normal(1.00, 0.20), truncated at 0.10
δ (credibility weight)	0.45	normal(0.45, 0.15), truncated at 0
θ (participation friction)	0.80	normal(0.80, 0.22), truncated at 0.05
γ (bank incentive intensity)	0.60	normal(0.60, 0.20), truncated at 0
k_F/k_S (bank costs)	1.00/0.55	fixed
c_F/c_S (borrowing costs)	2.00/3.20	Fixed
φ (enhancement pass-through)	0.45	normal(0.45, 0.12), truncated at 0
ρ (bank franchise benefit)	0.50	normal(0.50, 0.20), truncated at 0
k_e (enhancement cost)	0.70	normal(0.70, 0.20), truncated at 0
b_F/b_0 (bond-branch standby)	0.30/0.50	fixed

Table 3. Cont.

Parameter	Baseline Value	Sampling Distribution
q (signal precision)	0.80	fixed
π_0 (prior, strong credibility)	0.50	fixed

Notes: Values are expressed in normalized units and are illustrative; they are chosen so that the reference point lies in a region of the parameter space in which neither instrument dominates across all states. They are not estimates from market data. Monte Carlo draws: N = 200,000; seed = 20,260,820. Source: Authors' elaboration.

The regulatory regime now bears on the choice of instrument, not merely on the level of payoffs. In the moderate-demand, weak-credibility state, the equilibrium instrument flips from a green bank loan under a weak regime to a green bond under a strong regime, because only a strong regime makes the bank willing to enhance the marginal issuance and thereby render it feasible. Elsewhere the regime still shifts the level of financing costs: a favorable loan lowers c_t , raising the loan payoff and compressing the bond advantage, so that the advantage in the high-demand strong-credibility state is +4.00 under a strong regime against +5.20 under a weak one. This is the deterministic counterpart of the broken neutrality quantified in Section 4.6, where the regulatory regime flips the equilibrium instrument in 19.4% of parameter draws: the demand channel governs whether bonds clear the net-benefit threshold, while the institutional channel now bears both on the level of financing costs and, at the margin, on the choice of instrument itself.

Table 4. Deterministic equilibrium at the baseline calibration, by state.

D	E	R	Enhance	Subscribe	Bank Terms	Instrument	π_F	$\Delta\pi_F$
H	S	Strong	No	Yes	F	GB	102.00	+4.00
H	S	Weak	No	Yes	S	GB	102.00	+5.20
H	W	Strong	No	Yes	F	GB	102.00	+4.00
H	W	Weak	No	Yes	S	GB	102.00	+5.20
M	S	Strong	No	Yes	F	GB	98.70	+0.70
M	S	Weak	No	Yes	S	GB	98.70	+1.90
M	W	Strong	Yes	Yes	F	GB	98.90	+0.90
M	W	Weak	No	No	S	GBL	96.80	−4.80

Notes: π_F is the firm's equilibrium payoff; $\Delta\pi_F$ is the payoff of the green bond route minus the payoff that of the green loan route, evaluated at the bank's equilibrium stance, as given by Equation (17) when investors subscribe and by Equation (19) when they do not. "Enhance" is the bank's Stage-2 credit-enhancement action in the bond branch. In the moderate-demand, weak-credibility state, the regulatory regime flips the equilibrium instrument. Source: Authors' elaboration.

4.5. Equilibrium Regions in Parameter Space

Figure 2 maps the equilibrium correspondence over the (θ, CGB) plane for the four combinations of demand and credibility, under a strong regulatory regime so that the bank enhances marginal issuances. Two boundaries delimit the green bond region. The vertical boundary is the participation threshold: without enhancement the bond is feasible only for $\theta^* = \beta \cdot \text{ERR}(D) + \delta \cdot 1\{E = S\}$, but where the bank enhances a marginal issuance the feasible range extends to $\theta \leq \beta \cdot \text{ERR}(D) + \delta \cdot 1\{E = S\} + \varphi$, so credit enhancement widens the region rightward by φ . The horizontal boundary is the net-benefit threshold $C_G B^* = \alpha D - b(e) + c_t$; above it bonds are feasible but dominated by loans. Because the full loan cost c_t now enters this ceiling, the admissible issuance-cost range is wider than the demand advantage αD alone. The green bond region is the intersection of the two half-planes and shrinks

monotonically as demand weakens and as credibility deteriorates, but the enhancement channel keeps a feasible sliver open in states that would otherwise be closed.

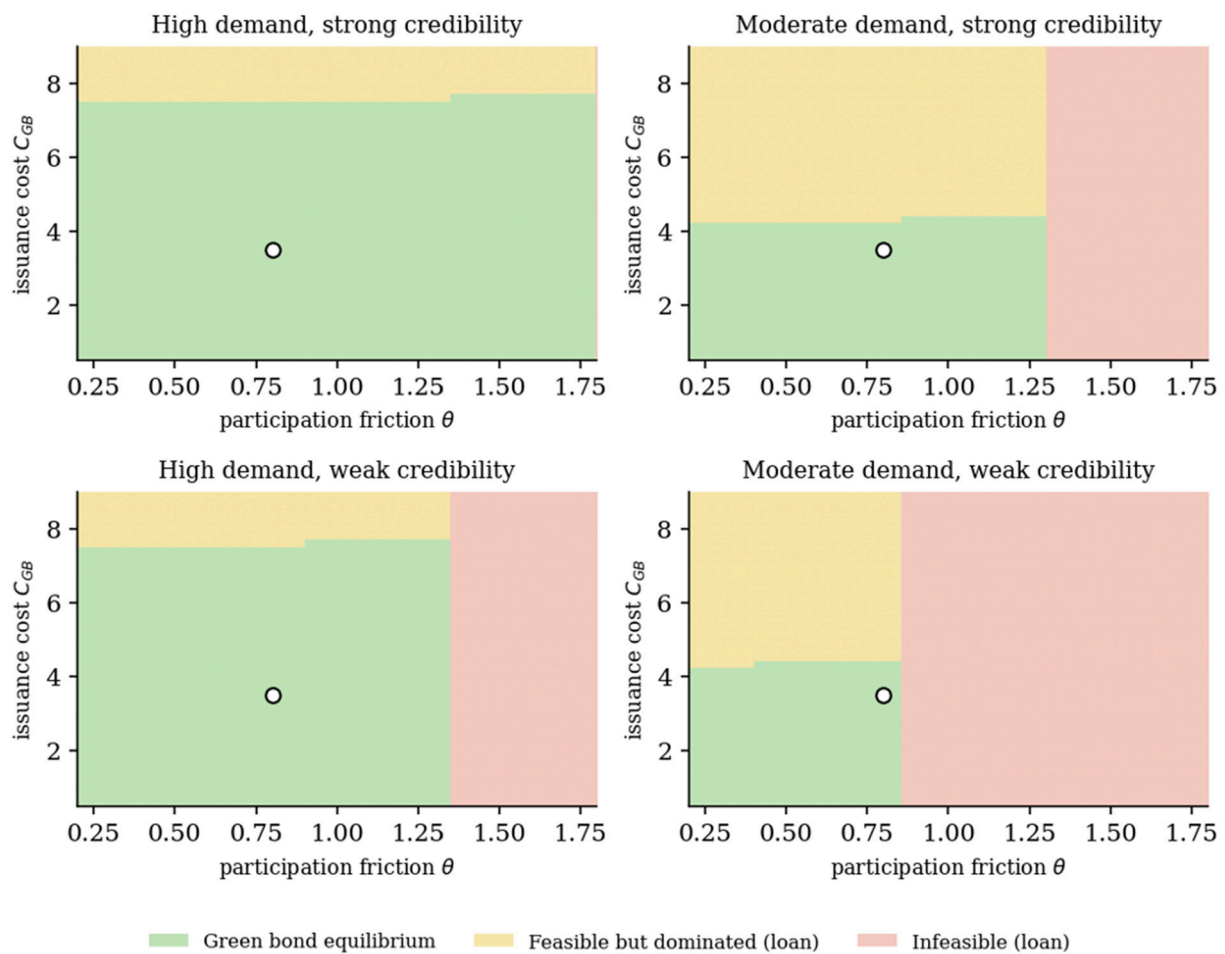


Figure 2. Equilibrium regions of the sequential green-financing game in the (θ, C_{GB}) plane. Notes: Each panel partitions the parameter space for one combination of the demand state D and the credibility state E , holding all remaining parameters at the baseline values of Table 3 and setting $R = \text{Strong}$. The green area is the green bond equilibrium; the red area is infeasible (loan). The rightward step in the green boundary reflects the range of participation frictions over which bank credit enhancement is pivotal. The open circle marks the baseline parameterization. Source: Authors' elaboration based on the numerical solution of Equations (7)–(16).

The comparison across panels quantifies the substitutability between demand and credibility and the cushioning role of enhancement. The participation threshold, inclusive of enhancement, falls from $\theta^* = 1.80$ with strong credibility to $\theta^* = 1.35$ with weak credibility; under moderate demand, the corresponding thresholds are 1.30 and 0.85. The net-benefit ceiling, $C_{GB}^* = \alpha D - b(e) + c_t$, falls from 7.50 under high demand to about 4.20 under moderate demand at favorable loan terms. Credibility therefore does not merely shift outcomes at the margin: in the moderate-demand, weak-credibility panel, the green bond region is confined to configurations combining low participation frictions with low issuance costs, and it exists at all only because bank enhancement extends feasibility by φ . This is the formal sense in which verification ecosystems and disclosure quality operate as equilibrium-shaping constraints on sustainable debt markets rather than as background conditions, and in which bank credit enhancement partially substitutes for weak credibility [1,2,5].

4.6. Monte Carlo Results and Global Sensitivity

Table 5 reports the Monte Carlo experiment over $N = 200,000$ parameter draws. The share of draws in which investors subscribe falls from 99.3% under high demand and strong credibility to 92.1% when credibility weakens, to 90.3% when demand instead weakens, and to 17.0% when both deteriorate; the intermediate levels are higher than in the first submission because the bank now enhances marginal issuances. The share of draws yielding a green bond equilibrium follows the same ordering, declining from 93.4% under high demand and strong credibility to 69.1% under weak credibility, to 54.7–63.8% under moderate demand, and to 14.2% when both demand and credibility are weak. Conditional on subscription, bonds are chosen in about 94% of high-demand draws but in 71–84% of moderate-demand draws, because the demand-driven advantage more frequently fails to cover the fixed issuance cost even once the loan cost is netted out.

Table 5. Monte Carlo shares.

D	E	R	Subscribe	Enhance	Green Bond (s.e.)	GB Subscribe
H	S	Strong	0.993	0.381	0.934 (0.0006)	0.940
H	S	Weak	0.967	0.010	0.935 (0.0006)	0.967
H	W	Strong	0.921	0.528	0.867 (0.0008)	0.941
H	W	Weak	0.714	0.078	0.691 (0.0010)	0.968
M	S	Strong	0.903	0.555	0.638 (0.0011)	0.706
M	S	Weak	0.662	0.090	0.547 (0.0011)	0.827
M	W	Strong	0.508	0.633	0.362 (0.0011)	0.713
M	W	Weak	0.170	0.127	0.142 (0.0008)	0.836

Notes: Entries are shares of $N = 200,000$ parameter draws from the sampling distributions in Table 3 which the stated outcome obtains, by state (D = demand, E = issuer credibility, R = regulatory regime). Subscribe: investors participate; Enhance: the bank provides credit enhancement; Green bond (s.e.): share of draws yielding a green bond equilibrium, with binomial standard error; GB | subscribe: green bond share conditional on investor subscription. The pooled green bond share, with states weighted equally, is 0.640, against 0.380 in the degenerate special case without the enhancement channel. Shares are properties of the model under the illustrative calibration and must not be interpreted as measured frequencies in any real market. Seed = 20,260,820. Source: authors' elaboration based on the numerical solution of Equations (7)–(16).

The two shares differ by the second, issuer-side constraint. Moving from high to moderate demand lowers the green bond share by roughly thirty percentage points at strong credibility, operating mainly through the net-benefit condition, since the conditional share given subscription falls from about 0.94 to about 0.71. Moving from strong to weak credibility lowers the share mainly through the participation constraint, since the conditional share given subscription is little changed. Demand and credibility therefore act through partially distinct channels: credibility governs whether the market validates the label, while demand governs both validation and the economics of issuance.

The regulatory regime is no longer neutral for instrument choice. Holding the state (D, E) and the continuous draw fixed and switching the regime from weak to strong flips the equilibrium instrument in 19.4% of draws, against exactly 0.0% in the degenerate special case that reinstates a common financing cost and switches off the enhancement channel. The flip share is largest where the enhancement and loan-cost channels are most marginal—26.3% in the moderate-demand, weak-credibility state and 25.2% under moderate demand with strong credibility—and smallest under high demand with strong credibility, at 5.0%. The pooled green bond share is 0.640 in the interactive model against 0.380 in the degenerate case. This is the numerical counterpart of the analytical result of Section 4.3: once the two branches carry economically distinct bank costs and the bank can enhance a marginal issuance, regulation reaches the choice of instrument, not merely the level of financing cost.

Table 6 and Panel (a) of Figure 3 report a variance-based global sensitivity analysis, replacing the correlation ranking of the first submission. Total-order Sobol indices identify the issuance cost C_{GB} (0.445) and the participation friction θ (0.335) as the dominant primitives, followed by the demand sensitivity α (0.240) and the investor return sensitivity β (0.130). The enhancement primitives carry small but non-negligible total-order effects—the enhancement cost k_e (0.084), the bank franchise benefit ρ (0.072) and the pass-through φ (0.062)—as does the regulatory parameter γ (0.045), which is no longer inert: the institutional channel is now active, though secondary to demand and cost. The execution loss L has a total-order index of exactly 0.000, because it never determines the equilibrium instrument; it governs only how costly a failed issuance would be off the equilibrium path. Morris elementary effects give the same ordering, confirming that the ranking is not an artifact of the variance decomposition.

Table 6. Sobol sensitivity indices.

Primitive	First-Order S_1	Total-Order S_T
C_{GB}	0.263	0.445
θ	0.205	0.335
α	0.095	0.240
β	0.068	0.130
k_e	0.033	0.084
ρ	0.019	0.072
φ	0.021	0.062
γ	0.012	0.045
δ	0.009	0.041
L	0.000	0.000

Notes: Saltelli sampling, 4096 base points; Morris elementary effects give the same ordering. Source: Authors' elaboration.

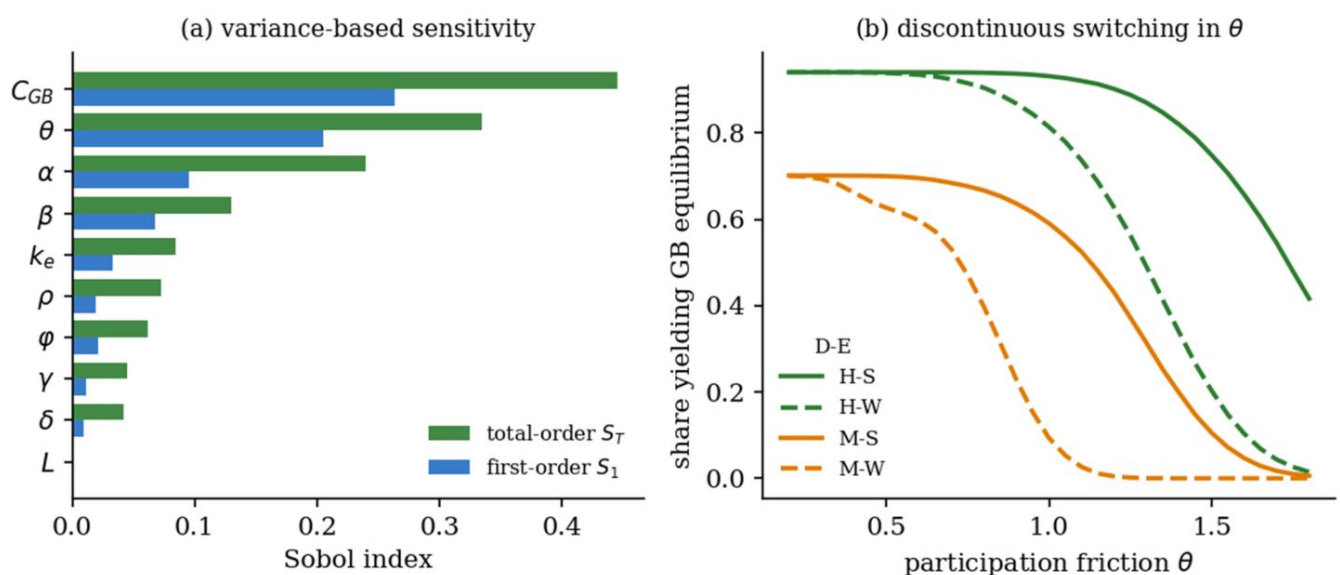


Figure 3. Global sensitivity (Sobol first- and total-order indices) and discontinuous switching at the participation threshold. Notes: Panel (a) reports Sobol first-order (S_1) and total-order (S_T) indices for the fraction of states in which a green bond equilibrium obtains, computed by Saltelli sampling with 4096 base points. Panel (b) reports the share of draws yielding a green bond equilibrium as the participation friction θ varies continuously, holding the remaining parameters at their sampling distributions and the regulatory regime at strong. Source: Authors' elaboration based on the numerical solution of Equations (7)–(16).

The pooled green bond share is stable across sampling schemes: 0.640 under the baseline distributions, 0.580 under uniform distributions, 0.659 under correlated (Gaussian-copula) sampling and 0.683 under empirically motivated non-equal state weights.

Panel (b) traces the share of draws yielding a green bond equilibrium as the participation friction varies continuously. The curves are not smoothly declining but fall steeply around the state-specific participation threshold, beyond which the green bond share collapses towards zero within a narrow interval of θ ; the collapse occurs at progressively lower θ as demand and credibility deteriorate, and bank enhancement shifts each threshold outward relative to the no-enhancement case. This is the quantitative signature of the dominance result in Equation (19): as parameters deteriorate, the model does not predict less bond issuance but the disappearance of bond issuance from the firm's optimal set. This discontinuity is a property of the individual issuer's threshold problem and should not be read as a prediction of sudden contractions in aggregate issuance volume: with heterogeneous issuers whose thresholds are dispersed across the population, the aggregate relationship is smooth, and the model speaks to the composition of financing—which issuers switch instrument—rather than to the size of any market-wide movement.

Finally, as the signal precision q rises from $\frac{1}{2}$ (uninformative) to 1 (perfect verification), the greenwashing residual $1 - \mu_s$ falls from 0.500 to 0, and the share of favorably signaled issuers reaching a green bond equilibrium rises from 66.3% to 76.4%. Better verification therefore raises the feasibility of labeled issuance for issuers that look green while shrinking the residual probability that such an issuer is not; the complete-information benchmark is recovered as $q \rightarrow 1$. Panel (b) of the figure reports the corresponding share of draws in which the regulatory regime flips the instrument, by state.

5. Discussion

5.1. Main Equilibrium Message

A key message of the model is that a green label advantage is neither automatic nor uniform across instruments. Green bonds are observed in equilibrium only when two conditions are jointly satisfied. First, issuance must be feasible in the continuation game, which requires that the combined financial and credibility-related benefits outweigh participation frictions. This formalizes the idea that labeled debt markets are governed by belief-sensitive participation: the issuer does not unilaterally choose a bond outcome unless investors validate the label by subscribing. Second, conditional on feasibility, issuance must be optimal relative to green bank loans, which requires that the demand-related advantage is large enough to compensate for the fixed issuance, certification and disclosure burden. The model therefore predicts heterogeneity in instrument choice even among issuers that can successfully place a green bond.

The simulation converts these statements into magnitudes. Under the baseline parameterization, market-based green financing is the equilibrium in about 93% of parameter configurations when demand is deep and the issuer is credible, but in only about 14% when both conditions deteriorate. The intermediate cases are the informative ones for policy: a credible issuer facing moderate demand retains a high probability of investor validation—around 90% under a strong regulatory regime—but a lower probability of issuing, around 64%, because the fixed cost of the label is not always amortized even once the avoided loan cost is taken into account. This distinction between validation and viability is invisible in reduced-form spread comparisons.

5.2. Interpretation of the Comparative Statics

Because the equilibrium is characterized by threshold inequalities, the model predicts both marginal effects and regime changes. On the investor side, stronger demand raises

the return component and expands the subscription region; stronger credibility adds the credibility benefit and relaxes the participation constraint; and higher participation frictions, interpretable as greenwashing concerns, uncertainty about label meaning, monitoring burdens or reputational sensitivity, tighten it. Conditional on subscription, higher issuance costs shrink the bond-choice region even when issuance is feasible, while higher demand sensitivity or stronger demand states expand it. This clarifies why observed instrument choice may differ across issuers and across market regimes: issuers with high compliance burdens or limited ability to monetize demand will rationally prefer loans even when they could place a bond.

On the banking side, a shift from a weak to a strong regulatory regime has two effects on the firm's problem. It expands the set of environments in which the bank offers favorable loan terms, lowering the firm's effective borrowing cost and, other things equal, making the loan route more attractive; additionally, it makes the bank willing to provide credit enhancement to a marginal bond, relaxing the participation constraint and making the bond route feasible in states where it otherwise fails. These two routes push instrument choice in opposite directions, so the net regulatory effect is state-dependent rather than zero. The numerical results sharpen this interpretation: the regulatory regime flips the equilibrium instrument in 19.4% of draws, concentrated in the marginal states where enhancement is pivotal. The institutional channel therefore bears on both the level of financing costs and the composition of instruments, and cross-jurisdictional variation in supervisory frameworks can produce systematic variation not only in loan pricing but in the bond-versus-loan mix, holding issuer fundamentals constant.

5.3. Implications for Empirical Interpretation and Measurement

The model provides a structure for interpreting observed patterns in sustainable debt markets by separating three mechanisms that can otherwise be conflated. First, empirical analysis should distinguish between feasibility and pricing. Observed bond spreads conditional on issuance reflect outcomes in the subset of states where the participation constraint is satisfied; they do not capture states in which bonds are infeasible and therefore unobserved. Analyses focusing only on issued bonds may consequently understate the economic role of credibility and participation frictions unless issuance incidence, withdrawal or under-subscription events are explicitly considered. The Monte Carlo results quantify the potential magnitude of this selection: in the moderate-demand, weak-credibility state, between 64% and 86% of parameter configurations produce no observable green bond, depending on whether the regulatory regime is strong or weak.

Second, the model clarifies the role of fixed issuance burdens. Even when bonds are feasible, the bond-versus-loan choice depends on whether the demand-driven advantage compensates for the certification and disclosure cost. Empirically, this suggests that issuer characteristics related to compliance capacity and to the amortization of fixed costs, such as scale, frequency of issuance and established frameworks, should systematically correlate with instrument choice independently of short-run pricing. Third, the model highlights an institutional intermediation channel operating through banks, which should be treated as a driver of equilibrium outcomes rather than as background context, motivating careful attention to supervisory environments when interpreting cross-country differences in the prevalence and terms of green lending.

Two recent studies bear on these mechanisms. Liu et al. [40] find that green bonds co-move more strongly with traditional fixed-income markets than with green assets and that short-term spillovers and uncertainty dominate, which supports treating the demand state D and the participation friction θ as transmission-sensitive and time-varying. Zhou and Xu [41] document a nonlinear, U-shaped relationship between green finance and

regional ecological development with pronounced regional heterogeneity, paralleling the threshold and regime-switching behavior of the present model and reinforcing the case for jurisdiction-specific empirical calibration.

5.4. Implications for Risk Assessment and Policy Design

Read as a risk-assessment device, the framework returns, for any institutional configuration, the probability that market-based green financing is attainable. Three implications follow for issuers, lenders and supervisors. First, because the equilibrium exhibits threshold behavior, exposure to labeled bond markets carries a discontinuous risk profile: a small deterioration in perceived credibility or in the meaning of the label can eliminate market access rather than merely raise its price. Contingency planning that assumes a gradually rising cost of issuance will therefore understate the funding risk faced by marginal issuers. Second, the sensitivity ranking indicates where regulatory effort is most productive. Interventions that lower participation frictions, such as harmonized taxonomies, assurance standards and enforcement against greenwashing, act directly on the binding constraint. Interventions that support bank credit enhancement operate more selectively: because the bank enhances only marginal issuances, and, at the margin, only under a strong regime, credit-enhancement or guarantee, schemes expand bond-market access precisely for the issuers on the participation boundary, while broad loan-rate subsidies mainly lower financing costs for issuers whose instrument choice is already settled.

5.5. Limitations and Future Research

As a benchmark, the model deliberately abstracts from several complexities to preserve tractability. First, the baseline adopts complete information. An incomplete-information extension (Section 4.6) relaxes this by making credibility a private type observed through a noisy signal, which gives greenwashing risk an explicit formal representation as the residual probability that a favorably signaled issuer is not in fact credible; a fuller signaling environment with endogenous certification, in which issuers choose verification intensity strategically, remains for future work. Second, investor behavior is represented by a reduced-form participation rule, whereas the investor base is heterogeneous in ESG mandates, reputational sensitivity, benchmark constraints and risk tolerance; allowing heterogeneity would yield richer predictions about over-subscription, market segmentation and the dispersion of pricing outcomes. Third, the bank's payoff is modeled in reduced form. The model already generates an instrument-margin effect of the institutional channel through credit enhancement; a richer intermediation structure incorporating capital constraints, risk-weight incentives, funding costs and competition would endogenize the enhancement and concession costs and could sharpen the conditions under which this effect is strongest. Fourth, the baseline project value is held constant across instruments to isolate incremental financing incentives, whereas in practice financing choice can affect project timing, governance and investment scale.

A fifth limitation concerns the numerical layer itself. The simulation solves the model; it does not confront it with data: the calibration is illustrative and the reported probabilities are properties of the model rather than measured market frequencies. The natural next step is therefore empirical, namely, to estimate the participation and net-benefit thresholds from issuance-incidence data covering both issued and withdrawn transactions, and to discipline the calibration with observed certification costs and spread differentials. Building on the incomplete-information extension of Section 4.6 and together with the investor-heterogeneity and banking extensions, this would preserve the model's strategic core while substantially improving its empirical relevance.

6. Conclusions

This paper set out to explain why firms alternate between green bonds and green bank loans, why the prevalence of these instruments differs across issuers and jurisdictions, and how credibility and institutional incentives shape sustainable debt market outcomes. The guiding premise was that sustainable debt markets cannot be understood solely through static price comparisons: instrument choice is a strategic decision formed under sequential interaction, in which feasibility and contractual conditions are endogenously shaped by the behavior of capital providers and intermediaries.

The framework yields a disciplined equilibrium account of instrument coexistence. By explicitly modeling both a market-based route and a relationship-based route, the analysis clarifies why green bonds and green loans can coexist even when they appear to serve similar sustainability objectives and shows that instrument choice emerges from a genuine strategic interaction among the firm, investors and bank—in which the bank's credit-enhancement decision enters the investors' participation condition—rather than from issuer preferences alone. It further distinguishes the market-based validation of labeled finance, through investor subscription, from the bank-based provisioning of green credit, through term-setting under incentives, preventing conceptually distinct mechanisms from being conflated in interpretation.

The numerical implementation converts these mechanisms into quantities. The share of parameter configurations yielding a green bond equilibrium ranges from about 93% under deep demand and strong credibility to about 14% when both deteriorate; at the level of the individual issuer, the fall is concentrated in a narrow interval around the participation threshold rather than distributed smoothly; and the regulatory regime affects not only the level of financing costs but, through bank credit enhancement, the choice of instrument itself, flipping the equilibrium instrument in 19.4% of parameter draws. A variance-based sensitivity analysis identifies participation frictions and fixed certification costs as the dominant determinants of access to market-based green finance, with bank credit enhancement decisive for issuers at the margin; the execution loss, by contrast, never determines the instrument. The framework thereby provides a rigorous foundation for interpreting sustainable debt markets and a tractable simulation platform for assessing sustainability-related financing risk under alternative institutional configurations.

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Abbreviations

The following abbreviations are used in this manuscript:

GB	Green bond
GBL	Green bank loan
ESG	Environmental, social and governance
SPNE	Subgame-perfect Nash equilibrium
KPI	Key performance indicator
PPP	Public–private partnership
ERR	Expected risk-adjusted return

Appendix A

Appendix A provides the path-coding convention used to index terminal histories of the extensive-form game. It is referenced in Section 3.3 and supports the backward-induction argument developed in Section 4.

Table A1. Path coding of terminal histories.

Path	Stage 1 (Firm)	Stage 2 (Bank)	Stage 3 (Investor)	Payoff Mapping (Table 2)
1	GB	Enhancement ($\bar{e}$)	Invest	Panel A, Enhancement, Invest
2	GB	Enhancement ($\bar{e}$)	Not	Panel A, Enhancement, Not
3	GB	No enhancement (0)	Invest	Panel A, No enhancement, Invest
4	GB	No enhancement (0)	Not	Panel A, No enhancement, Not
5	GBL	Favorable	—	Panel B, Favorable
6	GBL	Standard	—	Panel B, Standard

Notes: The table enumerates terminal histories by the sequence of actions taken at each stage and provides a compact indexing scheme for referencing terminal outcomes in the equilibrium analysis. Stage 2 is the bank (enhancement in the GB branch, loan terms in the GBL branch) and Stage 3 is the investor (GB branch only). Source: Authors' elaboration.

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