Evolving Sustainable Material Culture (SMC): Emerging Trends and Strategic Implications for Green Finance

Romina Fucà[1,*], Serena Cubico[1], Piermatteo Ardolino[1] and Francesco Rosiello[2]

[1]*Department of Management, University of Verona, Via Cantarane 24, I-37129 Verona, Italy*

[2]*Department of Public Health and Infectious Diseases, University La Sapienza, 00161 Rome, Italy*

Abstract: This paper examines the integration of Sustainable Material Culture (SMC) within the Green Finance (GF) framework, focusing on decision-making strategies inspired by game theory, inference rules, and advanced financial modeling to support sustainable economic principles. Since the 2008 financial crisis, traditional investment strategies have increasingly sought alignment with long-term sustainability goals. However, they inherently carry risks when adapting to the evolving complexities of environmental challenges, such as biodiversity loss, climate change, and infrastructure inequity. SMC is defined here as the material objects, practices, and frameworks reflecting human efforts to promote sustainability, driven by individual and collective investments. Our analysis identifies significant challenges in GF, such as the dual roles of investors as contributors to and beneficiaries of SMC, alongside the application of advanced decision-making frameworks, including Pareto efficiency and Bayesian-Nash equilibrium, to support these roles effectively. We explore how GF initiatives, exemplified by global sustainable finance instruments, address (and sometimes struggle to meet) the multidimensional requirements of SMC. We illustrate how these investments foster economic transformation and resilience by building on case studies of innovative GF initiatives—including sovereign green bond issuances, community-led projects, and energy transition programs in emerging markets. Nuanced trade-offs between commissions and omissions by stakeholders highlight the ethical challenges in designing and promoting sustainable financial products.

Keywords: Green Finance (GF), Sustainable Material Culture (SMC), Environmental, Social, and Governance (ESG) Considerations, Game Theory in Green Finance, Decision-Making under Uncertainty, Institutional Credibility, Emerging Markets, Economic Transformation.

1. INTRODUCTION

In Green Finance (GF), decision-making is pivotal, involving complex strategies that echo game theory dynamics. This decision-making process influences Sustainable Material Culture (SMC)—which we have previously defined as a subset of material culture concerned with human actions and the artifacts they produce, specifically those embodying sustainable values and responding to environmental challenges (Fucà *et al*., 2023). SMC focuses on creating and managing objects and practices that align with sustainability, effectively merging cultural expression with ecological responsibility. This broader concept we have previously highlighted helps to net together the need for ascertaining, at least theoretically, the necessary knowledge and management (Broccardo *et al*., 2024) to allow for substantial environmental and social commitment while making financial choices and a consistent framework of related reporting and performance metrics to share financial expertise even with ordinary individual investors.

GF represents a transformative strategy within the financial sector, directing capital flows toward sectors that offer long-term environmental benefits, such as renewable energy, energy efficiency, sustainable agriculture, and green infrastructure (Fu *et al*., 2024). The goal is a strategic, global shift to a low-carbon economy where investments are informed by Environmental, Social, and Governance (ESG) considerations. By doing so, GF can influence traditional financial institutions (Palmaccio *et al*., 2023) and foster economic development that prioritizes resource conservation and the well-being of communities (Fu *et al*., 2024). Investors and policymakers must strive to get insights by employing advanced analytical methods and statistical models to achieve resilience to environmental challenges and downturns in the global economic market. They must also expect to oppose systemic resilience “to a wide array of systemic threats” (Hynes *et al*., 2022, p. 381), such as unemployment, decreasing growth, climate change, lockdowns, and structural inequalities.

We will, therefore, investigate a theoretic model that increases consciousness and government attention to the environment, mainly thanks to GF investments, allowing for material objects and practices reflecting human efforts to promote sustainability. These last must be driven by individual and collective contributors who can apply decision frameworks to support their roles effectively over and beyond a substratum of information asymmetry.

*Address correspondence to this author at the Department of Management, University of Verona, Via Cantarane 24, I-37129 Verona, Italy; Tel: +393333379170, +393406538736; E-mail: romina.fuca@univr.it

E-ISSN: 2817-2302/24

Figure 1: A visual representation of the "forest" of actors, players, investors, shareholders, and stakeholders as part of the broader Green Finance (GF) game.

Figure **1** below illustrates the interconnectedness and collaboration among participants, symbolized through a network of tree branches and eco-financial elements.

Like players strategizing in the face of moral hazard or adverse selection, players and stakeholders in GF must weigh both immediate and long-term impacts. They should also be motivated to pursue the natural environment's objectives, like its preservation, while accounting for their instrumental objectives, such as profit maximization, and being able to balance conflicting interests "for the betterment of the common good." (Arunachalam, 2024) Successful strategies may incorporate Pareto-efficient outcomes, balancing the interests of various parties while minimizing environmental impact. By advancing these strategies, GF can play a crucial role in reshaping economies on local and regional scales, promoting sustainable production, ethical distribution, and resource-efficient practices that support the transition to a circular economy (Palmaccio *et al*., 2023). GF initiatives can prioritize funding for technologies and systems that enable the recovery of anthropogenic resources, reducing the need for virgin geogenic sources; by recognizing the potential of anthropogenic resources, investments can consider the entire lifecycle of materials, from extraction to end-of-life, encouraging sustainable practices (Zeng *et al*., 2022, p. 3). Investments in anthropogenic resource recovery—i.e., secondary resources generated through human activity as waste or byproducts of industrial, urban, or economic processes (e.g., metal scrap, electronic waste, construction debris)—have a lower ecological footprint, aligning with ESG criteria increasingly required in GF frameworks (Zeng *et al*., 2022). In addition, this shift promotes a culture of reuse and material stewardship, which is central to SMC. It aligns with global goals like the Sustainable Development Goals (SDGs), particularly Goal 12 (Responsible Consumption and Production).

1.1. Green Finance (GF) For Sociologists

This section introduces GF to sociologists, highlighting its potential to reshape societal norms through targeted investments and equitable resource allocation. We explore GF strategies' ethical and cultural dimensions by examining SMC as a lens. We will explore:

- The role of GF instruments in sustainable investments.
- The connection between GF and SMC.
- The relevance of Pareto efficiency and predictive modeling.

Section 2 will delve into decision-making challenges in GF, such as balancing short-term gains against long-term sustainability. It will discuss financial tools like green bonds and sustainability-linked loans (SLLs), focusing on how their design supports effective decision-making and mitigates risks.

The discussion will use Contract Theory (CT) principles to highlight mechanisms for addressing systemic challenges in GF, including market volatility, inconsistent standards, and integrating equity and bond strategies.

Additionally, we will address ethical and operational challenges, such as moral hazard, transparency, and impact measurement, alongside the importance of verification mechanisms (e.g., audits and reporting requirements). This section concludes by considering the need to balance short- and long-term objectives, manage risks, and ensure the viability of GF initiatives.

1.2. GF For Analysts

In Section 3. Hazard and Games in Finance, we have included Harsanyi's transformation as an outstanding theoretical framework for GF decision-making. Explaining how uncertainty in sustainability commitments and impact metrics can be modeled through probabilistic scenarios helps create awareness of the enormous challenges this transformative finance poses to players.

We have then incorporated Bayesian Nash Equilibrium (BNE) and the "Pest Control Game," emphasizing quantitative tools, models, and real-world applications for GF strategies. These theoretical tools will illustrate key concepts in game theory, such as the prisoner's dilemma, grounding them in real-world examples.

Quantitative approaches optimize decision-making also in GF, including mathematical representations of investment strategies. Insights from Belloni *et al*. (2020) align these models with real-world dynamics, addressing factors like "greenium," ESG fund resilience, risk exposure, and greenwashing. These tools balance financial performance with sustainability, providing actionable strategies for stakeholders.

Section 4 integrates practical applications of GF, such as Thailand's Green Energy Auction Programme, the Philippines' Renewable Energy Act, and Moldova's EU4Moldova initiative.

Sub-Saharan Africa's potential and challenges are analyzed deeply, emphasizing the need for blended finance and risk-sharing mechanisms.

The concept of "greenium" is further explored, emphasizing its benefits, limitations, and diminishing reliability in maturing markets.

This analysis ties into the broader narrative of aligning incentives for stakeholders while maintaining sustainability goals. In Section 5, we have finally highlighted the key principles for effective GF expressed by the European Investment Bank, a prominent financial European authority. The EIB 11 environmental and social standards include addressing environmental and social risks, fostering stakeholder engagement, promoting resource efficiency, protecting biodiversity, mitigating climate change, and ensuring equitable outcomes for vulnerable groups and indigenous populations.

Therefore, GF's transformative potential lies in blending traditional and sustainable assets, incentivizing eco-friendly behavior, and reducing barriers for underserved groups through Inclusive Green Finance (IGF).

2. LOGICS, ECONOMICS, AND EFFICIENT-VERSUS-INEFFICIENT MODELS IN GF

GF encompasses various financial instruments that support sustainable investments, including loans, bonds, equity, and insurance. The integration of SMC within GF is essential for advancing a sustainable economy, as SMC objects serve as tangible representations of human efforts to address environmental challenges and align financial practices

by individual investors with sustainable economic principles operating on a larger scale.

2.1. GF Economics as a Complex System

GF products may face several risks, including credit, market, and operational risks. Green Bonds are designed to finance projects with environmental benefits, such as renewable energy, sustainable agriculture, energy efficiency, or water resource management.

Profit mechanisms are tied to interest payments made by the issuer (e.g., governments, corporations) and the bondholder's return on investment. Risk to investors is generally tied to the creditworthiness of the issuer, not the success of the green project itself.

Investors do not directly bear project risks; however, reputational risks may exist if projects fail to deliver promised environmental benefits (e.g., greenwashing concerns).

While green bonds and catastrophe bonds (cat bonds) are both financial instruments that support environmental and social objectives, their mechanisms, profit structures, and roles in managing risks differ significantly. Cat bonds are specifically aimed at transferring the financial risks of natural disasters (e.g., hurricanes, floods, wildfires) from insurers or governments to the capital markets. Investors are exposed to event-based risks: if a specified catastrophe occurs, they lose part or all of their principal, which is used to cover claims.

Risk management indicators, such as i. capital adequacy ratio, ii. non-performing loan ratio, iii. loan to deposit ratio, iv. debt to equity ratio, v. total debt ratio, and vi. return on risk-adjusted capital, recall the strategies used in banks and financial institutions to manage risks « include risk transfer, risk avoidance, mitigation of negative risk effects, and acceptance of some or all of the consequences of a particular risk. » (Nasratullah, 2021, p. 15).

As referenced in (Jirásková, 2017, p. 280), this management entails also the arising of i. collusion risks, ii. risks resulting from conflicts of interest, iii. fraud risks, iv. secondary risks, and v. residual risks.

When discussing GF, these general risks must be tied explicitly to green-specific challenges:

1. **Capital Adequacy**: Green projects often require long-term funding. Insufficient capital reserves might hinder financial institutions from issuing green loans or bonds.

2. **Non-Performing Loans**: Projects tied to environmental outcomes may face delays or underperformance due to factors like regulatory changes, climate conditions, or technological risks.

3. **Loan-to-Deposit and Debt Ratios**: Institutions investing heavily in green finance must balance their liquidity and leverage, as green assets may have longer gestation periods for returns.

Another challenge in GF from a macro perspective is the greater complexity of sovereign liabilities, where creditors include a larger share of commercial and nontraditional lenders.

Creditors and debtors should explore and accelerate innovative and unconventional solutions to swap portions of debt that would most likely never be paid back to be used for environmental purposes (such as debt for nature-swaps), health-related purposes (such as example, debt-for-health swaps), or broader targets (such an example, debt for SDG swaps) (Yue & Nedopil, 2022).

These innovative mechanisms directly link sovereign debt restructuring to environmental outcomes, aligning perfectly with GF's objectives. For example, debt-for-nature swaps allow countries to reduce external debt in exchange for investing in conservation projects, addressing climate vulnerability while easing fiscal burdens.

Green sovereign bonds (GSB) are increasingly popular as governments issue debt to fund renewable energy projects, urban infrastructure, or climate adaptation efforts.

However, the complexity of sovereign liabilities can influence the perception of these bonds, especially in countries with high debt-to-GDP ratios. From the point of view of market confidence, sovereign liabilities impact the cost of borrowing for green projects, as countries with high debt levels face higher interest rates, affecting the scalability of green initiatives.

Just as players in Lewis's coordination game—a type of simultaneous game found in game theory where players will earn higher payoff when selecting the same course of action as other players—aim to choose the same meeting place to maximize mutual

benefit, GF stakeholders—investors, policymakers, and communities—must "meet" on shared standards, goals, and expectations to achieve sustainable outcomes.

2.2. The Value of Coordination Games

In GF, effective coordination is crucial for aligning diverse stakeholder interests and ensuring sustainable outcomes.

Similar to Lewis's coordination game, where players achieve higher payoffs by aligning actions, GF requires investors, policymakers, and communities to "meet" on shared standards, goals, and expectations. However, as Kets *et al*. (2022) emphasize, the value of coordination games is about achieving equilibrium and understanding how changes in payoffs and policies influence behavior and welfare outcomes (Kets *et al*., 2022).

Kets *et al*. highlight two critical dimensions relevant to GF: direct and indirect effects on the game's value. Direct effects occur when payoff changes immediately impact outcomes, while indirect effects influence how players coordinate.

For instance, policies that eliminate coordination failure may inadvertently increase miscoordination, where stakeholders need to align on a Pareto-optimal strategy (Kets *et al*., 2022). This insight is particularly significant for GF, where sustainability objectives often hinge on avoiding such misalignments.

In GF, miscoordination can manifest as fragmented standards or conflicting policy goals, undermining collective efforts. As Kets *et al*. argue, non-economic factors, such as environmental goals' salience or sustainability commitments' perceived credibility, can significantly influence coordination outcomes (Kets *et al*., 2022). This underscores the importance of integrating social and cultural factors into GF frameworks to reduce the costs of miscoordination.

2.2.1. Application to Policy Design in GF

Drawing from Kets *et al*., policies that incentivize green investments must carefully balance the risks of coordination failure and miscoordination (Kets *et al*., 2022). For example:

1. **Subsidies for Sustainable Projects**: While subsidies can encourage participation in green initiatives, they may lead to inefficiencies if stakeholders adopt divergent strategies or fail to align on critical goals.
2. **Standardization of Metrics**: Unified ESG metrics can reduce the ambiguity of sustainability goals, minimizing the risk of stakeholders pursuing conflicting priorities.

2.2.2. Key Takeaways for GF

While GF investments promise alignment between financial returns and environmental objectives, they often carry hidden complexities like a 'Trojan horse.' Key Takeaways for GF are, therefore:

- **Strategic Effects and Non-Monotonic Outcomes**: As noted by Kets *et al*., the relationship between payoff changes and welfare outcomes is non-monotonic (Kets *et al*., 2022). Policies that appear beneficial on the surface may have unintended consequences if they disrupt delicate strategic balances.
- **Integration of Non-Economic Factors**: In GF, factors like cultural norms, salience of sustainability goals, and perceived credibility must be explicitly considered to foster alignment among stakeholders.

Much like the Greek soldiers hidden within the Trojan horse, who emerged only at the last moment to overtake the city of Troy, appealing investment opportunities in GF can conceal challenges that, if not properly coordinated, may result in unforeseen and potentially catastrophic systemic risks (Fucà *et al*., 2023).

As with coordination games, where the value lies in aligning actions, GF investments require transparency, standardization, and a shared understanding of social equity to mitigate potential pitfalls (Popescu *et al*., 2021).

2.3. Contract Theory (CT) and GF

Contract Theory (CT) is a branch of economics that studies how individuals and organizations create and enforce agreements, particularly when information asymmetry (unequal access to information) and conflicts of interest exist.

It seeks to design optimal contracts that align the incentives of all parties involved, addressing potential issues like moral hazard (risk-taking when protected from the consequences) and adverse selection (risks associated with hidden information).

The previous discussion on coordination games, particularly the importance of shared standards, goals,

and expectations in GF, highlights the complexities of stakeholder alignment.

CT provides tools to design agreements that mitigate these challenges by aligning incentives, managing risks, and promoting accountability.

CT directly addresses issues such as miscoordination or unintended outcomes by focusing on mechanisms to counter moral hazards, adverse selection, and other strategic inefficiencies.

While coordination games focus on aligning strategies, CT provides a structured framework for designing contracts that ensure commitment to sustainability goals, especially under information asymmetry and conflicting incentives among GF stakeholders.

GF stakeholders, such as governments, investors, and corporations, often operate in hierarchical relationships rather than on an equal footing. The Stackelberg-type game effectively models such leader-follower dynamics, where one player (e.g., the government or a major investor) acts as a leader and others (e.g., private firms or smaller investors) respond strategically.

For example, Mukhopadhyay *et al*. (2008) modeled a Stackelberg-type game where a manufacturer (leader) and a retailer (follower) navigate strategic interdependencies to optimize their outcomes. This dynamic mirrors the hierarchical relationships in GF, where leaders, such as governments or major investors, establish sustainability goals or incentives. At the same time, smaller stakeholders respond strategically to align with these objectives.

Figure **2** below highlights the dangers investors need clear, authoritative guidance, emphasizing urgency and caution.

The game is instrumental in capturing scenarios where stakeholders may exploit information asymmetries or adopt self-serving strategies (Mukhopadhyay *et al*., 2008; 2011), which are common issues in GF. For example, a leading institution may design green policies or incentives that others follow, but without proper alignment, these followers may act opportunistically, undermining collective goals.

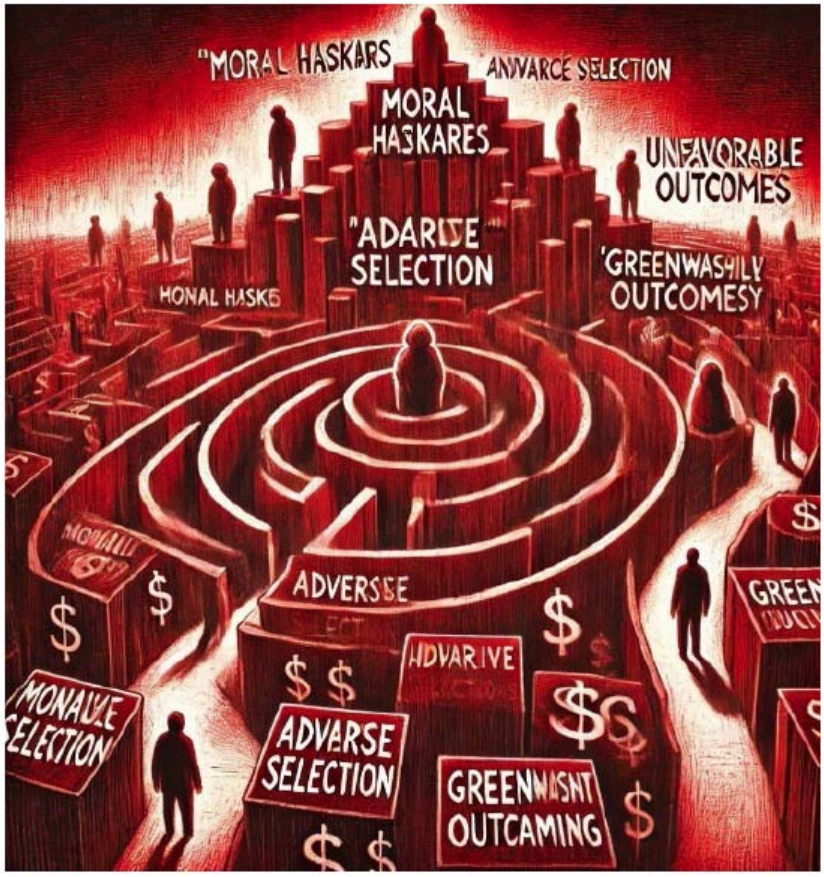

Figure 2: A red-hued drawing representing hidden risks such as “moral hazards,” “adverse selection,” “unfavorable outcomes,” and “greenwashing” in high-financial planned investments.

Governments issuing green bonds can lead as the "manufacturer." At the same time, private investors or companies act as the "retailers," adjusting their strategies based on the terms and policies set by the issuer.

When stakeholders fail to coordinate effectively, the decline in one investment's performance can impact others, creating a cascading effect across the economic landscape and leading to an overall downturn.

So, the financial landscape must be prepared to answer to multi-shareholders and multi-stakeholders perspectives (DesJardine *et al*., 2022, p. 401).

To further enhance this process, CT principles can be applied to design agreements that align stakeholder incentives, mitigate risks, and promote accountability. These agreements, which form the GF backbone, address the challenges of incomplete information and ensure that funds are directed toward genuine sustainability efforts.

2.3.1. Effective Decision-Making in GF

Effective decision-making in GF requires stakeholders to evaluate the trade-offs between immediate financial returns and long-term environmental benefits. For instance, stakeholders often prioritize investments in green bonds or sustainability-linked loans (SLLs), simultaneously offering measurable ecological impact and financial returns.

This structure addresses moral hazard by discouraging borrowers from making superficial promises or misallocating funds to non-sustainable projects. The penalties ensure accountability and alignment with sustainability objectives. Similarly, adverse selection is mitigated through detailed and transparent reporting requirements, enabling lenders to identify credible projects and committed borrowers while filtering out less trustworthy ones.

2.3.2. Broader Challenges in GF

High ethical standards in GF contexts are essential to prevent conflicts of interest and maintain fiduciary responsibility, as evidenced in the previous sub-section.

Figure **3** highlights how transparency, authoritative guidance, and sustainable principles illuminate the path, guiding investors past hidden risks to achieve secure and responsible financial decisions.

While managing moral hazard is essential for maintaining the integrity of green projects and investor

Figure 3: An optimistic illustration depicting investors safely navigating out of the GF labyrinth.

confidence, a practical GF framework also depends on robust impact verification, transparency, incentive alignment, and risk management. Other critical elements include:

1. **Impact Measurement and Verification**: Reliable methods to track green projects' environmental and social impact are essential to avoid "greenwashing," where projects seem sustainable on paper but lack real-world results. Webster's New Millennium Dictionary of English defines it as promoting eco-friendly initiatives to divert attention from harmful practices.

   Concise Oxford English Dictionary (1999) describes it as disinformation to create a misleadingly responsible environmental image (de Freitas Netto, 2020, p. 6).

   Lyon and Montgomery (2020) note the term's multifaceted nature, challenging a rigid definition (de Freitas Netto, 2020, *idem*). It encompasses intentional or perceived misrepresentation of an organization's environmental commitment (de Freitas Netto, 2020, *idem*).

2. **Transparency and Accountability**: Ensuring funds are used as intended, with clear visibility for stakeholders such as investors, customers, and regulators, fosters trust and credibility in GF markets.

3. **Incentive Alignment**: Structuring financial products to align investor goals with sustainable outcomes, such as rewarding borrowers for meeting green targets, promotes genuine engagement with environmental goals. As highlighted by UNCTAD (2020), the number of sustainability-themed funds worldwide has grown significantly, reaching 7,485 in 2023 with nearly $3 trillion in total assets. This growth demonstrates the increasing importance of integrating sustainability into financial markets, particularly in Europe and the United States, which dominate the market with 85 per cent of global assets. Despite challenges like high interest rates and concerns about greenwashing, sustainability-themed funds remain a vital tool for driving capital toward projects that align with environmental and social objectives. These trends underscore the potential of green finance as a subset of sustainable finance to incentivize meaningful environmental progress.

4. **Long-term Viability and Risk Management**: Balancing short-term costs with long-term environmental gains ensures stability and scalability of green initiatives while accounting for potential risks like market fluctuations or regulatory changes (Ekins, 2021, pp. 950-951).

3. HAZARDS AND GAMES IN FINANCE

The complexities of GF arise not only from the multiplicity of stakeholders involved but also from the inherent uncertainty surrounding their intentions, constraints, and strategies. These challenges mirror the dynamics of games with incomplete information, where players must make decisions without full knowledge of others' preferences or actions.

In this context, Harsanyi's transformation provides a critical framework for understanding and addressing these uncertainties. By introducing subjective probability distributions to model players' beliefs, utility functions to capture their trade-offs, and conditional probabilities to reflect evolving strategies, Harsanyi's work (Harsanyi, 1967) lays the foundation for navigating the strategic complexities of GF.

GF involves multiple players with diverse objectives and incomplete knowledge of each other's intentions, constraints, or strategies. This is analogous to the incomplete information games Harsanyi formalized (Harsanyi, 1967, pp. 163-164).

The focus shifts to beliefs and probabilistic reasoning (Harsanyi, 1967, pp. 164-165). Players must estimate the likelihood of others' types or actions and adapt their strategies accordingly (Harsanyi, 1967).

The central question is: How can players make optimal decisions given their uncertainty about others?

Harsanyi's transformation is an ideal bridge between theoretical constructs and practical applications because it:

- **Simplifies complex interactions**: By modeling incomplete information as random events, the transformation avoids the pitfalls of overly intricate, recursive probability models.
- **Enhances decision-making frameworks**: GF involves multiple stakeholders with competing priorities and incomplete knowledge. Harsanyi's method provides a foundation for developing cooperative strategies despite these challenges.

- **Supports probabilistic reasoning**: In GF, stakeholders often deal with probabilities—e.g., the likelihood of achieving green project targets or the risk of non-compliance. The transformation formalizes how to reason about these probabilities in strategic contexts.

By modeling such uncertainties, Harsanyi's transformation allows us to:

- Predict how different types of players (e.g., committed vs. superficial sustainability proponents) will behave.
- Design strategies that align diverse interests while accounting for hidden information.
- Address risks like greenwashing or adverse selection that arise from misaligned incentives.

For example:

1. **Unknown Sustainability Commitments**: Investors may not fully know whether borrowers (e.g., corporations or governments) are genuinely committed to meeting environmental goals or are merely engaging in greenwashing.
2. **Uncertainty in Impact Metrics**: Borrowers may face uncertainty about how their environmental initiatives will be measured or perceived by investors, regulators, and the public.

For instance:

- Investors can assign probabilities to a genuinely committed borrower based on signals like ESG ratings, past performance, or third-party audits.
- Borrowers can commit by adopting sustainability-linked financial products or agreeing to independent monitoring.

Harsanyi's transformation underscores that uncertainty does not preclude informed decision-making; instead, it focuses on probabilistic reasoning and structured analysis.

3.1. Key Contributions of Harsanyi's Framework to GF

Other than introducing the idea of using subjective probability distributions to represent players' beliefs about others' types in GF, assigning probabilities to different scenarios, and updating these beliefs based on observed behavior, Harsanyi's Bayesian reasoning is central to designing adaptive and resilient GF strategies.

1. **Sequential-Expectations Model:** In GF, sequential decision-making is critical, as investments unfold over time, with players adjusting their strategies based on evolving information. Harsanyi's sequential-expectations model **(**Harsanyi, 1967, pp. 164-165**)** provides a framework for stakeholders to optimize their decisions dynamically, balancing short-term risks and long-term sustainability goals.
2. **Utility Functions and Conditional Probabilities:** By incorporating utility functions **(**Harsanyi, 1967, p. 167**)**, Harsanyi's framework captures stakeholders' trade-offs in GF between financial returns and sustainability impacts. Conditional probabilities **(**Harsanyi, 1967, p. 174**)** further enable modeling how new information (e.g., progress on a green project) affects decision-making, enhancing transparency and accountability in financial intermediation.

3.2. Dynamic Management for Better Decisions

As we have seen, stakeholders who invest in gathering, analyzing, and interpreting information can better navigate uncertainty, optimize strategies, and achieve desirable outcomes even in complex, dynamic environments (Lowell, 2009) because of the achievement of the following theoretical assets:

In coordination games, players have complete information about the game's structure, including payoffs and the strategies available to all players.

The challenge is not about unknowns but about aligning strategies to achieve mutually beneficial outcomes, such as avoiding coordination failure or miscoordination. Harsanyi's transformation is not just theoretical; it directly addresses practical challenges in GF:

- **Greenwashing Risks**: By modeling the probability of stakeholders' true types, Harsanyi's framework helps detect and mitigate misrepresentation or superficial compliance risks.
- **Adverse Selection**: It provides tools to design contracts and incentives that filter out less committed players, ensuring funds are directed to genuinely sustainable projects.

- **Moral Hazard**: The framework helps align incentives among stakeholders, reducing the likelihood of opportunistic behavior that undermines collective goals.

This transformation facilitates Bayesian reasoning, enabling stakeholders to make more informed decisions in uncertain environments. In fact, rather than viewing uncertainty as a barrier, investors often face uncertainty about how external factors (e.g., political changes and technological advancements) will affect the long-term viability of green projects.

Example: A venture capital firm funding renewable energy startups might use Bayesian models to adjust its portfolio allocation as more data on project performance or regulatory trends emerges.

Strategies in coordination games are explicitly aligned through mutual understanding or external cues, such as clear policies or standardized metrics. Players benefit directly from cooperation; the primary challenge is ensuring everyone coordinates effectively.

Players may not directly communicate or have shared standards but infer likely actions based on observed behavior and prior knowledge. This is especially relevant in information asymmetry situations where one player might have hidden motives or capabilities.

3.3. The Bayesian-Nash Equilibrium (BNE)

The Bayesian-Nash Equilibrium (BNE) steps in at this point to describe the strategic agreement or alignment among players. BNE assumes that:

- Each player optimally chooses a strategy given their beliefs about other players' types (preferences, information, payoffs).
- These beliefs are formed based on subjective probability distributions, as modeled in Harsanyi's framework.

By transitioning to BNE, the focus shifts from representing uncertainties to resolving them through equilibrium strategies, where each player's actions are optimal given their beliefs and the actions of others.

Here, differently from conflicting or asymmetrical information, as well from coordination or cooperation, players may align strategies not out of a desire to cooperate but because it maximizes their payoffs given their subjective beliefs. Players can rationally align their actions to reach a Pareto-optimal outcome, similar to a coordination game but grounded in probabilistic reasoning. While Harsanyi's transformation establishes the foundation of probabilistic reasoning under uncertainty, BNE provides the behavioral resolution, showing how players act on these probabilities to achieve equilibrium. Examples:

1. Signaling through Sustainability-Linked Loans (SLLs):

- Borrowers "signal" their commitment to sustainability by agreeing to terms that include financial rewards for meeting specific environmental targets, such as reduced carbon emissions or renewable energy adoption.
- Investors, in turn, use these signals to adjust their beliefs about the borrower's type (e.g., "highly committed" vs. "superficially engaged").
- The equilibrium occurs when both parties optimize their strategies: the borrower maximizes their financial benefits while adhering to sustainability goals, and the investor minimizes risks by selecting credible projects.

Example: A borrower might agree to an SLL with an interest rate reduction contingent on achieving a 30% reduction in greenhouse gas emissions within five years. The agreed-upon milestones and monitoring mechanisms serve as signals that reduce information asymmetry and align incentives.

2. Screening for Adverse Selection:

- Bayesian equilibria help design contracts that "screen" for borrower types, ensuring that only those genuinely committed to sustainability receive favorable terms.
- This can involve incorporating penalty clauses for non-compliance, which deter borrowers with lower sustainability commitments from seeking GF products.
- Similarly, tiered interest rates based on progress reports allow investors to adjust their expectations and returns based on new information dynamically.

3.3.1. A Comparison of Harsanyi's Transformation and BNE

In Harsanyi's transformation, the players operate within a predetermined probabilistic framework established by the transformation itself. This setup:

- Converts the incomplete information game into a "complete" game by introducing random events to represent uncertainties.
- Positions players as entities whose decisions are influenced by an overarching structure (e.g., predefined probabilities and game rules).
- Suggests that players' behaviors are guided by external "chance moves," embedding them in a broader, deterministic game framework.

In contrast, BNE brings forward the players' subjective reasoning and freedom to act:

- Players construct their beliefs based on available information and choose strategies to maximize their expected payoffs.
- Emphasizes agency, where players are not just passive components of a larger system but active participants shaping outcomes through their choices.
- Highlights the importance of self-determined alignment with others' strategies, guided by probabilistic reasoning.

3.3.2. Subjective Beliefs and Regulatory Rules in GF

This shift from manipulation to subjective reasoning reflects a more dynamic and participatory model relevant to GF. Whether they potentiate their beliefs, GF stakeholders can design contracts and strategies that align incentives, reduce risks, and foster collaboration. By leveraging subjective probabilities, stakeholders actively navigate uncertainties, turning abstract frameworks into actionable strategies that balance financial and sustainability goals.

Harsanyi's transformation reflects the systemic nature of GF, where stakeholders (e.g., governments, investors, corporations) operate within predefined regulatory and market frameworks. For example, random events in Harsanyi's model could represent regulatory changes or market shocks that dictate the game's structure.

BNE, on the other hand, captures the subjective strategies of stakeholders as they negotiate contracts, choose investments, or respond to ESG metrics.

Successfully managing subjective beliefs and regulatory rules in GF financial markets requires market participants to adapt dynamically to evolving regulations. By prioritizing awareness, diversification, monitoring, advocacy, and technological innovation, they can navigate the complex choreography of Green Finance without missing a step.

Figure **4** emphasizes stakeholder collaboration and strategic alignment using tools like green bonds, SLLs, and transparency reports.

Figure 4: Strategic Alignment and Stakeholder Collaboration in GF.

3.4. Strategic Dilemmas in GF: The 'Pest Control Game'

We will then discuss how to balance short- and long-term profitability while keeping the collective goals of sustainability and sustainable material culture. Here are some key points drawn from Game Theory:

- **Prisoner's Dilemma**: This game is a standard model in game theory used to show how rational decision-makers might fail to cooperate, even when it's in their best collective interest. Each participant in the prisoner's dilemma must choose between cooperation and defection, with defection often being the dominant (individual best) strategy. However, if both parties defect, they have worse outcomes than if they had cooperated. This illustrates a strategic conflict between individual short-term gains and collective, long-term benefits.

- **Pest Control Game**: Similar to the prisoner's dilemma, the pest control game is a situation where individuals or entities (e.g., farmers) face a choice: invest in pest control collectively (which would benefit all) or save costs individually and rely on others to handle the problem. If everyone attempts to "free ride" by letting others take action, pest problems worsen, leading to losses. This game illustrates a "public goods" dilemma, where the benefits of individual cooperation (effective pest control) are shared, but the costs might deter individual participation.

A few examples illustrate how this dilemma surfaces in GF:

1. **Investment Shortfalls in Green Projects**: If investors focus solely on quick returns, they may underfund or avoid green projects that require significant upfront costs but yield long-term environmental benefits. This creates a "tragedy of the commons" where the lack of adequate green investment harms collective welfare.

2. **Greenwashing**: Companies may pursue superficial sustainability initiatives (greenwashing) to attract capital while maintaining unsustainable practices in core operations. This can lead to losing credibility for the green finance market and hampers genuine progress.

3. **Neglecting Long-term Risks**: Short-term profit motives can lead to ignoring the financial risks of climate change (such as regulatory shifts, extreme weather, or resource scarcity), which could undermine future profitability. For instance, heavy investments in fossil fuel assets could become liabilities due to future regulatory or market shifts.

3.5. Dilemmas and Cooperative Strategies

Many dilemmas arise from imbalances in risk or incentives (e.g., free-rider problems, moral hazard). The "skin in the game" is crucial in managing ethical hazards because it aligns the parties' interests by ensuring everyone shares the risks and rewards. When the risk-taking party has something to lose, they are more likely to act responsibly, minimizing reckless or opportunistic behavior.

In GF, implementing "skin in the game" practices might involve mechanisms like:

1. **Equity Stakes**: Requiring project developers or companies to invest a certain amount of their capital in green projects ensures they have a vested interest in the project's success.

2. **Performance-Based Incentives**: Structuring financial products with rewards that kick in only when environmental goals are achieved helps mitigate moral hazard by making benefits contingent on positive outcomes. For instance, a lower interest rate could be offered if a borrower meets specific emission reduction targets.

3. **Penalty Clauses**: Including financial penalties in green finance agreements for failing to meet agreed-upon sustainability standards or objectives discourages the misuse of funds or inadequate commitment to environmental goals.

4. **Co-Funding Requirements**: Having multiple investors share the financing responsibilities for green projects also distributes the risks. This approach incentivizes oversight from different parties, encouraging more stringent monitoring of environmental and social impacts.

5. **Independent Auditing and Reporting Requirements**: Transparency mechanisms, such as third-party audits or regular impact reports, act as checks that compel the parties to remain accountable for their green finance commitments.

By implementing these mechanisms, GF structures can reduce moral hazard, encourage more prudent decision-making, and foster genuine environmental commitment, ensuring that projects produce real, measurable impact rather than just appearing sustainable on paper.

3.6. Pareto Efficiency and The Payoff Matrix

The Pareto criterion states that allocation A is better than allocation B if:

- At least one person would be strictly better off under A than B, and
- Nobody would be worse off under A compared to B.

If an allocation meets these conditions, A Pareto-dominates B, and moving from B to A is considered a Pareto improvement.

Key concepts are the following:

1. Pareto Efficiency:

- An allocation is Pareto efficient if there is no other feasible allocation where at least one person could be made better off without making someone else worse off.
- A Pareto-efficient outcome is not necessarily desirable or fair but represents a state where no further Pareto improvements are possible.

2. Caution with Pareto Efficiency:

- Multiple Pareto-efficient outcomes may exist, and the criterion does not rank them.
- A Pareto-efficient allocation might still be undesirable due to inequities (e.g., one person has everything while others have nothing).

By analyzing these dynamics, it becomes clear that achieving the cooperative outcome—akin to the (I, I) strategy in the pest control game—requires stakeholders in GF to adopt a collaborative approach that maximizes the collective pay-offs and ensures the fair distribution of benefits.

In the following sub-section payoff matrix, the main stakeholders will be:

1. Commissioners/Shareholders (Player A)
2. Private Investors (Player B)

Each player has two strategies:

- **T (Take dominant strategy)**: Focus on maximizing short-term profitability and individual gains.
- **I (Invest in cooperative strategy)**: Prioritize long-term sustainability and alignment with SMC principles, even if it means sacrificing some short-term gains.

As shown in Table **1** below, this matrix reflects the alignment with SMC (general achievement), long-term profitability, and potential conflicts between stakeholders' interests.

Table 1: Pay-Off Matrix for Conflicting Stakeholders

Player B: Private Investors	T (Take)	I (Invest)
Player A: Commissioners	T (Take)	Payoff: (80, 20)
I (Invest)	Payoff: (20, 80)	Payoff: (100, 100)

3.6.1. The Payoff Matrix Explained

The percentages in the payoff matrix are arbitrarily chosen for illustrative purposes. They illustrate key dynamics of cooperation and conflict in GF. While they are not derived from real-world data, they serve as a conceptual tool to highlight:

- The benefits of cooperative strategies.
- The risks of short-term, self-interested behavior.
- The alignment of stakeholder interests with SMC goals.
- **(80, 20):** When both stakeholders (Commissioners and Private Investors) focus on short-term gains (T, T), the Commissioners benefit significantly more than the Private Investors, reflecting an imbalance. The general achievement for SMC is suboptimal because neither party fully prioritizes long-term sustainability.
- **(20, 80):** When Commissioners invest cooperatively (I), but Private Investors focus on short-term profits (T), Private Investors reap substantial benefits while Commissioners achieve minimal gains. This outcome might represent a misaligned strategy where one stakeholder exploits the cooperative effort of the other.

- **(100, 100):** When both stakeholders invest cooperatively (I, I), they achieve maximum gains. This reflects the ideal Pareto-efficient outcome where both align their strategies with SMC principles, balancing financial returns and sustainability.

- **(T, I):** If Commissioners prioritize short-term gains (T) and Private Investors invest cooperatively (I), the imbalance shifts, with Commissioners benefiting disproportionately while Private Investors achieve minimal gains.

The percentages were designed to:

1. **Highlight Trade-offs:** The numbers illustrate how different strategies lead to varying degrees of alignment between stakeholder interests and SMC goals.

2. **Reflect Real-world Dynamics:**

   - In many economic scenarios, short-term strategies yield higher individual payoffs at the expense of collective gains.

   - Cooperative strategies require trust and collaboration and lead to higher cumulative benefits

3. **Simplify Interpretation:** The percentages create a straightforward matrix that emphasizes:

   - The dominance of cooperative strategies for mutual benefit.

   - The inherent conflicts in self-interested behavior.

3.6.2. Gains and Imbalances in The Matrix

The arbitrarily chosen percentages, while not derived from real-world data, serve as a conceptual tool to highlight:

- The benefits of cooperative strategies.

- The risks of short-term, self-interested behavior.

- The alignment of stakeholder interests with SMC goals.

These percentages can be fine-tuned to reflect specific scenarios, making the matrix a versatile framework for analyzing stakeholder interactions.

Imbalance in Self-Interested Strategies (T, T):

- The imbalance in (80, 20) or (20, 80) demonstrates that self-interest leads to unequal benefits, potentially causing distrust or reluctance to cooperate in the future.

Incentive for Cooperation (I, I):

- The symmetrical, high payoffs (100, 100) incentivize both stakeholders to align their strategies, reinforcing the importance of mutual trust and shared accountability for SMC goals.

Risk of Exploitation (T, I and I, T):

- The scenarios (T, I) and (I, T) highlight how one stakeholder might exploit the cooperative effort of the other, leading to potential conflicts or reluctance to collaborate in future initiatives.

In real-world scenarios:

- **Context-Specific Factors:** Actual payoffs depend on market conditions, regulatory frameworks, stakeholder priorities, and resource availability.

- **Flexibility:** The percentages can be adjusted to reflect specific industries, regions, or projects, making the matrix adaptable for diverse contexts.

Figure **5** is the graphical representation of the payoff matrix analysis. It visually contrasts the payoffs for commissioners and investors under different strategy pairs:

T, T: Both prioritize short-term gains, leading to suboptimal outcomes.

T, I: Imbalance where commissioners benefit more, while investors sacrifice.

I, T: Imbalance where investors benefit more, while commissioners sacrifice.

I, I: Ideal cooperative outcome, achieving maximum gains for both stakeholders.

This visualization emphasizes the superiority of the cooperative strategy (I, I) over the dominant self-interest strategy (T, T).

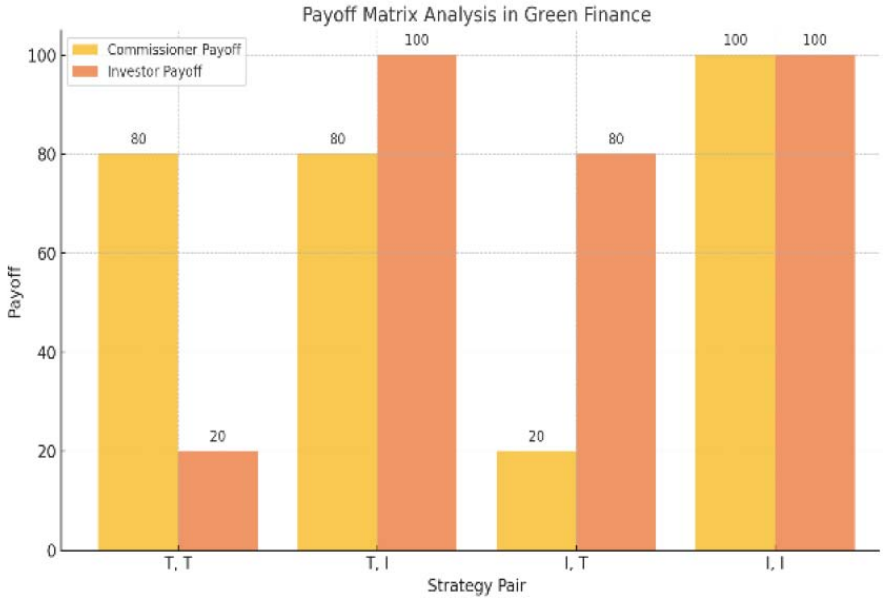

Figure 5: A bar graph representation of the payoff matrix analysis.

4. The New Perspective Generation of Finance

The transformative potential of green finance (GF) lies in its ability to redefine how financial systems address global challenges like economic transformation, climate change, biodiversity, natural capital preservation, environmental integrity, and infrastructure inequity.

While useful in their time, traditional financial models often need to address these interconnected issues. The risk of applying outdated financial tools to GF—akin to "old wine in new bottles"—can mask the complexities of sustainability challenges, resulting in superficial solutions that fail to drive systemic change (Dryzek, 2013).

GF is a pivotal mechanism for mobilizing capital toward sectors essential for sustainable development, such as renewable energy, biodiversity conservation, climate-resilient infrastructure, and equitable resource access (European Commission, 2018).

These investments are not merely financial activities but instruments for economic transformation, helping nations build resilient economies while addressing systemic inequities in infrastructure and natural capital distribution. GF facilitates a comprehensive approach that integrates climate-conscious policy goals with mechanisms to support economic growth, particularly in underserved regions like Sub-Saharan Africa and Southeast Asia, where the need for inclusive financial solutions is most pressing.

However, integrating sustainability into financial systems requires innovative approaches to overcome traditional limitations. Conventional financial models risk oversimplifying the challenges of sustainable investments, focusing narrowly on short-term returns without considering long-term environmental and societal impacts (Merton, 1995).

GF has evolved into a "second- and third-generation finance" framework to address this, integrating ethical principles and systemic accountability into its core practices (Scholtens & Dam, 2007). GF issuers are now designing products that incentivize sustainable behaviors. For instance:

Eco-Incentivized Investments: Products offering enhanced returns or reduced fees for eco-friendly projects encourage responsible investment (Cheng *et al*., 2014). These initiatives drive investment into renewable energy, sustainable agriculture, and low-carbon technologies, reducing infrastructure inequity while fostering biodiversity preservation.

Inclusive Green Finance (IGF): Targeted financial instruments lower entry barriers for MSMEs and low-income households, enabling access to green technologies previously unattainable (AFI, 2023). This approach expands the reach of GF while promoting equitable economic growth.

GF portfolios strategically balance traditional and sustainable assets to manage risks while achieving environmental objectives (Busch & Hoffmann, 2011).

These portfolios incorporate diverse investments, such as:

- Renewable energy projects to reduce carbon footprints.
- Green infrastructure to address urban equity and climate resilience.
- Sustainable agriculture to ensure food security and biodiversity.

In addition, GF models emphasize long-term benefits by reflecting unique sustainability risks in asset pricing, ensuring accurate valuations of environmental impacts (Choi *et al*., 2020).

Adopting GF at scale requires an adaptive governance framework. Borrowing from principles used in iterative optimization, GF must be continuously recalibrated through "posterior propagation" mechanisms to align with evolving sustainability objectives. These frameworks:

- Provide real-time feedback loops for policy adjustment and risk management.
- Integrate technological innovations to monitor performance and adapt asset pricing.
- Promote systemic transparency and accountability to align individual actions with collective goals.

Collaborative efforts across governments, private sectors, and multilateral organizations are crucial for scaling GF's impact. For instance:

Investments in smart regional development, such as Thailand's focus on renewable energy and public transportation, showcase how GF supports national policy goals.

Sub-Saharan Africa's potential to leapfrog into low-carbon industries demonstrates the role of GF in driving economic transformation and infrastructure equity.

4.1. The Transformative Potential of GF

One key characteristic of GF is the potential for issuers to achieve a "greenium"—a premium price for green bonds that reflects higher investor demand. Green bonds are sometimes issued at a lower yield than conventional bonds, which might deter some investors from seeking higher returns. Evidence suggests that sovereign issuers from emerging markets or regions highly vulnerable to climate change, like Sub-Saharan Africa (OECD, 2024), may experience more sizable greeniums than advanced markets. However, as the market matures, the greenium's reliability diminishes, emphasizing the importance of issuer credibility. Appointing external reviewers can enhance trust, positively influencing pricing advantages for issuers (Simeth, 2022).

For regions like the Philippines, regulatory hurdles, high upfront equity requirements, and limited financial instruments tailored to small-scale energy efficiency projects hampers investment scalability. The lack of pooled assets or securitization options increases transactional costs, further discouraging commercial lenders. Despite these obstacles, frameworks like the Green Energy Auction Programme have demonstrated potential by successfully auctioning 2 GW of renewable energy capacity, showcasing that targeted policy instruments can drive incremental growth in renewable sectors (OECD, 2024).

The International Energy Agency (IEA) advocates halting new coal plant construction while retrofitting existing facilities to reduce emissions. This is particularly urgent in regions like Southeast Asia, where the average coal plant age is just 13 years, and in economies like India and China, where coal is central to electricity supply. The transition from coal represents a financial and policy challenge and an opportunity to integrate low-carbon technologies and renewable energy generation into energy systems (IEA, 2021).

Table **2** will show how the distribution of green investments across regions reveals significant disparities driven by varying levels of economic development, financial infrastructure, and environmental priorities. Several regional trends and gaps are apparent:

1. High-Investment Regions: Thailand and Sub-Saharan Africa

Thailand:

- Investments such as the USD 7.1 billion sustainability bond issuance and the USD 9.5 billion in GSS bonds by private issuers highlight Thailand's proactive stance toward green finance.

- These investments focus on climate-conscious development, including clean transportation and renewable energy projects, demonstrating a well-developed local green bond market.
- This level of investment suggests robust financial infrastructure and government support, emphasizing Thailand's leadership in Southeast Asia for green finance.

Sub-Saharan Africa:

- The total reported green investment in Sub-Saharan Africa is smaller (USD 4.6 billion in GSS bonds), but its significance lies in its untapped potential.
- Opportunities include leveraging natural capital and transitioning to low-carbon industries, particularly in countries like Botswana and Mauritius with investment-grade sovereign credit ratings.
- However, barriers such as weak capital markets, low sovereign credit ratings, and limited fiscal space prevent the region from fully capitalizing on green investment opportunities.

2. Moderate-Investment Regions: Moldova

- Moldova has demonstrated notable progress in integrating green finance into urban development and public service improvements:
  - The EU4Moldova Focal Regions Programme allocated EUR 5 million (approximately USD 5 million) for urban redesign.
  - The European Investment Bank (EIB) loan of **EUR 100 million** showcases the role of international financial institutions in addressing Moldova's infrastructure challenges.
- While the amounts are smaller than in more developed regions, Moldova's strategic focus on leveraging external funding reflects its commitment to green economic transformation.

3. Emerging Regions: The Philippines

- The Philippines has emphasized renewable energy development, driven by government initiatives like the Renewable Energy Act and the Green Energy Auction Programme:
  - While monetary amounts are not specified, the 2 GW of auctioned renewable capacity and policy incentives such as Feed-in Tariffs (FITs) represent significant steps toward energy transition.
  - Challenges include liquidity issues, delayed implementation, and high upfront equity requirements, which limit scalability and restrict the role of commercial lenders in energy efficiency finance.

4. Low-Investment Regions: Sub-Saharan Africa

- Sub-Saharan Africa faces systemic barriers, including limited access to international capital markets and unsustainable debt burdens:
  - GSS bonds make up only 0.7% of the global market, despite the region's high vulnerability to climate change and significant renewable energy potential.
  - Investments are constrained by underdeveloped financial systems and low investor confidence, reflected in the region's patchy issuance of GSS bonds across just nine countries since 2014.

Figure **6** shows the significant contribution of global initiatives like Enel Green Power compared to region-specific investments in Thailand, the Philippines, Moldova, and Sub-Saharan Africa.

4.1.1. Key Observations on Disparities

Economic development, financial infrastructure, policy frameworks, and climate vulnerability shape these disparities. While some regions, like Thailand, demonstrate proactive leadership and robust financial mechanisms, others, such as Sub-Saharan Africa, need help with systemic barriers that limit their participation in the green finance ecosystem.

This sub-section presents **key observations on regional disparities**, emphasizing their implications for equitable and sustainable economic transformation. By analyzing investments detailed in the accompanying table, we identify patterns and gaps that highlight:

- The role of financial market maturity in mobilizing capital.
- The dependence on international support for green transitions.

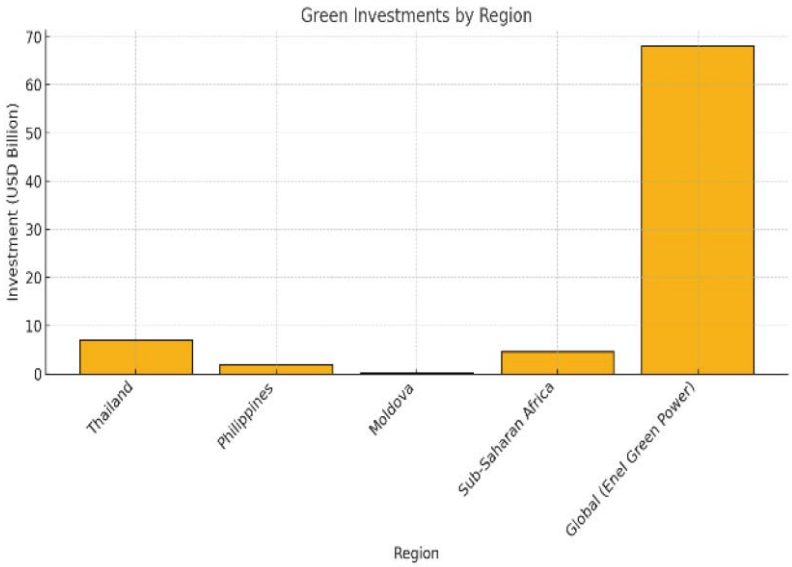

Figure 6: A bar graph representing green investments by region highlights the disparities among different areas.

- The influence of regulatory and policy frameworks in driving investments.
- The paradox of climate vulnerability paired with low financial readiness.

1. Infrastructure and Market Development:

- Regions with developed financial markets (e.g., Thailand) mobilize significantly higher green investments than those with nascent or fragmented markets (e.g., Sub-Saharan Africa).
- Effective capital market development, as seen in Thailand, enables greater participation by private issuers and investors.

2. Role of International Support:

- Countries like Moldova heavily rely on international funding and partnerships (e.g., EIB loans and EU programs) to finance green transitions.
- These collaborations are essential for countries with limited domestic resources but come with risks of over-reliance and slow implementation.

3. Policy and Regulatory Frameworks:

- Thailand and the Philippines have established clear regulatory frameworks to attract green investments, like the Green Energy Auction Programme and the Renewable Energy Act.
- Sub-Saharan Africa and other low-investment regions face a lack of cohesive policy mechanisms and high-risk premiums, deterring significant investments.

4. Climate Vulnerability vs. Financial Readiness:

- Regions like Sub-Saharan Africa, highly vulnerable to climate change, paradoxically receive fewer investments due to financial instability and lack of institutional capacity.
- This disparity underscores the need for blended finance, credit guarantees, and risk-sharing mechanisms to attract private investors.

4.1.2. Key Observations from the Table

Examples from Table **2** have illustrated how countries and institutions operationalize these principles through targeted GF projects. For instance, Thailand's sustainability bonds and the Philippines' renewable energy initiatives demonstrate how financial instruments can address infrastructure inequities, climate change, and biodiversity goals. Similarly, Moldova's focus on community-led initiatives and Sub-Saharan Africa's efforts to mobilize private clean energy investments underscore the role of GF in addressing global environmental challenges and supporting economic transformation.

Key goals and strategies from these initiatives include:

- Facilitating Renewable Energy Transitions: Investments in projects like Thailand's Green Energy Auction Programme and the Philippines' Renewable Energy Act drive shifts toward low-carbon technologies.

Table 2: Global Green Finance Initiatives by Organization and Region

Name of Organization/Firm	Country	Projected Investment Related to Natural Capital	Goal	Additional Goals	Starting Date	Link/Source
Government of Thailand	Thailand	THB 247 billion (~USD 7.1 billion)	Finance green and social projects (clean transportation, COVID-19 recovery)	Support COVID-19 recovery packages	2020	Ministry of Finance of Thailand, 2022
Thai Sustainable Finance Working Group	Thailand	Not specified (Framework development)	Develop sustainable finance taxonomy and promote investment flows	Improve data environment, create demand-led products, build human capital	2019	Thailand Working Group on Sustainable Finance, 2021
Private Issuers (Various)	Thailand	USD 9.5 billion (Outstanding GSS Bonds)	Increase GSS bond issuance for climate-related projects	Raise awareness of sustainability risks and opportunities	Ongoing as of 2022	ESCAP, 2023
Government of the Philippines	Philippines	2 GW of renewable energy (auctioned capacity)	Develop renewable energy generation through RE Act initiatives	Support low-carbon generation and consumer incentives like the Net Metering Programme (NMP)	2008 (RE Act), 2023 (Offshore Wind Executive Order)	DOE, 2023
Renewable Energy Developers	Philippines	Not specified (includes tax incentives, FIT, and other support)	Promote renewable energy projects through tax and financial incentives	Enhance market attractiveness with FIT, VAT exemptions, and duty-free imports	Ongoing since 2008	IEA, 2017
Energy Regulatory Commission (ERC)	Philippines	Green Energy Auction Programme with technology-specific bands	Facilitate renewable energy auctions and ensure fair pricing	Enable 20-year power supply contracts under Green Energy Tariff (GET)	2021 (Green Energy Auction Programme)	OECD, 2024
Global Environment Facility (GEF) - SGP	Moldova	USD 50,000 to USD 150,000 per project (SGP grants)	Support community-led initiatives and sustainable urban development	Promote innovation, inclusion, and impact in agriculture, biodiversity, energy, and waste	2021 (SGP programme for 2021-25)	GEF, 2020
EU4Moldova Focal Regions Programme	Moldova	EUR 5 million for urban redesign in Ungheni and Cahul	Develop public transportation and improve socio-economic growth	Prepare strategic action plans for smart regions and mobilize further investments	2019 (Five-year programme running through 2024)	OECD, 2024
European Investment Bank (EIB)	Moldova	EUR 100 million loan available for public service improvements	Improve solid waste management services and urban infrastructure	Complement EU4Moldova interventions and catalyze other initiatives	Ongoing as of 2023	EIB, 2024
African Union (Agenda 2063)	Sub-Saharan Africa	Capital market development for domestic resource mobilization	Strengthen domestic resource mobilization and support development financing	Double domestic contribution to development financing	Ongoing (Agenda 2063)	OECD, 2023
International Monetary Fund (IMF)	Sub-Saharan Africa	Innovative private funding for clean energy projects	Improve risk-return profiles for private clean energy investments	Prepare bankable projects and lower entry costs for investors	2022	IMF, 2022
Various Issuers (GSS Bonds)	Sub-Saharan Africa	EUR 4.6 billion in GSS bond issuances (as of 2022)	Facilitate renewable energy investments and develop financial sector diversification	Increase renewable energy generation and address SDG financing gaps	2014 (First GSS bond issuance)	OECD, 2023
Enel Green Power	Italy	34.5 MW new wind capacity, 27.2 MW hydro repowering, 0.83 MW new solar projects	Develop new renewable energy capacity, repower existing plants	Support decarbonization objectives, extend plant life, and replace conventional sources with zero-emission ones	2021	Enel Green Power website

Note*: This table summarizes notable green finance initiatives across regions, highlighting projected investments, goals, and additional objectives. While entries like Enel Green Power are detailed due to the availability of specific data, this does not imply a disproportionate contribution relative to other issuers. Data limitations mean some entries represent only a fraction of the initiatives under those organizations or regions. Regional categories emphasize diverse strategies and challenges in aligning green finance with sustainable development goals.

- Urban Development and Infrastructure Equity: Programs like Moldova's EU4Moldova initiative focus on enhancing public infrastructure, socio-economic growth, and smart regional planning.

- Community and Capacity Building: Grants from organizations like the Global Environment Facility (GEF) empower local stakeholders to implement sustainable practices and pilot innovative solutions.

- Addressing Inequities in Financial Access: Mechanisms like the EIB's loans for Moldova emphasize bridging resource gaps in underserved regions while promoting urban equity and climate resilience.

Key Observations from the Table are:

1. Diverse Financial Mechanisms: These initiatives employ various tools, such as grants, loans, auctions, and blended finance, to achieve sustainability goals.

2. Regional Focus: Programs reflect regional priorities, such as Southeast Asia's focus on renewable energy and Sub-Saharan Africa's emphasis on infrastructure development.

3. Scalable Models: Examples like Thailand's Green Bond Framework highlight replicable models that other nations can adapt for their contexts.

4. Global Collaboration: International partnerships underpin most initiatives, demonstrating the importance of collective efforts in overcoming financial and technical barriers.

These case studies exemplify the operationalization of GF objectives, providing a roadmap for scaling sustainability-focused investments globally. By understanding these examples, policymakers and investors can identify best practices to enhance green finance's impact across diverse regions.

4.2. Barriers and Opportunities in Scaling GF

The expansion of GF faces significant barriers that challenge its scalability and effectiveness, yet these hurdles also present opportunities for innovation and systemic change. Addressing these barriers is essential to fully leverage GF's transformative potential, enabling it to meet global sustainability goals. This subsection examines key obstacles and outlines strategies to overcome them, emphasizing the role of financial instruments, policy frameworks, and technological innovations.

Barriers to Scaling GF include the following:

1. Regulatory and Structural Constraints

- Issue: Fragmented regulatory environments and complex approval processes limit the scalability of GF initiatives, especially in emerging and developing economies (EMDEs). For instance, slow authorization procedures hinder the deployment of renewable energy projects, as seen in Italy's lengthy processes for wind and solar installations.

- Opportunity: Streamlining regulatory frameworks and adopting standardized procedures can accelerate project approvals and reduce investment delays.

2. Greenwashing and Trust Deficit

- Issue: Greenwashing undermines the credibility of GF instruments, leading to skepticism among investors. Superficial sustainability claims can erode trust and diminish the market's integrity.

- Opportunity: Strengthening third-party verification mechanisms and ensuring transparency through regular impact reporting can build investor confidence and establish market credibility.

3. Financial Accessibility and Inclusivity

- Issue: High upfront costs and limited access to tailored financial instruments restrict participation by Micro, Small, and Medium Enterprises (MSMEs) and low-income households in green projects.

- Opportunity: Inclusive Green Finance (IGF) can lower entry barriers through microfinancing, concessional loans, and blended finance approaches, democratizing access to sustainable investments.

4. Market Liquidity and Scalability

- Issue: Limited liquidity in green bond markets, particularly in Sub-Saharan Africa and Southeast Asia, constrains their attractiveness to institutional investors.

- Opportunity: Developing secondary markets for green bonds and fostering regional collaborations can enhance liquidity and investor engagement.

5. Data Gaps and Impact Measurement

- Issue: Inconsistent data collection and reporting hinder accurate measurement of environmental and social impacts, complicating the evaluation of GF projects.

- Opportunity: Advancements in digital technologies, such as blockchain and AI-powered analytics, can enhance data transparency and improve impact assessment methodologies.

Among the opportunities for Governments and international organizations can implement tax incentives, subsidies, and auction-based frameworks to stimulate green investments. Initiatives like the Philippines' Green Energy Auction Programme showcase how targeted policies can unlock renewable energy potential, even in markets with structural challenges.

Expanding human capital through targeted training programs for financial and technical professionals can improve decision-making and execution in GF projects. For example, Thailand's Sustainable Finance Working Group emphasizes building expertise to support sustainable finance development.

Partnerships between public and private sectors can enhance resource mobilization and innovation. Examples include blended finance approaches in Sub-Saharan Africa and community-led initiatives under Moldova's EU4Moldova Focal Regions Programme.

Adopting frameworks like the EU Green Bond Standard can harmonize practices across regions, promoting consistency and reducing the risks associated with fragmented markets.

Scaling GF requires collective action by stakeholders across the financial, governmental, and corporate sectors. By addressing barriers and leveraging opportunities, stakeholders can:

- Foster resilience in financial systems through diversified and inclusive investment strategies.

- Enhance the credibility and impact of GF instruments, ensuring alignment with global sustainability goals.

- Promote innovation in financial products and policy mechanisms, driving the transition to a sustainable economy.

This analysis underscores the dual need for systemic innovation and localized solutions, highlighting the interconnected nature of global finance and sustainability efforts.

5. CONCLUSIONS

The evolution of GF reflects a growing recognition of the need to align financial systems with sustainability objectives. The integration of SMC within GF strategies offers a transformative approach, enhancing the effectiveness of financial instruments to address pressing environmental and social challenges. To achieve this, superordinate technological expertise and institutional commitment are critical in navigating complex financial landscapes (Luskin & Peters, 2020).

The European Investment Bank's (EIB) 11 environmental and social standards provide a comprehensive framework for understanding how GF initiatives can address these challenges across diverse dimensions. These standards emphasize key principles such as:

Environmental and Social Impacts and Risks: Mitigating potential adverse outcomes associated with financial projects and ensuring sustainability throughout their lifecycle.

Stakeholder Engagement: Encouraging transparency and inclusivity by involving affected communities and other stakeholders.

Resource Efficiency and Pollution Prevention: Promoting the efficient use of resources while minimizing pollution.

Biodiversity and Ecosystems: Safeguarding ecosystems and biodiversity by ensuring projects do not harm natural habitats.

Climate Change: Designing projects to mitigate climate risks and adapt to changing environmental conditions.

Involuntary Resettlement: Addressing the socio-economic impacts of displacement caused by projects.

Vulnerable Groups and Indigenous Peoples: Ensuring equitable outcomes for marginalized communities and respecting the rights of indigenous populations.

Labour Rights: Upholding fair labor practices and ensuring worker protections.

Health, Safety, and Security: Prioritizing the well-being of affected populations and workers involved in GF projects.

Cultural Heritage: Preserving cultural assets that projects may impact.

Intermediated Finance: Establishing safeguards for projects implemented through financial intermediaries.

By adhering to these standards, GF initiatives can systematically integrate environmental, social, and governance (ESG) considerations, ensuring capital's ethical and sustainable deployment. These principles complement the innovative tools and frameworks discussed in this paper, including Pareto efficiency and game-theoretical models, to promote balanced decision-making in the face of competing interests.

The findings in this paper emphasize that blending traditional assets with sustainable investments and designing portfolios that reflect the unique risks and benefits of sustainability are essential to ensuring long-term viability (Busch & Hoffmann, 2011). Additionally, financial products incentivizing eco-friendly behavior and Inclusive Green Finance (IGF) initiatives can lower barriers to entry for underserved groups like MSMEs and low-income households, enabling broader participation in sustainability efforts (World Bank, 2020).

However, achieving the transformative potential of GF requires vigilance against risks like greenwashing and superficial compliance. Adopting rigorous verification mechanisms, including independent audits, reporting requirements, and transparent stakeholder engagement processes, is vital to maintaining accountability and trust in GF initiatives.

GF represents more than a financial mechanism—it is a societal and environmental transformation tool. By channelling investments into strategic areas, embracing innovation, and fostering collaboration, GF can address the pressing challenges of our time while unlocking opportunities for inclusive, sustainable growth. Its success hinges on a dynamic, adaptive approach that balances financial returns with ethical and environmental imperatives, ensuring that GF achieves economic targets and advances global sustainability.

AUTHOR CONTRIBUTIONS

Conceptualization: R.F.; Literature review: R.F.; Hypothesis development: R.F.; Data collection and data sorting: R.F. and S.C.; Hypothesis evaluation: R.F.; Discussion: R.F.; Reviewing: R.F., S.C., P.A. and F.R. All authors have read and agreed to the published version of the manuscript.

FUNDING

This research received no external funding.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

AFI (Alliance for Financial Inclusion). 2021. “Inclusive Green Finance: From Concept to Practice.” Online source, April, pp. 1–7. Available from: AFI (last accessed May 3, 2023).

Arunachalam, M. 2024. “Analysis of Stakeholders Interests in Green Finance.” In: A.I. Hunjra, and J.W. Goodell, (eds) *The Palgrave Handbook of Green Finance for Sustainable Development*. Palgrave Studies in Impact Finance. Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-031-65756-6_4

Azam, M., Haroon, M., Rahman, S.u., Ali, H., and Chani, M. 2024. The Theoretical Perspective of Green Finance. In: A.I. Hunjra and J.W. Goodell, (eds) *The Palgrave Handbook of Green Finance for Sustainable Development*. Palgrave Studies in Impact Finance. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-65756-6_2

Belloni, M., Giuzio, M., Kördel, S., Radulova, P., Salakhova, D., and Wicknig, F. 2020. *The performance and resilience of green finance instruments: ESG funds and green bonds*. European Central Bank | Eurosystem. Formerly part of Financial Stability Review, November 2020. Online: The performance and resilience of green finance instruments: ESG funds and green bonds (last accessed November 26, 2024).

Broccardo, L., Giordino, D., Yaqub, M.Z., and Alshibani, S.M. 2024. “Implementing sustainability: What role do knowledge management and management accounting play? Agenda for environmentally friendly businesses.” *Corporate Social Responsibility and Environmental Management*, Online Version of Record, September 10. https://doi.org/10.1002/csr.2936

Busch, T., and Hoffmann, V.H. 2011. “How Hot is Your Bottom Line? Temperature Effects on the Financial Performance of Green Firms.” *Strategic Management Journal*, *32*(5), 636–651. https://doi.org/10.1002/smj.897

Cheng, B., *et al*. 2014. “Corporate Social Responsibility and Sustainable Finance: An Empirical Analysis.” *Journal of Banking & Finance* 48, 246–263. https://doi.org/10.1016/j.jbankfin.2014.01.002

Choi, J. J., *et al*. 2020. “The Pricing of Sustainability Risk in the Financial Market.” *Financial Review*, *55*(2), 215-236. https://doi.org/10.1111/fire.12245

de Freitas Netto, S.V., Sobral, M.F.F., Ribeiro, A.R.B. *et al.* 2020. “Concepts and forms of greenwashing: a systematic review.” *Environ Sci Eur* 32, 19. https://doi.org/10.1186/s12302-020-0300-3

DesJardine, M. R., Zhang, M., and Shi, W. 2023. “How Shareholders Impact Stakeholder Interests: A Review and Map for Future Research.” *Journal of Management*, *49*(1), 400–429. https://doi.org/10.1177/01492063221126707

Dryzek, J.S. 2013. The Politics of the Earth: Environmental Discourses. Oxford: Oxford University Press.

Ekins, P., Zenghelis, D. 2021. "The costs and benefits of environmental sustainability." *Sustain Sci* 16, 949–965. https://doi.org/10.1007/s11625-021-00910-5

European Commission. 2018. Communication 97/2018. *Action Plan: Financing Sustainable Growth*. Brussels, 8 March, pp. 1–20.

Finance and Investment, OECD Publishing, Paris. https://doi.org/10.1787/7a13719d-en

Fu, C., Lu, L., and Pirabi, M. 2024. "Advancing green finance: a review of climate change and decarbonization." *DESD* 2, 1. https://doi.org/10.1007/s44265-023-00026-x

Fucà, R., Cubico, S., Ardolino, P., Rosiello, F., Leitão, J., and Favretto, G. "The Sustainable Material Culture (SMC): A Review." *Preprints* 2023, 2023090956. https://doi.org/10.20944/preprints202309.0956.v2

Harsanyi, J.C. 1967. "Games with Incomplete Information Played by "Bayesian" Players, I-III. Part I. The Basic Model." *Management Science*, Nov., *14*(3), Theory Series, pp. 159–182. https://www.jstor.org/stable/2628393

Hynes, W., Trump, B.D., Kirman, A. *et al.* 2022. "Systemic resilience in economics." *Nat. Phys.* 18, 381–384. https://doi.org/10.1038/s41567-022-01581-4

International Energy Agency (IEA). 2022. "The Role of Low-Carbon Fuels in the Clean Energy Transitions of the Power Sector." Paris: IEA, pp. 1–115.

Jirásková, S. 2017. "Financial Risk Management." *Land Forces Academy Review*, vol. XXII, 4(88), pp. 276–280.

Kets, W., Kager, W., and Sandroni, A. "The value of a coordination game." *Journal of Economic Theory* 201, April, 105419. https://doi.org/10.1016/j.jet.2022.105419

Lowell, B. 2009. "Dynamic Management: Better Decisions in uncertain times." *McKinsey Quarterly*, December, pp. 1–7.

Merton, R.K. (1995). Theoretical Analysis of Social Structures. Chicago: University of Chicago Press.

Mukhopadhyay, S. K., Zhu, X., and Yue, X. 2008. "Optimal Contract Design for Mixed Channels Under Information Asymmetry." *Production and Operations Management*, *17*(6), 641–650. https://doi.org/10.3401/poms.1080.0069

Mukhopadhyay, S.K., Yue, X., and Zhu, X. 2011. "A Stackelberg model of pricing of complementary goods under information asymmetry." *Int. J. Production Economics* 134, pp. 424–433. https://doi.org/10.1016/jipe.2009.11.015

Noori, N. 2021. "The Effects of Financial Risks Management on Financial Performance of Commercial Banks in Malaysia." MBA Thesis, Finance and Banking Department, University of Limkokwing, Malaysia.

OECD. 2024. "Clean Energy Finance and Investment Roadmap of Thailand." Green Finance and Investment, OECD Publishing, Paris. https://doi.org/10.1787/d0cd6ffc-en

OECD. 2024. "Clean Energy Finance and Investment Roadmap of the Philippines." Green

OECD. 2024. "Cross-border investment into low-carbon infrastructure: An empirical glance." OECD Working Papers on International Investment, No. 2024/01, OECD Publishing, Paris. https://doi.org/10.1787/e82ee163-en

Palmaccio, M., Galeone, G., and Shini, M. "Green Finance: Past, Present and Future Studies." Journal of Financial Management, *Markets and Institutions*, *11*(2), December, pp. 1–19. https://doi.org/10.1142/S2282717X23500135

Popescu, I-S., Hitaj, C., and Benetto, E. 2021. "Measuring the sustainability of investment funds: A critical review of methods and frameworks in sustainable finance." *Journal of Cleaner Production* 314, 128016, ISSN 0959-6526, pp. 1–13. https://doi.org/10.1016/j.jclepro.2021.128016

Scholtens, B., and Dam, L. 2007. "Cultural Values and International Differences in Business Ethics." *Journal of Business Ethics* 75: 273–284. https://doi.org/0.1007/s10551-006-9252-9eng

Simeth, N. 2022. "The value of external reviews in the secondary green bond market." *Finance Research Letters* 46, Part A, May, 102306. https://doi.org/10.1016/j.frl.2021.102306

United Nations Trade & Development (UNCTAD). 2024. "Sustainable finance trends." Chapter III, pp. 1–30. In: ID, *Promoting investment for sustainable development*. *UNCTAD's latest monitoring of SDG investment and sustainable finance trends*. World Investment Report. Geneva: United Nations. wir2024_ch03_en.pdf

Yue, M., and Nedopil, C. 2022. "China's Role in Public External Debt in DSSI Countries and the Belt and Road Initiative (BRI) in 2020", *Green Finance & Development Center*, March. https://doi.org/10.13140/RG.2.2.33997.72169

Zeng, X., Ogunseitan, O.A., Nakamura, S., Suh, S., Kral, U., Li, J., and Geng, Y. 2022. "Reshaping global policies for circular economy," *Circular Economy*, *1*(1), 100003, ISSN 2773-1677. https://doi.org/10.1016/j.cec.2022.100003

Received on 14-11-2024 Accepted on 18-12-2024 Published on 31-12-2024

https://doi.org/10.6000/2817-2302.2024.03.13