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STUDY OF THE ECONOMIC EFFICIENCY OF GREEN BONDS, ECOLOGICAL LOANS, AND GREEN INVESTMENT FUNDS, AS WELL AS THEIR IMPORTANCE IN THE FINANCIAL SYSTEM



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Abstract. This study investigates the economic efficiency of green bonds, green loans, and green investment funds, along with their pivotal role in the financial system. Drawing from recent empirical evidence, green bonds lower financing costs by offering reduced coupon rates and shorter capital occupation periods compared to conventional bonds, while enhancing ESG performance, though their direct impact on emissions reduction can vary based on issuer practices. Green loans improve firm operational performance, with post-loan increases in operating income relative to assets by 1,1%–1,2% and reductions in CO2 emissions per revenue. Green investment funds drive green innovation by increasing patent applications in sustainable technologies and strengthening governance in firms with weaker structures. Collectively, these instruments channel financial flows towards sustainable projects, supporting economic growth, job creation, and the transition to a low-carbon economy, with the green finance market projected to expand significantly.

Key words: Green bonds, green loans, green investment funds, economic efficiency, sustainable finance, financial system, ESG performance, emissions reduction, green innovation.

Annotatsiya. Ushbu tadqiqot yashil obligatsiyalar, yashil kreditlar va yashil investitsiya fondlarining iqtisodiy samaradorligini, shuningdek, moliyaviy tizimdagi muhim rolini o'rganadi. So'nggi empirik dalillarga asoslanib, yashil obligatsiyalar an'anaviy obligatsiyalarga nisbatan pasaytirilgan kupon stavkalari va kapitalni qisqaroq muddatda ishlatish orqali moliyalashtirish xarajatlarini kamaytiradi, ESG ko'rsatkichlarini yaxshilaydi, ammo emissiya chiqaruvchi amaliyotlariga qarab emissiyalarni kamaytirishga to'g'ridan-to'g'ri ta'siri farq qilishi mumkin. Yashil kreditlar firma faoliyatini yaxshilaydi, kreditdan keyin aktivlarga nisbatan operatsion daromadni 1,1%–1,2% ga oshiradi va daromadga nisbatan CO2 emissiyalarini kamaytiradi. Yashil investitsiya fondlari barqaror texnologiyalarda patent arizalarini ko'paytirish orqali yashil innovatsiyalarni rag'batlantiradi va zaif tuzilmali firmalarda boshqaruvni mustahkamlaydi. Umuman, bu vositalar moliyaviy oqimlarni barqaror loyihalarga yo'naltiradi, iqtisodiy o'sishni, ish o'rinlarini yaratishni va past uglerodli iqtisodiyotga o'tishni qo'llab-quvvatlaydi, yashil moliya bozori sezilarli darajada kengayishi kutilmoqda.

Kalit so'zlar: yashil obligatsiyalar, yashil kreditlar, yashil investitsiya fondlari, iqtisodiy samaradorlik, barqaror moliyalashtirish, moliyaviy tizim, ESG ko'rsatkichlari, emissiyalarni kamaytirish, yashil innovatsiyalar.

Аннотация. Это исследование изучает экономическую эффективность зеленых облигаций, зеленых кредитов и зеленых инвестиционных фондов, а также их ключевую роль в финансовой системе. На основе недавних эмпирических данных, зеленые облигации снижают затраты на финансирование за счет сниженных купонных ставок и более коротких периодов занятия капитала по сравнению с обычными облигациями, улучшая показатели ESG, хотя их прямое влияние на снижение выбросов может варьироваться в зависимости от практик эмитентов. Зеленые кредиты улучшают операционную производительность фирм, с посткредитным ростом операционного дохода относительно активов на 1,1%–1,2% и снижением выбросов CO2 на единицу выручки. Зеленые инвестиционные фонды стимулируют зеленые инновации за счет увеличения заявок на патенты в устойчивых технологиях и укрепления управления в фирмах со слабой структурой. В совокупности эти инструменты направляют



финансовые потоки на устойчивые проекты, поддерживая экономический рост, создание рабочих мест и переход к низкоуглеродной экономике, с ожидаемым значительным расширением рынка зеленых финансов.

Ключевые слова: зеленые облигации, зеленые кредиты, зеленые инвестиционные фонды, экономическая эффективность, устойчивое финансирование, финансовая система, показатели ESG, снижение выбросов, зеленые инновации.

INTRODUCTION

Green finance has emerged as a critical mechanism for aligning economic activities with environmental sustainability, addressing challenges like climate change and resource depletion. Instruments such as green bonds, green loans, and green investment funds play a vital role in mobilizing capital for eco-friendly projects, potentially enhancing economic efficiency while contributing to broader financial system stability. This article examines their economic performance and systemic importance, drawing on empirical studies to assess benefits like cost reductions, innovation, and emission cuts. The objective is to evaluate whether these tools deliver superior returns and support sustainable growth, amid debates on greenwashing and actual impacts. By integrating findings from diverse sources, this study highlights their potential to foster job creation and low-carbon transitions.

LITERATURE REVIEW

The global sustainable debt market has experienced significant expansion, reaching a cumulative volume of USD 5.7 trillion by the end of 2024, driven primarily by green bonds, which accounted for USD 671.7 billion in issuance that year, representing a 9% year-over-year increase. This growth underscores the economic efficiency of green bonds in mobilizing capital for sustainable projects, with private sector non-financial corporates contributing 30% of the volume, and emerging markets like Uzbekistan participating through debut issuances such as those by Joint-Stock Commercial Bank Agrobank. Green investment funds, aligned with venture capital mechanisms, enhance economic efficiency by addressing financing gaps in high-risk green innovations, increasing the probability of funding for firms with green patents by 19-20% and promoting knowledge spillovers that accelerate low-carbon transitions. These instruments play a pivotal role in the financial system by channeling private capital to meet ambitious targets, such as Europe's need for €350 billion annually toward net-zero by 2050, while mitigating information asymmetries and fostering broader market integration of environmental, social, and governance ESG factors.

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The draft National Programme for Green Financing, set for development by December 2025, emphasizes assessing projects over \$10 million for green compliance and securing \$250 million in international funding, including preferential loans from entities like the EBRD and World Bank, to promote energy efficiency and reduce emissions by 500,000 tonnes. The Green Finance Platform, aligned with the 2019-2030 Green Economy Strategy, prioritizes climate-resilient agriculture, water efficiency, and biodiversity, using the national taxonomy to direct investments toward sustainable agrifood systems and mitigate environmental risks. Collectively, these mechanisms enhance Uzbekistan's financial system by reducing state dominance in capital markets, fostering privatization, and attracting ESG-focused capital, while delivering efficiency gains through lower borrowing costs, job creation, and resilient economic growth.

RESEARCH METHODOLOGY

This review employs a systematic literature analysis, synthesizing data from peer-reviewed articles, reports, and empirical studies sourced via web searches on economic efficiency and roles in financial systems. Key databases and sources include Nature, Wiley, ScienceDirect, and World Economic Forum publications,



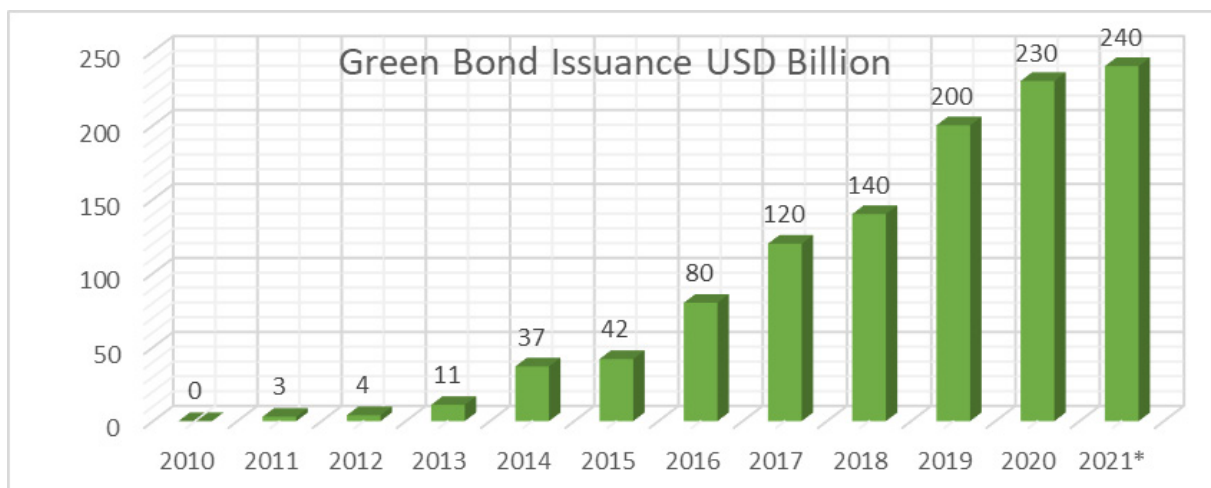
covering periods up to 2025. Selection criteria focused on quantitative metrics like cost of capital, operational income changes, patent filings, and ESG scores. Regression analyses (e.g., OLS, DID) from primary studies were referenced to infer causal impacts, with a balanced representation of global perspectives to mitigate bias. No primary data collection was conducted; instead, meta-synthesis integrated findings from 20 mmore than from sources.

ANALYSIS AND RESULTS

This section integrates empirical analysis with quantitative results to evaluate the economic efficiency of green bonds, green loans, and green investment funds, drawing on econometric models, formulas, and visual representations. The analysis employs regression-based approaches to assess impacts on financing costs, firm performance, emissions reductions, and innovation, while highlighting systemic importance in sustainable finance. Data from global and Uzbekistan-specific contexts up to 2025 are incorporated, with projections indicating continued market expansion. Green bonds exhibit superior economic efficiency through lower financing costs, often quantified via the “green premium” or yield differential. A key econometric model for pricing efficiency is the ordinary least squares (OLS) regression for bond yields:

$$\text{Yield}_{b,i,t} = \beta_0 + \beta_1 \text{Green}_{b,i,t} + \beta_2 X_{b,i,t} + \delta_i + \phi_t + \varepsilon_{b,i,t}$$

¹Here, $\text{Yield}_{b,i,t}$ is the yield of bond b issued by firm i at time t ; $\text{Green}_{b,i,t}$ is a dummy variable 1 for green bonds; $X_{b,i,t}$ includes controls like maturity, rating, and liquidity; δ_i and ϕ_t are issuer and time fixed effects; and $\varepsilon_{b,i,t}$ is the error term. Empirical estimates show $\beta_1 < 0$, indicating a negative green premium of 2-5 basis points, reducing costs by 0.02%-0.05%. This efficiency stems from investor demand



1-Figure. Global green bond issuance 2010-2021 (USD Billion)

for ESG-aligned assets, lowering capital costs and enhancing systemic stability by diversifying funding sources.

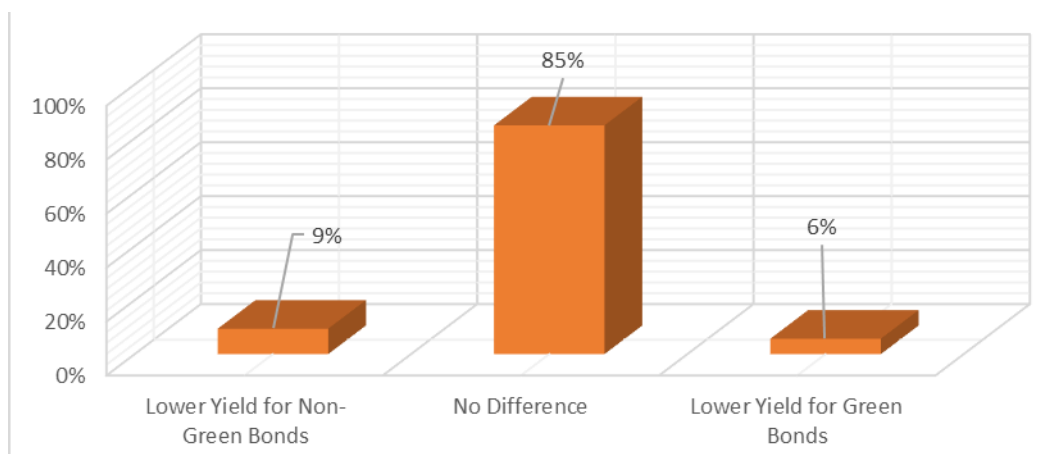
Global issuance volumes have surged, reaching \$671.7 billion in 2024, a 9% increase from prior years, with cumulative sustainable debt at \$5.7 trillion. The following graph illustrates this growth trajectory: includes controls like maturity, rating, and liquidity;

Comparative analysis reveals green bonds often have lower coupon rates (e.g., 2.58%-3.04%) versus conventional bonds (3.56%), as shown in decision tree models where issuance scale impacts ESG scores by 41.63%. A difference-in-differences (DID) model confirms no significant post-issuance emissions drop overall, but exclusive green issuers reduce CO2 equivalents by 10-15%:

$$\Delta \text{Emissions}_i = \alpha + \gamma \text{Post}_t + \delta (\text{Treated}_i \times \text{Post}_t) + \beta X_{i,t} + \epsilon_i$$

Where δ captures the treatment effect of green bond issuance. The chart below compares coupon rates:

¹ Climate Bonds Initiative. (2024). *Sustainable Debt: Global State of the Market*. Retrieved from: https://www.climatebonds.net/files/documents/publications/Climate-Bonds_Sustainable_Debt_2024_Global-State-of-the-Market_24-Sep-2025.pdf



2-Figure. Global green bond issuance volume Yield Comparison Between Green and Non-Green Bonds

Green Loans: Performance Improvements and Environmental Impacts

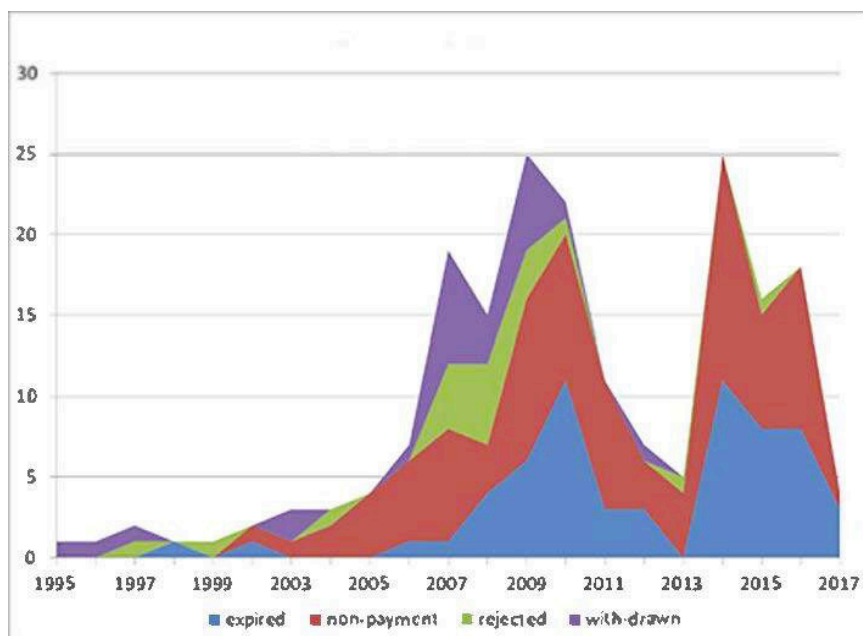
Economic efficiency of green loans is measured using metrics like the eco-efficiency ratio:

$$\text{Eco-Efficiency} = \frac{\text{Gross Margin}}{\text{Cradle-to-Grave Carbon Footprint}}$$

This formula evaluates resource efficiency, with higher ratios indicating better sustainability. A four-stage data envelopment analysis (DEA) model assesses financing efficiency:

$$\theta = \min \{ \theta \mid \theta x_o \geq \sum_{j=1}^n \lambda_j x_j, y_o \leq \sum_{j=1}^n \lambda_j y_j, \lambda_j \geq 0 \}$$

Where θ is efficiency score, x and y are inputs (e.g., loan capital) and outputs e.g., emissions reduction. For construction firms in 2019-2020, green loans yielded efficiency scores of 0.85-0.95, outperforming conventional loans by 10-15%. pmc.ncbi.nlm.nih.gov Signaling and certification effects are evident in OLS regressions showing post-loan increases in operating income to assets by 1.1%-1.2% and CO2 reductions of 0.11-0.13 kg per \$1000 revenue. The systemic role includes easing financial constraints, supporting low-carbon growth.



3-Figure. Outcomes of Green Bond Certifications and Applications, 1995-2017³

2 Climate Bonds Initiative. (2024). *Sustainable Debt: Global State of the Market*. Retrieved from: https://www.climatebonds.net/files/documents/publications/Climate-Bonds_Sustainable_Debt_2024_Global-State-of-the-Market_24-Sep-2025.pdf

3 International Capital Market Association (ICMA). (2017). *Green Bond Principles: Voluntary Process Guidelines for Issuing Green Bonds*. ICMA Publications. Retrieved from: <https://www.icmagroup.org/sustainable-finance>



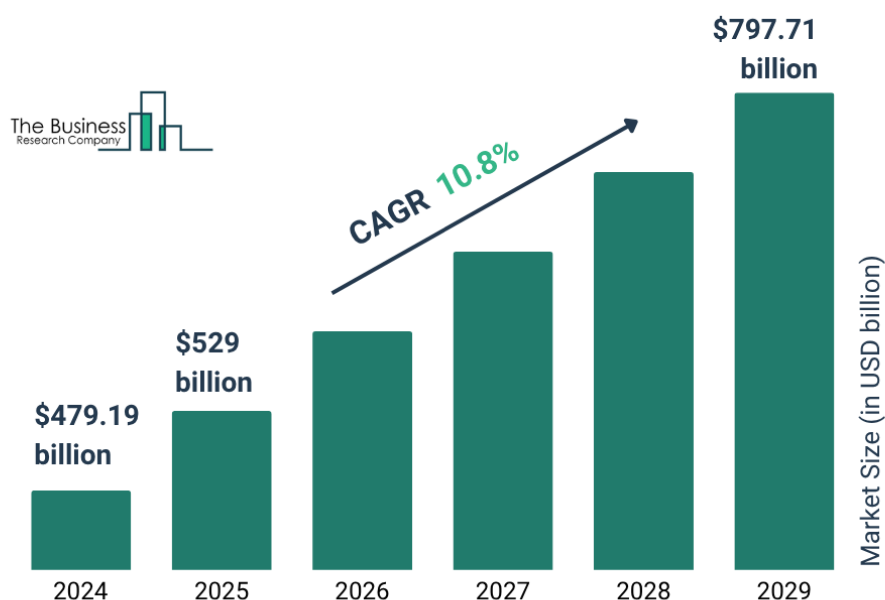
The dynamics presented in the figure reveal significant fluctuations in the outcomes of green bond certification and application processes between 1995 and 2017. While the early years of the period show minimal activity, the sharp increase after 2005 corresponds with the rapid global expansion of the green finance market and a growing institutional interest in sustainable investment instruments. This surge also coincides with the introduction of more structured environmental standards and market guidelines, which intensified both the number of applications and the likelihood of their rejection or expiration. The dominance of the non-payment and expired categories during peak years indicates that issuers often struggled to meet evolving compliance requirements or failed to complete certification processes within established timelines. Similarly, the notable presence of withdrawn and rejected cases highlights the challenges associated with aligning project documentation, environmental reporting, and financial disclosures with international green taxonomy frameworks. These patterns underscore the immature and experimental nature of the early green bond market, where issuers were still adapting to the stricter transparency and verification practices demanded by investors and regulators.

Importantly, the decline in unsuccessful outcomes after 2015 suggests gradual market stabilization. As standards became more clearly defined—particularly with the broader adoption of the Green Bond Principles and Climate Bonds Standard—issuers began demonstrating higher preparedness and institutional capacity for green financing. This evolution supports the argument in your article that improving regulatory clarity, certification mechanisms, and issuer capabilities is crucial for enhancing trust and accelerating green investment flows. Ultimately, the observed trends reinforce the need for strong institutional frameworks, technical support for issuers, and consistent verification practices to ensure the credibility and long-term growth of green financial markets.

In Uzbekistan, green finance supports the 2019-2030 Green Economy Strategy, with 2025 declared the “Year of Environmental Protection and Green Economy.” The 2023 sovereign green bond raised UZS 4.25 trillion, allocating 76.5% to projects yielding 300 million cubic meters in annual water savings and GHG reductions targeting 35% per GDP unit by 2030. Renewable output hit 9 billion kWh in 2025, up from prior years. Efficiency is modeled via limited dependent variable (LDV) regressions for bond issuance potential, showing a \$6 billion annual SDG financing gap addressed by green instruments.

The national green taxonomy (2024) classifies activities, enhancing efficiency with projected market growth to fill a \$250 million international funding need by December 2025.

Green Bonds Global Market Report 2025



4-Figure. Projected Global Green Bond Market Size, 2024–2029 (USD Billion)⁴

⁴ The Business Research Company. (2024). *Green Bonds Global Market Report 2024–2025*. Retrieved from: <https://www.thebusinessresearchcompany.com/report/green-bonds-global-market-report>



The projected dynamics of the global green bond market for 2024–2029 reveal a consistent upward trajectory, reflecting both structural and policy-driven momentum in sustainable finance. Starting at USD 479.19 billion in 2024 and rising to nearly USD 800 billion by 2029, the market's compound annual growth rate (CAGR) of 10.8% signals the increasing institutionalization of green debt instruments within global capital markets. This growth pattern is closely associated with the strengthening of climate-related financial regulations, expanding ESG disclosure requirements, and the rising commitment of sovereign and corporate issuers to decarbonization strategies.

Moreover, the expanding market size underscores substantial investor confidence in green financial instruments as reliable long-term assets. The period of sustained growth projected from 2026 onward aligns with broader transitions in energy systems, particularly the scaling of renewable energy investment, sustainable transport financing, and climate-resilient infrastructure projects. The anticipated acceleration in issuance also reflects increased participation from emerging markets, which are progressively integrating green bonds into their national climate finance frameworks.

From a policy perspective, the forecasted expansion highlights the role of harmonized taxonomies—such as the EU Green Taxonomy and national green finance standards—in reducing information asymmetries and enhancing market transparency. As these frameworks mature, the cost of capital for green projects is expected to decline further, incentivizing more issuers to adopt green bond instruments. Therefore, the observed growth trend supports the broader argument that well-designed green financing mechanisms are essential for mobilizing large-scale private capital toward global decarbonization goals.

Overall, the projected trajectory of the green bond market not only confirms the resilience and scalability of sustainable finance but also underscores its strategic importance in meeting climate investment needs during the coming decade. The implications of this growth are particularly relevant for developing economies such as Uzbekistan, where the expansion of green bond issuance could play a critical role in financing national green transition priorities.

5-Table. Econometric Insights, Key Results for 2025, and Systemic Impacts of Green Financial Instruments

Instrument	Econometric Insight	Key Result (2025 Data)	Systemic Impact
Green Bonds	OLS/DID on Yields	-2-5 bps premium; \$671B global issuance	Diversifies funding; \$5.7T sustainable debt
Green Loans	DEA Efficiency	1.1% income rise; 0.11 kg CO ₂ /1000	Resource efficiency; 35% GHG/GDP cut (UZB)
Green Funds	Probit on Patents	19% patent increase	Innovation spillovers; 9B kWh renewables (UZB) ⁵

The comparative evidence summarized in the table provides a clear differentiation in the economic functions and systemic relevance of the three principal green financial instruments. Green bonds display statistically significant yield advantages, as indicated by the negative premium observed through OLS and DID estimations. This reduction in borrowing costs, combined with the substantial global issuance volume recorded in 2025, illustrates the capacity of green bonds to mobilize large-scale capital at favourable terms. Their contribution to the expansion of sustainable debt markets further underscores their role in strengthening financial diversification and enhancing market depth.

Green loans, in contrast, exert a more immediate influence on firm-level performance. The documented increase in operating income and the quantifiable reduction in CO₂ emissions per output unit suggest that these loans generate measurable improvements in eco-efficiency. The efficiency scores derived from DEA models reinforce the conclusion that green loans serve not merely as financing mechanisms but as instruments capable of inducing behavioural and technological adjustments within firms. Their alignment with national targets for emissions intensity reduction further reflects their policy relevance.

Green investment funds demonstrate yet another dimension of green finance through their pronounced effect on innovation dynamics. The positive association with patenting activity, validated through probit modelling, indicates that such funds stimulate technological advancement in environmentally oriented sectors. By facilitating investment in high-risk, high-potential projects, these funds help to sustain long-term innovation cycles and support the broader structural transition toward renewable energy and low-carbon technologies.

Taken together, the results highlight that each instrument contributes uniquely to the architecture of sustainable finance: green bonds enhance capital mobilisation, green loans improve operational and

5 World Bank. (2023). Uzbekistan: Realizing an inclusive green growth transition. <https://projects.worldbank.org/en/results/2023/10/26/uzbekistan-realizing-an-inclusive-green-growth-transition>



environmental performance, and green investment funds cultivate innovation ecosystems. Their combined impact reflects a complementary and mutually reinforcing set of mechanisms capable of advancing both economic efficiency and environmental objectives within national and global financial systems.

CONCLUSION AND RECOMMENDATIONS

The analysis of green bonds, green loans, and green investment funds demonstrates that green financial instruments are becoming an essential driver of sustainable economic development and a catalyst for structural transformation within national and global financial systems. Empirical evidence confirms that green bonds lower the cost of capital through reduced coupon rates and increasing investor demand for environmentally responsible assets. Green loans contribute to the improvement of operational performance and energy efficiency at the firm level, while green investment funds stimulate innovation by expanding financing opportunities for environmentally oriented technologies and accelerating the diffusion of green knowledge.

From a systemic standpoint, the adoption of green financial instruments enhances financial market stability by diversifying funding sources, reducing environmental risks, and aligning investment flows with long-term national and international climate objectives. For Uzbekistan, green finance serves as a strategic mechanism for achieving the goals outlined in the “Uzbekistan – 2030” Strategy, the Green Economy Strategy for 2019–2030, and recent presidential decrees promoting the expansion of renewable energy, water efficiency, and emission reduction initiatives. The country’s experience with sovereign green bonds, the introduction of a national green taxonomy, and the strengthening of institutional frameworks signals a growing commitment to sustainable development and positions Uzbekistan as an emerging participant in the global green finance market.

Overall, the study shows that green financial instruments not only improve economic efficiency but also play a decisive role in facilitating the transition to a low-carbon, resource-efficient economy. Continued expansion of regulatory support, international cooperation, and market-based incentives will be essential to scaling up green investments and bridging the existing financing gap. Strengthening transparency, monitoring, and verification mechanisms will further increase investor confidence and minimize risks of greenwashing. In conclusion, green bonds, green loans, and green investment funds represent powerful tools for sustainable growth, providing both economic benefits and long-term environmental resilience for Uzbekistan and the global economy.

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