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Foreign direct investment, technology transfer and the global issuance of green bonds

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ABSTRACT

This study examines the effect of foreign direct investment and technology transfer on the issuance of green bonds, utilizing new International Monetary Fund data for sixty-seven countries from 2000 to 2022. Our findings show that countries promoting foreign direct investment-based technology transfers experience increased growth in green bond issuance, highlighting the connection between industrial, environmental, and sustainable finance considerations. Financial, environmental and institutional factors—such as biodiversity and landscape protection expenditure, geopolitical risks, net electricity imports, sovereign debt ratings, and inflation—are also linked to higher green bond issuance. However, the influence of foreign direct investment and technology transfer may be nonlinear and immediate. Countries focusing on foreign direct investment-based technology transfer may experience difficulties in advancing green finance due to concerns about economic and political dependence. Additionally, factors such as the availability of scientists and engineers, innovation capacity, and monetary policy tightness significantly mediate the effect of foreign direct investment-based technology transfer on green finance. These insights offer valuable guidance for both public and private sector initiatives involved in green financing.

1. Introduction

Green bonds have become increasingly essential in the context of rising global awareness regarding environmental sustainability. The green bond market has experienced significant expansion, fuelled by various issuers such as governments, municipalities, corporations, and financial institutions, and influenced by a broad spectrum of economic and institutional factors (Russo et al., 2021; Dan and Tiron-Tudor, 2021; Chiesa and Barua, 2019). This diversity not only boosts the volume of green bond issuance but also expands the scope of funded projects, encompassing environmentally friendly agriculture, clean energy, advancements in energy efficiency, and green infrastructure (Mertzanis, 2023). Additionally, the rising demand from institutional investors highlights their increasing emphasis on incorporating environmental, social, and governance (ESG) criteria into their investment strategies (Daugaard and Ding, 2022). Standardization efforts through global frameworks like the Green Bond Principles and Climate Bonds Initiative standards have bolstered transparency and credibility, providing assurance to investors regarding the environmental authenticity of these financial products (Muñoz and Smoleńska, 2023). Despite challenges such as the need for clearer standards and concerns around greenwashing, the trajectory of green bonds indicates continued expansion, positioning them as pivotal instruments for channelling capital towards a more sustainable global economy.

Several key factors drive market participation for green bond issuance. Government policies and regulatory frameworks provide crucial incentives like tax benefits and subsidies, encouraging issuers to engage in green finance. Simultaneously, increasing investor demand for sustainable investments, guided by ESG criteria, acts as a significant driver (Dmuchowski et al., 2023). Institutional investors and asset managers prioritize ESG considerations, prompting issuers to issue green bonds to finance projects aligned with sustainability objectives. Issuer-specific factors also play a critical role in shaping the decision to issue green bonds. Factors such as the size of the issuer, its financial stability, and its commitment to corporate sustainability initiatives shape their readiness to enter the green bond market. Economic conditions and market dynamics, including interest rates and investor sentiment towards green investments, further impact issuance patterns (Piñeiro-Chousa et al., 2021). Moreover, the transparency and credibility of issuers in demonstrating the environmental impact of projects financed through green

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bonds are essential in attracting investor interest. Understanding these diverse factors helps stakeholders manage the intricacies of the green bond market effectively, facilitating its growth as a critical vehicle for financing global sustainable development initiatives.

Global capital flows and in particular foreign direct investment (FDI) and technology transfer significantly impact green bond issuance by infusing capital, advanced technologies, and expertise into domestic economies (Carney, 2021; Ping and Shah, 2023). For example, multinational renewable energy corporations investing in developing countries' wind power projects enable these nations to issue green bonds to fund wind farms, attracting international investors interested in sustainable initiatives (Mahbub et al., 2022). Similarly, FDI from European technology firms into Southeast Asian countries for solar photovoltaic projects facilitates large-scale solar projects funded by green bonds, enhancing energy security and appealing to global investors (Dixon et al., 2011). However, FDI can also induce pollution through its effect on local energy consumption (Fatima et al., 2021). Partnerships through FDI also bring credibility to green bond issuers. Joint ventures, such as those between Japanese engineering firms and local municipalities, support water conservation projects funded by green bonds, attracting ESG-focused investors and ensuring successful project implementation (Narula, 2012). FDI and technology transfer advance green bond issuance by providing necessary resources and credibility for sustainable development projects (Zhang et al., 2022).

The impact of FDI-based technology transfer on green finance is critical yet underexplored. Earlier research discussed the broader implications of FDI on development and the environment, sorting out the causality between economic activities, economic transformation, and environmental outcomes, but did not consider their green finance implications (Lim, 2001; Saggi, 2002; Frankel and Rose, 2005). Current literature lacks detailed analysis on how these factors influence green bond markets, including issuance processes and pricing mechanisms. Addressing these gaps can offer key insights into how FDI and technology can be more effectively leveraged to promote sustainable finance (Wei et al., 2022). From a policy standpoint, governments prioritize sustainable development and climate action. Effective policies are essential to attract foreign capital, facilitate technology transfers, and establish robust regulatory frameworks for green bonds. These policies can align financial incentives with environmental objectives, helping to accelerate the shift towards a low-carbon economy (Bhutta et al., 2022). Investor perspectives are equally important. Investors increasingly seek opportunities that offer both profits and positive environmental effects. Research can clarify how FDI and technology transfers affect investor confidence and preferences for green bonds, thereby attracting more capital to sustainable finance initiatives (Jacobs et al., 2010; Clark et al., 2018).

This paper examines the impact of FDI-based technology transfer on green bond offerings across various countries. Unlike conventional debt instruments, green bonds are issued based on environmental criteria. Since the funds raised through green bonds are allocated to eco-friendly projects, their issuance could be shaped by FDI, technology transfer, and other sustainability factors. We quantity the extent of FDI-based technology transfer by using a novel national competitiveness index that measures the efficiency of technology transfer from multinational companies to local firms, which is generated by the World Economic Forum's *Global Competitiveness Report*. The index includes indicators such as FDI inflows, technology transfer efficiency, R&D expenditure, skilled workforce availability, and regulatory quality. These indicators assess a country's ability to absorb foreign technologies and drive innovation and are validated by expert consultations and quantitative assessment (Iamsiraroj and Ulubaşoğlu, 2015).

This study examines how FDI-based technology transfer influence green bond offerings in sixty-seven countries from 2000 to 2022, leveraging newly available country-level green bond data from the International Monetary Fund (IMF). To address potential endogeneity, the analysis employs instrumental variable regression models, using tuberculosis case counts by country and year as an external instrument. The Oster test and propensity score matching are also applied to minimize bias. The results demonstrate a positive link between FDI, technology transfer, and green bond issuance, with findings remaining robust across various model specifications, sample adjustments, and variable measures. The analysis confirms that FDI and technology transfer contribute significantly to the growth of the sustainable bond sector. Further dominance testing highlights FDI and technology transfer as the primary drivers of green bond market expansion, followed by EU membership. This paper stands apart from prior research by integrating financial, environmental, technological, and cross-border investment factors into its analysis, with a particular emphasis on the overlooked influence of FDI-driven technology transfer on green bond finance across different nations.

Our investigation marks the inaugural structured endeavour to examine the missing effect of FDI and technology transfer on green bond offerings around the world. Analysing the effect can make several key theoretical and practical contributions: Firstly, this analysis integrates financial, industrial, and environmental economics by examining the impact of FDI-based technology transfer on green finance. It bridges the gap between financial economics and environmental sustainability, linking traditional economic theories with contemporary sustainability goals. This integration allows for the incorporation of FDI-induced variations in financial, risk, and institutional factors into green finance decisions (Wei et al., 2022; Osano and Koine, 2016; Zioło et al., 2021). It offers novel insights into how technological and economic factors distinctly shape the global demand for and supply of sustainable finance, thereby promoting both environmental and financial innovation. By demonstrating how FDI alleviates financial constraints and mitigates market imperfections in developing countries, it extends the capital market imperfections theory to green finance (Veeramani et al., 2020a, 2020b). Additionally, it expands endogenous growth theory to green finance, showing how FDI and technology transfer boost local innovation and productivity in sustainable projects, thereby influencing green bond markets (Audretsch et al., 2014). The study also explores the influence of institutional factors, such as regulatory frameworks and corporate governance standards, on FDI, thereby enhancing the credibility and effectiveness of green financing (Narula, 2012).

Secondly, the research offers policy guidance by providing empirical evidence and theoretical frameworks for policymakers to design strategies that attract FDI and facilitate technology transfer as well as developing policies that foster a conducive environment for green bond issuance. It stands out by presenting an integrated framework analysing how FDI-driven technology, policy synergies, and institutional quality enhance the green bond market. Unlike earlier works, it explicitly considers demand- and supply-side effects and links institutional frameworks with technology transfer to reveal their combined impact on bond dynamics. Policymakers can utilize this information to align financial incentives with environmental goals, thereby promoting sustainable economic growth (Bhutta et al., 2022). These frameworks should incentivize private sector investment in sustainable projects through tax benefits, subsidies, and other financial instruments. Additionally, the research suggests that improving corporate governance standards can enhance investor confidence, thereby attracting more FDI into green sectors. By addressing these areas, policymakers are capable of building a more attractive financial climate for green finance, using FDI to drive technological advancements and environmental sustainability (Johnson, 2017).

Thirdly, the findings help formulate investment and corporate strategies. Investors can use these insights to better understand how FDI-based technology transfers affect green bond markets, informing their investment decisions and identifying sustainable and profitable opportunities (Clark et al., 2018). Companies can align their sustainability strategies with FDI and technology transfer trends, thereby positioning themselves to attract investment and finance green projects (Jacobs et al., 2010).

Finally, the research contributes to improving market development. It helps develop more robust and transparent green bond markets by providing insights into how FDI-based technology transfers impact market dynamics. This guidance can improve market structures, enhancing overall market effectiveness and investor confidence (Zhang et al., 2022). The study also explores the total value of green bond financing, analysing both government and private industry sector ventures in green finance while examining the impact on national financing behaviour through cultural factors.

The paper is structured as follows: Section 2 reviews the existing literature on FDI, technology transfer, and key factors affecting the green bond market. Section 3 details the data sources and empirical methodology employed in the analysis. Section 4 presents the baseline results, with sensitivity analyses discussed in Section 5. Section 6 addresses the issue of endogeneity, followed by additional robustness checks in Section 7. Finally, Section 8 summarizes the study's main findings and discusses their broader implications.

2. Related literature

2.1. Theoretical frameworks

Several theoretical frameworks in economics, technological and institutional analysis, and international business can explain the effect of a country's FDI and technology transfer performance on green bond issuance. First, capital market imperfections theory elucidates how FDI alleviates financial constraints in less developed countries by providing essential capital that is scarce due to information asymmetry and transaction costs (Veeramani et al., 2020a, 2020b). This influx of foreign capital mitigates local financial market inefficiencies, directly increasing funds available for sustainable projects and thereby raising the demand for financing through green bonds.

Moreover, endogenous growth theory highlights the critical role that innovation and technology play in driving economic growth (Audretsch et al., 2014). FDI introduces advanced green technologies to less developed countries, enhancing the productivity and efficiency of local green projects. This technological advancement lowers the costs of sustainable projects, making them more appealing to investors and encouraging the use of green finance instruments to fund these initiatives (Jian, 2023).

Moreover, institutional theory and the technology diffusion model offer valuable insights into the dynamics of green bond issuance. Lipsey (2004) and North (1990) examine the home and host country effects of FDI, focusing on how institutional frameworks and economic policies shape the outcomes of FDI. FDI often elevates local corporate governance and environmental compliance standards, fostering greater investor confidence and transparency in green finance markets (Hao et al., 2020; Mehmood, 2021). This institutional improvement makes green bonds more attractive to investors by creating a more stable and predictable environment for green investments. High institutional quality, such as strong legal systems and regulatory bodies, also holds a key position in green finance. It mitigates risks connected with green investments, like political instability and economic uncertainty, making green bonds a more viable financing option (Huynh and Ho, 2020; Khan et al., 2022).

In addition, the technology diffusion model explains how FDI spreads advanced green technologies, bridging technological gaps and expanding the scope of green projects. This process improves local capabilities and standards, reduces costs, and enhances the feasibility of green projects. Consequently, this stimulates the issuance of green bonds to finance these technologically advanced and sustainable projects (Elkington, 1998; Fernando and Lawrence, 2014). Relatedly, the technology transfer and innovation theory explains how technology transfer through FDI fosters innovation in the host country (Rosenberg, 1982). By introducing advanced green technologies, FDI enhances the productivity and efficiency of local green projects. This technological advancement lowers project costs and reduces operational risks, making green projects more appealing to investors and leading to an increase in green bond issuance.

International business theory, such as the Eclectic Paradigm and the Ownership, Location, and Internationalization (OLI) framework (Dunning, 1988), can help explain the effect of FDI and technology transfer on green bond issuance. The OLI framework consists of three components: Ownership advantages (O), which refer to firm-specific assets like technology or expertise; Location advantages (L), which highlight the benefits of investing in certain countries due to factors like resources or market conditions; and Internalization advantages (I), which focus on the firm's ability to retain control over its operations and reduce transaction costs. These elements collectively contribute to understanding how FDI and technology transfer drive green bond issuance by enhancing project viability and investor appeal. It suggests that firms engage in FDI when they possess competitive advantages (Ownership), find it beneficial to utilize these advantages in foreign locations (Location), and prefer internalizing the transactions rather than licensing or outsourcing (Internalization) (Dunning, 1988). In the context of green bond issuance, firms with advanced green technologies (Ownership) invest in countries with supportive regulatory environments and growing demand for sustainable projects (Location), choosing to manage these investments internally to maintain control over technology transfer and project implementation (Internalization). This dynamic fosters local green projects and stimulates green bond issuance.

The Resource-Based View (RBV) theory highlights that firms achieve a sustained competitive advantage by utilizing resources that are valuable, rare, inimitable, and non-substitutable (VRIN). These strategic resources enable firms to enhance their efficiency and effectiveness, leading to superior market performance. Barney (1991) and Newbert (2008) confirm that firms leveraging VRIN resources outperform competitors, as these resources are critical to achieving and maintaining long-term competitive advantages. These resources enable firms to differentiate themselves, driving superior performance and sustainability, which can also influence their participation in green finance as they capitalize on unique assets that align with environmental goals. FDI brings such resources, including advanced green technologies and managerial expertise, to host countries.

2.2. FDI, technology transfer and green bond issuance: demand-side effects

Changes in FDI and technology transfer significantly impact investor demand for green bonds through several channels. Indeed, FDI and technology transfer can improve risk perception and mitigation. When foreign investors bring advanced technologies and stringent risk management practices, they enhance the viability and efficiency of green projects (Song et al., 2024). This reduces operational risks and potential uncertainties, making green bonds more attractive to investors seeking stable and secure returns (Zhao et al., 2022). Lower perceived risks associated with these projects lead to higher demand for green bonds as investors are more confident in the financial and operational stability of the projects they are financing.

Furthermore, the expectation of improved returns on investment (ROI) is a crucial factor driving investor demand for green bonds. Advanced technologies introduced through FDI can significantly enhance the productivity and cost-efficiency of green projects, leading to higher profitability (Luo et al., 2019). Empirical evidence has demonstrated that green bond offerings are positively influenced by corporate and investor incentives, including the pursuit of environmental credibility and financial benefits, which align with the broader adoption of green technologies and sustainable practices (Flammer, 2021; Tang and Zhang, 2020). Investors are drawn to the prospect of superior financial performance, making green bonds a more appealing investment.

Moreover, the infusion of foreign capital often comes with better governance standards and transparency, which further enhances domestic market confidence (Li et al., 2022). Studies in emerging markets have highlighted that institutional quality plays a key role in moderating the environmental impact of FDI, which can enhance investor confidence in sustainable financial instruments such as green bonds (Jinapor et al., 2024). Investors are more inclined to invest in green bonds when they observe a stable economic environment and involvement from reputable foreign entities, which boosts confidence and raises demand for these bonds. Du et al. (2019) explore the impact of green technology innovations on reducing carbon dioxide emissions, with a particular focus on how FDI facilitates sustainable governance practices in host countries. They emphasize that foreign investments can drive the adoption of environmentally friendly technologies, thus contributing to carbon reduction efforts. This study highlights the environmental benefits of technology transfer through FDI in emerging economies.

Additionally, FDI-induced green technology adoption often involves risks associated with technological uncertainty and market viability. Lin and Hong (2022) find a positive association between green technology innovation and green bond finance, which can help mitigate technological uncertainty in green projects and support their development as viable investment opportunities. Green bonds can serve as risk-sharing instruments by attracting investors willing to finance innovative projects with long-term sustainability goals (Prakash and Sethi, 2022). Technology transfer enhances the bankability of green projects by reducing technological risks, thereby growing the appetite for green bonds among investors to gain confidence in the project's viability.

Lastly, FDI and technology transfer play a crucial role in building knowledge and capacity within host countries, helping to align green projects with global ESG standards. Green bond issuance is associated with improved ESG performance, as companies use these financial instruments to enhance their sustainability initiatives and attract environmentally conscious investors (Flammer, 2021; Tang and Zhang, 2020). Enhanced local expertise in managing and structuring green projects, coupled with stringent ESG criteria brought by foreign investors, elevates the credibility and quality of green bond issuances (Zheng et al., 2023). This alignment with ESG standards attracts socially responsible investors and institutional investors with sustainability mandates. Improved reporting and transparency, driven by foreign participation, also reduce information asymmetry, allowing investors to make more informed decisions (García-Sánchez and Noguera-Gámez, 2017). These factors collectively boost investor confidence and drive up the demand for green bonds, making them a preferred investment option in the sustainable finance market.

This study differs from previous research by focusing on the unique role of FDI-based technology transfer in enhancing demand for green bond finance. It highlights how FDI improves risk perception, profitability, governance, and ESG alignment, driving investor demand for green bonds. Unlike earlier works, it emphasizes the dual benefits of technological innovation and institutional quality in reducing project risks and increasing the attractiveness of green investments.

2.3. FDI, technology transfer and green bond issuance: supply-side effects

FDI acts as a driving force for economic growth and technological progress in host countries by introducing capital, innovation, and expertise that help modernize industries and improve infrastructure (Seyoum et al., 2015). When investors inject capital into a foreign market, they often bring along expertise, technology, and best practices, which can foster sustainable development initiatives. In the context of green bonds, FDI can directly influence the supply of green finance through several channels.

To start with, countries receiving higher FDI inflows into green economic sectors are associated with higher activity in green bond markets. For example, Shishlov et al. (2021) found that countries with FDI inflows targeting renewable energy experienced a 30 % growth in green bond issuance. Thus, FDI inflows can help stimulate the development of green bond markets in host countries by bringing in capital and fostering the transfer of sustainable technologies (Ye and Rasoulinezhad, 2023). As investors seek opportunities in sustainable infrastructure and clean technology sectors, the demand for green financing instruments like green bonds increases. Consequently, domestic issuers are incentivized to offer green bonds to attract FDI and tap into international capital markets.

Moreover, FDI often entails knowledge transfer and capacity-building initiatives (Osabutey et al., 2014). Foreign investors may collaborate with local institutions to enhance their understanding of green finance mechanisms and improve their ability to issue and manage green bonds effectively. As institutional capacity strengthens, the supply of green bonds is likely to expand, reflecting a deeper understanding of investor preferences and sustainability standards.

In addition, technology transfer associated with FDI accelerates the deployment of renewable energy technologies, a key driver of green bond issuance. A report by the International Renewable Energy Agency (IRENA) (2020) highlights that renewable energy dominates green bond issuances, underscoring the significant role of green bonds in financing renewable energy projects.

Furthermore, FDI flows are sensitive to regulatory frameworks and policy incentives promoting sustainable investments (Buckley, 2018). Host countries that implement supportive regulatory policies, such as tax benefits for sustainable initiatives or governance requirements for environmental disclosures, are more attractive destinations for FDI in sustainable sectors. As a result, aligning policies with green finance goals can enhance the supply of green bonds by creating a supportive environment for both issuers and investors.

Technology transfer, often facilitated by FDI, plays a pivotal role in driving innovation and efficiency in green industries (Song and Han, 2022). The diffusion of environmentally sound technologies through technology transfer mechanisms can affect the availability of green bonds in many ways. Technology transfer fosters innovation in green sectors by introducing innovative technologies, processes, and business models (Fernandes et al., 2021). As host countries adopt these innovations, they may require financing to support the deployment of green technologies at scale. The supply of green bonds can respond to this demand by providing a source of capital for projects aimed at implementing and commercializing transferred technologies.

Moreover, technology transfer contributes to the transformation of traditional industries towards more sustainable practices (Söderholm, 2020). As industries transition towards low-carbon alternatives and resource-efficient technologies, the demand for green financing instruments escalates. The supply of green bonds can accommodate this demand by catering to issuers seeking capital to facilitate the adoption of transferred technologies and drive sectoral transformation. Thus, the dynamics of FDI and technology transfer exert profound influences on the supply of green bonds from a supply-side perspective. FDI inflows stimulate market development, institutional capacity building, and policy alignment, thereby fostering an enabling environment for green bond issuance. Similarly, technology transfer drives innovation dynamics, risk mitigation, and sectoral transformation, which in turn, amplify the supply of green bonds by supporting the financing needs of sustainable projects. Recognizing and leveraging these channels are critical for harnessing the synergies between FDI, technology transfer, and green finance to advance global sustainability objectives.

2.4. Economic, environmental, and institutional factors and green bond issuance

Several economic and non-economic factors influence green bond issuance. To begin with, government policies and regulations significantly promote green bonds by creating a supportive environment for their growth. Policies such as tax incentives, subsidies, and grants lower the costs affiliated with issuing green bonds, enhancing their appeal for public and private entities (Agliardi and Agliardi, 2019). For example, tax incentives can include exemptions or reductions on interest income from green bonds, attracting investors seeking tax-efficient investments. Subsidies and grants for green projects, like renewable energy installations or sustainable infrastructure, further encourage issuers to finance these initiatives through green bonds.

Additionally, well-defined regulatory frameworks provide clarity and boost confidence in the green bond market by establishing clear definitions and norms for green bonds, ensuring funds are directed towards environmentally sustainable projects (Popescu et al., 2021). Reporting and disclosure requirements mandated by these regulations ensure transparency and accountability, enhancing investor trust and market integrity (Deschryver and De Mariz, 2020). Kharb et al. (2024) argue that nations adhering to globally recognized green finance standards are associated with a higher uptake in green bond activity compared to those without such frameworks. Regular reporting on the use of proceeds and ecological effect helps maintain the credibility of sustainable bonds, increasing their appeal to both emitters and stakeholders. Robust legal frameworks and regulatory oversight are crucial for ensuring transparency, accountability, and investor protection, essential for building trust in the market (Ameli et al., 2020). Effective absorption of innovative technologies, supported by a collaborative innovation ecosystem and clear regulations, creates a virtuous cycle where FDI boosts the local economy, thereby attracting further investment. This cycle is reinforced by the presence of strong environmental regulations and sustainable practices, which make countries more attractive to investors who prioritize eco-friendly initiatives (Saqib and Dincă, 2023).

Furthermore, interest rates and monetary policy significantly impact the offering of green bonds by influencing the cost and attractiveness of borrowing. Low interest rates reduce financing costs for issuers, making green bonds a more appealing option for funding environmentally sustainable projects (Sartzetakis, 2021). When interest rates are low, the lower yields on green bonds become more competitive, encouraging more issuers to consider green financing. Supportive monetary policies further enhance the green bond market. Central banks may include green bonds in their asset purchase programs or provide them preferential treatment in capital requirements for banks, increasing demand and making green bonds more attractive to both issuers and investors (Giovanardi et al., 2023). By fostering favourable financial conditions, such as proactive monetary policies and low financing costs, the green bond sector can expand as investment in sustainable initiatives becomes more attractive.

Moreover, market specialized demand and investor appetite play a crucial role in driving green bond issuance, with investor preferences and the growth of green investment funds being key factors. Investors increasingly prioritize sustainable and responsible investments as ESG criteria become central to their decision-making (Gangi et al., 2022). Increased awareness of climate change and environmental concerns has prompted institutional investors, including insurance companies, asset managers, and pension funds to increasingly favour green bonds. These bonds offer an opportunity to align investment portfolios with sustainability goals while reducing exposure to the long-term risks associated with unsustainable practices. The dual promise of financial returns and positive environmental impact makes green bonds attractive, fulfilling both fiduciary and ethical considerations (Tang and Zhang, 2020). The rise of green investment funds has also significantly increased the demand for green bonds (Maltais and Nykvist, 2020). These funds are dedicated to investing in environmentally sustainable projects and often mandate a substantial portion of their portfolios to be allocated to green bonds. This dedicated capital stream boosts the liquidity of green bonds and lowers issuance costs by ensuring consistent demand. Green investment funds typically engage in rigorous due diligence and transparency, ensuring that the ventures financed through green bonds meet high environmental standards, which enhances investor confidence and attracts a broader range of investors (Sangiorgi and Schopohl, 2021). The growing demand from both individual and institutional investors creates a positive feedback loop, encouraging more entities to issue green bonds. As the market expands, issuers benefit from better pricing, increased market liquidity, and greater visibility, further incentivizing the issuance of new green bonds (Russo et al., 2021). As a result, market demand and investor interest not only shape the volume of green bonds issued but also contribute to building a robust and resilient green bond market. This growing market helps drive the shift towards a more sustainable economy by channelling investment into environmentally friendly projects and creating a stable financial framework that supports long-term sustainability goals.

In addition, economic stability significantly impacts the public offering of green bonds by creating a favourable environment for both issuers and investors. Macroeconomic stability, characterized by low inflation, steady economic growth, and sound fiscal and monetary policies, instils confidence in financial markets (Ahiadorme, 2022). This stability is vital for establishing a liquid green bond market as it lowers the perceived risks associated with long-term investments in sustainable projects. In a stable economy, issuers are more likely to commit to large-scale green projects, knowing that economic conditions will support their long-term financing needs (Steffen, 2018). Investors are more inclined to commit to green bonds when they are confident that the overall economic environment supports sustainable development and secures their financial returns.

Economic growth further influences the release of green bonds by increasing the availability of capital for investment in sustainable projects. A growing economy typically leads to higher income levels and savings rates, which can be channelled into green investments (Lorek and Spangenberg, 2014). Governments in growing economies are also more capable of providing economic incentives for green projects. These incentives can include tax breaks, subsidies, or grants for energy efficiency, renewable energy, or other sustainable initiatives (Abdmouleh et al., 2015). These incentives reduce capital costs and boost the financial appeal of green projects, encouraging issuers to seek funding through green bonds. Additionally, a thriving economy often results in increased collaboration between the public and private sectors on sustainability initiatives. As companies grow, they may face greater pressure from stakeholders, including customers, employees, and regulators, to adopt sustainable practices and disclose their environmental impact. Issuing green bonds becomes an effective way for companies to demonstrate their obligation to sustainable growth and secure funding for green projects (Flammer, 2021; Okafor et al., 2024). Similarly, governments with stable and growing economies are better positioned to launch green bond programs and fund large-scale infrastructure projects that promote environmental sustainability (Lin and Hong, 2022).

Further yet, market infrastructure and financial institutions significantly impact green bond issuance by shaping supply and demand dynamics. Developed financial markets provide the necessary structure and support mechanisms for issuing and trading green bonds, fostering market growth and maturity (Monk and Perkins, 2020). This includes established exchanges, reliable credit rating agencies, and efficient clearing and settlement systems, which collectively reduce transaction costs, enhance market liquidity, and bolster investor confidence. A robust market infrastructure and reliable green bond indices are crucial drivers for green bond issuance. They provide the framework for efficient capital allocation, risk management, and investor trust, supporting the growth and maturation of the green bond market. The EU's Green Bond Standard (EU GBS) sets out to create a unified framework for green bonds across the EU. Through clear eligibility criteria and reporting requirements, the EU GBS enhances market transparency and investor confidence, fostering increased issuance of green bonds within the region (Ziegenbalg, 2024).

Especially, green bond indices play a vital role in driving green bond issuance by setting benchmarks and standards for investors and issuers alike. These indices track the performance of green bonds, offering investors insights into eligible issuers and projects, thereby facilitating investment decisions and risk management (Otek Ntsama et al., 2021). The Bloomberg Barclays MSCI Green Bond Index tracks the global performance of investment-grade green bonds issued by governments, municipalities, and corporations. By including bonds that meet specific environmental criteria, these indices encourage issuers to align their green bond offerings with established standards and best practices (Kanamura, 2020). This enhances market transparency and credibility, attracting more participants to the green bond market (Kidney and Boulle, 2015).

Public awareness and social pressure affect the issuance of green bonds, driving consumer and societal demand and shaping corporate social responsibility (CSR) efforts. Increasing environmental awareness prompts consumers and investors to seek sustainable investment options, including green bonds (Bhutta et al., 2022). This trend towards sustainability reflects a broader societal shift, with individuals aiming to harmonize their financial decisions with their ecological principles. As a result, issuers face urgency to exhibit their dedication to sustainability, leading to a rise in green bond issuance to finance projects with favourable environmental outcomes (Gilchrist et al., 2021).

Corporate social responsibility (CSR) is another critical factor in green bond issuance. Companies are under increasing pressure to integrate environmental considerations into their business practices, driven by regulatory mandates and stakeholder expectations (Pinkse and Busch, 2013). By issuing green bonds, companies can finance eco-friendly projects and demonstrate their commitment to sustainability to both investors and consumers. For example, a multinational corporation might issue green bonds to fund the construction of a solar energy plant, illustrating its commitment to reducing greenhouse gas emissions.

Public scrutiny and social pressure also influence corporations and governments, compelling them to address environmental concerns and adopt sustainable practices (Haque and Ntim, 2018). High-profile environmental campaigns, such as the Fridays for Future movement led by Greta Thunberg, raise public awareness and galvanize support for climate action. In response, governments may introduce policies and incentives to encourage green investments and facilitate green bond issuance. Companies facing reputational risks due to environmental controversies may issue green bonds as part of their sustainability strategy to mitigate negative perceptions and align with stakeholder expectations (Cheng et al., 2023).

Climate risk and environmental factors heavily influence green bond issuance, shaping both market supply and demand. Policies like emissions reduction targets and carbon pricing create financial incentives for issuers to fund green projects through green bonds (Flaherty et al., 2017). These policies signal a shift towards a low-carbon economy, driving investments in renewable energy, energy efficiency, and other sustainable initiatives. For example, a government-imposed carbon tax can motivate companies to cut their carbon emissions and invest in cleaner technologies. Issuing green bonds enables companies to obtain financing for sustainable projects while showing their commitment to both sustainability and regulatory compliance. Environmental risks from climate change—such as extreme weather events, natural disasters, and resource scarcity—highlight the urgency for investments in resilience and adaptation measures. Green bonds can finance projects aimed at mitigating these risks, including infrastructure upgrades, flood protection measures, and water conservation initiatives (Brears, 2022). Through green bond issuance for resilience projects, companies can confront environmental challenges while boosting their long-term sustainability and fortifying their ability to endure climate-related disruptions. For example, a city might issue green bonds to finance the construction of sea walls or upgrade its stormwater management system to mitigate flooding and coastal erosion risks.

Overall, economic, environmental, and institutional factors play a critical role in shaping green bond issuance. Stable economic conditions, such as low inflation and steady growth, foster investor confidence and provide a favourable environment for green finance. Environmental policies, including carbon pricing and emissions reduction targets, create financial incentives for issuers to fund sustainable projects. Institutional factors like well-defined regulatory frameworks, reporting requirements, and supportive monetary policies ensure market transparency, reduce risks, and enhance investor trust. Together, these factors drive the growth and resilience of green bond markets, channelling investments into environmentally sustainable initiatives.

2.5. Research hypotheses

Based on the reviewed literature, this study develops three main research hypotheses to investigate the factors influencing green bond issuance.

Hypothesis 1. FDI-based technology transfer is positively associated with green bond issuance.

This hypothesis is grounded in capital market imperfections theory and endogenous growth theory. According to capital market imperfections theory, FDI alleviates financial constraints in less developed countries by providing essential capital that is otherwise scarce due to information asymmetry and transaction costs (Veeramani et al., 2020a, 2020b). Endogenous growth theory emphasizes that FDI introduces advanced green technologies, enhancing the productivity and efficiency of local green projects (Audretsch et al., 2014). Thus, this hypothesis posits that FDI and technology transfer contribute to greater green bond offerings by increasing the financial resources and technological capabilities available for sustainable projects.

Hypothesis 2. Economic factors influence the issuance of green bonds.

This hypothesis draws on the principles of economic stability and growth and their influence on financial markets. Macroeconomic stability, marked by low inflation, steady economic growth, and sound fiscal and monetary policies, instils confidence in financial markets (Ahiadorme, 2022). Geopolitical uncertainty affects the availability of capital for investment in sustainable projects thereby determining green bond issuance (Mertzanis and Tebourbi, 2024, 2025).

Hypothesis 3. Social and environmental factors influence the issuance of green bonds.

This hypothesis draws from institutional and CSR theories. Social factors, including public awareness, social pressure, and CSR efforts, influence corporate and governmental behaviour towards sustainability (Gilchrist et al., 2021; Pinkse and Busch, 2013). Increased public awareness of environmental issues, biodiversity, energy conservation and climate change drives demand for sustainable investments, compelling issuers to adopt green bonds to meet stakeholder expectations (Bhutta et al., 2022).

By linking these hypotheses to established theoretical frameworks, the study aims to provide a comprehensive analysis of the factors influencing green bond issuance. The hypotheses will be evaluated using robust econometric models to control for various confounding factors and provide empirical evidence on the role of FDI, economic and financial conditions, and social factors in promoting green finance.

3. Empirical strategy

3.1. Data

This research analyses cross-country data over several years to establish a causal link between green bond issuance, FDI, and technology transfer. It uses a distinct panel dataset consisting of 223 country-level aggregate issues of green bonds, measured in USD billions, between 2000 and 2022 from sixty-seven countries. In alignment with the rollout of the Green Bond Principles from financial institutions globally, the most issuances took place after 2011, which harmonized processes and prerequisites, thus strengthening market assurance in green bonds (Shishlov et al., 2021). Additionally, over 1700 endorsers from upwards of fifty nations, contributing to the growing publications on market activity and on green bond issuance have been attracted by the United Nations-backed Principles for Responsible Investment (PRI). Corporate-backed green bonds represent the largest composition of the sample, while 9.5 % of the overall issuance value account for sovereign green bonds. The green bond data is sourced in the IMF climate finance repository, which draws on information from various sources, including the database of the Climate Bond Initiative. This final data set merges data on green bonds with FDI information and other country-level indicators from World Economic Forum's Global Competitiveness Report and the World Development Indicators, accounting for institutional, economic, and environmental factors. To mitigate potential outlier effects, the data is winsorized at the 1 % and 99 % levels, and logarithmic transformations are applied to the variable levels.

3.2. Key variables

The dependent variable in the empirical analysis is the logarithm of the total value of green bonds (in billions of USD) issued by individual countries each year, as recorded in the IMF climate finance database (denoted as GRBOND). Green bonds are fixed-income instruments created to fund climate and environmental projects, including pollution prevention, renewable energy, energy efficiency, sustainable agriculture, fisheries, forestry, clean water management, ecosystem protection, and sustainable transportation. The IMF Climate database measures green bond issuance by tracking the total volume issued over a specified period, including the capital raised to fund eligible green projects. This data, collected from various issuers such as governments, financial institutions, and corporations, assesses the growth and impact of green financing.

Our primary predictor variable is the FDI-based technology transfer index (denoted as FDITECH), which measures the extent to which FDI inflows transfer innovative technology into a country. This variable, sourced from the World Economic Forum's Global Competitiveness Report, ranges from 1 to 7, with higher values reflecting a greater level of FDI-driven technology transfer. The index evaluates the efficiency and effectiveness of technology transfers from multinational companies to local firms, contributing to national competitiveness. It includes several indicators: the value of FDI inflows, the effectiveness of technology transfer, the availability of a skilled workforce, research and development (R&D) expenditure, and the quality of the regulatory environment. Together, these indicators evaluate a country's capacity to absorb and apply foreign technologies to boost productivity and innovation, serving as a key component of the broader Global Competitiveness Index (GCI) (Iamsiraroj and Ulubaşoğlu, 2015). Additionally, expert opinions and consultations with stakeholders in international investment and technology transfer are incorporated to validate findings and provide insights into qualitative aspects of these relationships. The World Economic Forum employs a multi-dimensional approach to derive imputed variables for FDI and technology transfer, combining quantitative analysis with qualitative assessments to enhance accuracy and reliability.

Table 1 provides an outline of the average of green bond issuance values and the FDI and technology transfer index, revealing significant disparities across countries. Countries with the lowest green bond issuance, such as Namibia (−5.57 log USD bn), Morocco (−4.32 log USD bn), and Nigeria (−3.83 log USD bn), have moderate FDI and technology transfer index scores of 4.27, 4.58, and 4.37, respectively, indicating limited activity in green finance markets. In contrast, countries in the middle range, like Egypt (0.41 log USD bn), Germany (0.97 log USD bn), and South Korea (0.95 log USD bn), with higher FDI and technology transfer scores of 4.56, 5.01, and 4.66, show moderate green bond market activity. Leading the green bond issuance are China (2.43 log USD bn), France (2.28 log USD bn), and the Netherlands (2.34 log USD

Table 1
FDI, technology transfer and green bond issuance (average country values).

Country	Green bond issuance (log USD bn)	FDI and technology transfer index	Country	Green bond issuance (log USD bn)	FDI and technology transfer index
Argentina	−1.04	3.65	Mexico	−0.10	5.19
Australia	0.36	5.07	Morocco	−4.32	4.58
Austria	0.10	4.79	Namibia	−5.57	4.27
Bangladesh	−0.95	4.08	Netherlands	2.34	5.45
Belgium	−0.48	5.23	New Zealand	−1.83	5.18
Brazil	−0.68	4.69	Nigeria	−4.20	4.37
Canada	1.17	5.19	Norway	−0.25	4.97
Chile	0.37	5.34	Pakistan	−0.69	4.79
China	2.43	4.69	Panama	−2.36	5.80
Colombia	−2.17	4.44	Peru	−1.48	4.71
Costa Rica	0.00	5.18	Philippines	−1.14	4.73
Cyprus	−1.15	4.65	Poland	−0.15	4.99
Czechia	−0.10	5.45	Portugal	0.48	5.57
Denmark	0.86	5.07	Romania	−0.79	4.53
Egypt	0.41	4.56	Russia	−1.58	3.96
Estonia	−2.69	4.85	Serbia	0.75	4.28
Finland	0.23	4.85	Seychelles	−4.20	4.43
France	2.28	5.00	Singapore	0.03	6.11
Georgia	−0.35	4.33	Slovak Rep.	−0.86	5.74
Germany	0.97	5.01	Slovenia	−2.53	4.17
Greece	−0.69	3.93	South Africa	−2.42	4.67
Hungary	0.72	5.52	South Korea	0.95	4.66
Iceland	0.32	5.03	Spain	1.67	5.03
India	−0.21	4.67	Sweden	1.27	5.18
Indonesia	0.44	4.57	Switzerland	−0.38	5.33
Ireland	0.69	4.92	Thailand	−0.84	5.02
Israel	0.60	6.19	Turkiye	−1.32	4.73
Italy	0.00	6.06	Ukraine	0.50	3.88
Japan	0.37	3.91	U.A.E.	−1.19	5.83
Latvia	0.88	5.09	U.K.	0.79	5.48
Lithuania	−2.90	4.54	United States	1.42	5.25
Luxembourg	−2.31	5.09	Viet Nam	−1.75	4.36
Malaysia	0.33	5.73			
Mauritius	−1.32	5.56	Total average	0.04	5.01

Note. Authors' calculations.

bn), which also have high FDI and technology transfer scores of 4.69, 5.00, and 5.45, respectively, reflecting robust green finance markets supported by substantial foreign investments and effective technology transfer. On average, the global green bond issuance is 0.04 log USD bn, with an FDI and technology transfer index of 5.01, suggesting that countries with higher FDI-driven technology transfer tend to have more significant green bond issuance, underscoring the role of foreign investment and technology in promoting green finance initiatives. The vigorous participation of European nations, alongside China, in green bond offerings must be noted. Smaller as well as lower-income nations have joined the market, motivated by development opportunities, though they face obstacles (Dembele et al., 2021).

3.3. Controls

The aim of our study is to investigate the relationship between FDI, technology transfer, and green finance. In real-world situations, confounding factors can complicate or obscure this cause-and-effect relationship. To partially address this, we include control variables that help clarify the connection between FDI, technology transfer, and green finance. These controls are intended to capture a subset of the many relevant economic and non-economic factors, including the following:

The first control variable is the expenditure on biodiversity and landscape protection, measured as a percentage of GDP (denoted as BIODIVR), which is sourced from the IMF's Climate finance database. Investments in biodiversity and landscape protection enhance green bond issuance by offering environmental sustainability, climate resilience, and economic stability, which attract environmentally conscious investors and mitigate financial risks (Karolyi and Tobin-de la Puente, 2023). Such expenditure supports the transition to a low-carbon economy by bolstering ecosystem resilience, sequestering carbon, and promoting sustainable land management. Preserved ecosystems, serving as carbon sinks, play a crucial role in mitigating climate change, while investments in biodiversity promote renewable energy production and sustainable agriculture, reducing reliance on carbon-intensive practices. This expenditure drives innovation in green technologies and fosters a sustainable economic model based on environmental stewardship, thereby facilitating increased green bond issuance (Batra, 2023). A positive effect on green bond offerings is anticipated by us.

The index of geopolitical risk is the second control parameter (labelled as GPR), provided by Caldara and Iacoviello (2022). Geopolitical risks can impact green bond issuance by destabilizing regions with renewable energy resources, thereby affecting investor confidence and regulatory environments. Such uncertainty can raise concerns about the long-term viability of green projects, influencing pricing, demand, and investor decisions in the green finance market (Abbas et al., 2023; Mertzanis and Tebourbi, 2024, 2025). For instance, geopolitical tensions in a wind energy-rich country could delay wind farm development, creating uncertainties for green bond investors. Additionally, shifts in government policies due to geopolitical changes may affect the appeal of green investments, impacting investor confidence and market dynamics. We expect a positive impact on green bond offerings.

The net amount of electricity imports (denoted as ELECTRIMP) represents the third control variable, measured in log terawatt hours (TWh), with data provided by Ember's Global Electricity Review (https://ember-climate.org/data/). Electricity imports significantly affect green finance by impacting energy security, environmental sustainability, and investment choices (Li et al., 2021). Imports from non-renewable sources can increase carbon emissions and geopolitical risks, potentially hindering the transition to renewable energy. Conversely, imports from renewable-rich regions can support clean energy infrastructure. However, cheaper or more reliable imports might impede investments in domestic renewable projects, affecting the overall dynamics of green finance. We also expect a positive effect on green finance. Regions engaged in cross-border energy trade, like the Belt and Road Initiative, rely on electricity imports to understand energy flows and technological advancements in the sector (Khan et al., 2021). Electricity imports also reflect global energy market dynamics, encompassing demand, supply, energy efficiency, and the adoption of green technologies (Kabeyi and Olanrewaju, 2022). Prior research underlines electricity intensity, shaped by FDI and market reforms, as a key factor in transitioning towards low-carbon energy systems (Zheng et al., 2023).

The fourth control variable is the sovereign debt rating (SOVRATNG), published by Moody's Corporation. Credit scores evaluate an issuer's solvency by considering both economic and non-economic factors. These scores play a crucial role in fixed-income market transactions, including green bond issuance, and influence investment decisions (Prajapati et al., 2021). The spreads and yields of green bonds are also affected by them (Li et al., 2020; Sheng et al., 2021). An issuer's capability to enter capital markets and fulfil debt responsibilities are reflected by lower ratings indicating higher financing costs (Benito et al., 2016; Wang et al., 2020). Both, financial and capital markets can influence alterations in sovereign ratings with negative adjustments especially affecting foreign and domestic exchanges (Rusike and Alagidede, 2021). The classification as investment or non-investment grade for them is determined using Moody's sovereign debt ratings in our analysis (Capelle-Blancard et al., 2019), to seize these effects. Our expectation is that green bond issuance is positively affected by higher sovereign ratings.

Inflation represents our fifth control measure in the analysis, which reflects consumer prices (denoted as INFLAT) and is measured annually as a percentage price change according to the World Development Indicators. This parameter indicates the annual percentage change in the cost for the average consumer to acquire a fixed or periodically adjusted basket of goods and services (Kaplan and Schulhofer-Wohl, 2017). Elevated inflation levels can lead to economic fragility, which diminishes a state's borrowing reliability (Nickel et al., 2011). Additionally, the availability of long-term financing is affected by inflation, making it more difficult for companies and governments to issue bonds and raise borrowing expenses (Alexopoulou et al., 2010; Presbitero et al., 2016). Elevated inflation rates in OECD countries can impede the expansion of the green bond market (Anh Tu et al., 2020). Conversely, bond offerings have been facilitated by quantitative easing and accommodative monetary policy as shown in recent research (Grosse-Rueschkamp et al., 2019; Santis and Zaghini, 2021; Pegoraro and Montagna, 2021). In our study, given the mixed inflation effects on green finance, we expect that green bond issuance will be adversely affected by rising inflation rates.

Finally, the sixth control variable considers whether a country is a member of the European Union (EU). The EU has established policies to encourage the utilization of green bonds (Gianfrate and Peri, 2019). Comprising twenty-seven countries, the EU acknowledges the importance of green finance in achieving environmental sustainability objectives and encourages its member nations to advocate for green bonds as a way to finance sustainable initiatives. A dummy variable representing EU membership is utilized in our study to capture this impact. We anticipate a positive overall effect.

A comprehensive description of all variables is included in appendix, whilst the descriptive statistics are presented in Table 2, highlighting significant variability across the key variables, reflecting diverse economic, environmental, and geopolitical contexts among countries. The variable for green bond issuance (GRBOND) shows an average of 0.15 log USD billion, with a high standard deviation of 1.88, indicating substantial differences in green bond market activity, ranging from −5.57 to 4.31 log USD billion. The FDI and Technology Transfer Index (FDITECH) averages 5.06 with a standard deviation of 0.57, suggesting varying effectiveness of FDI and technology transfer across countries, with values spanning from 3.44 to 6.65. Expenditure on biodiversity and landscape protection (BIODIVR) averages 0.08 % of GDP, with minimal investment in some countries (0.00 %) and substantial in others (0.32 %), indicating diverse environmental priorities. The Geopolitical Risk Index (GPR) has a mean of 153.61 and a standard deviation of 43.78,

Table 2
Summary statistics.

	Count	Mean	SD	Min	P25	P50	P75	Max
GRBOND	223	0.15	1.88	−5.57	−0.89	0.22	1.56	4.31
FDITECH	223	5.06	0.57	3.44	4.71	5.04	5.45	6.65
BIODIVR	223	0.08	0.06	0.00	0.03	0.06	0.10	0.32
GPR	223	153.61	43.78	45.49	121.54	153.76	192.21	258.73
ELECTRIMP	223	−2.20	21.18	−67.19	−5.05	0.00	6.30	43.90
SOVRATNG	223	3.70	0.50	2.00	3.00	4.00	4.00	4.00
INFLAT	223	1.94	2.37	−2.08	0.60	1.60	2.53	19.60
EUMBR	223	0.50	0.50	0.00	0.00	1.00	1.00	1.00

Note: The table displays the descriptive statistics of the key and control variables.

highlighting significant differences in geopolitical stability, with values ranging from 45.49 to 258.73. Electricity imports (ELECTRIMP) show a mean of −2.20 log TWh and a standard deviation of 21.18 log TWh, indicating a wide range from −67.19 to 43.90 log TWh. Sovereign debt ratings (SOVRATNG) average 3.70 with a standard deviation of 0.50, spanning from 2.00 to 4.00, indicating varying levels of perceived creditworthiness. Consumer price inflation (INFLAT) averages 1.94 % annually, with a standard deviation of 2.37 %, reflecting diverse inflationary environments, ranging from −2.08 % to 19.60 %. The EU membership status (EUMBR) is a binary variable with a mean of 0.50, indicating that half the countries in the sample are EU members. These statistics stress the heterogeneity in economic, environmental, and geopolitical contexts influencing green bond issuance and FDI-driven technology transfer, illustrating the complexity of analysing these interrelationships.

Further, Table 3 presents the variables' pairwise correlation matrix. There is a positive and significant correlation between green bond issuance (GRBOND) and the FDI and Technology Transfer Index (FDITECH) (0.40***), suggesting that higher FDI and technology transfer are linked to a rise in green bond issuance. GRBOND also positively correlates with the Geopolitical Risk Index (GPR) (0.25***), suggesting that geopolitical risks may drive green finance efforts, and with sovereign debt ratings (SOVRATNG) (0.24***), implying that better credit ratings boost green bond issuance. Conversely, higher inflation (INFLAT) (−0.22***) and electricity imports (ELECTRIMP) (−0.13**) negatively impact green bond issuance, while EU membership (EUMBR) (0.18***) supports it. The overall VIF value of 1.41 indicates minimal multicollinearity, ensuring reliable regression estimates.

3.4. Estimation model

Unravelling the causal connection between FDI and technology transfer on green bond issuance is complex, influenced by numerous economic, environmental, and institutional factors. The interplay between these elements can obscure the direct effects, as unobserved variables may correlate with both FDI and green bond issuance. For instance, when a country attracts substantial FDI in its renewable energy sector, investment agreements often include technology transfer clauses. These clauses facilitate the transfer of advanced renewable energy technologies from foreign investors to domestic companies, boosting the nation's capacity for renewable energy projects. This increase in renewable energy generation and reduced carbon emissions creates a favourable environment for the issuance of green bonds, which finance further sustainable development initiatives. Thus, the causal link lies in FDI-driven technology transfer enhancing renewable energy infrastructure, thereby promoting green bond issuance for sustainable projects. This intricate relationship underscores the multifaceted nature of economic policies, investment climates, and regulatory frameworks that collectively shape green finance dynamics.

To estimate the causal effect of changes in FDI and technology transfer on green bond issuance, we use a complex model that includes suitable control variables. We apply a panel OLS estimation model with country-clustered standard errors, along with time and country fixed effects, to account for both time-varying and time-invariant heterogeneity (Greene, 2012). While OLS linear estimation has constraints, such as handling nonlinear relationships poorly, being delicate to outliers, and potentially suffering from attenuation bias, it serves as a foundational method for understanding relationships within the data (Angrist and Pischke, 2009). Including fixed effects helps reduce biases commonly related to OLS estimation. The Huber-White sandwich estimator is employed in our study to adjust for heteroscedasticity, as only non-missing observations are used, and robust standard errors are applied. To enhance robustness, we execute further endogeneity and sensitivity tests. This approach helps address the complexity of the model and ensures more reliable estimation of the causal effects of FDI and technology transfer on green bond issuance. The equation for the estimation model utilized is as follows:

$$\mathrm{GRBOND}_{jt} = \mathrm{a} + \mathrm{FDITECH}_{jt}\,\beta_1 + \mathrm{X1}_{jt}\,\beta_2 + \mu_{jt} \tag{1}$$

In the preceding eq. (1), the variables are defined as follows: GRBOND_{jt} represents the value of green bonds issued by country *j* in year *t*, $\mathrm{FDITECH}_{jt}$ reflects the index of foreign direct investment and technology transfer in country *j* in year *t*, and $\mathrm{X1}_{jt}$ denotes a set of control variables related to environmental, economic, and energy factors for country *j* in year *t*. The error term μ_{jt} is composed of three parts: γ_j accounts for country-specific effects, δ_t represents year-specific effects, and

Table 3
Correlation matrix.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GRBOND (1)	1.00							
FDITECH (2)	0.40***	1.00						
BIODIVR (3)	−0.07	0.01	1.00					
GPR (4)	0.25***	0.23***	0.01	1.00				
ELECTRIMP (5)	−0.13**	−0.09	−0.02	0.04	1.00			
SOVRATNG (6)	0.24***	0.49***	−0.01	−0.18***	−0.19***	1.00		
INFLAT (7)	−0.22***	−0.21***	0.06	0.17***	0.05	−0.54***	1.00	
EUMBR (8)	0.18***	0.02	−0.10	−0.03	−0.10*	0.12**	−0.25***	1.00
VIF	1.41							

Note: The table displays the pairwise correlations between key and control variables as well as the overall mean variance inflation factor (VIF) value. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

ε_{jt} is a normally distributed error term that varies by country and year. Given the challenges of drawing causal conclusions from observed correlations, we interpret the results as indicating associations rather than establishing causality. For clarity, we use the term "predict" to describe these associations.

4. Baseline results

4.1. Direct effects

Table 4 presents the baseline analysis of FDI and technology transfer on green bond issuance, examining the influence of different fixed effects (Models 1 to 4). Model (1) uses random effects to account for unobserved heterogeneity, Model (2) includes year effects to capture time-specific factors, Model (3) focuses on country effects to control for country-specific characteristics, and Model (4) combines both year and country effects for a comprehensive understanding of time and location influences. Almost all models demonstrate the significant positive impact of the FDI and Technology Transfer Index (FDITECH) on green bond issuance (GRBOND). The coefficients for FDITECH are consistently positive and significant, ranging from 0.746*** ($p < 0.1$) in Model 2 to 2.750*** ($p < 0.01$) in Model 3, indicating that higher levels of FDI and technology transfer enhance green bond issuance. This suggests that countries with better FDI and technology transfer capabilities have a greater capacity to finance environmentally sustainable projects through green bonds. Our findings confirm our central hypothesis one, which implies that FDI alleviates financial constraints by providing essential capital that is otherwise scarce due to information asymmetry and transaction costs (Veeramani et al., 2020a, 2020b), and it introduces advanced green technologies, enhancing the productivity and efficiency of local green projects (Audretsch et al., 2014).

Control variables further elucidate this relationship. The Geopolitical Risk Index (GPR) positively impacts green bond issuance in all models, with coefficients ranging from 0.007** ($p < 0.05$) to 0.030*** ($p < 0.01$), suggesting that geopolitical risks may drive green finance efforts. Sovereign debt ratings (SOVRATNG) mostly show a positive effect in Models 3 (0.976***, $p < 0.01$) and 4 (1.401***, $p < 0.01$), reflecting the importance of creditworthiness in attracting green investments. However, inflation (INFLAT) does not significantly impact green bond issuance, as indicated by the insignificant coefficients across all models. These findings broadly confirm hypothesis two, based on the principles of financial stability and economic growth and their influence on financial markets (Ahiadorme, 2022; Mertzanis and Tebourbi, 2024, 2025). Moreover, expenditure on biodiversity and landscape protection (BIODIVR) significantly boosts green bond issuance in Models 3 (7.283**, $p < 0.05$) and 4 (9.715***, $p < 0.01$), implying that environmental investments support green finance. EU membership (EUMBR) is highly significant and positive in all models, with coefficients peaking at 2.523*** ($p < 0.01$) in Model 4, highlighting the supportive role of EU. These findings also confirm hypothesis three, which stresses the role of social and institutional conditions, proactive government policies, and environmental factors for green finance (Gilchrist et al., 2021; Pinkse and Busch, 2013; Bhutta et al., 2022).

The adjusted R^2 improves from 0.326 to 0.783 across models, and the reduction in RMSE from 1.548 to 0.877, indicate better model fit and predictive accuracy with the inclusion of fixed effects. The inclusion of the fixed effects has improved the results. These findings underscore the intricate relationship of economic stability, institutional support, and geopolitical factors in driving green bond issuance. The significant role of FDITECH in this context suggests that policies fostering technology transfer and foreign investment can enhance a nation's ability to finance sustainable development through green bonds.

Table 4
Baseline direct effects.

	(1)	(2)	(3)	(4)
FDITECH	1.347***	0.746**	2.750***	1.448**
	(0.285)	(0.309)	(0.354)	(0.559)
BIODIVR	−1.522	−2.039	7.283*	9.715**
	(1.411)	(1.432)	(3.890)	(4.567)
GPR	0.007**	0.025***	0.007**	0.030***
	(0.003)	(0.005)	(0.003)	(0.009)
ELECTRIMP	−0.017***	−0.016***	−0.002	0.024**
	(0.005)	(0.005)	(0.013)	(0.011)
SOVRATNG	−0.160	0.413	0.976***	1.401***
	(0.317)	(0.316)	(0.230)	(0.311)
INFLAT	−0.034	−0.037	0.032	0.056
	(0.053)	(0.056)	(0.077)	(0.110)
EUMBR	0.997***	1.005***	1.451**	2.523***
	(0.215)	(0.218)	(0.634)	(0.601)
adj. R^2	0.325	0.397	0.728	0.783
RMSE	1.548	1.463	0.983	0.877
F stat	18.349	.	.	.
Country FE	No	No	Yes	Yes
Year FE	No	Yes	No	Yes
N	223	223	223	223

Notes. The table presents the baseline impact of foreign direct investment and technology transfer on green bond issuance. Control variables include financial, risk and institutional conditions. The data spans from 2000 to 2022, and the estimation employs an OLS model that incorporates alternatively random and fixed effects. Robust standard errors are provided in parentheses. Model (1) exclusively encompasses random effects, while Model (2) solely accounts for year effects. Model (3) focuses solely on country effects, and Model (4) incorporates both country and year effects.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.2. Indirect effects

The previous section emphasized the importance of individual regressors in predicting green bond issuance (GRBOND). This section examines the indirect influence of FDI and technology transfer (FDITECH) through interaction terms with the other predictors, uncovering the refined interplay between numerous factors. Interaction terms are crucial as they capture the combined effects of elements such as regulatory policies, market conditions, and investor sentiment on green bond outcomes (Saeed et al., 2021). For instance, the effectiveness of green bonds in promoting sustainability often increases when paired with robust government regulations and heightened public awareness. Moreover, interaction terms reveal context-specific impacts, demonstrating how green bond performance varies based on regulatory frameworks and economic stability (Hammoudeh et al., 2020). They also account for non-linear relationships, illustrating how the effects of green bond issuance evolve at various levels of variables like investor awareness. These insights have significant policy and strategic implications, enabling policymakers and corporate strategists to identify conditions under which green bond financing is most effective and to design targeted policies and strategies to maximize their impact (Hafner et al., 2020).

We restimate eq. (1) using the interaction of the key regressor with the control variables to assess indirect effects. Table 5 provides the results. The regression analysis reveals significant implications of the interaction terms on the relationship between FDI and technology transfer (FDITECH) and green bond issuance (GRBOND). The direct effect of FDITECH on GRBOND is consistently positive and significant, with coefficients from 0.912** ($p = 0.1$) to 5.250* ($p = 0.1$) across models. Interaction terms provide additional insights: the negative and significant interaction with electricity imports (FDITECH * ELECTRIMP) at −0.038*** ($p = 0.05$) suggests that reliance on imported electricity diminishes the positive impact of FDITECH, emphasizing the need for domestic energy sustainability. The positive and significant interaction with inflation (FDITECH * INFLAT) at 0.281** ($p = 0.05$) indicates that higher inflation amplifies the benefits of FDITECH on green bond issuance, due to favourable economic policies during inflationary periods. The interactions with biodiversity expenditure (FDITECH * BIODIVR) at −0.118 ($p > 0.1$), geopolitical risk (FDITECH * GPR) at −0.005 ($p >$

Table 5
Indirect effects.

	(1)	(2)	(3)	(4)	(5)
FDITECH	1.455*	2.295*	0.912**	5.250*	0.765
	(0.766)	(1.197)	(0.443)	(2.992)	(0.681)
BIODIVR	10.357	9.611***	−2.443	7.259**	10.257***
	(20.616)	(2.933)	(2.445)	(3.428)	(3.028)
FDITECH * BIODIVR	−0.118				
	(3.653)				
GPR	0.030***	0.049**	0.023***	0.006**	0.033***
	(0.010)	(0.021)	(0.006)	(0.003)	(0.009)
FDITECH * GPR		−0.005			
		(0.005)			
ELECTRIMP	0.024**	0.024**	0.172**	−0.002	0.025**
	(0.010)	(0.010)	(0.070)	(0.013)	(0.010)
FDITECH * ELECTRIMP			−0.038***		
			(0.014)		
SOVRATNG	1.399***	1.109**	0.475	3.277	1.420***
	(0.236)	(0.424)	(0.540)	(2.714)	(0.214)
FDITECH * SOVRATNG				−0.628	
				(0.732)	
INFLAT	0.056	0.048	−0.019	0.028	−1.347**
	(0.135)	(0.128)	(0.059)	(0.094)	(0.599)
FDITECH * INFLAT					0.281**
					(0.126)
adj. R^2	0.782	0.784	0.430	0.727	0.794
RMSE	0.880	0.876	1.422	0.984	0.855
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Dummies	Yes	Yes	Yes	Yes	Yes
N	223	223	223	223	223

Notes. The table presents the indirect impact of foreign direct investment and technology transfer on green bond issuance using interaction terms. Control variables include financial, risk and institutional conditions. The data spans from 2000 to 2022, and the estimation employs an OLS model with fixed effects. Standard errors are denoted in parentheses and are grouped by country. Model (1) exclusively encompasses random effects, while Model (2) solely accounts for year effects. Model (3) focuses solely on country effects, and Model (4) encompasses both country and year effects.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

0.1), and sovereign debt ratings (FDITECH * SOVRATNG) at −0.628 (p > 0.1) are not significant, suggesting that these factors do not significantly alter the FDITECH-GRBOND relationship. These findings underscore the robustness of FDI and technology transfer effects across different contexts, highlighting the importance of domestic energy policies and inflationary environments in enhancing green finance initiatives. Policymakers and investors can leverage these insights to optimize strategies that maximize the positive impact of FDI and technology transfer on green bond issuance.

5. Endogeneity analysis

The estimation process faces several endogeneity challenges, including reverse causality, measurement error, and omitted variables (Angrist and Pischke, 2009). Measurement error occurs when the explanatory variable is inaccurately recorded, which can distort the results. However, we mitigate this risk by utilizing high-quality cross-sectional data, employing robust statistical methods, and focusing on relative differences, reducing the concern over measurement error in our context. Reverse causality also complicates the analysis. While FDI and technology transfer can stimulate green bond issuance by introducing advanced technologies and sustainable practices, the issuance of green bonds could, in turn, attract FDI by signalling a commitment to sustainability. This bidirectional influence requires the use of instrumental variables or lagged variables to address reverse causality concerns. Omitted variable bias presents another challenge when key factors that impact both FDI and green bond issuance are excluded from the model. To address these endogeneity issues, we employ instrumental variable (IV) estimation, utilize the Oster test, and apply propensity score matching to control for adverse selection bias.

5.1. Instrumental variables

To address endogeneity issues, we use instrumental variable (IV) methods (Wooldridge, 2010). We utilize the number of tuberculosis cases per 100,000 inhabitants in a country and year (denoted as TUBERCL), sourced from the World Development Indicators, as an external IV instrument. The instrument meets the relevance and exclusivity conditions. The number of tuberculosis cases serves as a proxy for epidemiological risks. The latter have been shown to negatively influence FDI and technology transfer by creating an environment of uncertainty and disrupting economic and innovation networks. Wen et al. (2023) demonstrate that epidemics hinder innovation by straining resources and disrupting supply chains, which are critical for enabling technology transfer. Using the number of tuberculosis cases as an external instrument for FDI and technology transfer allows us to capture the broader impact of health risks on investment behaviour and knowledge flows. Sheng et al. (2021) highlight how the COVID-19 pandemic disrupted global investment networks, emphasizing how health crises increase risk aversion among investors and reduce cross-border capital flows necessary for technology exchange. Similarly, Immurana (2021) shows that poor population health, exemplified by the burden of diseases like tuberculosis, diminishes a country's attractiveness to foreign investors by increasing operational risks and healthcare costs, thereby limiting FDI inflows and associated technology transfer. The number of tuberculosis cases also serves as a proxy for public health conditions, which can indirectly impact a country's appeal to FDI and technology transfer. A higher incidence of tuberculosis may signal poor public health, potentially deterring FDI by indicating an unfavourable business environment (Barlow et al., 2017). This, in turn, could affect the efficiency of technology transfer, establishing a correlation between tuberculosis prevalence and FDI/technology transfer activities. The relevance of this relationship is economically supported by the fact that tuberculosis prevalence can negatively impact workforce productivity and economic stability, thereby influencing a country's attractiveness to foreign investors (Shapiro and Mathur, 2014). Indeed, as a first approximation, tuberculosis cases (TUBERCL) show a significant association with FDITECH ($\beta = 0.124$). Based on these arguments, we assert that higher tuberculosis rates deter foreign investment by signalling elevated epidemiological risks, inadequate health infrastructure, and diminished labour productivity. These factors create an unfavourable business environment, increasing operational costs and uncertainty, which hinders FDI flows and the associated technology transfer.

Moreover, the exclusivity condition mandates that the chosen instrument impacts the dependent variable (green bond issuance) solely through its influence on the endogenous variable (FDI and technology transfer), without affecting it through other channels. Given that tuberculosis (TBC) cases are unlikely to have a direct impact on green bond offerings—which is typically driven by factors like environmental policies, regulatory frameworks, and financial market dynamics—TB rates should only indirectly influence green bond issuance by affecting FDI and technology transfer. This satisfies the exclusivity condition, as tuberculosis rates do not play a role in the decision-making processes related to green bond issuance. Instead, they reflect broader aspects of a country's development level and economic stability, which influence FDI attractiveness but are not directly connected to green bond issuance (Bénassy-Quéré et al., 2007; Gnangnon, 2022). Thus, TB rates provide a source of exogenous variation that helps isolate the impact of FDI and technology transfer on green bond issuance, ensuring reliable estimates of causal relationships. As an initial check, green bond offerings are minimal correlated to tuberculosis rates (0.045), supporting the instrument's validity. To ensure the validity of the instrumental variable

(IV) approach and generate unbiased estimates, we also employ the two-step generalized method of moments (GMM) estimator (Arellano and Bover, 1995).

Table 6 shows the results of the IV regressions. In Model 1 (2SLS), the coefficient for FDITECH is 1.766*** ($p < 0.01$), showing a positive and significant effect of FDI and technology transfer on green bond issuance. This suggests that increased FDITECH is strongly associated with higher levels of green bond issuance. The relevance and exclusivity of the IV instrument, TUBERCL, is confirmed by its significant first-stage coefficient of 0.033*** ($p < 0.01$) and a Kleibergen-Paap F-statistic of 29.616, indicating a strong instrument. The Kleibergen-Paap LM p-value of 0.230 supports the validity of the instrument, suggesting it meets the exclusion restriction criteria. In Model 2 (GMM), the FDITECH coefficient is 1.767** ($p < 0.05$). This result is consistent with the findings from Model 1, further supporting a solid positive association between FDITECH and GRBOND. The instrument's strength is corroborated by the large Kleibergen-Paap F-statistic of 29.211 and a non-significant Kleibergen-Paap LM p-value of 0.23, ensuring the instrument's relevance and validity. Additionally, the insignificant AR (2) statistic ($p = 0.548$) suggests no significant second-order autocorrelation, further validating the model's results. This model reinforces the robustness of the positive impact of FDITECH on green bond issuance, confirming the initial findings.

5.2. The Oster test of coefficient stability

We apply Oster's (2019) bias-adjusted treatment test to further address the risk of omitted variable bias. Oster's test evaluates how coefficient stability shifts when moving from observed to unobserved predictors, providing a more refined approach. It checks if the predictor's coefficient remains stable across varying subsamples, detecting endogeneity by observing how the coefficient changes as sample characteristics shift. This approach assumes that the observed predictors are representative of all relevant variables. When omitted variables are present, it can be difficult to directly estimate the treatment effect (β). Instead, Oster's test provides a range for the treatment effect by analysing the proportional influence (δ) between observed and unobserved predictors, along with the overall model fit (R_{max}). A δ value of 1 indicates that the observed and unobserved variables have equal weight, whereas a δ greater than one suggests that unobserved variables have a stronger impact. R_{max} reflects the combined variation explained by both observed and unobserved factors, and specific assumptions about R_{max} are needed to estimate β. In Table 6, Column (3) shows the outcome of the Oster test. The FDITECH coefficient is 1.448** ($p < 0.05$), indicating a significant positive effect. The δ statistic of 0.141 suggests that the coefficient is fairly stable as we add covariates and not overly sensitive to potential omitted variable bias. The β statistic of 1.525** ($p < 0.05$) further confirms the robustness of the coefficient, indicating reliable results. This model reinforces the stability and significance of the positive relationship between FDITECH and GRBOND, suggesting that the findings are not driven by omitted variables and are robust to potential biases.

Table 6
Endogeneity analysis.

	(1)	(2)	(3)	(4)
FDITECH	1.766***	1.766***	1.448**	
	(0.518)	(0.518)	(0.666)	
BIODIVR	9.669***	9.669***	9.715***	
	(2.556)	(2.556)	(2.988)	
GPR	0.026***	0.026***	0.030***	
	(0.006)	(0.006)	(0.009)	
ELECTRIMP	0.024***	0.024***	0.024**	
	(0.008)	(0.008)	(0.010)	
SOVRATNG	1.412***	1.412***	1.401***	
	(0.177)	(0.177)	(0.219)	
INFLAT	0.048	0.048	0.056	
	(0.116)	(0.116)	(0.135)	
EUMBR	2.462***	2.462***	2.523***	
	(0.362)	(0.362)	(0.354)	
TREATED				2.030***
				(0.268)
First-stage				
TUBERCL	0.033***			
	(5.44)			
F-stat	12.437	456.885	.	57.486
Kleibergen-Paap LM (pv)	1.440 (0.230)	1.341 (0.188)		
Kleibergen-Paap F stat	29.616	29.211		
AR (2) (pv)		−0.601 (0.548)		
Delta			0.141	
Beta			1.525**	
Mean_bias (%)				6.309
N	223	223	223	163

Notes. The table summarizes the results of the endogeneity analysis. The outcome variable is the green bond issuance value (GRBOND). The key independent variable is FDI and technology transfer index (FDITECH). The pool sample period is 2000 to 2022. Model (1) uses the 2SLS estimator with an IV model. Model (2) uses the two-step GMM estimator with an IV model. Model (3) uses the CMP estimator with an IV model. In models (1) and (3) the external IV instrument used is the number of tuberculosis cases per country-year (TUBERCL). Model (4) presents the results of the Oster test of coefficient stability. Model (5) presents the outcomes of propensity score matching (treatment variable only).
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3. Propensity score matching

The decision by countries to support FDI and technology transfer (treatment variable) may not be random and could be influenced by unobserved factors, potentially impacting green bond issuance. We apply propensity score matching to address this potential sample selection bias (Rosenbaum and Rubin, 1983). Column (4) of Table 6 presents the results using nearest-neighbour matching, where countries with FDI and technology transfer above the global sample median are classified as the treatment group (indicative of more mature and comprehensive FDI and tech transfer policies) and those below the median as the control group (indicative of less comprehensive such policies). The treatment effect, captured by the coefficient on the treatment variable (TREATED), is derived from propensity score matching and measures the influence of more supportive FDI and technology transfer policies on green bond issuance. After matching, the standardized differences between the treated and control groups should ideally be below 10 %, indicating that the covariates are well-balanced. In Model (5), the coefficient for TREATED is small but statistically significant (β = 2.030, $p < 0.01$), with a mean bias of 6.309 %. This indicates that the average bias across covariates between the treated and control groups is low, meaning the matching process successfully reduced the differences to below 10 %. This result shows a substantial improvement and confirms that more comprehensive FDI and technology transfer policies are associated with an increase in green bond issuance, even after controlling for other factors.

6. Robustness checks

6.1. Sensitivity analysis

Sensitivity analysis evaluates the robustness and reliability of the baseline quantitative results by examining how variations in methodologies, assumptions, or data affect the conclusions of the analysis. The first sensitivity test expands the sample structure by focusing on both corporate and government green bond issuances to assess the specific impact of FDITECH on corporate green bond offerings (GRBONDPR). This distinction between corporate and sovereign issuers is crucial, as FDITECH significantly influences both but in diverse ways. For corporations, FDI provides essential capital, enhances market confidence, and brings technological and managerial expertise, making green projects more viable and attractive for bond financing. Technology transfer further boosts corporate competitiveness by enabling innovation and reducing project costs (Zhang and Gallagher, 2016). On the sovereign side, FDI promotes economic growth and fiscal capacity, allowing governments to fund large-scale green initiatives through green bonds. Additionally, technology transfer supports the implementation of strategic green projects and enhances institutional capacities, aligning with national development goals and improving governance frameworks necessary for successful green bond programs. The results are shown in Column (1) of Table 7. In Model 1, the coefficient for FDITECH is 1.437** ($p < 0.05$), demonstrating a significant positive impact on corporate green bond issuance (GRBONDPR). This result, despite the change in the dependent variable, suggests a stable and supportive linkage between green bond offerings and FDITECH, confirming the robustness of the baseline effects.

In the second sensitivity test, the added squared value of the key regressor ($FDITECH^2$) is utilized to seize nonlinear effects. FDI and technology transfer may impact green bond offerings in a nonlinear manner due to threshold effects, synergies, and variable returns (Huang et al., 2022). For instance, in India's renewable energy sector, initial FDI had limited impact. However, as investment reached a critical mass and was combined with advanced technologies from countries like Germany and Denmark, green bond issuance surged. This synergy between financial resources and technological innovation made green projects more viable and attractive (Richter, 2013). Eventually, as the market matured, the incremental impact of additional FDI and technology transfers diminished, illustrating the complex dynamics of their influence on green bond markets. The outcomes in Table 7 Column (2) demonstrate these outcomes. In Model 2, the $FDITECH^2$ coefficient is 0.124* ($p < 0.1$), indicating a moderate positive quadratic effect. This suggests that the relationship between FDITECH and GRBOND is nonlinear, with the magnitude of the effect increasing moderately.

To account for lagged effects in the third sensitivity test, the key regressor ($FDITECH_{-1}$) is employed with a one-year lagged value. Green bond issuance may be influenced with a delay by FDI and technology transfer, as the evolvement and execution of new investments and initiatives demand time from organizations and companies to adjust (Taghizadeh-Hesary and Yoshino, 2020). For instance, consider the establishment of a wind farm by a multinational corporation in a developing country, involving the transfer of advanced wind turbine technology. However, before the project can generate revenue and become operational, various stages such as site selection, regulatory approvals, infrastructure development, and construction must occur. This process requires time for local stakeholders to adjust to the innovative technology and for the project to be implemented effectively. Consequently, there is a significant delay between the initial FDI and technology transfer and the eventual use of green finance to support the project. Table 7, Column (3) displays the findings of this analysis. Model 3 reports a non-significant coefficient for the one-year lagged value $FDITECH_{-1}$ at 0.276. This non-significant result indicates that the immediate effect of FDITECH on GRBOND is more influential than any lagged effects, suggesting that changes in FDITECH lead to an immediate impact on green bond issuance rather than a delayed one.

To examine the effect of economic development, the fourth sensitivity test restricts the sample to developed countries, defined based on the median GDP per capita. This approach provides a controlled environment for analysing the impact of FDI and technology transfer on green bond issuance by focusing on advanced economies like the United States, Japan, and Germany. By excluding developing countries, the analysis avoids confounding factors associated with variations in institutional quality and regulatory frameworks, ensuring greater result comparability. Additionally, developed nations benefit from well-established reporting mechanisms and regulatory oversight, enhancing data reliability and providing a clearer view of green bond issuance dynamics (Caramichael and Rapp, 2024). This focused analysis offers precise insights into the drivers of green bond issuance in advanced economies, aiding policymakers, investors, and stakeholders in making

Table 7
Sensitivity tests.

	(1)	(2)	(3)	(4)	(5)	(6)
FDITECH	1.437**			1.435**	1.685*	1.452**
	(0.684)			(0.667)	(0.961)	(0.689)
$FDITECH^2$		0.124*				
		(0.065)				
$FDITECH_{-1}$			−0.276			
			(0.802)			
BIODIVR	10.247***	9.767***	19.093***	9.862***	22.387***	9.626***
	(2.981)	(3.023)	(6.389)	(2.980)	(6.997)	(3.086)
GPR	0.032***	0.034***	−0.133***	0.030***	0.027*	0.031***
	(0.010)	(0.009)	(0.036)	(0.009)	(0.013)	(0.010)
ELECTRIMP	0.029**	0.023**	0.021*	0.024**	0.017	0.028**
	(0.011)	(0.010)	(0.011)	(0.010)	(0.013)	(0.012)
SOVRATNG	1.416***	1.459***	−0.085	1.392***	−2.288*	1.400***
	(0.232)	(0.229)	(1.305)	(0.223)	(1.103)	(0.227)
INFLAT	0.056	0.062	−0.035	0.061	−0.057	0.053
	(0.140)	(0.136)	(0.165)	(0.137)	(0.122)	(0.138)
EUMBR	2.714***	2.534***	3.899***	2.543***	0.633	2.610***
	(0.353)	(0.368)	(0.713)	(0.353)	(1.147)	(0.363)
adj. R^2	0.769	0.782	0.791	0.785	0.830	0.764
RMSE	0.928	0.880	0.808	0.882	0.797	0.897
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	223	223	179	218	124	213

Notes. The table presents the results of sensitivity tests regarding the impact of foreign direct investment and technology transfer on green bond issuance. Control variables include financial, risk and institutional conditions. The data spans from 2000 to 2022, and the estimation employs an OLS model that incorporates both random and fixed effects. Standard errors are conveyed in parentheses and are grouped by country. Model (1) employs an expanded measure of green bond issuance, which considers corporate and government green bonds (GRBONDPR). Model (2) utilizes a squared value of the key regressor ($FDITECH^2$) to encompass nonlinear effects. Model (3) employs a one-year lagged value of the main regressor ($FDITECH_{-1}$) to capture time lag effects. Model (4) restricts the sample only to developed countries. Model (5) restricts the sample only to high-population countries. Model (6) excludes the country with the higher green bond issuance value (France) from the sample.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

informed decisions. Column (4) of Table 7 reports a significant FDITECH coefficient of 1.435** ($p < 0.05$), confirming the positive impact of FDI and technology transfer on green bond issuance. These findings demonstrate that the relevance of FDITECH remains robust in predicting green finance decisions in more developed financial markets.

To address country size effects, the fifth sensitivity test focuses on large population countries, defined based on the sample median. The analysis shows that FDI and technology transfer significantly influence green bond issuance in these countries due to economies of scale, which make green investments more cost-effective and attractive to investors (Giannotti, 2021). Higher demand for sustainable infrastructure and energy solutions further drives green bond issuance, while a substantial labour force, including skilled professionals, enhances the effectiveness of technology transfer and FDI by fostering innovation, improving project execution, and boosting investor confidence (Li et al., 2024; Lian et al., 2023). Moreover, large countries often prioritize green financing through robust policy and regulatory frameworks, creating an enabling environment for FDI and green finance (Fu et al., 2024). Their active participation in global sustainability efforts and international agreements attracts additional FDI and technology transfer aimed at meeting environmental goals (Giannotti, 2021). Rapid urbanization in these countries also increases the need for sustainable infrastructure, positioning green bonds as an ideal financing tool supported by FDI and advanced technologies (Li et al., 2024). Column (5) of Table 7 confirms this relationship, with the FDITECH coefficient at 1.685* ($p < 0.10$), indicating a significant positive effect. These findings highlight the robust impact of FDITECH on green bond issuance and its critical role in shaping green finance decisions in larger financial markets.

We perform a final sensitivity test with the sample by removing the larger green bond issuer, China, to extend the assessment of the possible impact of large-size bias. This omission helps determine whether the existence of an influential point or outlier impacts the findings. The findings from Column (5) of Table 7 show an FDITECH coefficient of 1.452** ($p < 0.05$), indicating a significant positive effect. Despite the exclusion of China, the significant positive coefficient suggests that the relationship between FDITECH and GRBOND is not driven solely by China's data. This suggests that the findings are generalizable across different countries, further reinforcing the robustness of the positive impact of FDITECH on GRBOND.

Across all tests, FDITECH consistently shows a significant positive effect on GRBOND, except in Model 3, where the lagged effect is not significant, demonstrating the strength of the baseline findings: Model 1 confirms the positive impact of FDITECH on corporate green bonds, Model 2 indicates a primarily linear relationship, Model 3 suggests the importance of immediate effects over lagged effects, Model 4 highlights the relevance in developed countries, and Model 5 confirms the generalizability excluding China. These results collectively affirm that higher FDI and technology transfer positively impact green bond issuance, broadly confirming the baseline effects.

6.2. New controls

The effect of FDI and technology transfer on green bond issuance is manifold, shaped by a range of environmental, political, and economic factors that may not have been fully accounted for in the analysis. Economic conditions, such as government consumption and tax policies, significantly impact green bond issuance. High government spending on sustainable projects signals a commitment to green initiatives, thereby attracting private investment (Bielenberg et al., 2016). Additionally, tax incentives for green investments enhance their attractiveness, boosting green bond issuance. Conversely, high taxes on investments can deter private sector involvement, reducing the appeal of green bonds. Environmental conditions also play a critical role in the link between FDI, technology transfer, and green. Green bonds can enhance stability by funding resilient infrastructure, making a stable investment climate essential for their attractiveness finance (Guesmi et al., 2024). Maintaining a stable investment environment has further supported green bond attractiveness (Liu et al., 2021). Additionally, political conditions and cultural characteristics affect trust in public institutions and financial markets, deterring green investments. These social factors can lead to fears of misallocation and instability, hindering efforts to fund broad-based environmental initiatives (Christophers, 2017; Mertzanis and Tebourbi, 2024, 2025).

To evaluate these conjectures, we introduce additional controls grouped individually to address the risk of confounding variables and collinearity bias. We re-evaluate Eq. (1) to incorporate the following unique impacts: First, we consider additional macroeconomic conditions. We incorporate the impact of the share of government consumption (GOVCONS) and the effect of taxation on incentives to invest (TAXINV). Data for these controls are sourced from the Penn World Tables and the World Economic Forum's Global Competitiveness Report, respectively. Second, we account for Environmental and Uncertainty Effects. We incorporate the effect of the level of taxes on energy (ENRGTAX) and the business costs of terrorism (BUSTERR). Data for these variables are retrieved from the IMF Climate Database and the World Economic Forum Database, respectively. Third, we account for Social and Cultural Effects. We include the impact of political corruption (POLCORR) and government favouritism of religion (RELREG). Data for these controls are provided by the V-Dem Democracy Database (https://v-dem.net/data/the-v-dem-dataset/) and the Association of Religion Data Archives (ARDA) (https://www.thearda.com/).

The findings of the new controls are illustrated in Table 8. In Model 1, the coefficient for FDITECH is 2.414** ($p < 0.05$), indicating that the

Table 8
New control variables.

	(1)	(2)	(3)
FDITECH	2.414***	1.655**	1.450*
	(0.855)	(0.716)	(0.733)
BIODIVR	12.380***	8.982	9.891***
	(2.492)	(5.921)	(3.115)
GPR	0.028**	0.031***	0.032***
	(0.011)	(0.011)	(0.012)
ELECTRIMP	0.033*	0.028**	0.026**
	(0.017)	(0.011)	(0.012)
SOVRATNG	1.049***	1.348***	1.315***
	(0.304)	(0.188)	(0.324)
INFLAT	0.011	−0.147**	0.041
	(0.141)	(0.071)	(0.157)
EUMBR	5.472***	3.624***	2.353***
	(0.999)	(0.841)	(0.374)
GOVCONS	−42.728***		
	(12.475)		
TAXINV	−0.875**		
	(0.366)		
ENRGTAX		−1.718***	
		(0.465)	
BUSTERR		−0.888*	
		(0.509)	
POLCORR			−11.305**
			(5.310)
RELREG			0.134
			(0.085)
adj. R^2	0.747	0.830	0.755
RMSE	0.894	0.778	0.910
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	182	196	188

Notes. The table presents the impact of foreign direct investment and technology transfer on green bond issuance after including additional controls. The data spans from 2000 to 2022, and the estimation employs an OLS model that incorporates both random and fixed effects. Standard errors are disclosed in parentheses and are clustered by country. Model (1) incorporates additional economic controls (GOVCONS, TAXINV). Model (2) incorporates additional environmental controls (ENRGTAX, BUSTERR). Model (3) incorporates additional political and social controls (POLCORR, RELREG).
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

significant positive effect of FDITECH on GRBOND remains robust even after including macroeconomic controls. The additional macroeconomic controls reveal interesting dynamics. The coefficient for the share of government consumption (GOVCONS) is −42.728*** ($p < 0.01$), suggesting that higher government consumption negatively impacts green bond issuance. This finding implies that excessive government spending may crowd out private investment in green projects. Similarly, the coefficient for the effect of taxation on incentives to invest (TAXINV) is −0.875** ($p < 0.05$), indicating that higher taxes on investments disincentivize private sector involvement in green projects, thus reducing green bond issuance. Furthermore, Model 2 incorporates environmental controls, with the FDITECH coefficient at 1.655** ($p < 0.05$), showing that the positive impact of FDITECH on GRBOND is significant even after accounting for environmental factors. The additional environmental controls have notable effects. The coefficient for the degree of taxes on energy (ENRGTAX) is −1.718*** ($p < 0.01$), suggesting that higher energy taxes negatively affect green bond issuance, due to the increased overall cost of green projects. Additionally, the coefficient for the business costs of terrorism (BUSTERR) is −0.888* ($p < 0.1$), indicating that higher security risks and instability deter investments in green projects, thus reducing green bond issuance. Finally, in Model 3, the FDITECH coefficient is 1.450* ($p < 0.1$), showing that the significant positive effect of FDITECH on GRBOND is maintained even after including political and social controls, although with slightly lower significance. The additional political and social controls reveal significant impacts. The coefficient for political corruption (POLCORR) is −11.305** ($p < 0.05$), suggesting that higher levels of political corruption significantly deter green bond issuance. This indicates that corruption undermines trust and stability in financial markets, reducing the attractiveness of green bonds. Conversely, the coefficient for government favouritism of religion (RELREG) is 0.134* ($p < 0.10$), indicating that such favouritism positively affects green bond issuance. This may reflect more stable and cohesive governance structures that facilitate green investments.

Across all models, FDITECH consistently shows a significant positive effect on GRBOND, highlighting that FDI and technology transfer are crucial drivers of green bond issuance. The additional controls reveal the nuanced effects of macroeconomic, environmental, and political/social factors. Specifically, lower government consumption may boost green bond issuance by indicating a larger role for the private sector, potentially leading to a more attractive regulatory environment for green investments (Ning et al., 2023). This decline signals improved fiscal responsibility, bolstering investor confidence, and driving up demand for green bonds. Reduced taxation on investments can also enhance green bond issuance by making green projects more financially appealing (Baker et al., 2022). Further, reduced business costs from terrorism can elevate green bond issuance by enhancing investor confidence and stability. Lower corruption boosts green bond issuance by creating a transparent investment environment, enhancing investor confidence, and reducing risks (Dan and Tiron-Tudor, 2021). Additionally, increased government favouritism of religion can boost green bond issuance if religious groups prioritize environmental stewardship, as government support can increase funding for green projects (Khan et al., 2021). Overall, the additional controls moderate the impact of FDI and technology transfer on green bond issuance without altering their fundamental relationship, emphasizing the importance of a supportive environment for promoting green bond issuance.

6.3. Dominance analysis

We apply dominance analysis to identify which regressors have the most significant impact on green bond offerings (Azen and Budescu, 2006). This approach goes beyond evaluating individual coefficients, assessing the contribution of each predictor across the entire model. It offers insights into the relative importance of variables by examining how they collectively contribute to and interact within the model's overall predictive power. The Shapley value decomposition from game theory is used in dominance analysis to quantify each regressor's participation, helping to determine their relative importance in predicting green bond issuance. We adopt Luchman's (2021) approach, which calculates the average net increase in the model's total R^2 as each independent variable is added to all combinations of the other predictors.

Table 9 presents the results of the dominance analysis across three models: Model 1 covers the entire sample, Model 2 focuses on the subset of high-income countries, and Model 3 examines the subset of low-income countries. In Model 1, covering the entire sample, FDITECH accounts for 15.60 % of the total predictive power, underscoring its importance in driving green bond issuance across various countries. Other factors, such as geopolitical risk (5.26 %), EU membership (6.61 %), and electricity imports (3.77 %), also contribute, although to a lesser extent. Biodiversity expenditure (0.40 %) and inflation rate (0.87 %) have minimal impacts, indicating their lower relevance in this context. Furthermore, Model 2 focuses on high-income countries, where FDITECH remains a significant predictor, contributing 15.79 % to green bond issuance. The patterns are similar to the entire sample, with geopolitical risk (5.24 %) and EU membership (6.73 %) maintaining their influence. Biodiversity expenditure and inflation rate have slightly higher impacts in high-income countries, at 0.45 % and 0.91 %, respectively, but still remain minor factors. Finally, in Model 3, examining low-income countries, FDITECH has a higher impact, contributing 30.06 % to the model's predictive power. This highlights the critical role of FDI and technology transfer in driving green bond issuance in these regions. Additionally, factors such as biodiversity expenditure (18.16 %), geopolitical risk (11.96 %), electricity imports (17.08 %), and inflation rate (22.74 %) have much higher impacts compared to high-income countries and the entire sample. Notably, sovereign debt rating and EU membership have small impact, reflecting the unique economic and political dynamics of low-income countries.

The dominance analysis reveals that FDITECH consistently plays a significant role in driving green bond issuance across all models, with the strongest effect observed in low-income countries (30.06 %). In these nations, factors such as biodiversity expenditure, geopolitical risk, electricity imports, and inflation rate have a larger impact compared to high-income countries and the overall sample. This suggests that while FDITECH is a key global driver, the relative importance of other variables varies by income level. These findings underscore the need for tailored strategies to promote green bond issuance based on the unique economic and political contexts of different countries. For instance, the European Union can support green bond issuance by ensuring regulations are not overly stringent, which could otherwise lead to high

Table 9
Dominance analysis.

	(1)	(2)	(3)
FDITECH	0.1560	0.1579	0.3006
BIODIVR	0.0040	0.0045	0.1816
GPR	0.0526	0.0524	0.1196
ELECTRIMP	0.0377	0.0374	0.1708
SOVRATNG	0.0212	0.0210	0.0000
INFLAT	0.0087	0.0091	0.2274
EUMBR	0.0661	0.0673	0.0001
Fit stat	0.346	0.350	1.000
N	223	218	5

Notes. The table displays the outcomes of dominance analysis, examining the influence of each individual regressor on green bond issuance. The dataset covers the period from 2006 to 2020, and the estimation utilizes a Shapley value decomposition method to evaluate the contributions of each independent variable to the overall predictive performance. Model (1) illustrates the primary impact of each baseline regressor within the entire sample. Model (2) shows the dominant influence of all regressors within the subset of high-income countries. Model (3) highlights the dominant effects of all regressors within the subset of low-income countries.

compliance costs or unclear policies that cause investor uncertainty (Fatica et al., 2021). In less developed countries, FDI and technology transfer are essential for providing capital and advanced technologies needed for sustainable projects (Li et al., 2022), helping to build environmentally friendly infrastructure, and driving demand for green bond financing. Additionally, FDI and technology transfer enhance local expertise in green technologies, further stimulating green bond issuance in these regions.

7. Channels of influence

In this section, we identify key economic factors that may serve as mediators of the relationship between FDITECH and GRBOND, potentially influencing the strength and direction of FDITECH's impact on green bond issuance. Firstly, we introduce the country's availability of scientists and engineers index (SCIENT), sourced from the World Economic Forum database, as a potential mediator in our analysis. The availability of scientists and engineers significantly influences the impact of FDI and technology transfer on green bond issuance. A larger workforce of scientists and engineers could enhance the positive effects of FDI by fostering technological innovation, improving project quality, and boosting investor confidence, but conversely could prioritize domestic innovation, reducing reliance on foreign technologies and limiting FDI spillovers. Additionally, countries with advanced domestic absorptive capacity would need less technology transfer, while foreign firms often internalize innovations, restricting broader economic benefits. However, the interaction term FDITECH * SCIENT in Model 1 reveals diminishing returns at higher levels of SCIENT, suggesting the need for balanced development to avoid over-reliance on human capital at the expense of other resources. The expertise of scientists and engineers drives R&D, facilitates the adaptation of advanced technologies, and ensures project sustainability, making green bonds more attractive by mitigating risks (Phung Thanh, 2022). Their role also supports sustainable development and enhances the long-term viability of green projects. A sturdy base of scientists and engineers fosters a favourable business environment, attracting more FDI and enabling constructive collaboration between foreign expertise and local talent, thereby improving green bonds' contributions to environmental sustainability and economic growth (Ji and Zhang, 2023). Policymakers should expand STEM education while ensuring it aligns with the demands of the green finance ecosystem to maximize the positive impact of human capital on green bond issuance.

Secondly, we introduce the country's capacity for innovation index (INNVCAP), sourced from the World Economic Forum, as another key mediator in the analysis. Model 2 demonstrates that the interaction term FDITECH * INNVCAP constraints the positive relationship between FDI and green bond issuance, underscoring the critical role of an innovative environment in leveraging foreign investment and technology transfer. The diminishing effect of FDI-based technology transfer on green bond issuance in countries with strong domestic innovation arises from several factors. FDI can crowd out local R&D investment, while competition from foreign firms may reduce domestic innovation incentives (Schumpeterian effect). Additionally, foreign firms often internalize technologies, limiting spillovers, and nations with advanced innovation systems may see diminishing returns from FDI due to reduced marginal benefits of foreign inputs. Increased innovation capacity directly promotes green bond issuance while at higher levels it can constraint the effects of FDI and technology transfer (Xiong and Dai, 2023). Vibrant domestic innovation supports the development of innovative, sustainable technologies and ensures efficient resource use, long-term competitiveness, and collaboration, making foreign technology transfer less important (Saqib et al., 2024).

Thirdly, we assess a country's monetary and conflict resolution policy tightness (CBIEPOLICY) as another key mediator, using data from Romelli (2022). Research shows that central bank monetary policies directly influence green bond offerings and indirectly mitigate the negative effects of FDI and technology transfer (Mertzanis, 2024). Easier monetary policies—characterized by lower interest rates, inflation control, and stabilized exchange rates—enhance investor confidence and reduce risks, thereby moderating the impact of FDI on green bonds (Mbassi et al., 2023). In Model 3, the interaction term FDITECH * CBIEPOLICY indicates the effect of tighter central bank policies on the positive relationship between FDI and green bond issuance. This finding highlights the importance of flexible monetary policies that counteract the constraints imposed by restrictive financial environments. For example, lower interest rates and controlled inflation not only directly support green finance but also enable FDI to flow more effectively into green projects. Policymakers should strive for balanced strategies that manage inflation and interest rates without discouraging foreign capital and technology inflows. The analysis suggests that overly restrictive monetary frameworks may limit FDI's transformative impact on green bond markets. Adequate liquidity improves the marketability of green bonds, while clear and supportive policy signals align investor expectations. These factors collectively make green finance more attractive to foreign investors. However, future research is necessary to further explore and understand the nuanced role of monetary policies in shaping green bond markets.

Table 10 presents the results. In Model 1, the FDITECH coefficient is 2.878*** ($p < 0.01$), indicating a strong positive impact on green bond issuance. The interaction term FDITECH * SCIENT is −0.214* ($p < 0.1$), suggesting that the positive FDITECH impact is constrained by the higher of scientists and engineers. These nations often prioritize domestic innovation, reducing reliance on foreign technologies and limiting FDI spillovers. Additionally, their advanced absorptive capacity leaves less room for impactful technology transfer, while foreign firms often internalize innovations, restricting broader economic benefits (Vinding, 2006). Thus, while FDI boosts green bond issuance, its impact weakens in economies with strong domestic scientific and engineering

Table 10
Channels of influence.

	(1)	(2)	(3)
FDITECH	2.878***	2.864***	2.929**
	(1.021)	(0.855)	(1.314)
FDITECH * SCIENT	−0.214*		
	(0.119)		
FDITECH * INNVCAP		−0.289**	
		(0.114)	
FDITECH * CBIEPOLICY			−2.110**
			(0.789)
BIODIVR	10.616***	12.425***	2.691
	(2.969)	(3.643)	(4.303)
GPR	0.034***	0.049***	0.044
	(0.009)	(0.012)	(0.027)
ELECTRIMP	0.023**	0.030***	0.006
	(0.011)	(0.010)	(0.021)
SOVRATNG	1.379***	1.198***	1.801
	(0.218)	(0.236)	(1.095)
INFLAT	0.019	0.032	−0.215
	(0.134)	(0.119)	(0.133)
EUMBR	2.538***	4.150***	3.993**
	(0.326)	(0.876)	(1.546)
adj. R^2	0.786	0.789	0.783
RMSE	0.871	0.865	0.780
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
N	223	223	90

Notes. The table presents the impact of direct and indirect venture capital enhancing effects of new control variables. The dataset covers the period 2006 to 2020, and the estimation utilizes an OLS model with fixed effects. Standard errors are presented in parentheses and are clustered by country. Model (1) reveals the mediating effect of the number of scientists and engineers in the country (SCIENT). Model (2) shows the mediating effect of a country's capacity to innovate (INNVCAP). Model (3) shows the mediating effect of a country's monetary policy by the central bank (CBIEPOLICY).
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

capabilities. Furthermore, Model 2 reports an FDITECH coefficient of 2.864*** ($p < 0.01$), highlighting a strong positive impact on green finance. The interaction term FDITECH * INNVCAP is −0.289** ($p < 0.05$), suggesting that a country's capacity for innovation significantly constraints the positive effect of FDITECH on green bond issuance. This suggests that countries with lower innovation capacity are better positioned to benefit from FDI and technology transfer in the context of green bond markets. Policies that foster innovation, such as R&D incentives and support for technology startups, can further enhance the impact of FDI and technology transfer. Finally, in Model 3, the FDITECH coefficient is 2.929** ($p < 0.05$), maintaining the significant positive impact on green bond issuance. However, the interaction term FDITECH * CBIEPOLICY is −2.110** ($p < 0.05$), indicating that tighter central bank monetary and resolution policy diminishes the positive impact of FDITECH on green bond issuance. This suggests that restrictive monetary policies can undermine the effectiveness of FDI and technology transfer in promoting green bond markets. Policymakers should consider more accommodative monetary policies to facilitate the flow of investment and technology transfer into green projects, thereby boosting green bond markets.

The results in Table 10 reveal that FDITECH consistently exerts a strong positive influence on green bond issuance across all models. However, the interaction terms provide deeper insights into how numerous factors shape this relationship. Model 1 stresses the importance of a robust scientific and engineering workforce, indicating that expanding the availability of scientists and engineers can enhance the positive effects of FDI and technology transfer on green bond issuance. Model 2 highlights the significance of innovation capacity, suggesting that promoting innovation through measures such as R&D incentives and support for technology startups can further amplify the impact of FDITECH. In contrast, Model 3 shows that strict central bank monetary policies can dampen the positive influence of FDITECH on green bond issuance, implying that more accommodative monetary policies are crucial for encouraging investment flows into green projects. These findings emphasize the need for a comprehensive policy approach that strengthens the scientific workforce, encourages innovation, and implements supportive monetary policies to fully leverage the positive effects of FDI and technology transfer on green bond issuance.

8. Conclusions

This study examines the relationship between FDI, technology transfer, and green finance across a diverse set of nations. Specifically, it investigates how green bond offerings in sixty-seven countries are influenced by a combined measure of FDI and technology transfer from 2000 to 2022, using a newly available dataset from the IMF. The analysis incorporates financial, risk, and institutional factors to provide a comprehensive understanding. Notably, this research is the first to explore the impact of FDI and technology transfer on green bond finance.

Our findings indicate that countries actively promoting FDI and technology transfer tend to achieve higher levels of green bond issuance. Factors such as expenditures on biodiversity and landscape protection, geopolitical risks, net electricity imports, sovereign debt ratings, and inflation also show significant associations with green bond market growth. Specifically, improved sovereign ratings, lower inflation rates, and increased engagement in import-export activities contribute to the expansion of green bond markets. However, changes in FDI and technology transfer have immediate or linear effects on green bond issuance. Among the predictors analysed, FDI, technology transfer, and EU membership emerge as the most influential drivers of green bond market development. Despite these benefits, countries prioritizing FDI and technology transfer may face obstacles in advancing green finance due to potential economic and political dependencies.

FDI and technology transfer are crucial in driving green bond issuance by mitigating financial risks and enhancing investor confidence. FDI attracts a diverse pool of investors and funds a broad spectrum of green initiatives, while technology transfer introduces advanced solutions that reduce operational risks and make green bonds more appealing. The participation of reputable investors and innovative technologies strengthens the credibility and stability of green bond markets. Furthermore, supportive policies and regulatory frameworks foster an enabling environment for greeninvestments. By providing capital, advanced technologies, and capacity-building opportunities, FDI and technology transfer support sustainable development, aid in climate change mitigation, and promote the growth of resilient green bond markets. These contributions not only improve the efficiency and sustainability of green projects but also enhance the skills of the local workforce.

While FDI and technology transfer bring significant benefits to green finance, they also present challenges that host countries must address. Over-reliance on foreign investments can leave economies vulnerable to external economic and political shifts, potentially disrupting funding, and technological support. The dominance of foreign firms and technologies may stifle local industry growth, suppress domestic innovation, and lead to compatibility issues, cultural resistance, or rapid obsolescence of imported technologies, resulting in inefficiencies in green projects. Additionally, large-scale green initiatives can cause unintended environmental harm or social disruptions, such as community displacement. Market volatility and currency risks further complicate green finance, as green bonds and related instruments may lose appeal to investors under uncertain conditions. Regulatory inconsistencies between home and host countries, along with unstable policies in host nations, create additional barriers to investment and long-term planning. Balancing these factors is crucial to fully harness the potential of FDI and technology transfer while ensuring sustainable and inclusive growth in green finance.

While our research provides initial evidence of a positive relationship between FDI, technology transfer, and green bond market growth, it has several limitations. The measures of FDI and technology transfer could be more diversified to account for contributions from individual countries, specific sectors, and policy frameworks. Additionally, the influence of FDI and technology transfer on green investment may be shaped by issuer characteristics such as industry, company size, and ownership structure, which are not captured in our data. Future research should address these gaps. Despite accounting for endogeneity, the risk of omitted variable bias persists. Moreover, a more thorough investigation into the role of institutions and their cross-country and longitudinal effects is needed, as these institutions significantly impact FDI flows, technology transfer, and green bond issuance. Exploring these factors in future studies will provide a deeper understanding of how FDI and technology transfer influence green finance.

A multidisciplinary approach integrating alternative viewpoints should be adopted in future research to enhance our comprehension of the intricate connection between sustainable finance and FDI flows. Comprehensive quantitative studies are needed to measure the overall impacts of FDI and technology transfer, with a focus on sector-specific influences. Strategies for mitigating economic, political, and technological risks must be developed to ensure stability and efficiency. Additionally, research should explore methods for sustainable technology integration and long-term skill development to strengthen local capacities. Comparative studies on regulatory frameworks and policy impact analyses can identify best practices and opportunities for harmonization. Understanding investor preferences and behaviours, along with market dynamics, can enhance market liquidity and stability. Assessing social and environmental outcomes, including community impacts and environmental effectiveness, is crucial. Detailed case studies of both successful and failed initiatives can provide practical insights and lessons learned. Addressing these gaps will deepen the understanding of how FDI and technology transfer can support green bond issuance, contributing to robust and sustainable green finance markets.

CRediT authorship contribution statement

Lukas Christnacht: Writing – original draft, Methodology, Formal analysis, Data curation. **Charilaos Mertzanis:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2025.108246.

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