

Green Investment: Instruments, Drivers, Financial Performance, and the Transformation of Capital Markets

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Abstract

Green investment has moved from a niche of ethical finance to a defining force in contemporary capital markets. This paper provides an integrative review of the instruments through which capital is channelled to environmentally beneficial activities, the drivers of demand and supply, the evidence on financial performance, and the market, policy, and measurement challenges that accompany the growth of the green segment. We begin by defining green investment and mapping its principal instruments, from green bonds and green loans to green equities, funds, and supporting hybrid instruments. We then examine the demand-side drivers, including climate risk awareness, investor preferences, and regulation, and the supply-side factors that shape issuance. We synthesize the empirical literature on green asset pricing and performance, distinguishing the measured "green premium" from the expected-return logic that emerges when investors value sustainability. We analyse how climate risk enters portfolios and how ESG data, ratings, and divergences among them condition investment decisions. We assess the implications of green investment for corporate behaviour and for the design of policy and regulation, and we identify persistent challenges such as greenwashing, fragmentation of standards, and the uneven development of green markets in emerging economies. We conclude that green investment has real potential to mobilize capital for the transition to a low-carbon economy, but that its effectiveness depends on credible measurement, harmonized standards, and a regulatory architecture that aligns private returns with environmental objectives.

Keywords: green investment, green bonds, sustainable finance, ESG, climate risk, asset pricing, investor preferences, regulation, greenwashing, financial performance

1. Introduction

Green investment, broadly defined as the allocation of capital to assets and projects that generate measurable environmental benefits, has grown from a marginal concern of socially responsible investors into a central theme of contemporary finance. Green bonds, green equities, thematic funds, and a widening array of supporting instruments now channel substantial flows toward renewable energy, energy efficiency, clean transport, and climate adaptation. The scale of the transformation is remarkable. In little more than a decade, the market for green and sustainable debt has expanded from a niche to a multi-trillion-dollar asset class, and institutional investors increasingly treat environmental considerations as an integral part of portfolio construction rather than an optional overlay (Giglio, Kelly, & Stroebe, 2021). Governments, central banks, and standard-setters have responded with taxonomies, disclosure requirements, and prudential guidance that together are reshaping how capital is allocated across the economy.

The economic rationale for green investment rests on a simple but profound observation: financial markets are information-processing and risk-pricing devices, and climate change is both a systemic risk and a source of investment opportunity. Because the environmental performance of firms and projects varies, and because investors and regulators increasingly care about that performance, environmental information has become relevant to the pricing of securities. Academic research has documented that markets partially price climate risk, that investors value sustainability, and that green assets can trade at different prices from otherwise similar conventional assets (Hong, Li, & Xu, 2019; Baker, Bergstresser, Serafeim, & Wurgler, 2018). Understanding green investment therefore requires understanding how preferences, information, risk, and regulation interact to determine the flow of capital.

This review takes a broad but focused perspective. It is not a survey of the entire sustainable finance literature, but a structured account of the instruments, drivers, performance, and institutions of green investment. We organize the

discussion around a central question: what determines whether capital is directed to environmentally beneficial activities, and with what consequences for prices, firms, and the real economy? The answer, we argue, has four components. First, a set of instruments has evolved that lowers the cost of matching green capital with green projects. Second, demand is driven by a combination of risk, preference, and regulation that varies across investors and markets. Third, the financial performance of green assets is determined by the interaction of investor preferences with risk, and is therefore more subtle than a simple claim that green pays or green underperforms. Fourth, the credibility of the entire enterprise depends on measurement, disclosure, and verification, which remain incomplete and uneven.

The remainder of the paper is organized as follows. Section 2 defines green investment and maps its principal instruments. Section 3 examines the drivers of demand and supply. Section 4 reviews the evidence on pricing and financial performance. Section 5 analyses climate risk and the portfolio channel. Section 6 addresses ESG data, ratings, and measurement. Section 7 examines investor behaviour and the ESG-efficient frontier. Section 8 considers the implications for corporate behaviour. Section 9 discusses policy, regulation, and market development. Section 10 identifies persistent challenges, and Section 11 sketches future directions. Section 12 concludes.

2. Definitions and Instruments of Green Investment

A precise definition of green investment is surprisingly elusive, because "green" is a continuum rather than a binary attribute and because definitions are supplied by markets, standard-setters, and regulators with different purposes. In practice, green investment is usually identified by the destination of funds: proceeds are earmarked for projects with clear environmental benefits, such as renewable energy, energy efficiency, sustainable water and waste management, clean transport, and climate adaptation. This use-of-proceeds logic is at the heart of the most developed instrument, the green bond (Ehlers & Packer, 2017). Green bonds are fixed-income securities whose proceeds are committed to environmentally beneficial projects, and they are governed by voluntary principles and certification mechanisms that seek to give investors confidence that the label is meaningful (Deschryver & de Mariz, 2020). Table 1 summarizes the principal instruments of green investment and their distinguishing features.

Table 1. Principal instruments of green investment and their features

Instrument	Description	Key features
Green bonds	Debt whose proceeds fund green projects	Use-of-proceeds label, certification, reporting
Green loans	Earmarked bank credit for green projects	Bilateral, use-of-proceeds covenants
Sustainability-linked bonds	Debt tied to issuer sustainability targets	Coupon linked to KPIs, not earmarked use
Green equity / stocks	Shares of low-carbon or pure-play firms	Thematic exposure, index constituents
Green / ESG funds and ETFs	Collective vehicles with green mandates	Screening, tilts, thematic exposure
Impact funds (PE/VC/infra)	Private capital with measurable impact	Long horizon, active stewardship
Green deposits / notes	Bank deposits earmarked for green lending	Simple entry, retail participation
Carbon credits / blended finance	Hybrid instruments leveraging public funds	De-risking, additionality, guarantees

The green bond market illustrates both the promise and the ambiguity of labels. Ehlers and Packer (2017) document how certification mechanisms evolved to give more granularity and continuity to the green label, from the International Capital Market Association Green Bond Principles to the Climate Bonds Initiative taxonomy and national frameworks. The European Union has gone furthest in codifying a common taxonomy that defines which economic activities count as environmentally sustainable, providing a reference point that issuers, investors, and

regulators increasingly use. Deschryver and de Mariz (2020) argue that the scalability of the green bond market depends on closing the gap between supply and the ambitions of the transition, and on harmonizing the standards that govern what can be labelled green.

Beyond debt, equity instruments extend green investment to the ownership of firms whose activities are aligned with environmental objectives. Green equities range from pure-play renewable-energy and clean-technology companies to broad low-carbon indices and thematic exchange-traded funds. Collective investment vehicles, including green and ESG mutual funds, exchange-traded funds, and private impact funds, allow investors to obtain diversified exposure without directly selecting projects. Supporting and hybrid instruments, including green deposits, carbon credits, and blended-finance structures, broaden participation and can de-risk projects that would not attract purely private capital. Figure 1 illustrates the ecosystem through which investors, instruments, and eligible projects are connected, and Figure 2 presents a taxonomy of green investment instruments.

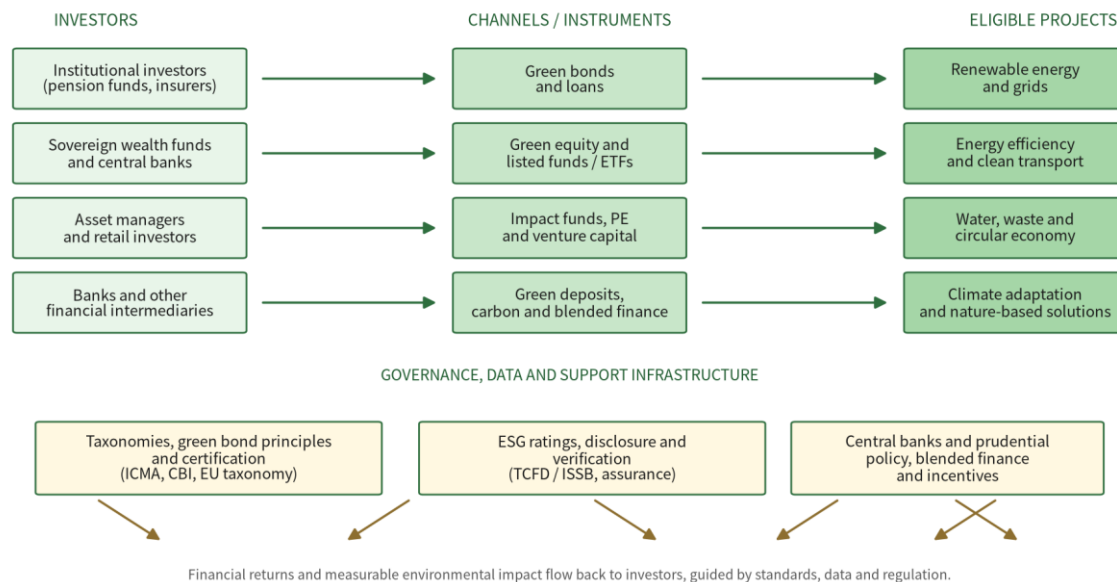


Figure 1. The green investment ecosystem: from investors and instruments to eligible projects, governed by standards, data and regulation

The taxonomy in Figure 2 highlights that green investment is not a single asset class but a family of instruments with different risk-return profiles, liquidity, and informational requirements. The choice among them depends on the investor's horizon, mandate, and tolerance for illiquidity, as well as on the credibility of the environmental claims attached to each instrument. This diversity is a strength, because it allows capital of many types to participate, but it also complicates measurement and comparison, because instruments that carry the same label may differ substantially in their environmental impact and financial characteristics.

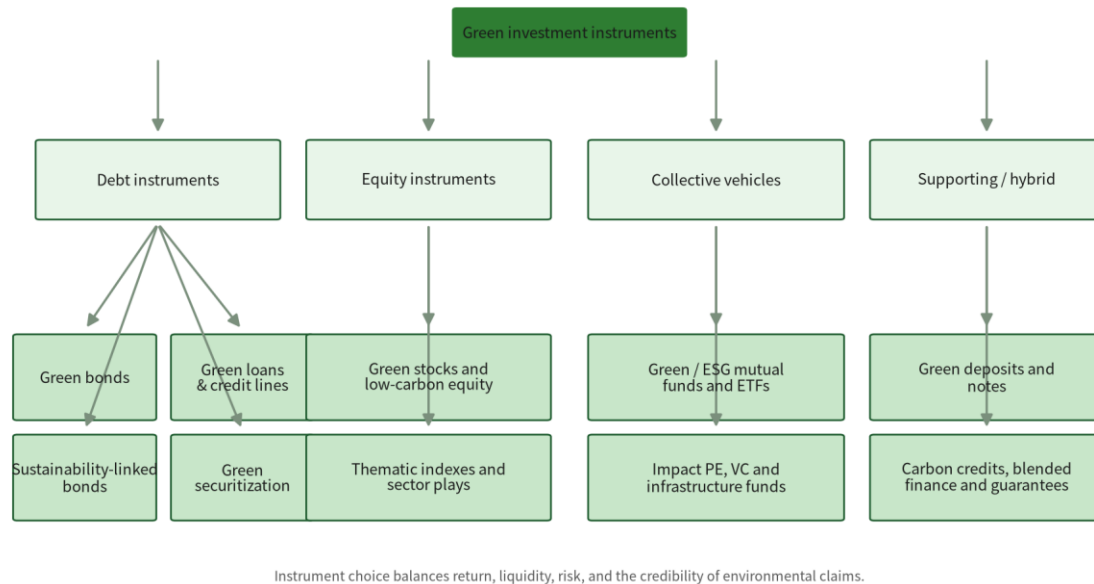


Figure 2. Taxonomy of green investment instruments, grouped by debt, equity, collective vehicles, and supporting or hybrid instruments

Two conceptual distinctions run through the definitions. The first is between use-of-proceeds instruments, which earmark capital for specific green projects, and performance-based instruments, such as sustainability-linked bonds, which tie the cost of capital to the issuer achieving measurable sustainability targets without earmarking specific projects. The second distinction is between labelled green investment and investments that are green in substance but unlabelled, including the climate-aligned but uncertified segment that is estimated to be several times larger than the labelled market. Both distinctions matter for measurement, for the credibility of the green label, and for the design of policy, because they determine whether capital is genuinely additional to what would have been invested anyway (Kölbel, Heeb, Paetzold, & Busch, 2020).

The co-evolution of instruments and institutions has been rapid. From the first labelled green bonds issued by development banks to establish the market, the segment has expanded to include sovereigns, municipalities, and a wide range of corporations, spanning many currencies and maturities. Certification schemes, taxonomies, and second-party opinions have multiplied, each intended to give investors confidence in the environmental credentials of the instrument. The economic function that all of these devices perform is to reduce the cost of conveying credible information about environmental quality, so that investors can direct capital toward projects they value and issuers can be rewarded for genuine environmental performance. In this sense, the green segment operates on the same logic as any differentiated market, in which information, verification, and trust determine how effectively capital is matched with objectives (Ehlers & Packer, 2017; Deschryver & de Mariz, 2020).

3. The Drivers of Green Investment

The growth of green investment is driven by forces on both the demand and the supply side of capital markets. On the demand side, the most fundamental driver is the growing recognition that climate change poses material financial risk. Institutional investors, as fiduciaries, increasingly treat climate risk as a risk-management issue rather than a purely ethical one. Krueger, Sautner, and Starks (2020) survey institutional investors and find that they perceive climate risks to be important, expect these risks to affect asset prices, and believe that the transition to a low-carbon economy presents significant investment opportunities as well as risks. This perception has been reinforced by the accumulation of scientific and economic evidence on the consequences of unmitigated climate change and by the policy momentum toward decarbonization.

Investor preferences constitute a second demand-side driver. A substantial literature documents that investors value sustainability for its own sake, independent of expected returns. Hartzmark and Sussman (2019) exploit a shock to the salience of sustainability ratings in the mutual fund market and show that investors reallocate flows toward funds

rated highly sustainable and away from those rated poorly, consistent with non-pecuniary motives. Amel-Zadeh and Serafeim (2018) find, in a global survey of investors, that environmental, social, and governance information is used primarily for client demand, risk management, and financial performance reasons, in addition to ethical considerations. These preferences, amplified by beneficiary pressure on pension funds and insurers, translate into persistent demand for green assets.

Regulation and policy constitute a third demand-side force. Taxonomies, disclosure requirements, and stewardship expectations push investors toward green assets, while public guarantees and blended finance pull private capital into projects that would otherwise struggle to attract funding. Choi, Gao, and Jiang (2020) show that investor attention to global warming affects the cross-section of stock returns, with stocks of carbon-intensive firms underperforming when attention rises, indicating that information and salience matter for how green preferences are expressed in prices. Sautner, van Lent, Vilkov, and Zhang (2023) develop firm-level measures of climate change exposure and show that exposure is priced, further confirming that climate considerations have entered the investment process.

On the supply side, the drivers include the falling cost of green technologies, the need of governments and corporations to finance the transition, and the development of instruments that make green finance feasible and attractive. Falling costs of renewables have improved the fundamentals of green projects, while the sheer scale of required transition investment creates demand for new financing structures. Issuers use green bonds not only to raise capital but also as a signal of environmental commitment, which can lower the cost of capital and improve access to financing (Flammer, 2021; Tang & Zhang, 2020). The interaction of these demand and supply forces has produced rapid growth, yet it also means that the trajectory of green investment is sensitive to policy credibility, to the persistence of investor preferences, and to the performance of green assets relative to conventional ones.

The supply response has also been shaped by the development of the instruments themselves and by the demonstration effects of early issuers. As green bonds and green funds have become larger and more liquid, the costs of issuance and of structuring green portfolios have fallen, and the market has attracted a broader base of issuers and investors. The increasing availability of green benchmark indices and of standard reporting frameworks reduces the fixed costs that initially deterred participation. The result is a virtuous cycle in which liquidity attracts participation and participation deepens liquidity. At the same time, the supply of genuinely green projects is ultimately constrained by the real economy, and the growth of green finance can outpace the growth of credible green investment opportunities, which is one reason why the quality of the underlying projects and the credibility of the label are central to the sustainability of the market (Flammer, 2021).

4. Pricing and Financial Performance of Green Assets

A central question in the green investment literature is whether green assets earn systematically different returns from their conventional counterparts. The evidence, summarized in Table 2, points to a nuanced answer. On the bond side, Zerbib (2019) uses a matching approach to estimate the yield differential between green and conventional bonds and finds a small negative premium: green bonds trade at slightly lower yields, implying lower borrowing costs for issuers and lower returns for investors, a result attributed to pro-environmental preferences. This negative premium, often called the "greenium," has been confirmed in a range of studies, although its magnitude varies with sample, certification, and liquidity.

Table 2. Selected empirical studies on green asset pricing and performance

Study	Asset / setting	Main finding
Zerbib (2019)	Green vs conventional bonds	Small negative green premium (-2bp), pro-environmental preferences
Baker et al. (2018)	US municipal green bonds	Green bonds priced at a premium, more heavily held by responsible investors
Flammer (2021)	Corporate green bonds	Green issuers improve environmental and financial performance post-issuance
Tang & Zhang (2020)	Corporate green bonds	Positive shareholder reaction at announcement; improved stock

		liquidity
Friede et al. (2015)	Meta-analysis (2000+ studies)	Most studies find positive or neutral ESG-performance relation
Renneboog et al. (2008)	SRI funds	No robust outperformance of SRI funds relative to conventional
Reboredo & Ugolini (2020)	Green bond / financial markets	Strong price connectedness; limited diversification benefits
Pástor et al. (2022)	Green vs brown stocks	Green assets outperform when climate concerns rise, but lower expected returns

On the equity side, the evidence is more mixed and more theory-dependent. Friede, Busch, and Bassen (2015) aggregate more than two thousand empirical studies and find that the large majority report a positive or at least non-negative relation between environmental, social, and governance performance and financial performance, although the relation is heterogeneous and the causal interpretation is contested. Studies of socially responsible funds, such as Renneboog, ter Horst, and Zhang (2008), generally fail to find robust outperformance, suggesting that any benefits of ethical screening may be offset by diversification costs or by the fact that green preferences are already priced. Baker, Bergstresser, Serafeim, and Wurgler (2018) find that US municipal green bonds are priced at a premium and are more heavily held by tax-exempt and responsible investors, consistent with a clientele effect.

The key insight of the modern literature is that the financial performance of green assets depends on the interaction of preferences with risk and information. Pástor, Stambaugh, and Taylor (2022) dissect green returns and show that green assets delivered high realized returns in recent years, but that this reflects unexpectedly strong increases in environmental concerns rather than high expected returns. In equilibrium, green assets have lower expected returns than brown assets, because investors enjoy holding them and because they hedge climate risk; they outperform only when environmental shocks occur. This logic has profound implications: a claim that green investing "pays" in realized returns is not evidence that green assets will continue to outperform, and the appearance of a green premium in prices may coexist with lower future expected returns. The distinction between realized returns and expected returns is therefore central to interpreting the evidence.

Reboredo and Ugolini (2020) examine the connectedness between green bonds and financial markets and find strong price linkages, which limits the diversification benefits that green bonds might otherwise offer, while also implying that green markets transmit shocks from other markets. Taken together, the pricing literature suggests that green assets trade at prices that reflect investor preferences and climate risk, that the green premium is real but modest and variable, and that the financial performance of green investment relative to conventional investment depends critically on the state of environmental concern and on expectations, rather than on a fixed "alpha." These findings have direct implications for investors, for the credibility of green products, and for the ability of green finance to channel capital at scale.

Two further considerations sharpen the interpretation of the pricing evidence. First, the green premium is not homogeneous: it varies with the credibility of certification, the liquidity of the instrument, and the segment of the market. Green bonds with independent verification tend to exhibit different premia from self-labelled bonds, and the premium can change sign and size in different conditions and markets. Second, the distinction between the primary and secondary markets matters, because the price at issuance and the subsequent trading price can differ, and the premium observed in one may not persist in the other. The modest and variable nature of the green premium implies both that green finance is not systematically costly for issuers and that investors cannot rely on a stable return advantage, which reinforces the expected-return logic of Pástor, Stambaugh, and Taylor (2022). These nuances matter for the practical use of green instruments and for the design of policy intended to encourage their adoption.

5. Climate Risk and the Portfolio Channel

Green investment is intimately connected to the management of climate risk in portfolios. Climate risk has two broad dimensions. Physical risk refers to the direct impact of climate events, such as storms, floods, and heat stress, on firms and assets. Transition risk refers to the financial impact of the shift to a low-carbon economy, including changes in policy, technology, and market preferences that can strand carbon-intensive assets. Both dimensions are relevant to asset pricing, and both create a role for green assets as hedges or as exposures to be managed. Hong, Li,

and Xu (2019) provide evidence that markets price climate risk incompletely, showing that firms in climate-exposed industries are affected by temperature anomalies in ways that are only partially incorporated into prices, indicating potential mispricing and opportunities for informed investors.

The portfolio channel operates through the construction of hedges. Andersson, Bolton, and Samama (2016) propose low-carbon index strategies that allow long-term investors to hedge climate risk by tilting toward low-carbon firms without sacrificing performance, arguing that such strategies reduce exposure to transition risk while maintaining broad market exposure. Engle, Giglio, Kelly, Lee, and Stroebe (2020) develop a climate change news factor and show that a portfolio can be constructed to hedge innovations in climate risk, providing a practical tool for institutional investors seeking climate hedges. The option market also reveals the pricing of climate risk: Ilhan, Sautner, and Vilkov (2021) show that carbon tail risk is priced in the equity option market, with out-of-the-money put options of carbon-intensive firms trading at a premium, consistent with investors demanding compensation for the risk of adverse climate-policy shocks.

The carbon-risk premium documented by Bolton and Kacperczyk (2021) reinforces these findings. They show that firms with higher carbon emissions earn higher stock returns, consistent with investors demanding compensation for carbon risk, and that this effect is concentrated in emission levels rather than emission intensities. Choi, Gao, and Jiang (2020) complement this evidence by showing that stocks of carbon-intensive firms underperform when investor attention to global warming rises, indicating that green preferences are expressed through information channels that vary over time. Together, these studies establish that climate risk is priced in equity, bond, and option markets, and that green assets provide a channel through which investors can adjust their exposure to that risk.

The implications for green investment are twofold. First, green assets can serve as hedges against transition risk, which is one reason why long-term investors hold them even if their expected returns are lower. Second, because climate risk is priced imperfectly and attention varies over time, green assets can also offer speculative opportunities related to the evolution of environmental concern. Both roles are consistent with the equilibrium logic of Pástor, Stambaugh, and Taylor (2021, 2022), in which green assets provide insurance against climate risk and deliver high returns when environmental concerns strengthen. The practical consequence is that green investment is not merely an ethical preference but a component of rational portfolio construction in a world where climate risk is material and increasingly priced.

The portfolio implications of climate risk go beyond the construction of hedges. Because climate risk is priced incompletely and evolves over time, investors face a dynamic asset-allocation problem in which the optimal exposure to green assets depends on expectations about policy, technology, and environmental concern. The evidence that attention to climate risk varies over time, and that this variation is reflected in returns (Choi, Gao, & Jiang, 2020), implies that a static allocation to green assets is unlikely to be optimal; active management of climate exposure, or exposure through instruments that are explicitly designed to hedge climate risk, may be preferable. At the same time, the pricing of carbon tail risk in options markets (Ilhan, Sautner, & Vilkov, 2021) shows that sophisticated investors can obtain protection against extreme climate outcomes, which is directly relevant to the risk management of portfolios containing carbon-intensive assets. The development of climate risk data and of instruments for transferring and hedging that risk is therefore an active frontier of green finance.

6. ESG Ratings, Data, and Measurement

The functioning of green markets depends on information about the environmental quality of assets, and that information is largely supplied by ESG ratings and disclosure. Yet the ESG data infrastructure is characterized by substantial disagreement among rating agencies about how to measure sustainability. Berg, Kölbel, and Rigobon (2022) quantify this divergence using data from six major rating agencies and find that the correlation among their ratings is only moderate, far lower than the correlation among credit ratings. They decompose the disagreement into differences in scope, measurement, and weights, showing that all three contribute and that measurement differences are particularly important. Table 3 summarizes the main dimensions along which ESG data and ratings diverge.

Table 3. Dimensions of ESG data and ratings divergence

Dimension	Description	Consequence
Scope	Agencies assess different attributes	Ratings capture different concepts
Measurement	Different proxies for the same attribute	Large, poorly understood divergence
Weights	Different aggregation of E, S, G	Correlation of aggregates only moderate
Disclosure	Voluntary, heterogeneous reporting	Disclosure can amplify disagreement
Outcome vs input	Outcome metrics diverge more than policies	Harder to measure actual impact
Data gaps	Missing data across firms and markets	Biased or noisy ratings

The consequences of rating divergence extend beyond measurement. Christensen, Serafeim, and Sikochi (2022) show that ESG rating disagreement is associated with higher return volatility, larger absolute price movements, and a lower likelihood of issuing external financing, indicating that disagreement imposes real costs on firms and investors. Gibson Brandon, Krueger, and Schmidt (2021) find that stocks with greater ESG rating disagreement earn lower returns, consistent with divergence being priced as an information risk or a source of investor uncertainty. These findings imply that the quality and harmonization of ESG data are not merely technical concerns but are central to the credibility and efficiency of green markets.

Disclosure plays an ambivalent role. On the one hand, disclosure is essential to give investors the information they need to direct capital to green activities. On the other hand, because disclosure is voluntary, heterogeneous, and unstandardized, it can amplify rather than resolve disagreement. Christensen, Serafeim, and Sikochi (2022) find that ESG disclosure generally exacerbates rating disagreement rather than resolving it, because more information reveals more room for different interpretations. This finding underscores the importance of standardization, and it motivates the current regulatory push, epitomized by the ISSB climate disclosure standards and the EU taxonomy, toward common definitions and mandatory, comparable reporting (Amel-Zadeh & Serafeim, 2018).

The measurement challenge is compounded by the fact that environmental impact is intrinsically difficult to observe. Unlike financial performance, which is anchored in audited accounts, environmental performance often requires estimating emissions, resource use, and forward-looking risks from imperfect data. Outcome metrics diverge more than input or policy metrics, precisely because they require more judgement (Berg, Kölbel, & Rigobon, 2022). This has two implications for green investment. First, investors cannot fully rely on ratings alone and must engage with underlying data and methodologies. Second, the credibility of the green label depends on verification and assurance, which remain uneven across markets and instruments. The evolution of a more robust ESG data infrastructure is therefore a precondition for green investment to scale without compromising its integrity.

The practical consequence of measurement problems is that ESG ratings should be treated as noisy signals rather than precise measures, and that investors cannot simply delegate environmental assessment to a single rating. The divergence documented by Berg, Kölbel, and Rigobon (2022) means that two funds claiming green status may hold portfolios that overlap only partially and that differ in environmental quality. This weakens the comparability of green products and complicates the measurement of the aggregate scale and impact of green investment. It also creates opportunities for informed investors who understand the underlying data and methodologies, but it raises the bar for the credibility of the green label. The direction of travel, toward standardized disclosure and assurance, is intended to address these problems, but the transition to a fully harmonized data infrastructure is likely to be gradual, and in the meantime investors must exercise judgement rather than relying on ratings alone.

7. Investor Behaviour and the ESG-Efficient Frontier

The behaviour of investors, and the equilibrium that their preferences create, lies at the heart of green asset pricing. Pástor, Stambaugh, and Taylor (2021) develop an equilibrium model in which investors have heterogeneous ESG preferences and green assets hedge climate risk. In their framework, green assets have lower expected returns than brown assets because investors value holding them and because they provide insurance, but green assets outperform when positive shocks to ESG concerns occur, such as new information about climate risk. The model delivers a clean

set of predictions about the green factor and about when green assets earn high returns, and it provides a theoretical benchmark against which the empirical evidence can be interpreted.

This framework reframes the classic tension between diversification and values. Pedersen, Fitzgibbons, and Pomorski (2021) introduce the concept of the "ESG-efficient frontier," which extends the mean-variance framework to incorporate investor preferences over ESG scores. In their model, investors choose portfolios that trade off expected return, risk, and ESG, and the efficient frontier shifts depending on the investor's ESG preference. A key insight is that the tangency portfolio depends on the extent to which investors value ESG, so that a higher ESG preference does not necessarily imply lower financial performance; it implies a different risk-return-ESG trade-off. This reconciles, in principle, the observation that green preferences are widespread with the evidence that green assets have lower expected returns.

The behavioural evidence is consistent with this framework. Hartzmark and Sussman (2019) show that investors value sustainability and act on it, with large net flows into high-sustainability funds, but find no evidence that high-sustainability funds outperform, consistent with the equilibrium prediction that the premium is already priced. The response of investor attention to climate shocks, documented by Choi, Gao, and Jiang (2020), fits the model's emphasis on time-varying environmental concern as a driver of green returns. The factor structure of green returns, which Pástor, Stambaugh, and Taylor (2022) relate to a green factor that explains the recent underperformance of value stocks, suggests that green investing is best understood within a factor framework that distinguishes exposure to environmental concern from exposure to traditional risk factors such as those in the Fama and French (2015) five-factor model.

Several implications follow for practitioners and researchers. First, the expected-return penalty of green investment is a consequence of preferences, not a failure of the market; investors who value sustainability should expect to pay for it in lower expected returns, even as they receive non-pecuniary benefits and insurance value. Second, realized outperformance of green assets in a given period is not evidence of persistent alpha but may reflect shocks to environmental concern. Third, the ESG-efficient frontier provides a coherent way to think about portfolio construction that respects both financial objectives and values. These conclusions do not imply that green investing is misguided; they imply that its benefits must be assessed in terms of the full utility of investors, including preferences and risk management, rather than in terms of returns alone.

8. Green Investment and Corporate Behaviour

Green investment affects the real economy not only by financing projects directly but also by changing the incentives and behaviour of firms. The availability of green finance gives firms an additional channel through which to fund environmental investments, and the pricing of green assets transmits investor preferences back to corporate decisions. Flammer (2021) studies corporate green bonds and finds that firms issue green bonds to signal their environmental commitment and that, following issuance, firms improve their environmental performance, including reductions in carbon emissions, as well as their financial performance and attractiveness to green investors. This suggests that the green label is not purely cosmetic but is associated with real changes in corporate behaviour.

Tang and Zhang (2020) examine the shareholder-value implications of green bond issuance and find positive announcement returns, indicating that investors react favourably to green issuance, and improvements in stock liquidity, suggesting that green bonds attract a broader investor base and reduce information asymmetry. The signalling and financing effects of green bonds are mutually reinforcing: by committing to use-of-proceeds reporting and certification, firms reduce the cost of conveying their environmental quality to investors, which can lower their cost of capital and improve access to financing (Flammer, 2021; Tang & Zhang, 2020).

The broader foundations of corporate social and environmental behaviour are analysed by Liang and Renneboog (2017), who show that corporate social responsibility is shaped by legal origins and institutional factors, indicating that the propensity of firms to engage in environmental behaviour is influenced by the environment in which they operate. The increasing pricing of climate exposure, documented by Sautner, van Lent, Vilkov, and Zhang (2023), gives firms an additional incentive to reduce their carbon footprint, because lower exposure is rewarded with a lower cost of capital. In this way, green investment, by making environmental performance financially relevant, creates market-based incentives that complement regulation and policy in steering the transition to a low-carbon economy.

At the same time, the effect of green investment on corporate behaviour is conditional on the credibility of the green label and on the additionality of the capital. If green finance merely relabels investment that would have occurred anyway, its impact on the real economy is limited; if it genuinely lowers the cost of capital for green projects and raises it for brown ones, it can accelerate the transition (Kölbel, Heeb, Paetzold, & Busch, 2020). The empirical

evidence on additionality is still developing, and it points to the importance of design: certification, use-of-proceeds verification, and the strictness of the standards governing what qualifies as green all determine whether green capital is truly additional. This links the microeconomics of corporate behaviour to the macro-level credibility of the green finance architecture.

The integration of ESG preferences into the investment process also raises questions about fiduciary duty and about the governance of institutional investors. Whether a pension fund or insurer may or should incorporate environmental considerations, and how those considerations interact with the obligation to pursue financial returns, depends on the legal and regulatory framework as well as on the preferences of beneficiaries. The equilibrium view, in which green assets have lower expected returns, implies that a fiduciary that prioritizes sustainability is effectively trading financial returns for non-pecuniary benefits, which some frameworks permit and others constrain. The resolution of these questions will shape the scale of institutional green investment, because institutions manage a large share of the capital that could be directed to green assets, and their mandates determine how much of that capital is available. The academic framework provides a useful language for these debates by clarifying the trade-offs and by distinguishing the financial from the non-pecuniary components of green returns (Pástor, Stambaugh, & Taylor, 2021).

9. Policy, Regulation, and Market Development

The development of green markets has been shaped, to an unusual degree, by policy. Because the environmental benefits of green investment are largely external to private investors, markets alone may under-provide green capital, and policy intervenes through several channels. The first is the definition of what counts as green. Taxonomies, such as the EU taxonomy and the Climate Bonds Initiative standard, provide a common language that reduces confusion and greenwashing and gives investors a basis for allocating capital (Ehlers & Packer, 2017; Deschryver & de Mariz, 2020). The second channel is disclosure and transparency. Mandatory climate disclosure, assurance, and standards such as the ISSB framework aim to improve the quality and comparability of the information that underpins green investment (Amel-Zadeh & Serafeim, 2018).

The third channel is the direct promotion of green finance through public institutions. Green bonds issued by development banks, central-bank facilities, and sovereign issuers help to establish the market and provide benchmarks and liquidity. Blended finance, in which public or philanthropic capital absorbs part of the risk of green projects, can mobilize private capital for projects in sectors and countries that would otherwise be underserved. Guarantees and concessional instruments reduce the risk premium demanded by private investors and can make green projects financially viable. These instruments are particularly important for adaptation and for green projects in emerging markets, where the risk-adjusted returns may be insufficient to attract private capital on their own.

The fourth channel is prudential and supervisory policy. Central banks and supervisors increasingly recognize climate risk as a source of financial vulnerability and are incorporating climate considerations into stress testing, disclosure expectations, and the management of their own portfolios. The Network for Greening the Financial System coordinates these efforts internationally. While there is debate about the appropriate role of central banks in climate policy, the prudential channel reinforces the demand for green assets by making climate risk a supervisory concern and by clarifying that environmental performance is relevant to the safety and soundness of financial institutions.

Table 4 summarizes the main categories of policy instruments used to develop green finance. The effectiveness of these instruments depends on their coherence and credibility. Fragmented or inconsistent standards can create arbitrage opportunities and undermine the green label, while credible and harmonized frameworks can reduce greenwashing and lower the cost of capital for green projects (Deschryver & de Mariz, 2020). The interaction between public and private provision is therefore central to the trajectory of green investment.

Table 4. Policy and regulatory instruments for green finance

Instrument	Examples	Objective
Taxonomies	EU taxonomy, CBI standard	Define eligible green activities
Disclosure standards	ISSB climate standard, TCFD	Improve information and comparability
Public issuance	Sovereign and development-bank green bonds	Establish market, provide benchmarks
Blended finance	Guarantees, concessional capital	De-risk projects, mobilize private capital
Prudential policy	Climate stress testing, disclosure	Internalize climate risk in supervision
Incentives	Tax preferences, subsidies, green deposit schemes	Lower the cost of green finance

10. Challenges: Greenwashing, Fragmentation, and Emerging Markets

Despite its growth, green investment faces persistent challenges that constrain its scale and threaten its credibility. The most visible is greenwashing: the risk that assets are labelled green without delivering corresponding environmental benefits, or that the label is used to divert attention or capital without genuine impact. Greenwashing arises because environmental performance is difficult to observe and verify, because standards are voluntary and fragmented, and because issuers have incentives to present themselves favourably. Deschryver and de Mariz (2020) identify the deficit of harmonized global standards and the risk of greenwashing as central barriers to the scalability of the green bond market. The credibility of green investment therefore depends on verification, assurance, and the enforcement of standards, none of which is fully developed.

A second challenge is the fragmentation of standards and definitions. Because taxonomies, certification schemes, and disclosure requirements differ across jurisdictions and markets, the same activity can be classified differently, and green assets can be incomparable. Fragmentation raises transaction costs, creates regulatory arbitrage, and complicates the construction of diversified green portfolios. It also undermines the informational value of the green label, because investors cannot be confident that "green" means the same thing across markets. The ongoing convergence toward international standards, exemplified by the ISSB and by efforts to align the EU and Chinese taxonomies, addresses this challenge, but the process is slow and uneven.

A third challenge is the uneven development of green markets, particularly in emerging economies. Most green issuance and investment is concentrated in advanced economies, and the projects most in need of transition finance, such as coal-dependent power systems and adaptation in vulnerable countries, are often the least served by private green capital. The risk is that green finance develops where it is easiest rather than where it is most needed, and that the transition exacerbates rather than reduces inequality in access to capital. Addressing this requires blended finance, technical assistance, and the development of local markets, all of which are priorities for policy but are difficult to scale quickly.

A fourth challenge concerns the measurement of impact and additionality. Even with credible labels, it is difficult to determine whether green investment is additional, that is, whether it finances projects that would not have been financed otherwise. If much green finance merely relabels existing investment, its environmental contribution is limited, even if it is genuine in intent. Kölbel, Heeb, Paetzold, and Busch (2020) review the mechanisms through which sustainable investing can affect the real economy and conclude that the dominant mechanisms, such as engagement and the reduction of the cost of capital for green firms, have limited and conditional effects, and that the additionality of divestment-based strategies is weak. The implication is that green investment is most effective when combined with engagement, standards, and regulation, rather than relying on portfolio tilts alone.

Finally, the informational challenges documented in Section 6 compound these problems. Divergent ESG ratings and incomplete data mean that even well-intentioned investors struggle to identify genuinely green assets (Berg, Kölbel, & Rigobon, 2022; Christensen, Serafeim, & Sikochi, 2022). The result is that green investment, in its current form, carries a measure of uncertainty about its environmental credentials that is difficult for individual investors to resolve. This is not an argument against green investment but an argument for the importance of measurement, standardization, and verification as complements to the growth of the market.

A further structural challenge is the interaction between green finance and the broader financial cycle. Green markets

can be susceptible to herding and to swings in investor sentiment, and the same attention dynamics that drive green outperformance in favourable periods can produce sharp corrections when environmental concern recedes or when the promised environmental benefits fail to materialize. The relative youth of the market, the uneven quality of data, and the dependence of some green instruments on policy support make the segment more exposed than mature markets to revisions in expectations. Building resilience therefore requires not only better standards and verification but also a diversified investor base and a realistic understanding of the expected-return profile of green assets. The future of green investment depends on whether it can retain credibility through the normal business cycle and through episodes of disappointment, and that will be determined as much by governance as by the underlying environmental benefits.

11. Future Directions

The future trajectory of green investment will be shaped by the evolution of several interacting forces. The first is the continued growth and institutionalization of the green asset base. As green bonds, green equities, and green funds become larger and more liquid, they are likely to attract a broader and more conventional investor base, reducing the premium required for green assets and deepening the market (Giglio, Kelly, & Stroebe, 2021). The second is the convergence and strengthening of standards. If taxonomies and disclosure requirements converge internationally, the credibility and comparability of the green label will improve, lowering the cost of green finance and reducing greenwashing.

The third force is the evolution of measurement. Advances in data availability, satellite monitoring, and machine learning may improve the measurement of emissions and environmental impact, reducing rating divergence and enabling more precise allocation of capital. The fourth is the deepening of the academic understanding of green asset pricing. As more is learned about the expected-return logic of green assets and about the factors that drive green returns, the design of green products and of policy can be improved (Pástor, Stambaugh, & Taylor, 2021, 2022). The fifth is the policy trajectory itself. The credibility and ambition of climate policy, including carbon pricing and disclosure mandates, will determine the speed of the transition and hence the demand for and return to green capital (Stroebe & Wurgler, 2021).

Several open questions will define the research agenda. What is the magnitude and persistence of the green premium across markets and instruments? How can additionality be measured reliably? What are the real effects of green investment on emissions and on the speed of the transition? How should the ESG-efficient frontier be integrated into institutional mandates and fiduciary frameworks? And how can green finance be extended to emerging markets and to the hard-to-abate sectors where it is most needed? The answers will require the combination of better data, sharper theory, and careful empirical work, and they will shape the practical design of green investment for years to come.

The long-run significance of green investment will depend less on the growth of any single instrument than on whether the financial system as a whole learns to price environmental externalities and to allocate capital consistently with the transition to a sustainable economy. In that sense, green investment is not a separate segment of finance but a test of whether financial markets can incorporate a major, slowly evolving risk into their operations. The developments reviewed in this paper suggest that the test is being taken seriously by investors, firms, and regulators, but that its outcome remains uncertain and will depend on the credibility of measurement and the coherence of policy.

12. Conclusion

Green investment has grown from a niche into a substantial and growing component of global capital markets. This paper has reviewed the instruments through which green capital is channelled, the drivers of demand and supply, the evidence on pricing and performance, and the measurement, policy, and credibility challenges that accompany the growth of the segment. Three conclusions emerge. First, a diverse set of instruments now allows capital of many types to participate in green finance, but the credibility of the green label depends on standards, verification, and measurement that remain incomplete. Second, the financial performance of green assets is determined by the interaction of investor preferences with climate risk and expectations, rather than by a fixed relation between sustainability and returns; green assets have lower expected returns when preferences are strong, but can outperform when environmental concerns strengthen. Third, green investment can affect corporate behaviour and contribute to the transition, but its real-world impact depends on additionality, which in turn depends on the strictness of standards and the effectiveness of engagement and regulation.

The implications for investors, firms, and policymakers follow directly. For investors, green investment offers a means of aligning portfolios with values and of managing climate risk, but its benefits must be assessed in terms of

preferences and risk management as well as returns, and its credibility depends on engagement with the quality of data and standards. For firms, green finance provides a channel to fund the transition and to signal environmental commitment, with measurable benefits documented in the empirical literature. For policymakers, the challenge is to provide the definitions, disclosure, and verification that make the green label credible, and to extend green finance to the sectors, countries, and projects where it is most needed. If these elements are aligned, green investment can mobilize capital at the scale required for the transition to a low-carbon economy; if they are not, the growth of green markets may outpace their integrity. The balance is not fixed by technology or preferences alone but by the institutions, standards, and policies that channel them, and the coming decade will reveal which path is taken.

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Authors' contributions

I am fully responsible for the entire manuscript.

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