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ABSTRACT

We study biodiversity finance—the use of private capital to finance biodiversity conservation and restoration—which is a new practice in sustainable finance. First, we provide a conceptual framework that lays out how biodiversity can be financed by pure private capital and blended financing structures. In the latter, private capital is blended with public or philanthropic capital, whose aim is to de-risk private capital investments. The main element underlying both types of financing is the "monetization" of biodiversity, that is, using investments in biodiversity to generate a financial return for private investors. Second, we provide empirical evidence using deal-level data from a leading biodiversity finance institution. Our findings are consistent with a three-dimensional efficient frontier (return, risk, and biodiversity impact)—deals with a favorable risk-return profile tend to be financed by pure private capital, whereas for other deals the biodiversity impact needs to be sufficiently large for blended finance to be used. Overall, our results suggest that blended finance is an important tool for improving the risk-return profile of these projects, thereby increasing their appeal to private investors and crowding in private capital. Finally, our results suggest that private capital is unlikely to substitute for effective public policies in addressing the biodiversity crisis.

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1. Introduction

Biodiversity loss is one of the grand challenges our society is facing. A recent study by the WWF (2022) reports an average 69% decline in global populations of mammals, fish, birds, reptiles, and amphibians since 1970, referring to the current situation as a "code red" alert for humanity (p. 6). The loss of biodiversity represents an existential threat to the global economy, as more than half of the world's GDP is dependent on nature and the services it provides (United Nations, 2022). Moreover, the climate and biodiversity crises are deeply intertwined. Meeting the goals of the Paris Climate Agreement depends on the successful conservation, restoration, and management of biodiversity (United Nations, 2022).[1] In short, protecting biodiversity is critically important and urgent—it is important for the planet, our health and well-being, as well as the world's economy.

Biodiversity provides many services to humans.[2] These include stabilizing the climate, enhancing food supplies, contributing to the development of medicines, providing recreational value, and strengthening a person's spiritual life, among many others. Most of these services are provided as public goods. That is, their consumption is non-rival, as they are available to everyone in a particular region and those unwilling to pay cannot be excluded from consuming the public good. A long-standing literature in public economics shows that the efficient provision of public goods is challenging, as the free-rider problem, along with the preference revelation problem, have proven hard to overcome (e.g., Dasgupta, 2021; Heal, 2000). In a nutshell, the key challenge is that self-interested individuals prefer to consume the public good without paying for it, and it is

[1] The importance and urgency of biodiversity conservation is stressed, e.g., by the United Nations' Biodiversity Finance Initiative (BIOFIN), the Taskforce on Nature-related Financial Disclosures (TNFD), as well as numerous other organizations and forums such as the Conference of the Parties to the UN Convention on Biological Diversity (COP 15).

[2] Biodiversity is a measure of the variability that exists in "living" natural capital, and hence represents a feature of natural capital. Natural capital can be defined as "the world's stocks of natural assets, which include geology, soil, air, water and all living things" (World Forum on Natural Capital, 2021).

difficult to persuade them to reveal how much they are willing to pay, as they realize that what they respond will influence how much they will be required to pay. This free-rider problem also implies that biodiversity as a public good is likely undervalued and underprovided. Despite these obstacles, there are frameworks within which we can hope to mitigate these challenges and enhance biodiversity protection.

Potential solutions to preserve and restore biodiversity include i) *intergovernmental measures* such as the Convention on Biological Diversity (CBD) and other global treaties, ii) *government measures* that aim to regulate the quantity of natural capital (e.g., by establishing protected areas, introducing technology standards, or adopting cap-and-trade programs) and the price of natural capital (e.g., through tax incentives and subsidies that encourage more sustainable production or consumption patterns), and iii) *biodiversity finance*, that is, the use of private capital to finance biodiversity conservation and restoration. While intergovernmental and governmental mechanisms play an important role in the public provision of biodiversity (e.g., Barrett, 2022), the implementation of these mechanisms is not without challenges (e.g., Dasgupta, 2021), which calls for other ways to help protect biodiversity.

In this regard, biodiversity finance is gaining momentum in practice and public policy. Yet, many investors feel underinformed about the risks and opportunities related to biodiversity (World Economic Forum, 2023). Similarly, academic research on biodiversity finance remains nearly nonexistent, as highlighted by Karolyi and Tobin-de la Puente's (2023) recent call for research in biodiversity finance. As they note, "there are no studies in the top tier journals in Finance that have framed the risks related to biodiversity loss, how those risks might be priced, or how the private financing flows need to be intermediated" (p. 1). This research gap was further echoed in Laura Starks' Presidential Address at the 2023 American Finance Association Meetings (Starks, 2023).

It is likely due to both i) a lack of awareness on how private capital can contribute to biodiversity conservation and restoration, and ii) a lack of data on biodiversity finance.

Our study aims to fill this gap by i) introducing a conceptual framework that lays out how private capital can contribute to biodiversity conservation, and ii) providing first evidence on biodiversity finance. In doing so, we aim to lay the ground and stimulate future research on biodiversity finance.

First, our conceptual framework lays out how biodiversity conservation can be financed by i) pure private capital and ii) blended finance. In the latter, private capital is "blended" with public or philanthropic capital, whose aim is to subsidize and de-risk private capital investments. The main element underlying both types of financing is the "monetization" of biodiversity, that is, using investments in biodiversity to generate a financial return for private investors. This monetization comes in different flavors—for example, the preservation of pollinators (such as bees, beetles, and butterflies) can enhance the farmland's productivity and hence improve the farmers' profits; the preservation of forest ecosystems generates carbon credits that can be sold for a profit; their preservation may also attract ecotourists and hence increase the income of local hotels and tour guide services; the protection of coastal ecosystems (e.g., mangroves) improves the habitat for fishes and other species, which can benefit local fisheries; their protection may also serve as a natural defense against flooding, thereby increasing real estate values around the protected area—and provides a direct mechanism through which biodiversity conservation projects can attract private capital.

A challenge with these monetization mechanisms is that the financial returns may not be high enough and/or they might be considered too risky to attract private investors. Their risk-return profile can be enhanced by using blended finance structures, in which philanthropic or public funding is used to subsidize and de-risk private capital. To characterize the underlying economics, we develop a simple portfolio selection model with mean-variance investors and a set of projects that differ based on their biodiversity impact. We assume that private capital can be blended with concessionary capital, such that an increase in the degree of blending raises the expected return and lowers the variance of the returns of the project, without affecting the level of biodiversity impact. In this setup, we show that the blending helps expand the efficient frontier to allow projects with a higher biodiversity impact to be part of the efficient set. Intuitively, blended finance is attractive for projects that have high biodiversity impact and whose risk-return profile can be "pushed" to a level that appeals to private investors. In an extension, we further formalize the possibility that biodiversity investments face higher ambiguity (Knightian uncertainty) due to the lack of familiarity with the monetization mechanisms of biodiversity conservation and/or the lack of track record of biodiversity investments. In this setup, the higher ambiguity of biodiversity investment induces a need for "fact-finding" (e.g., running pilot programs or establishing proof of concept) that can be financed by concessionary capital in blended financing structures. In this setup, the higher the ambiguity the higher the attractiveness of blended finance.

Second, we empirically examine this new asset class. To do so, we obtained access to the proprietary database of a recognized leader in biodiversity finance, which we refer to as "Biodiversity Investment Manager" (BIM) for confidentiality reasons. This database covers the 33 biodiversity finance deals that were closed by BIM between 2020 and 2022. For each deal, the database provides detailed information about the underlying biodiversity project, the expected biodiversity impact, the deal structure, the expected financial return (IRR), and the financial risk of the project.

Our analysis of these biodiversity deals provides several insights. First, we observe that about 60% of the deals are financed by pure private capital, while the remaining 40% are blended finance deals. This underscores the importance of both forms of financing. Second, the deals that have a higher expected financial return tend to be financed by pure private capital (on average, their expected IRR is 15%, compared to 12% for blended finance deals). Their scale is smaller, however, and so is their expected biodiversity impact. For larger-scale projects with a more ambitious biodiversity impact, blended finance is the more prevalent form of financing. While these projects have lower expected returns than those funded by pure private capital, they are also less risky (as measured by the potential deviation from the expected IRR). This suggests that the blending—and the corresponding de-risking of private capital—is an important tool for improving the risk-return tradeoff of these projects, thereby increasing their appeal to private investors. Overall, our findings point toward a tradeoff between financial returns and biodiversity impact, with implications for the type of financing. Profitable projects can be viably financed by pure private capital but tend to have lower biodiversity impact. Projects with higher biodiversity impact tend to be less profitable but can nevertheless appeal to private investors through blending. As such, our results suggest the existence of a three-dimensional "risk-financial return-biodiversity return frontier," which is in line with our conceptual framework. Moreover, we show that a significant fraction of the blended finance deals uses concessionary funding to finance fact-finding, which underscores the appeal of using blended finance structures for biodiversity projects with higher ambiguity.

Finally, BIM also granted us access to information on biodiversity projects that were under consideration for inclusion into their portfolios but were ultimately discarded. Compared to the projects that made it to the portfolio stage, these projects tend to be less profitable and have lower biodiversity impact to begin with. This suggests that i) a certain risk-return threshold needs to be met for the deal to appeal to private investors, and ii) the biodiversity impact needs to be sufficiently favorable for blended finance to be applicable. These findings offer additional insights into the three-dimensional frontier. They indicate that, while blended finance can help finance projects with higher biodiversity impact, such financing structures are unlikely to be considered if the investment's initial risk-return profile is too unfavorable. In other words, for a given biodiversity impact, the (pre-blending) risk-return tradeoff needs to meet a certain threshold for blended finance to be effective in "pushing" it to a level that would be attractive to private investors. Moreover, these findings indicate that private capital (either as standalone or in blended form) is unlikely to provide a silver bullet against the biodiversity crisis, but can nevertheless be a useful addition to the toolbox. Arguably, while private investing can help close the financing gap and contribute to the conservation and restoration of biodiversity, it is unlikely to substitute for the implementation of effective public policies.

Naturally, we caution that our results are obtained from a small sample of biodiversity deals. Given the lack of data on biodiversity deals (Karolyi and Tobin-de la Puente, 2023), we see this evidence as a first step in understanding biodiversity finance. Our hope is that, as biodiversity finance grows, new datasets will become available that will allow researchers to shed additional light on this new asset class.

This study makes several contributions to the academic literature. First, by exploring how private investing can contribute to the protection of biodiversity, it adds to the sustainable finance literature whose focus has been primarily on climate finance (e.g., Bolton and Kacpercyk, 2021, 2023; Flammer, 2021; Hong et al., 2020; Ilhan et al., 2023; Krueger et al., 2020; Pastor et al., 2022; Sautner et al., 2023). Second, our work contributes to the environmental economics literature that studies the economics of biodiversity conservation (Dasgupta, 2021; Heal, 2003, 2004, 2020), and the public provision of this public good through intergovernmental and governmental mechanisms (e.g., Barrett, 2022). Third, our study aims to spur follow-up work on the financing of biodiversity, in keeping with the initial effort of Karolyi and Tobin-de la Puente (2023), as well as the *Review of Finance*'s recent call for research proposals for an upcoming special issue on biodiversity and natural resource finance. Fourth, our study relates to the work by Coqueret et al. (2025), Garel et al. (2024), Giglio et al. (2023), and Xiong (2023), who examine how biodiversity risks affect equity prices.

The remainder of this paper is organized as follows. Section 2 provides a conceptual framework that lays out how private capital can contribute to biodiversity protection taken into account the public good nature of biodiversity. Section 3 describes the data and presents the results. Section 4 compares biodiversity finance versus impact finance. Finally, Section 5 concludes and discusses avenues for future research.

2. Private investing in natural capital—a conceptual framework

Historically, the conservation and restoration of biodiversity has been primarily financed through public funding and private philanthropic giving. Various public funding instruments are used to finance biodiversity conservation, including debt-for-nature swaps, official development assistance (ODA), sovereign biodiversity bonds (e.g., sovereign ocean bonds, rhino bonds, and others), payments for ecosystem services (PES), and biodiversity offsets, among others. Private philanthropic donors include environmental nonprofit organizations such as the Environmental Defense Fund (EDF), The Nature Conservancy (TNC), and the World Wildlife Fund (WWF), among others.[3]

[3] For more information about public funding instruments, see Deutz et al. (2020), OECD (2020), and Tobin-de la Puente and Mitchell (2021).

Despite the use of public funding and private philanthropic giving, a large financing gap for the protection of biodiversity remains. TNC estimates a $722-967 billion per year of additional financing that is needed to close the financing gap and effectively address the biodiversity crisis (TNC, 2020). With the aim of closing this financing gap, a new practice has emerged in recent years: private investments in natural capital. While still in its infancy, private investing in natural capital is a rapidly growing, yet not well-understood financing mechanism. Importantly, it raises puzzling questions: a) *how can the conservation and restoration of biodiversity yield financial returns to investors?* and b) *to the extent that this financial return is not competitive enough to attract capital from private investors, how can one design financial products that would nevertheless be of appeal to them?* In what follows, we provide conceptual arguments that guide the answer to these questions. In doing so, we describe how biodiversity protection can be "monetized" through the bundling of public and private goods, and characterize the financing structures that can be used to leverage these monetization mechanisms and ultimately appeal to private investors.

2.1. Monetization mechanisms

From the private capital market's perspective, it is critical to understand how the conservation and restoration of biodiversity can yield financial returns for investors. Typically, monetization mechanisms would include the transformation of natural capital (e.g., logging and mining). Yet, in the case of biodiversity finance, revenues need to be generated from *protecting* as opposed to transforming natural capital. While this question may seem puzzling at first, generating financial returns from biodiversity conservation is feasible—it requires the bundling of biodiversity with private goods whose value it enhances (Heal, 2003, 2004).

To name a few examples, the protection of natural parks, wildlife, and coral reefs can increase income from ecotourism and the value of real estate around the protected area. Sustainable agriculture and fisheries can enhance the local communities' revenues by both increasing productivity (e.g., through improved soil fertility, increase in pollinators, prevention of overfishing) and the prices that can be charged for biodiversity-friendly products. The protection of coastal ecosystems and green infrastructures in urban areas helps prevent flooding and damages to private (and public) property from climate events. Also, given that biodiversity helps nature absorb emissions—providing so-called nature-based solutions to climate change—its protection allows the relevant actors (such as investors and corporations) to earn carbon credits. Table 1 provides a more systematic overview of the different types of natural capital assets, along with the corresponding monetization mechanisms.

------ Insert Table 1 about here ------

Private investments in biodiversity span all types of natural capital assets. As an illustration, Table A1 of the Online Appendix provides examples of biodiversity funds by natural capital asset types.

2.2. Types of financing

2.2.1. Pure private capital and blended finance

Private investments in biodiversity can be grouped into two broad categories: pure private capital and blended finance. The former is akin to investing private capital in traditional asset classes. In the latter, private capital is blended with public or philanthropic capital, whose aim is to subsidize and de-risk private capital investments.

In both cases, private investors can gain i) direct financial returns from their investments in natural capital, ii) indirect financial returns from gaining biodiversity or carbon credits from their investments in natural capital, and iii) non-financial biodiversity returns (from their investments' biodiversity impact).

The direct financial returns are the monetary gains that are directly generated by their investments in natural capital and ecosystem services. Given the bundling of biodiversity with private goods, these direct financial returns are obtained through the monetization mechanisms described in Section 2.1.

In addition to the direct financial returns, investors may also benefit from indirect financial returns in the form of biodiversity credits from their investments in natural capital. Moreover, as biodiversity plays an important role in reducing carbon emissions, the protection of biodiversity can generate carbon credits, which further improves the attractiveness of such investment for investors who aim to fulfill their carbon pledges. Both biodiversity and carbon credits are commonly used in biodiversity finance.[4]

While traditional investors may only value their investments' (direct and indirect) financial returns, other investors—so-called "impact investors"—also value the non-financial returns gained from their investments.[5] In this regard, investments in the conservation and restoration of biodiversity yields non-financial "biodiversity returns" that can also appeal to private investors.

In the case of blended financing structures, the blending of private capital with public or philanthropic funding aims to improve the risk-return tradeoff faced by private investors, and hence increase the appeal of these investments to private investors. In what follows, we discuss the de-risking mechanisms used in blended finance.

[4] Carbon and biodiversity credits are not without challenges, however. Concerns have been raised about the measurement and valuation of these credits, and their potential for greenwashing practices, among others (e.g., Bloomberg, 2022; S&P Global, 2021; The Guardian, 2023; West et al., 2023).

[5] Conceptually, traditional investors can be viewed as a special case of impact investors who allocate zero value to non-financial returns. Considerable heterogeneity exists across impact investors in the extent to which they value financial versus non-financial returns (see, e.g., Gibson-Brandon et al., 2022; Heeb et al., 2023).

2.2.2. De-risking mechanisms of blended finance

In practice, there are several de-risking mechanisms through which blending can improve the risk-return profile of private investments. In the following, we distinguish between de-risking mechanisms at the i) fund level and ii) project level.

De-risking mechanisms at the fund level. Biodiversity funds are typically structured as partnerships with one general partner (GP) making the investment and multiple limited partners (LP) investing capital. Each LP commits a specific amount to the fund by the closing date. Once the closing date is reached, the investment process begins. Payments are made by the LPs during the life cycle of the fund through drawdown notices that apply to all LPs at a pro rata of their capital contributions. If an LP defaults on one of the payments, the GP can request additional drawdowns from the other LPs. In such cases, the required capital contribution of each LP is increased on a pro-rata basis to cover the amount that remains to be funded.

At the fund level, there are three different mechanisms through which blended financing can de-risk private capital investments: i) seniority, ii) preferred rate of return, and iii) financial guarantees.

- *Seniority*. Private investors can be granted a higher seniority compared to other LPs who provide capital for the blending. For example, development finance institutions—such as MIGA (the World Bank's Multilateral Investment Guarantee Agency), USAID (the U.S. Agency for International Development), and SIGA (the Swedish International Development Agency)—can commit the initial tranche of capital as junior LPs. Private investors would then commit capital as senior LPs. Due to their seniority, private investors are paid first, which reduces the risk of their investment.
- *Preferred rate of return*. The fund can allow for a different preferred rate of return (that

is, the minimum return LPs must receive before the profits can be shared with the GP), such that the preferred rate is higher for private investors relative to other LPs who provide capital for the blending.

- *Financial guarantees*. Relatedly, development finance institutions (such as MIGA, USAID, and SIDA) or other entities may provide financial guarantees that compensate private investors in case the preferred rate of return is not achieved by the fund.

In addition to these de-risking mechanisms at the fund level, blended financing structures can also feature de-risking mechanisms at the project level, which we describe next.

De-risking mechanisms at the project level. At the project level, de-risking mechanisms fall into three broad categories: i) concessional finance, ii) ex-ante risk mitigation, and iii) ex-post risk mitigation.[6]

- *Concessional finance*. In the case of concessional finance, public or philanthropic funders (including philanthropic foundations, donors, multi-donor funds, and development finance institutions) provide grants or funding at below-market rates to the investee to help "crowd in" private capital investments.[7]
- *Ex-ante risk mitigation*. In addition to concessional finance, the provision of i) design and preparation grants and ii) technical assistance grants can help de-risk the project ex ante. These grants are typically provided by philanthropic foundations, donors, and multi-donor funds. *Design and preparation grants* aim to improve the viability of the project before securing the necessary financing. These grants are used to support the

[6] See Earth Security (2021) for a more detailed discussion of these de-risking mechanisms at the project level, along with several practical examples.
[7] Concessional capital can also be granted conditional on the achievement of specific key performance metrics (so-called "impact-linked loans" or "results-based financing"), which provides additional assurance of the project's ability to meet the intended environmental and social impact.

proof of concept, establish a baseline, establish a monitoring and verification system, develop a pipeline, resolve some ambiguity and uncertainty about the project's outcome, and provide the pre-commercial funding needed prior to the investment stage. *Technical assistance grants* are used to build the technical capacity of investees and their key stakeholders such as local communities that may be crucial to the successful implementation and ultimately the commercial viability of the project. They can also be used to build capacity in other areas such as financial management, contracting, business model development, or impact monitoring and evaluation. These grants are often provided by donors through a dedicated fund that runs in parallel to the actual investment (Earth Security, 2021).

- *Ex-post risk mitigation*. Financial guarantees and risk insurance provide additional ways to de-risk biodiversity projects. These mechanisms operate ex post, as they protect private investors against realized losses from the project. The guarantor—often a development finance institution such as MIGA, USAID, SIDA—commits to cover the losses (in full or in part) that may arise from the project, which reduces the risk of private investments and provides a signal of the viability of the investment to private investors.[8]

As the above considerations illustrate, the de-risking of private investments through blended finance comes in different flavors. While a variety of de-risking mechanisms exist, their objective is always the same: act as a catalyst in attracting private capital by improving the risk-return tradeoff of biodiversity projects. Importantly, these de-risking mechanisms can foster

[8] Another potential benefit of guarantees is that private investors may remain committed to the investment even after the guarantees expire, which fosters the financial sustainability of such investments.

"additionality" if they lead to the financing of new biodiversity projects that would not have been undertaken otherwise.[9]

A summary of the above discussion is provided in Table 2, which compiles the different returns and de-risking mechanisms of biodiversity investments, and in Figure 1, which illustrates the structure of biodiversity finance deals.

------ Insert Table 2 and Figure 1 about here ------

2.3. Portfolio choice with biodiversity benefits and blended finance

As discussed above, the use of blended finance helps subsidize and de-risk private capital, thereby improving the risk-return trade-off of projects that have high biodiversity impact but too low of an expected return, or too high of a risk, to attract private capital. In what follows, we introduce a simple model of portfolio choice that formalizes this intuition.

Specifically, we adapt the mean-variance approach to portfolio choice and assume that a private investor in a biodiversity conservation project has a utility function that depends on the expected return r, the variance of returns v, and the level of biodiversity conservation B (for example, the number of species that are preserved at the project's location). That is, their utility is given by $U(r, v, B)$ such that $\frac{\partial U}{\partial r} > 0$, $\frac{\partial U}{\partial v} < 0$, and $\frac{\partial U}{\partial B} > 0$.

The return r and the variance v depend on the level of blending in the project b, $r(b)$ and $v(b)$. The private investor seeks to maximize their utility subject to the available investment opportunities, which are described by an efficient set $B = f(r, v)$. This function f satisfies $\frac{\partial f}{\partial r} < 0$, $\frac{\partial f}{\partial v} > 0$, meaning that more biodiversity conservation can be obtained at the cost of lower returns

[9] Additionality is an important challenge in sustainable finance. For a discussion of this challenge in the context of green financing, see Flammer (2020).

and higher risk. The investor's optimal portfolio selection problem is then given by:

$$\text{Maximize } U(r(b), v(b), B) \text{ subject to } B = f(r, v).$$

An increase in the degree of blending raises the mean return and lowers the variance of the returns of any project, $\frac{\partial r}{\partial b} > 0, \frac{\partial v}{\partial b} < 0$. This mirrors the way the blending is done in practice. For example, if the concessionary capital is in the form of a loan with a below-market interest, the blending increases the expected return r from the private investors' perspective. Similarly, if the concessionary capital is in the form of financial guarantees, the blending reduces the variance v of the returns.

Figure 2 illustrates how an increase in *b* affects the efficient frontier $B = f(r, v)$ along the $B - r$ and $B - v$ planes. In the figure, the solid (dashed) line denotes the new (old) efficient set following an increase in *b*, while the gray lines represent the investor's indifference curves. As can be seen, increased blending implies more r and less v for a given B. Figure 3 further combines the two planes into a 3-dimensional graph and shows how the efficient frontier is shifted through higher blending. For a given biodiversity impact *B*, increased blending implies a more favorable risk-return profile for private investors.

------ Insert Figures 2 and 3 about here ------

Formally, we write $B = f(r, v \mid b)$ to explicitly denote that the degree of blending is a parameter of the function f so that the relationship between B, r and v depends on the value of b. The assumptions made about the function $B = f(r, v \mid b)$ imply that if $b_1 < b_2$ then

$$\{B, r, v : B \leq f(r, v \mid b_1)\} \subset \{B, r, v : B \leq f(r, v \mid b_2)\}.$$

In words, the feasible set for b_1 is a subset of the feasible set for b_2. Accordingly, it follows that

$$\text{Max } U(r, v, B) \text{ subject to } B = f(r, v \mid b_1) < \text{Max } U(r, v, B) \text{ subject to } B = f(r, v \mid b_2).$$

If the income elasticity of demand for B is strictly positive, then this implies that a higher B is chosen at b_2 than at b_1. That is, blending is positively linked to the choice of projects with a greater biodiversity impact. Accordingly, a testable prediction is that, among the set of biodiversity investments, blended finance deals (as opposed to pure private capital deals) are likely to be more prevalent among projects that have higher biodiversity impact. In Section 3, we bring this prediction to the data and characterize the 3-dimensional efficient frontier that arises in this setup.

2.4. Fact-finding and the reduction of ambiguity

In biodiversity projects, the concessionary capital is often used to finance basic fact-finding (e.g., running pilot programs or establishing proof of concept) in order to clarify the nature and potential of the project. Such fact-finding is valuable given the lack of experience and familiarity with the monetization mechanisms listed in Table 1. In this regard, fact-finding helps reduce the ambiguity of the project. Conceptually, ambiguity (Knightian uncertainty) differs from risk—ambiguity refers to situations where probabilities are unknown, while risk refers to uncertainties described by known probability distributions.

Fact-finding in biodiversity projects can be seen as a means of reducing ambiguity in the above sense. In Online Appendix A, we develop a simple model that characterizes the value of reducing ambiguity through fact-finding. In the model, we assume that initially there are multiple probability distributions over the outcomes of a project that are consistent with what is known about it. If there are multiple distributions, then there are many possible expected outcomes, one per distribution. We then think of concessionary capital as funding investigations that convert ambiguity to risk by establishing which of these distributions over project outcomes is the real distribution, moving from a multiplicity of possible distributions to a unique one.

A direct prediction from this model is that blended financing (and hence the reliance on concessionary capital) is likely to be more prevalent among biodiversity projects that have higher ambiguity. While this prediction is not testable per se—ambiguity is difficult to measure empirically—we show in Section 3 that a significant share of the blended finance deals uses concessionary funding to finance fact-finding, which is in line with the above prediction.[10]

3. Private investing in natural capital—first empirical evidence on biodiversity finance

3.1. Data

To study private investments in biodiversity, we obtained access to the proprietary database of a recognized leader in biodiversity finance, and sustainable finance more broadly. As mentioned above, we refer to this entity as "Biodiversity Investment Manager" (BIM) for confidentiality reasons. BIM is a private equity firm that is fully dedicated to sustainable investing. BIM and its affiliates have about $30 billion in assets under management. It is active throughout the world, and its clientele comprises both individual and institutional investors. BIM offers equity and fixed income investment strategies to its clients and helps finance projects and companies at any stage of their life cycle.

Since all our data are obtained from BIM, a potential caveat is that our sample may not be representative of other providers of biodiversity finance investments. Unfortunately, it is difficult to provide a comparative analysis of BIM vs. other biodiversity finance funds due to the lack of quantitative information (e.g., on financial returns, deal structure, and biodiversity impact) for other biodiversity finance funds. Indeed, the only reason we were able to access BIM's data is

[10] Note that ambiguity differs from information asymmetry—information asymmetry refers to a situation in which an economic agent has more information than another (and incentives to act strategically based on this informational advantage), while ambiguity refers to a situation in which economic agents do not know the true probability distribution. Ambiguity is likely to be first order in the context of biodiversity projects because of the lack of familiarity with the monetization mechanisms of biodiversity conservation as well as the lack of track record of biodiversity investments. This is consistent with the fact-finding result, in that fact-finding is about understanding the feasibility/viability of biodiversity projects, as opposed to extracting information from other (better informed) agents.

through a restrictive non-disclosure agreement (NDA). That being said, this caveat is alleviated by the fact that BIM is one of the leading asset managers in biodiversity conservation and natural capital more broadly, and hence at the forefront of the market practices. Hence, at the very least, our analysis captures the practices of a key player in biodiversity finance.

While BIM is active in several areas of sustainable investing, we focus on their biodiversity finance deals. BIM invests in biodiversity projects throughout the world and across nearly all natural capital asset types. These projects are financed using blended finance as well as pure private capital investments.

The database covers all 33 biodiversity finance deals that were closed by BIM between 2020 and 2022.[11] Note that these deals are still ongoing (their average maturity is 8 years) and hence we do not have information about their realized performance. The data are very detailed. For each deal, we were granted access to BIM's internal documentation that contains a wealth of information about the underlying biodiversity project, the expected biodiversity impact, the deal structure, the expected financial return, and BIM's risk assessment, among others.

Out of the 33 biodiversity finance deals, 19 deals (58%) were financed by pure private capital, while the remaining 14 deals (42%) were financed through blended finance. In what follows, we characterize these deals across many dimensions.[12]

3.2. Descriptive statistics

Deals by natural capital asset types. Table 3 provides a breakdown of the 33 biodiversity finance deals by natural capital asset types. Note that the BIM deals span the full set of natural

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[11] In addition, we were granted access to a set of deals that were under consideration but ended up being discarded by BIM's management. We study these deals in Section 3.5.

[12] Due to confidentiality restrictions, we cannot disclose the identity of BIM's investors. However, we note that their private investors include large asset owners (insurance companies, banks, and foundations) as well as a few corporates that have made biodiversity commitments.

capital asset types listed in Table 1, except for ‘urban parks and other green infrastructures in urban areas.’ The deals are almost equally distributed across the two broad categories land (48.5% of the deals) and sea (51.5%). Within the land category, the main natural asset types are ‘agriculture: soil and pollinators’ (24.2%) and ‘forests’ (18.2%). Within the sea category, the main ones are ‘fisheries’ (30.3%), ‘coastal ecosystems’ (9.1%) and ‘oceans, incl. coral reef’ (9.1%).

------ Insert Table 3 about here ------

In the last four columns of Table 3, we distinguish between blended finance deals and deals that are financed by pure private capital. As is shown, the distribution across the different natural capital asset types is similar in both groups. At the margin, the land category tends to be more prevalent among blended finance deals (57.1%), while it is less prevalent among deals financed by pure private capital (42.1%).

Deals by countries. Table 4 provides a breakdown of the deals based on the countries of the biodiversity projects. As can be seen, most of the projects are undertaken in Latin America and the Caribbean (30.3%), Asia (24.2%), and Africa (18.2%). The distribution is again comparable across blended finance deals and deals that are financed by pure private capital.

------ Insert Table 4 about here ------

Figure 4 provides a visualization of the biodiversity projects’ location on the world map. Darker-shaded areas indicate a greater number of projects. Figure 5 provides separate maps for blended finance deals (panel A) and deals that are financed by pure private capital (panel B).

------ Insert Figures 4 and 5 about here ------

Deals by financing structure. In Table 5, we provide a breakdown of the deals based on their financing structure. Equity is the more prevalent form of financing (33.3% of the deals), followed by a mix of equity and debt (24.2%) and debt with profit sharing (18.2%). In the latter case, the interest paid on the debt is performance-based. It is typically specified as a floor interest rate plus a percentage of the project's EBITDA (sometimes subject to a cap). Other deals are financed through VERPA (voluntary emission reduction purchase agreement), either as standalone (12.1%), or combined with equity (6.1%). In VERPA-based financing, the investors purchase ownership of the carbon credits that are generated by the project.

------ Insert Table 5 about here ------

In the last four columns of Table 5, we distinguish between blended deals and pure private capital deals. As is shown, equity (28.6% of the blended deals and 36.8% of the pure private capital deals) and a mix of equity and debt (28.6% and 28.1%, respectively) remain the more prevalent forms of financing for both types of deals. VERPA-based financing is found among both types as well (14.3% and 21.1%, respectively). One nuance is that VERPA-based financing is more likely to be combined with equity for blended deals, while it is more likely to be used as standalone for pure private capital deals.

3.3. Deal characteristics

Table 6 provides the means and standard deviations for various deal characteristics across all BIM deals, and separately for blended finance deals and deals financed by pure private capital. The last column reports the *p*-value of the difference-in-means test comparing blended finance deals vs. pure private capital deals.

------ Insert Table 6 about here ------

As can be seen from panel A, the average biodiversity deal has a maturity of 7.9 years, a deal size of $22.8M, and a ticket size (that is, the amount invested by each investor) of $6.6M, out of which $3.2M (52%) is in the form of equity, $2.8M (35%) in the form of debt, and $0.6M (13%) in the form of VERPA-based financing. When comparing blended deals vs. pure private capital deals, the main difference is that blended deals tend to be larger—the average deal size is $29.2M compared to $18.2M (*p*-value = 0.074). This indicates that the blending helps scale up biodiversity investments. We also observe that blended deals tend to rely on a larger share of debt financing and a smaller share of VERPA-based financing, although these differences are not significant at conventional levels.

For each deal, the database provides the expected IRR. For about two-thirds of the deals, the BIM documentation also includes a sensitivity analysis that we use to compute a measure of the project's risk. Specifically, we compute the average deviation from the expected IRR in the pessimistic and optimistic scenarios, which we refer to as the "pseudo" standard deviation of the IRR.[13] We report both the expected IRR and the (pseudo) standard deviation in panel B. As can be seen, deals that have a higher expected IRR tend to be financed by pure private capital. On average, their expected IRR is 14.7%, compared to 11.9% for blended finance deals. The difference is significant in statistical terms (*p*-value = 0.026). While blended finance deals have lower expected returns, they tend to have lower risk as well. On average, their (pseudo) standard deviation from the target IRR is 6.3% compared to 6.7% for deals that are financed by pure private capital. When computing the ratio of the target IRR to the (pseudo) standard deviation from the expected IRR—similar in spirit to a Sharpe ratio—we find no significant difference between the two types of deals (*p*-value = 0.834). Overall, this suggests that the de-risking from the blending helps improve the risk-return tradeoff of these projects, thereby increasing their appeal to private investors.[14]

Panel C provides metrics that capture the environmental and social impact of the

[13] Online Appendix B describes how BIM computes the expected IRR, conducts the sensitivity analysis, and how we use the latter to compute the pseudo-standard deviation of the IRR.
[14] In Table A2 of the Online Appendix, we report how the expected IRR differs across the characteristics we considered in Tables 3-5. As can be seen, we find that the expected IRR tends to be higher for projects that rely on equity (vs. debt) financing, which is not surprising given the higher cost of equity.

biodiversity deals. A clear pattern emerges, in that the blended deals are significantly more impactful along multiple dimensions. First, the total impact area (e.g., in terms of reforestation and habitat conservation) is expected to be larger. On average, it is expected to be 114,798 hectares for blended deals compared to 26,844 hectares for pure private capital deals. The difference (based on the logarithm) is significant at the 10% level (*p*-value = 0.098). Similarly, blended finance deals are expected to reduce greenhouse gas (GHG) emissions by 9.5 million tons of CO2 equivalent (tCO2e), compared to only 2.6 million tCO2e for pure private capital deals (*p*-value = 0.096). What is more, the number of beneficiaries (that is, individuals who benefit from the project) is expected to be 19,133 people for blended deals, compared to 5,185 for pure private capital deals (*p*-value = 0.025). The number of new jobs created is also expected to be higher for blended finance deals (3,358) compared to pure private capital deals (838), although the difference is not significant at conventional levels (*p*-value = 0.279). Finally, the share of deals that are expected to be certified by third-party organizations—such as EcoVadis, the Forest Stewardship Council (FSC), and the Climate, Community, and Biodiversity (CCB) Standards, among others—is about the same across both types of deals.

Panel D further shows that the differences in Panel C are not merely reflective of the larger size of the blended finance deals. When scaling the above metrics by the size of the deal, we find that blended finance deals have a larger impact per dollar invested. In particular, on a per dollar basis, the total impact area, the reduction in GHG emissions, and the number of beneficiaries are 4.3 to 4.9 times larger for blended finance deals.[15]

Overall, the evidence from Panels B-D indicates that, while deals that have a higher expected financial return are more likely to be financed by pure private capital, they tend to be

[15] While these differences are large in economic terms, we caution that they are not significant at conventional levels.

smaller in scale and have lower biodiversity impact. For larger-scale projects with a more ambitious biodiversity impact, blended finance is the more prevalent mode of financing. While these projects have lower expected returns, they are also less risky. This suggests that the blending—and the corresponding de-risking of private capital—is an important tool for improving the risk-return tradeoff of projects with higher biodiversity impact, thereby increasing their appeal to private investors. This is consistent with the 3-dimensional frontier (return, risk, and biodiversity impact) that we formalized in Section 2.3, and the prediction that blended finance structures are more prevalent for projects with higher biodiversity impact.

In Panel E, we use information from the project description to code a dummy variable that is equal to one if part of the financing is used to fund fact-finding (e.g., pilot programs). We find that 21% of the blended finance deals entail fact-finding provisions, while none of the pure private capital deals does (the difference is significant at conventional levels with p-value = 0.035). This is not surprising, given that fact-finding is typically financed by concessionary capital that is only available in blended finance structures. Importantly, this finding lends support to our argument from Section 2.4 (and the underlying model in Online Appendix A) that projects with more ambiguity (Knightian uncertainty) are more likely to be funded by blended finance structures.

Naturally, we caution that, since our sample includes 14 blended finance deals, the 21% of deals with fact-finding provisions correspond to only 3 deals. Hence, we see this finding as suggestive given the small-sample nature of the analysis.

In addition to the quantitative information provided in Table 6, the BIM database also includes qualitative assessments of the biodiversity deals along several ESG dimensions. For each ESG dimension, the assessment is specified on a scale from 1 to 3 (1 referring to “Low,” 2 referring to “Medium,” and 3 referring to “High”). The means and standard deviations of these assessments are provided in Table A3 of the Online Appendix. In panel A (ESG assessment), a higher score represents a more positive assessment. In panel B (ESG risk), a higher score represents higher risk. In panel C (ESG risk management), a higher score represents a more positive assessment of the risk management process.

As can be seen from panel A, the ESG assessments are especially favorable with regard to environmental dimensions, including 'natural ecosystems,' 'sustainable product lands & seascapes,' and 'climate change mitigation.' Relatedly, the ESG risks in panel B tend to be assessed between low and medium. In particular, the categories 'pollution control, energy and water use risk' and 'biodiversity conservation risk' are rated favorably, in keeping with the nature of biodiversity projects. This is further reflected in the quality of the ESG risk management processes in panel C, which tend to be rated between medium and high.[16]

3.4. Ex-post performance

The 33 biodiversity finance deals considered in this paper were closed by BIM between 2020 and 2022, and have an average maturity of about 8 years (Table 6). Accordingly, all deals are still ongoing, and hence we cannot assess their realized performance. To nevertheless gain perspective on their ex-post performance, we asked BIM for information about the year-to-year performance of these deals. They agreed to share information on the environmental and social impact of the deals (corresponding to the metrics listed in Panel C of Table 6). We report this information in Figure 6.

------ Insert Figure 6 about here ------

For each metric—e.g., the total impact area (in terms of reforestation and habitat

[16] Due to the coarse, three-category answers underlying the ratings, these qualitative data are not well suited to detect differences across groups of deals. And indeed, in the last six of columns of the table, we see little variation in these ratings across the blended finance and pure private capital deals.

conservation)—we compute the ratio of the realized benefit relative to the target in any given year, where the years are recorded in event time relative to the closing year (year 0). For example, if a deal is closed in 2021, has a target impact area of 50,000 ha, and an actual impact area of 5,000 ha in 2021, 6,000 ha in 2022, and 10,000 in 2023, the ratio is computed as 10% in year 0, 12% in year 1, and 20% in year 2. We then take the average across all deals and event years for which data are available, and plot these averages in Figure 6.

As can be seen, the social impacts of the deals (in terms of job creation and the number of beneficiaries) are faster to generate compared to their environmental impacts (in terms of impacted area and GHG sequestration). After three years, about 54-76% of the targeted social gains are already achieved. This suggests that a large share of the expected social benefits is already achieved by setting up the project infrastructure and creating jobs at the project's location. In contrast, the environmental benefits take longer to materialize, with only 17% of the targeted impact area and 13% of the targeted GHG sequestration being achieved after three years. In our conversations with the BIM team, we learned that the environmental impacts typically follow a J-curve in which the bulk of the gains accrue in the last years of the project. This is consistent with the pattern we uncover in Figure 6, but of course incomplete since the ex-post impact metrics are not yet available for the later years of the projects.[17]

Interestingly, while BIM did not share data on the ex-post financial performance of the deals, they noted in our conversations that the financial performance of the biodiversity deals is also expected to follow a J-curve with the highest gains being realized relatively late in the

[17] In Table A4 of the Online Appendix, we examine whether the projects' ex-post environmental and social impact varies across deals that are financed by pure private capital vs. blended financing. Specifically, for each impact metric and each deal for which we have ex-post data available, we compute the realized impact (relative to the targeted impact) until the last year for which we have data (that is, up to three years post-closing). We then compute the mean among deals that are financed by pure private capital and blended financing. As can be seen, we find no significant difference between the two groups, which suggests that both types of projects contribute to their intended impact at a similar pace.

project's life. This suggests that the biodiversity gains and financial gains tend to be somewhat in-sync during the projects' life.

Finally, BIM also shared with us the set of Key Performance Indicators (KPIs) that they use internally to monitor the environmental and social performance of the projects. The list of KPIs is provided in Table 7.

------ Insert Table 7 about here ------

While BIM did not provide quantitative data on those KPIs, the list in itself is insightful. Indeed, a key challenge in biodiversity finance is how to come up with metrics that are relevant and informative as to the biodiversity impact of the underlying projects (Karolyi and Tobin-de la Puente, 2023). BIM relies on a series of metrics pertaining to i) the achievement of internationally recognized certifications, ii) sustainable productive lands and seascapes (e.g., hectares of reforestation and afforestation), iii) climate change mitigation (e.g., volume of GHG emissions that are avoided, reduced, or sequestered), and iv) natural ecosystems (e.g., hectares of land under conservation or restoration). In addition to these environmental and biodiversity metrics, BIM also tracks a set of KPIs pertaining to the social performance of the biodiversity projects, including metrics of i) community engagement, ii) livelihood and decent work, and iii) diversity and inclusion.

3.5. Deals that were discarded by BIM

In addition to the 33 in-portfolio deals described above, BIM also granted us access to a set of deals that were under consideration for portfolio inclusion but were ultimately discarded by BIM's management. While the information available for these deals is sparser, it nevertheless includes a set of relevant variables that can be used to characterize the selection process.

In total, we have relevant information for 32 of the discarded deals. In Table 8, we contrast these 32 deals ("discarded deals") vis-à-vis the 33 deals that made it to the portfolio stage ("portfolio deals") on the basis of several characteristics. The last column provides the *p*-value of the difference-in-means test for each characteristic.

------ Insert Table 8 about here ------

As is shown, the discarded deals tend to be both less profitable and less impactful. Specifically, their average target IRR is 11.3% (compared to 13.5% for in-portfolio deals, *p*-value = 0.035), their average total impact area is 19,684 hectares (compared to 73,408 hectares, *p*-value = 0.006), their average GHG emissions reduction is 1.3 million tCO2e (compared to 5.7 million tCO2e, *p*-value = 0.096), their average number of beneficiaries is 3,727 people (compared to 11,623 people, *p*-value = 0.045), and their average number of new jobs created is 1,192 (compared to 1,846, *p*-value = 0.652). This suggests that, in order to be financed by private capital—either as standalone or in blended structures—deals need to cross a certain threshold in terms of both their financial return and biodiversity impact. As such, these findings shed additional light into the three-dimensional frontier that we formalized in Section 2.3. Specifically, they indicate that, while blended finance can help improve the risk-return profile of projects with high biodiversity impact, such blended financing structures are unlikely to be considered if the investment's initial risk-return profile is not favorable enough. Intuitively, the initial (that is, pre-blending) risk-return tradeoff needs to cross a certain threshold for blended finance to be effective in enhancing the project's risk-return profile to a level that would be attractive to private investors. Accordingly—and this is the other side of the coin—this implies that private capital (even in blended financing structures) is unlikely to be a realistic option for a potentially large set of biodiversity projects.

4. Biodiversity finance vs. impact finance

While biodiversity finance is a relatively new asset class, it shares some similarities with impact finance. Like biodiversity funds, impact funds pursue both financial and societal objectives. In their characterization of impact investing, Barber et al. (2021) show that impact funds tend to achieve lower returns relative to traditional funds. By comparing the IRR of impact vs. traditional funds and estimating a willingness-to-pay (WTP) model with random utility, they estimate that investors are willing to accept IRRs that are lower by 2.5–3.7 percentage points for impact funds. In this regard, impact finance relies primarily on "impact investors," that is, investors who are willing to accept below-market returns for the nonpecuniary benefit of societal impact.

Biodiversity finance differs in a number of ways. First, the monetization mechanisms are quite distinct, in that they require the bundling of biodiversity (a public good) with private goods whose value it enhances. This is in contrast to traditional impact investments, in which the monetization mechanisms are usually directly tied to private goods (e.g., solar panels, wind turbines, business ventures in disadvantaged urban areas).[18] Second, the risk-return profile of biodiversity projects need not be competitive enough to attract private capital. This can be addressed through blended financing structures, in which concessionary capital is used to subsidize and de-risk private capital investments. Third, the lack of experience and familiarity with the monetization mechanisms of biodiversity projects, as well as the limited track record of biodiversity investments, increase the ambiguity of the projects. This in turn increases the value of fact-finding (e.g., pilot projects) that is often financed through concessionary capital in blended financing structures. In our conceptual framework (Section 2), we discuss these three dimensions in detail.

More broadly, it is informative to compare the returns of biodiversity finance with those of impact finance. In their 2024 report, Preqin (2024) reports an average IRR of impact funds of

[18] For example, see Boulongne et al. (2024) and Geczy et al. (2021).

13.5%, compared to 15% for non-impact private capital funds (based on a sample of 215 impact funds and 10,812 non-impact funds). The former is close to the average expected IRR in our sample which is 13.52% for private investors. Therefore, according to the IRR metrics, our sample offers limited financial trade-off compared to more traditional impact funds.

Finally, it is worth noting that blended finance is gaining traction in impact investing as well. However, little is known about the structure and economics of these deals.[19] As such, the insights from this study could help inform the practice of blended finance for non-biodiversity projects as well, especially among the set of projects whose monetization is based on the bundling of public and private goods (e.g., infrastructure projects).

5. Conclusion

As massive amounts of financing are required to effectively address the biodiversity crisis (TNC, 2020), biodiversity finance could play an important role by helping mobilize private funding for the protection and restoration of biodiversity.

While biodiversity finance is getting traction among investors, little is known about this new practice. The objective of this study was to shed light on it. In a nutshell, our contribution is twofold. First, we introduce a conceptual framework that lays out how biodiversity can be financed by pure private capital and blended financing structures. The main element underlying both types of financing is the monetization of biodiversity, that is, the extent to which investments in biodiversity can generate a financial return for private investors. Second, we provide first evidence on biodiversity finance. Using deal-level data from BIM, we show that projects with higher expected returns tend to be financed by pure private capital. Their scale is smaller, however, and

[19] An exception is the companion paper by Flammer et al. (2024) that studies the set of blended finance deals made by the World Bank's IFC (International Finance Corporation) and formalizes the decision-making of DFIs (development finance institutions) in providing blended financing.

so is their expected biodiversity impact. For larger-scale projects with more ambitious biodiversity impact, blended finance is the more prevalent form of financing. While these projects have lower expected financial returns, their risk is also lower. This suggests that the blending—and the corresponding de-risking of private capital—is an important tool for improving the risk-return tradeoff of these projects, thereby increasing their appeal to private investors. Finally, we examine a set of projects that were under consideration by BIM, but did not make it to the portfolio stage. These projects tend to have lower financial and biodiversity returns. This suggests that, in order to be financed by private capital—either as standalone or in blended structures—biodiversity projects need to exceed a certain threshold in terms of both their financial return and biodiversity impact. Accordingly, while private capital can help close the financing gap and contribute to the conservation and restoration of biodiversity, it is unlikely to provide a panacea against the biodiversity crisis.

More broadly, an important question is how to scale up private investments in biodiversity. While blended financing can help enhance the risk-return tradeoff of such investments, other hurdles are likely to hamper the growth of this market. First, coordination among the relevant actors is likely to be challenging. On one hand, project-holders ("sellers") and their local NGO partners have limited knowledge about international investors' preferences and requirements in terms of eligibility criteria and reporting KPIs. On the other hand, international investors ("buyers") know little about local markets and the challenges of biodiversity projects. Second, these challenges are compounded by the lack of common frameworks that could be used to assess biodiversity projects and provide a basis for third-party certification. Such frameworks are difficult to design due to the inherent challenges in measuring biodiversity benefits, as well as the projects' other societal benefits (e.g., community economic development). Arguably, making progress on these dimensions is likely to help foster the growth of this market.

Lastly, our study is subject to two main limitations. First, our empirical analysis is based on a sample of 33 biodiversity finance deals. While these deals provide helpful insights, we caution that they need not be representative of the broader population of biodiversity deals. In this regard, our hope is that, as biodiversity finance continues to grow and more comprehensive datasets become available, future work will be able to provide larger-scale evidence on this new phenomenon. Second, since the deals we examined are still ongoing, we only have limited information on their ex-post performance, and hence our analysis is based primarily on ex-ante projections at the time the deals were closed. We again hope that, as time passes and post-completion data become available, future work will shed additional light on the financial performance and biodiversity impact of such investments. More broadly, a key objective of this study was to lay the ground and stimulate future research on biodiversity finance. In particular, more research is needed to understand investors' and companies' attitudes toward biodiversity, their perception of the economic value of biodiversity conservation, and their perception of biodiversity risks; develop informative metrics of firm- and project-specific biodiversity footprint and exposure to biodiversity risks; understand the interaction between biodiversity and climate risks; understand the equilibrium implications of incorporating biodiversity and natural capital in portfolio construction; and understand how the increasing risks and costs associated with biodiversity loss are likely to affect portfolios' performance in the long run in the absence of mitigation. These are exciting avenues for future work to pursue.

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Figure 1. Structure of biodiversity finance deals

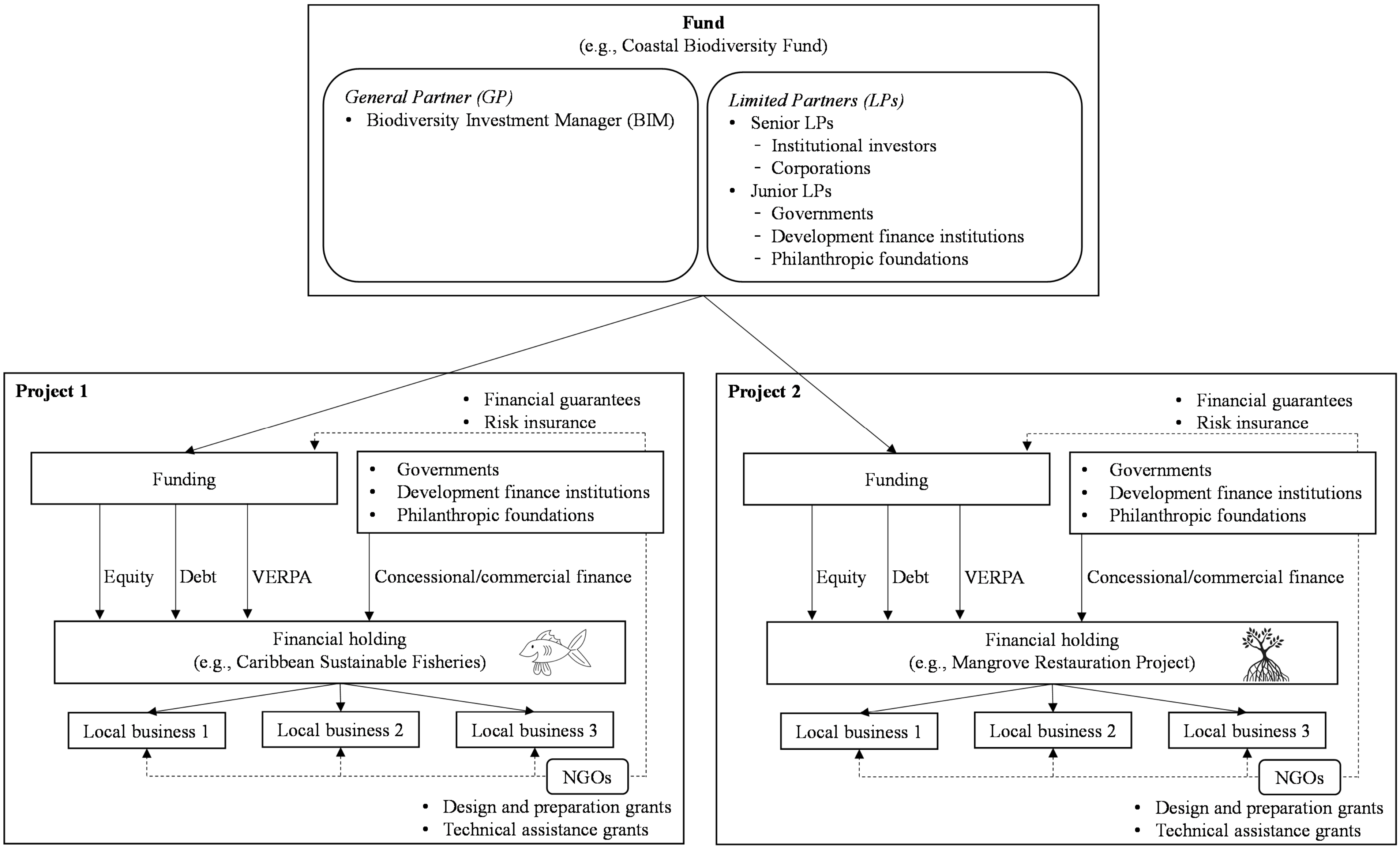
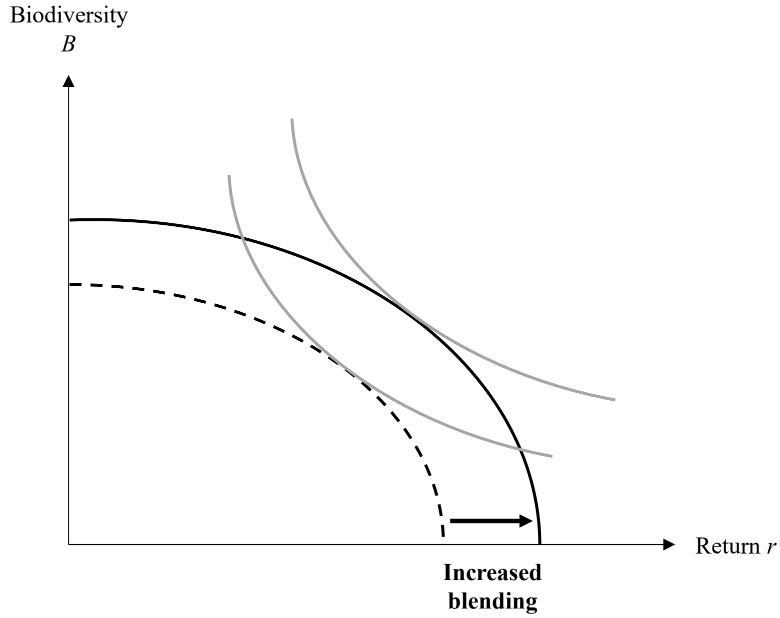
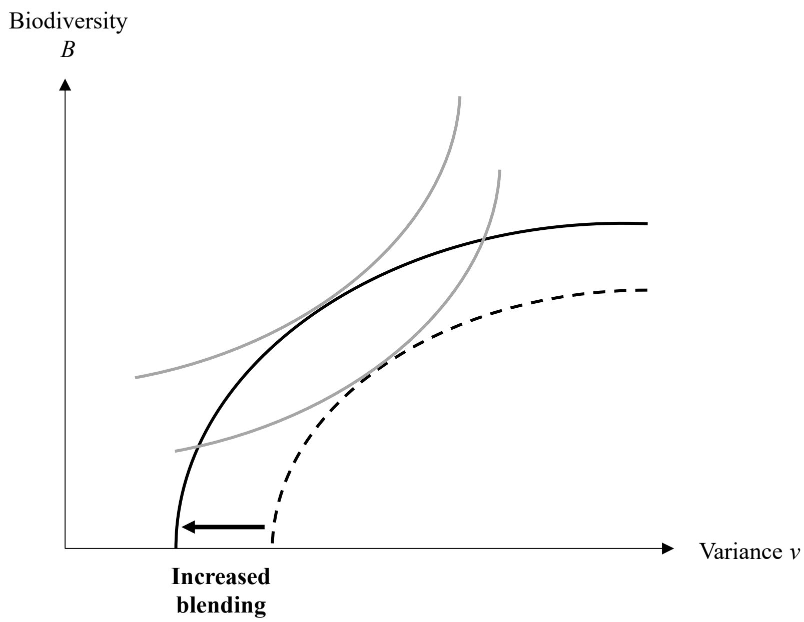


Figure 2. Blending and efficient frontier

A. Efficient frontier in the $(B - r)$ plane

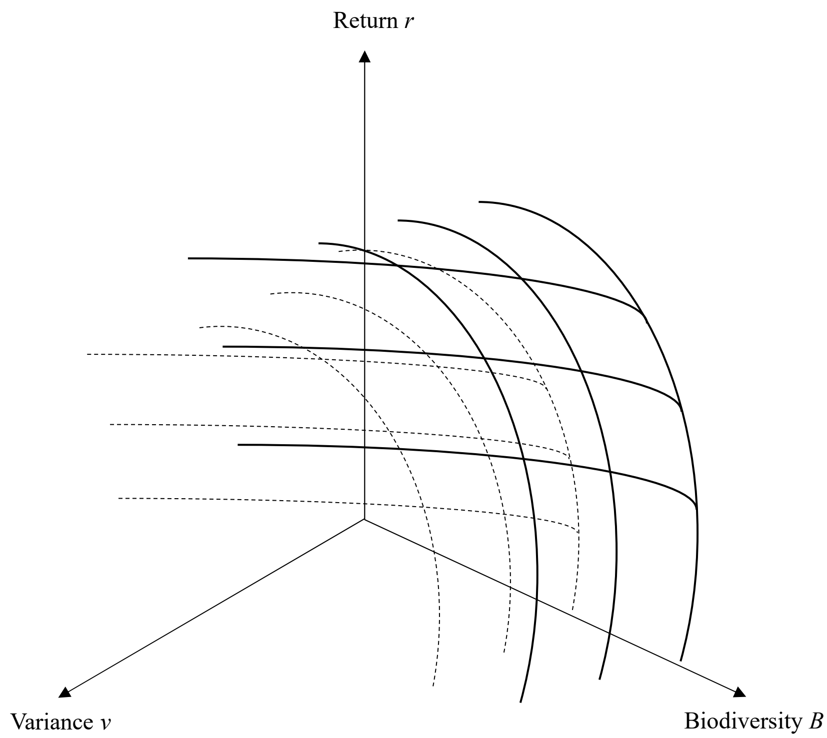


B. Efficient frontier in the $(B - v)$ plane



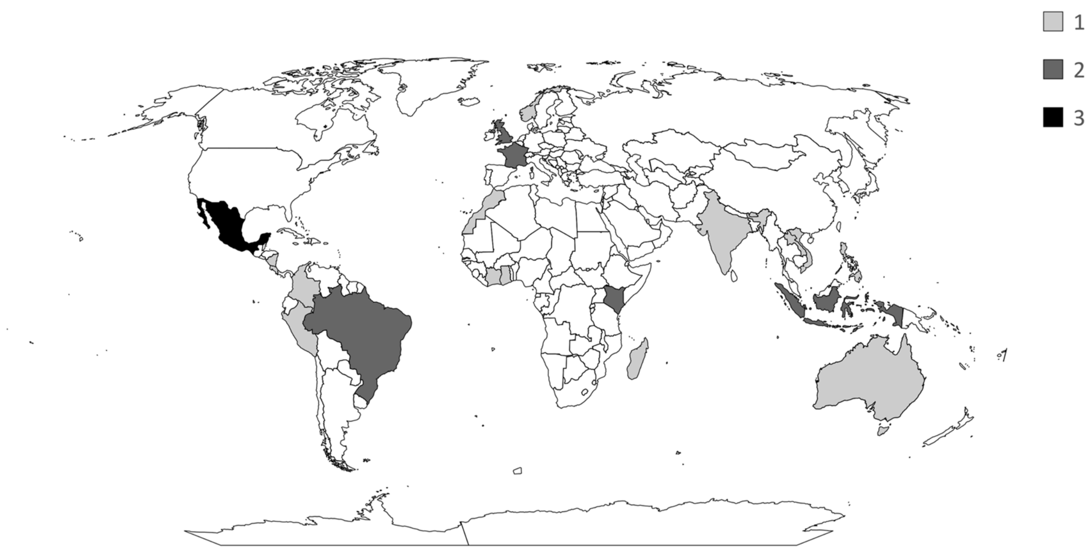
Notes. This figure illustrates how an increase in blending (represented by the shift from the dashed to the solid curve) affects the efficient frontier in the model of Section 2.3. Panel A refers to the biodiversity-financial return $(B - r)$ plane (holding the variance v constant), while Panel B refers to the biodiversity-variance $(B - v)$ plane (holding the return r constant). The gray lines represent the investors' indifference curves.

Figure 3. Three-dimensional efficient frontier



Notes. This figure combines the two planes of Figure 2 into a three-dimensional graph and shows how an increase in blending (represented by the shift from the dashed to the solid curves) affects the three-dimensional efficient frontier in the model of Section 2.3.

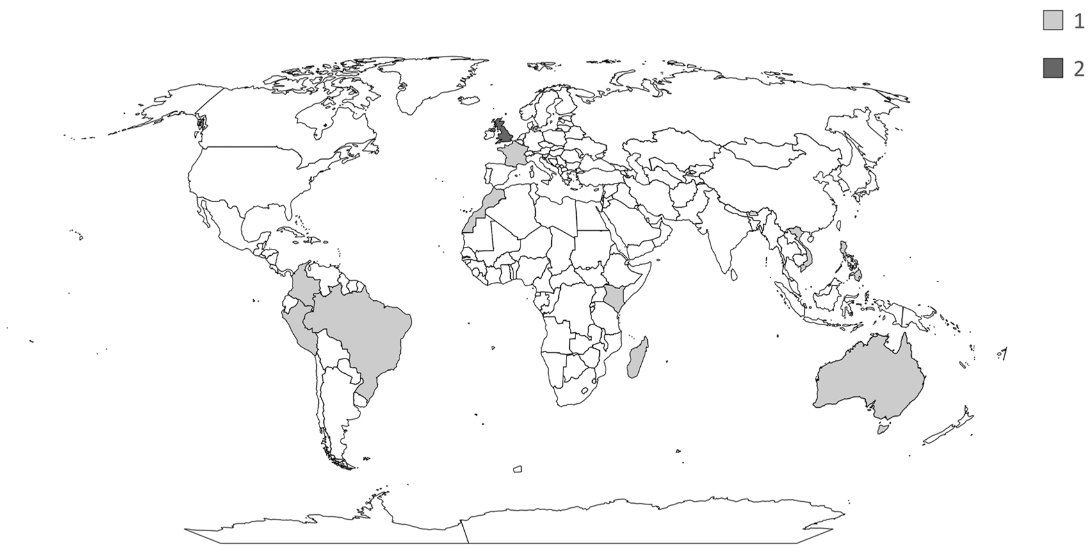
Figure 4. Biodiversity finance deals by countries



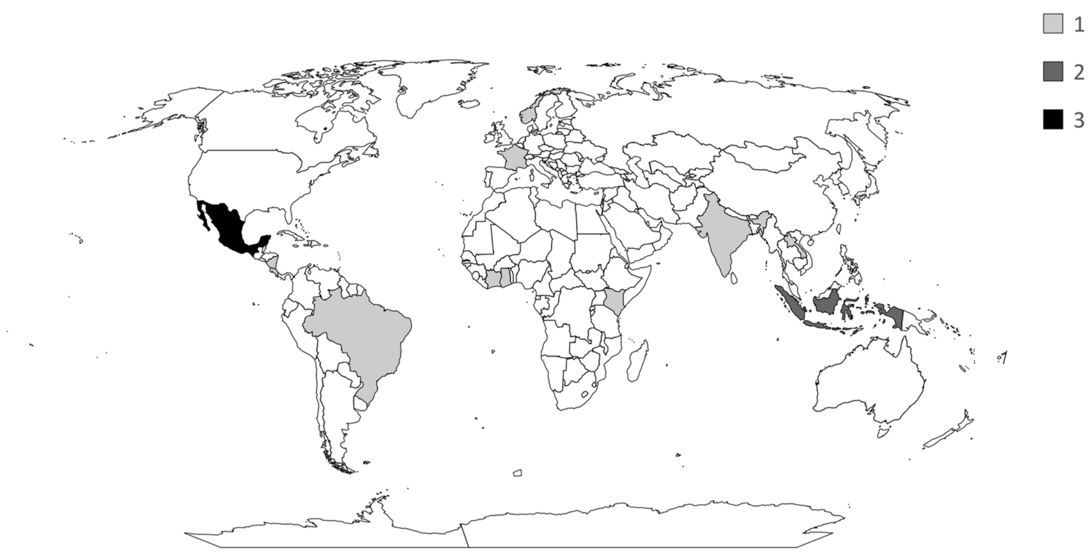
Notes. This figure plots the number of biodiversity finance deals of BIM by countries. Darker-shaded areas indicate a greater number of deals.

Figure 5. Types of biodiversity finance deals by countries

A. Blended finance

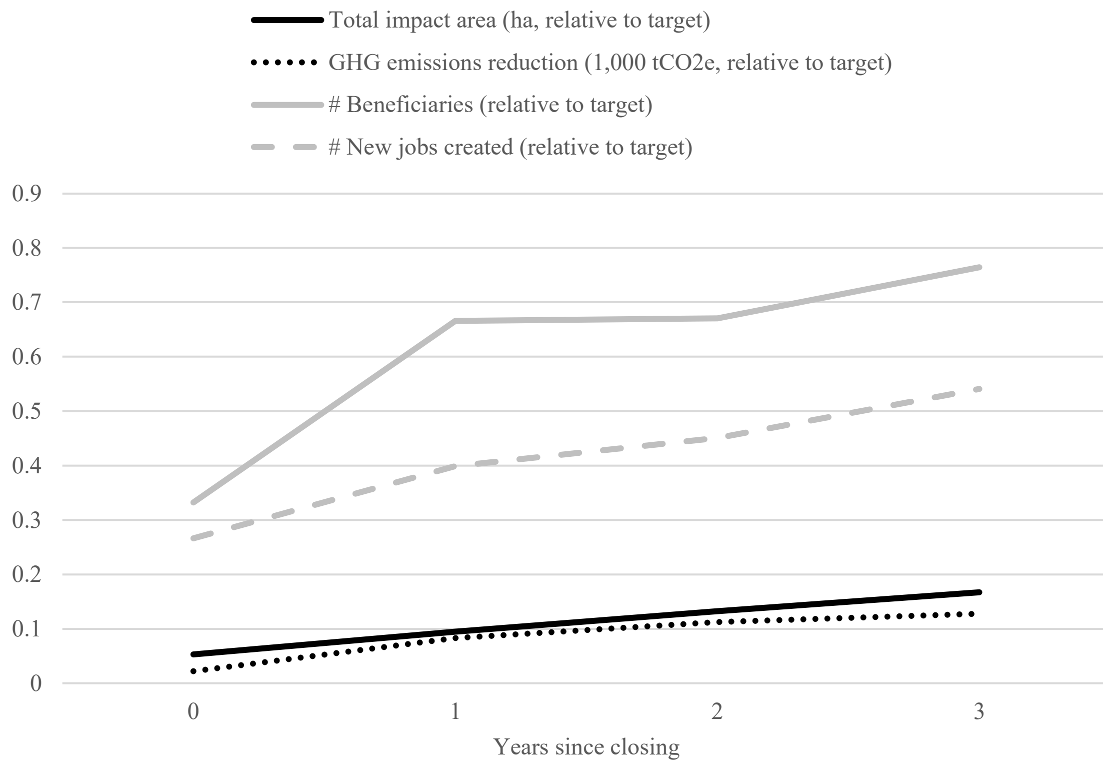


B. Pure private capital



Notes. This figure plots the number of biodiversity finance deals of BIM by type of deals and countries. Panel A refers to bended finance deals. Panel B refers to deals financed by pure private capital. Darker-shaded areas indicate a greater number of deals.

Figure 6. Ex-post performance



Notes. This figure plots the average realized environmental and social impact of the biodiversity projects in our sample in event time relative to the closing year (year 0). All impact metrics are expressed as a percentage of the project's targeted impact.

Table 1. Natural capital asset types and monetization mechanisms of ecosystem services

Natural capital asset types	Monetization mechanisms of ecosystem services
A. Land	
Agriculture: soil and pollinators	Agricultural productivity; price of farmland; certification as "biodiversity-friendly" agricultural products (higher prices); carbon credits; fire suppression; water quality
Forests	Ecotourism (hotel nights, tour guide services); carbon credits (carbon capture and storage); biodiversity credits; health; recreational value; bioprospecting for medicine; certification as "biodiversity-friendly" wood (higher prices); hydropower (pay for success)
Urban parks and other green infrastructures in urban areas	Value of real estate (proximity to park, green roofs provide heat isolation); prevention of flooding; carbon credits (carbon capture and storage); recreational value (e.g., birdwatching tours, sports activities, etc.)
Natural parks & wildlife protection	Ecotourism (hotel nights, tour guide services); value of real estate around the park; biodiversity credits
Genetic resources	Protection against diseases (humans, plants, food, animals); bioprospecting for medicine; biodiversity credits
B. Sea	
Watersheds	Green infrastructure services; water purification
Coastal ecosystems	Ecotourism (hotel nights, tour guide services); value of real estate (prevention of coastal flooding); carbon credit (carbon capture and storage); biodiversity credits; food production
Fisheries	Food production; certification as "biodiversity-friendly" seafood products (higher prices)
Oceans (incl. coral reef)	Ecotourism (hotel nights, tour guide services); carbon credits; biodiversity credits; value of real estate (prevention of hurricanes and coastal flooding)

Notes. This table provides examples of monetization mechanisms of ecosystem services by natural capital asset types.

Table 2. Returns and de-risking mechanisms of biodiversity investments

A. Returns

Direct financial returns

Indirect financial returns

- Biodiversity credits
- Carbon credits

Non-financial biodiversity returns

B. De-risking mechanisms

Fund-level de-risking mechanisms

- Seniority
- Preferred rate of return
- Financial guarantees

Project-level de-risking mechanisms

- Concessional finance
- Ex-ante risk mitigation
    - Design and preparation grants
    - Technical assistance grants
- Ex-post risk mitigation
    - Financial guarantees
    - Risk insurance

Notes. This table summarizes the returns and de-risking mechanisms of biodiversity investments discussed in Section 2.2.

Table 3. Biodiversity finance deals by natural capital asset types

	All (N = 33)		Blended finance (N = 14)		Pure private capital (N = 19)	
	# Deals	Percent	# Deals	Percent	# Deals	Percent
Land	16	48.5%	8	57.1%	8	42.1%
Agriculture: soil and pollinators	8	24.2%	3	21.4%	5	26.3%
Forests	6	18.2%	3	21.4%	3	15.8%
Natural parks & wildlife protection	1	3.0%	1	7.1%	0	0.0%
Genetic resources	1	3.0%	1	7.1%	0	0.0%
Sea	17	51.5%	6	42.9%	11	57.9%
Watersheds	1	3.0%	0	0.0%	1	5.3%
Coastal ecosystems	3	9.1%	0	0.0%	3	15.8%
Fisheries	10	30.3%	4	28.6%	6	31.6%
Oceans (incl. coral reef)	3	9.1%	2	14.3%	1	5.3%
Total	33	100.0%	14	100.0%	19	100.0%

Notes. This table reports the number and percentage of biodiversity finance deals by natural capital asset types. The statistics are reported for all BIM deals (first two columns), and separately for blended finance deals (middle two columns) and deals financed by pure private capital (last two columns).

Table 4. Biodiversity finance deals by countries

	All (N = 33)		Blended finance (N = 14)		Pure private capital (N = 19)	
	# Deals	Percent	# Deals	Percent	# Deals	Percent
Africa	6	18.2%	3	21.4%	3	15.8%
Ghana	1	3.0%	0	0.0%	1	5.3%
Ivory Coast	1	3.0%	0	0.0%	1	5.3%
Kenya	2	6.1%	1	7.1%	1	5.3%
Madagascar	1	3.0%	1	7.1%	0	0.0%
Morocco	1	3.0%	1	7.1%	0	0.0%
Asia	8	24.2%	3	21.4%	5	26.3%
Bhutan	1	3.0%	1	7.1%	0	0.0%
India	1	3.0%	0	0.0%	1	5.3%
Indonesia	2	6.1%	0	0.0%	2	10.5%
Laos	1	3.0%	0	0.0%	1	5.3%
Philippines	1	3.0%	1	7.1%	0	0.0%
Vietnam	1	3.0%	1	7.1%	0	0.0%
Multiple countries	1	3.0%	0	0.0%	1	5.3%
Europe	5	15.2%	3	21.4%	2	10.5%
France	2	6.1%	1	7.1%	1	5.3%
Norway	1	3.0%	0	0.0%	1	5.3%
United Kingdom	2	6.1%	2	14.3%	0	0.0%
Latin America and Caribbean	10	30.3%	3	21.4%	7	36.8%
Bahamas	1	3.0%	0	0.0%	1	5.3%
Brazil	2	6.1%	1	7.1%	1	5.3%
Colombia	1	3.0%	1	7.1%	0	0.0%
Costa Rica	1	3.0%	0	0.0%	1	5.3%
Mexico	3	9.1%	0	0.0%	3	15.8%
Nicaragua	1	3.0%	0	0.0%	1	5.3%
Peru	1	3.0%	1	7.1%	0	0.0%
Oceania	1	3.0%	1	7.1%	0	0.0%
Australia	1	3.0%	1	7.1%	0	0.0%
Multiple continents	3	9.1%	1	7.1%	2	10.5%
Total	33	100.0%	14	100.0%	19	100.0%

Notes. This table reports the number and percentage of biodiversity finance deals by countries. The statistics are reported for all BIM deals (first two columns), and separately for blended finance deals (middle two columns) and deals financed by pure private capital (last two columns).

Table 5. Biodiversity finance deals by type of financing

	All (N = 33)		Blended finance (N = 14)		Pure private capital (N = 19)	
	# deals	Percent	# deals	Percent	# deals	Percent
Equity	11	33.3%	4	28.6%	7	36.8%
Equity + Debt	8	24.2%	4	28.6%	4	21.1%
Equity + Debt with profit sharing	1	3.0%	0	0.0%	1	5.3%
Equity + VERPA	2	6.1%	2	14.3%	0	0.0%
Debt	1	3.0%	1	7.1%	0	0.0%
Debt with profit sharing	6	18.2%	3	21.4%	3	15.8%
VERPA	4	12.1%	0	0.0%	4	21.1%
Total	33	100.0%	14	100.0%	19	100.0%

Notes. This table reports the number and percentage of biodiversity finance deals by type of financing. The statistics are reported for all BIM deals (first two columns), and separately for blended finance deals (middle two columns) and deals financed by pure private capital (last two columns). VERPA refers to voluntary emission reduction purchase agreements.

Table 6. Biodiversity deal characteristics

	All			Blended finance			Pure private capital			Difference in means
	N	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.	*p*-value
A. Deal size and financing										
Maturity (years)	33	7.94	3.03	14	7.93	2.70	19	7.95	3.32	0.986
Deal size ($ million)	33	22.84	17.47	14	29.15	18.39	19	18.19	15.63	0.074*
Ticket size ($ million)	33	6.62	3.86	14	7.24	3.99	19	6.17	3.79	0.443
Equity ($ million)	33	3.21	4.00	14	3.44	4.45	19	3.04	3.74	0.781
Debt ($ million)	33	2.79	4.20	14	3.65	4.34	19	2.16	4.08	0.320
VERPA ($ million)	33	0.62	1.62	14	0.14	0.53	19	0.97	2.03	0.147
% Equity	33	0.52	0.44	14	0.50	0.44	19	0.53	0.46	0.881
% Debt	33	0.35	0.42	14	0.47	0.46	19	0.26	0.39	0.172
% VERPA	33	0.13	0.33	14	0.03	0.11	19	0.21	0.42	0.124
B. Financial performance and risk										
Project return (target IRR)	33	13.52%	3.68%	14	11.88%	2.86%	19	14.72%	3.81%	0.026**
Project risk (pseudo standard deviation)	20	6.55%	3.81%	8	6.32%	3.81%	12	6.71%	3.97%	0.832
Sharpe ratio (project return / project risk)	20	2.71	1.34	8	2.63	1.43	12	2.77	1.34	0.834
C. Environmental and social impact										
Total impact area (ha, expected)	17	73,408	167,115	9	114,798	226,016	8	26,844	27,805	0.098*
GHG emissions reduction (1,000 tCO2e, expected)	18	5,665	8,649	8	9,469	11,900	10	2,622	2,824	0.096*
# Beneficiaries (expected)	13	11,623	11,779	6	19,133	13,812	7	5,185	3,710	0.025**
# New jobs created (expected)	15	1,846	4,273	6	3,358	6,693	9	838	1,050	0.279
Certification (1/0 dummy)	33	0.79	0.42	14	0.79	0.43	19	0.79	0.42	0.980

D. Environmental and social impact relative to deal size										
Total impact area / deal size	17	2,793	5,669	9	3,849	7,565	8	1,606	2,235	0.433
GHG emissions reduction / deal size	18	233.59	306.75	8	306.06	392.40	10	175.62	222.64	0.386
# Beneficiaries / deal size	13	724.56	977.48	6	966.54	1,333.84	7	517.14	565.30	0.432
# New jobs created / deal size	15	130.03	392.79	6	271.56	624.17	9	35.69	38.22	0.270
E. Fact-finding										
Fact-finding provisions (1/0 dummy)	33	0.09	0.29	14	0.21	0.43	19	0.00	0.00	0.035**

Notes. This table reports the mean and standard deviation of several deal characteristics across all BIM deals and separately for blended finance deals and deals financed by pure private capital. VERPA refers to voluntary emission reduction purchase agreements. Total impact area is measured in hectares (ha). Greenhouse gas (GHG) emissions are measured in 1,000 metric tons of CO_2 equivalent (tCO_2e). The calculation of the expected IRR, the pseudo standard deviation, and the Sharpe Ratio is described in Online Appendix B. The last column reports the *p*-value of the difference-in-means test comparing blended finance deals vs. deals financed by pure private capital. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

Table 7. Key performance indicators (KPI)

A. Environmental

Certification

- Internationally recognized certifications achieved

Sustainable productive lands and seascapes

- Area of reforestation/afforestation (including agroforestry) [ha]
- Hectares of land under sustainable management (production or conservation/restoration) [ha]
- Hectares of land under sustainable productive management [ha]
- Carbon sequestration practices

Climate change mitigation

- Total GHG emissions avoided/reduced or sequestered [tCO2e]
- Avoided/reduced greenhouse gas emissions [tCO2e]
- Tons of GHG sequestered [tCO2e]
- Tons of GHG sequestered that led to the generation of verified tradable carbon units [tCO2e]
- Tons of GHG avoided/reduced that led to the generation of verified tradable carbon units [tCO2e]

Natural ecosystems

- Hectares of land under conservation or restoration [ha]
- Volume of waste treated or valued [metric tons]

B. Social

Community engagement

- Community engagement events held [#]
- Number of people attending community engagement events [#]

Livelihoods and decent work

- Number of employees [#]
- Employees expressed in full-time equivalent [#]
- People with their main source of income provided by the project (excluding direct employees), [#]
- People expected to benefit directly from the project (excluding employees) [#]
- Households benefitting directly from livelihoods generated by the project (excluding employees and individual beneficiaries) [#]

Inclusion

- Gender ratio for management roles [%]
- Gender ratio for senior executive roles [%]
- Gender ratio at board level [%]
- Ratio of female employees [%]

Notes. This table provides the list of key performance indicators (KPI) used by BIM to track the biodiversity, environmental, and social performance of their biodiversity deals on an annual basis.

Table 8. Deals that were discarded by BIM

	In-portfolio deals			Discarded deals			Difference in means
	N	Mean	Std. dev.	N	Mean	Std. dev.	*p*-value
A. Financial performance							
Project return (target IRR)	33	13.52%	3.68%	32	11.29%	4.60%	0.035**
B. Environmental and social impact							
Total impact area (ha, expected)	17	73,408	167,115	28	19,684	43,148	0.006***
GHG emissions reduction (1,000 tCO2e, expected)	18	5,665	8,649	12	1,253	2,094	0.096*
# Beneficiaries (expected)	13	11,623	11,779	11	3,727	3,899	0.045**
# New jobs created (expected)	15	1,846	4,273	12	1,192	2,813	0.652

Notes. This table reports the mean and standard deviation of several deal characteristics across all BIM deals that made it to the portfolio stage ("in-portfolio deals") and BIM deals that were discarded ("discarded deals"). Total impact area is measured in hectares (ha). Greenhouse gas (GHG) emissions are measured in 1,000 metric tons of CO2 equivalent (tCO2e). The last column reports the *p*-value of the difference-in-means tests comparing in-portfolio deals vs. discarded deals. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

Online Appendix for "Biodiversity Finance"

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Appendix A. Ambiguity aversion and the value of fact-finding in biodiversity projects

In biodiveristy projects, the role of concessionary capital is often to finance basic fact-finding, in order to clarify the nature and potential of the project. In this appendix, we introduce a simple framework that allows us to assess the value of such clarification. The framework builds on the distinction between uncertainty and risk—uncertainty refers to situations where probabilities are unknown, while risk refers to situations in which the probability distribution is known. This distinction dates back to the 1920s and was emphasized by Knight (1921) and Keynes (1921). More recently this distinction has been described as the difference between ambiguity and risk, ambiguity being a situation where multiple probability distributions are consistent with what is known (Ellsberg 1961, Gilboa and Schmeidler 1989, Klibanoff, Marinaci, and Mukherji 2005, Heal and Millner 2014).[1] We assume that initially there are multiple probability distributions over the outcomes of a biodiversity project that are consistent with what is known about it. We then think of concessionary capital in blended finance structures as funding investigations that convert ambiguity to risk by establishing which of these distributions over project outcomes is the real distribution, moving from a multiplicity of possible distributions to a unique one.

In the model that follows, we show how to assess the value of such a removal of ambiguity. As we show, under reasonable conditions, the value is given by a simple formula involving the degree of ambiguity aversion and the variance of the distribution of expected utilities.

We assume that before the investigation funded by concessionary capital there are N

[1] As an illustration, consider the well-known Ellsberg example of a person who is asked to bet on whether or not a ball of a specified color will be drawn from an urn containing red and black balls (Ellsberg 1961). Urn 1 contains 100 balls, 50 red and 50 black. Urn 2 contains 100 balls, each of which is either red or black, but no further information is available. This person faces ambiguity rather than risk, in that there is no probability distribution over outcomes from the second urn. Reducing the ambiguity here would naturally involve research on the mix of balls in urn 2, and finding a precise number for this would remove the ambiguity altogether.

possible probability distributions over project outcomes indexed by n and denoted by $\theta_n(x)$. Here $x \in X$ is the project outcome, where $X \subseteq R^K$ and x is a vector giving outcomes such as the number of hectares protected, the number of species protected, etc. Decision-makers are assumed to choose according to the axioms of smooth ambiguity aversion (Klibanoff, Marinaci, and Mukherji 2003), so the value they place on the project is given by

$$\sum_{n=1}^{n=N} \pi_n \phi\left(E \mid \theta_n U(x)\right),$$

where $U(x)$ is the decision-maker's utility function defined on outcomes x, ϕ is a concave real-valued function expressing ambiguity aversion, and $\pi_n \geq 0$ is the likelihood that the decision-maker assigns to the event that distribution θ_n is the true distribution. The expression $E \mid \theta_n$ is the expectation of the following variable according the the distribution θ_n. This expression is a non-linear weighted average of the expected utilities of the project according to the different distributions, where the weights are the likelihoods. An important point to note is that in a situation of risk, with a single probability distribution, although the outcome x is unknown, the expected utility of the outcome is known. However with multiple possible distributions (ambiguity) there are as many possible expected utilities as there are distributions, so the decision-maker is faced with a distribution of possible expected utilities. If as a result of fact-finding investigations they are assured that the correct distribution of possible outcomes is θ_k, then the value that they place on the project is

$$E \mid \theta_k U(x)$$

and the gain from the extra information is

$$E \mid \theta_k U(x) - \sum_{n=1}^{n=N} \pi_n \phi\left(E \mid \theta_n U(x)\right). \tag{1}$$

We do not know which distribution is the true one, so we need to take the expectation of (1) over all possible distributions. Since the relevant probabilities are the π_n, the expected gain from extra information is

$$\sum_n \pi_n \left\{ E \mid \theta_n U(x) - \sum_{n=1}^{n=N} \pi_n \phi\left(E \mid \theta_n U(x)\right) \right\},$$

which can be rewritten as

$$\sum_n \pi_n \left\{ E \mid \theta_n U(x) - \phi\left(E \mid \theta_n U(x)\right) \right\},$$

which is zero in the special case when $\phi(y) = y$, so that there is zero ambiguity aversion. The gain is in general the cost of ambiguity aversion. We can derive a relatively simple expression for this in the case of limited ambiguity. To do so, it is useful to replace the expression $E \mid \theta_n U(x)$ by E_n, so that the above expression can be rewritten as

$$\sum_n \pi_n \left\{ E_n - \phi(E_n) \right\}.$$

Next let $E^* = \sum_n \pi_n E_n$, the mean expected utility across the different distributions π_n. Then define z as the cost of ambiguity given by

$$\phi(E^* - z) = \sum_n \pi_n \phi(E_n).$$

The certain value of ϕ of the mean expected utility minus z is the same as the expected value of ϕ of the distribution of expected utilities arising under ambiguity. Using a second order Taylor expansion we can express it as

$$\begin{aligned}\phi\left(E^{*}-z\right)-\phi\left(E^{*}\right) &= \sum_{n}\left\{\phi\left(E_{n}\right)-\phi\left(E^{*}\right)\right\}\pi_{n} \\ &= \sum_{n}\pi_{n}\left\{\phi'\left(E^{*}\right)\left(E_{n}-E^{*}\right)+\frac{\phi''\left(E^{*}\right)}{2}\left(E_{n}-E^{*}\right)^{2}\right\} \\ &= \sum_{n}\pi_{n}\frac{\phi''\left(E^{*}\right)}{2}\left(E_{n}-E^{*}\right)^{2}=\frac{\phi''\left(E^{*}\right)}{2}\sigma_{E}^{2}\end{aligned}$$

where σ_E^2 is the variance of the distribution of E_n. The left-hand side of the fist line of this expression can be expressed as $-\phi'\left(E^{*}\right)z-\phi''\left(E^{*}\right)z^{2}/2$ so that

$$-\phi'\left(E^{*}\right)z=\phi''\left(E^{*}\right)\left\{\sigma_{E}^{2}+z^{2}\right\}/2$$

and assuming z to be small so that z^2 is negligible,

$$z=-\frac{\phi''\left(E^{*}\right)\sigma_{E}^{2}}{\phi'\left(E^{*}\right)2},$$

that is, the cost of uncertainty about the distribution is given by the index of absolute ambiguity aversion, $-\phi''/\phi'$, times half the variance of the distribution of expected utilities. This is therefore the value of resolving the ambiguity, that is, of establishing the true distribution of outcomes for the project. If the ambiguity is partially resolved and the variance reduced, then the same formula can be used for evaluating this change. Accordingly, the value of financing fact-finding through concessionary capital increases for projects with a higher variance of the distribution of expected utilities, that is, projects with a higher degree of ambiguity.

Appendix B. Expected IRR and sensitivity analysis

BIM computes the expected internal rate of return (IRR) as the annualized effective compounded return rate based on the cash flows—which include any coupons, dividends, and proceeds—that private investors are expected to receive over the lifecycle of the investment, as per the standard IRR formula

$$0 = NPV - \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0,$$

where C_0 is the investment cost, C_t is the net cash flow in year t, and T is the number of time periods. When projecting the cash flows, the BIM investment team applies different scenarios to obtain a distribution of the project's IRR that is used to compute the expected IRR. These scenarios are listed in Table A5 of the Online Appendix.

In our analysis, we use this scenario analysis to construct a risk estimate of the IRR. Specifically, we compute the average deviation from the base case (that is, in the upside and downside cases) as the "pseudo" standard deviation of the project's IRR.

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Klibanoff K., M. Marinaci, and S. Mukherji, 2005, A smooth model of decision making under ambiguity, *Econometrica* 73(6), 1849–1892.

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Table A1. Examples of biodiversity funds

Natural capital asset types	Examples of biodiversity funds
A. Land	
Agriculture: soil and pollinators	Agri3 Fund; &Green Fund; Eco.business Fund; Food Securities Fund; HSBC Pollination Climate Asset Management; Land Degradation Neutrality Fund; Livelihoods Carbon Fund 3; L'Oreal Fund for the Regeneration of Nature; Madagascar Sustainable Landscapes Fund; Moringa Fund; Nature+ Accelerator Fund; responsAbility Fair Agriculture Fund; Responsible Commodities Facility; SLM Australia Livestock Fund; Terra Bella Colombia Fund; Tropical Landscape Finance Facility
Forests	Africa Forest Carbon Catalyst; Africa Sustainable Forestry Funds I-II; Althelia Biodiversity Fund Brazil; Althelia Climate Funds; Cloud Forest Blue Energy Mechanism; Ecotrust Forest Funds I-III; Eco.business Fund; Forest Resilience Bond; Forestry and Climate Change Fund; HSBC Pollination Climate Asset Management; Livelihoods Carbon Fund 3; L'Oreal Fund for the Regeneration of Nature; Lyme Conservation Opportunities Fund; Lyme Forest Funds I-V; Madagascar Sustainable Landscapes Fund; Mobilising Finance for Forests; Moringa Fund; Nature+ Accelerator Fund; Restoration Seed Capital Facility; SLM Silva Fund; Smallholder Forestry Vehicle; Socio-Climate Benefits Fund Facility; Terra Bella Colombia Fund; Tropical Asia Forest Funds; Tropical Landscape Finance Facility; Working Forest Fund
Urban parks and other green infrastructures in urban areas	Border Impact Bond; DC Water Environmental Impact Bond; Atlanta Environmental Impact Bond
Natural parks & wildlife protection	Althelia Climate Funds; Eco.business Fund; L'Oreal Fund for the Regeneration of Nature; Madagascar Sustainable Landscapes Fund; Tropical Landscape Finance Facility; Wildlife Conservation Bond
Genetic resources	Madagascar Sustainable Landscapes Fund
B. Sea	
Watersheds	Border Impact Bond; DC Water Environmental Impact Bond
Coastal ecosystems	Althelia Sustainable Ocean Fund; Nature+ Accelerator Fund; Belize Blue Bonds; Livelihoods Carbon Fund 3; L'Oreal Fund for the Regeneration of Nature; Mesoamerican Reef Fund
Fisheries	Althelia Sustainable Ocean Fund; Aqua Spark; Belize Blue Bonds; Eco.business Fund; L'Oreal Fund for the Regeneration of Nature; Meloy Fund for Sustainable Community Fisheries; Mesoamerican Reef Fund; Seychelles Blue Bond
Oceans (incl. coral reef)	Althelia Sustainable Ocean Fund; Belize Blue Bonds; Global Fund for Coral Reefs; HSBC Pollination Climate Asset Management; Mesoamerican Reef Fund; Nature+ Accelerator Fund; Seychelles Blue Bond

Notes. This table provides examples of biodiversity funds by natural capital asset types. Note that certain biodiversity funds span more than one natural capital asset types.

Table A2. IRR across deal characteristics

	# Deals	Mean	Std. dev.
Natural capital			
Land	16	12.5%	2.9%
Sea	17	14.5%	4.1%
Continent			
Africa	6	11.0%	2.8%
Asia	8	13.3%	3.5%
Europe	5	15.5%	2.1%
Latin America and Caribbean	10	14.0%	3.6%
Oceania	1	5.4%	N/A
Multiple continents	3	16.8%	2.9%
Financing			
Equity	11	14.7%	3.5%
Equity + Debt	8	15.1%	3.1%
Equity + Debt with profit sharing	1	18.0%	N/A
Equity + VERPA	2	12.5%	3.5%
Debt	1	5.4%	N/A
Debt with profit sharing	6	11.9%	2.6%
VERPA	4	10.9%	3.1%

Notes. This table reports the mean and standard deviation of the expected IRR across the categories considered in Tables 3-5. The calculation of the expected IRR is described in Online Appendix B.

Table A3. ESG assessments

	All			Blended finance			Pure private capital		
	N	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.
A. ESG assessment									
Sustainability	27	2.78	0.42	12	2.75	0.45	15	2.80	0.41
Environmental	28	2.79	0.42	12	2.75	0.45	16	2.81	0.40
Social	27	2.48	0.58	10	2.40	0.52	17	2.53	0.62
Governance	18	1.78	0.73	8	1.50	0.76	10	2.00	0.67
Natural ecosystems	24	2.25	0.74	12	2.17	0.83	12	2.33	0.65
Sustainable product lands & seascapes	27	2.37	0.63	13	2.38	0.77	14	2.36	0.50
Climate change mitigation	24	2.17	0.87	11	2.18	0.87	13	2.15	0.90
Circular economy	20	1.75	0.97	9	1.78	0.97	11	1.73	1.01
Socio-economic development	25	2.24	0.72	10	2.00	0.67	15	2.40	0.74
Livelihoods and decent work	26	2.38	0.57	10	2.40	0.52	16	2.38	0.62
Climate adaptation	20	1.45	0.69	9	1.33	0.50	11	1.55	0.82
Inclusion	24	1.96	0.81	10	1.50	0.53	14	2.29	0.83
Quality of I&ESG management	17	1.71	0.59	8	1.50	0.76	9	1.89	0.33
Business ethics	19	1.68	0.75	8	1.25	0.46	11	2.00	0.77
B. ESG risk assessment									
ESG risk	11	2.00	0.63	5	2.00	0.71	6	2.00	0.63
Environmental risk	18	1.89	0.68	8	2.00	0.76	10	1.80	0.63
Social risk	18	2.06	0.64	8	2.13	0.83	10	2.00	0.47
Governance risk	18	2.06	0.64	8	2.13	0.64	10	2.00	0.67
Country risk and governance risk	9	2.22	0.67	5	2.60	0.55	4	1.75	0.50
Business ethics risk	10	2.00	0.67	5	2.00	0.71	5	2.00	0.71
Legal and regulatory E&S compliance risk	10	1.70	0.48	5	1.60	0.55	5	1.80	0.45
Certifications and standards risk	9	1.78	0.44	4	2.00	0.00	5	1.60	0.55
Environmental and social assessment and management risk	10	2.00	0.47	5	2.20	0.45	5	1.80	0.45

Pollution control, energy and water use risk	10	1.80	0.63	5	2.00	0.71	5	1.60	0.55
Biodiversity conservation risk	10	1.50	0.71	5	1.40	0.89	5	1.60	0.55
Human resources policies & procedures risk	10	1.90	0.57	5	2.00	0.71	5	1.80	0.45
Health & safety at work risk	10	2.20	0.63	5	2.40	0.55	5	2.00	0.71
Community health, safety and security risk	10	1.80	0.63	5	2.00	0.71	5	1.60	0.55
Land tenure and land use change risk	10	2.00	0.82	5	2.40	0.89	5	1.60	0.55
Indigenous peoples' rights and interests risk	8	1.75	0.89	4	2.00	1.15	4	1.50	0.58
Stakeholder engagement and grievance management risk	10	1.70	0.67	5	1.40	0.55	5	2.00	0.71
Gender risk	9	1.78	0.67	4	1.50	0.58	5	2.00	0.71
Cultural heritage risk	7	1.14	0.38	3	1.00	0.00	4	1.25	0.50
C. ESG risk management									
ESG risk management	24	2.50	0.51	10	2.60	0.52	14	2.43	0.51
Environmental risk management	17	2.06	0.24	8	2.13	0.35	9	2.00	0.00
Social risk management	17	2.06	0.24	8	2.13	0.35	9	2.00	0.00
Governance risk management	17	2.00	0.00	8	2.00	0.00	9	2.00	0.00
Country risk and governance management	8	2.00	0.00	3	2.00	0.00	5	2.00	0.00
Business ethics management	10	2.00	0.00	5	2.00	0.00	5	2.00	0.00
Legal and regulatory E&S compliance management	10	2.00	0.00	5	2.00	0.00	5	2.00	0.00
Certifications and standards management	10	2.00	0.00	5	2.00	0.00	5	2.00	0.00
Environmental and social assessment and management	9	2.11	0.33	5	2.20	0.45	4	2.00	0.00
Pollution control, energy and water use management	10	2.10	0.32	5	2.00	0.00	5	2.20	0.45
Biodiversity conservation management	9	2.00	0.00	5	2.00	0.00	4	2.00	0.00
Human resources policies & procedures management	11	2.00	0.00	6	2.00	0.00	5	2.00	0.00
Health & safety at work management	10	2.00	0.00	5	2.00	0.00	5	2.00	0.00
Community health, safety and security management	9	2.11	0.33	4	2.25	0.50	5	2.00	0.00
Land tenure and land use change management	9	2.00	0.00	4	2.00	0.00	5	2.00	0.00
Indigenous peoples' rights and interests management	8	2.00	0.00	4	2.00	0.00	4	2.00	0.00
Stakeholder engagement and grievance management	10	2.10	0.32	5	2.20	0.45	5	2.00	0.00
Gender management	9	2.00	0.00	4	2.00	0.00	5	2.00	0.00
Cultural heritage management	7	2.00	0.00	3	2.00	0.00	4	2.00	0.00

Notes. This table reports the mean and standard deviation of several ESG dimensions that were qualitatively assessed on a scale from 1 to 3. These statistics are reported across all BIM deals and separately for blended finance deals and deals financed by pure private capital. In panel A (ESG assessment), a higher score represents a more positive assessment. In panel B (ESG risk), a higher score represents higher risk. In panel C (ESG risk management), a higher score represents a more positive assessment of the risk management process.

Table A4. Ex-post performance by deal structure

	All			Blended finance			Pure private capital			Difference in means
	N	Mean	Std. dev.	N	Mean	Std. dev.	N	Mean	Std. dev.	*p*-value
Total impact area (ha, relative to target)	9	0.161	0.082	6	0.141	0.081	3	0.200	0.083	0.341
GHG emissions reduction (1,000 tCO2e, relative to target)	7	0.169	0.168	3	0.075	0.106	4	0.239	0.184	0.229
# Beneficiaries (relative to target)	7	0.696	0.405	5	0.771	0.314	2	0.506	0.699	0.484
# New jobs created (relative to target)	12	0.399	0.413	6	0.379	0.484	6	0.418	0.375	0.879

Notes. This table reports the mean and standard deviation of the ex-post impact measures considered in Figure 6. For each impact measure and each deal, we compute the realized impact (relative to the targeted impact) until the last year for which we have ex-post data (that is, up to three years post-closing). We then report the mean and standard deviation across all deals and separately for blended finance deals and deals financed by pure private capital. The last column reports the *p*-value of the difference-in-means test comparing blended finance deals vs. deals financed by pure private capital. *, **, and *** denotes significance at the 10%, 5%, and 1% level, respectively.

Table A5. Scenario analysis

	Upside case	Base case	Downside case
Model drivers			
Production (e.g., commodities, food, carbon capture) [% of base]	120%	100%	80%
Price scenario [high, medium, low]	High	Medium	Low
Cost overrun [% of base]	-10%	0%	+10%
Project delay [# years]	0	0	1 or more