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Green Bonds: The Time Is Now

Angelo A. Calvello, PhD
Founder, *Journal of Environmental Investing*

Green bonds, once characterized as novelty investments, are now an integral part of institutional investors' core fixed-income portfolios and represent the entire investment chain, ranging from corporate to municipal bonds and sovereign bonds.

Yet the discourse around green, or climate, bonds has tended to be insular and often myopic, confined to the cognoscenti.

In 2019, our guest editor, Dr. Kim Schumacher, Lecturer in Sustainable Finance and ESG Investment, School of Environment and Society, Tokyo Institute of Technology, Mary Cavanagh, the *JEI* managing editor, and I discussed dedicating an entire issue of the *Journal of Environmental Investing* to green bonds. Our explicit purpose was to include the voices of practitioners, professionals, business leaders, regulators, and academics and to have these voices explore both the intrinsic investment value of these bonds and their transformative power to mitigate the risks of climate change.

The challenges of 2020 altered our lives, as well as some aspects of publishing the *JEI*. In response, our managing editor, Mary Cavanagh, adjusted schedules and coordinated submissions of materials, managing the publishing process so we could still bring you this scholarship in its usual, professional format.

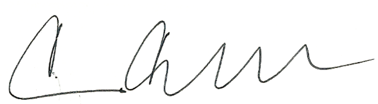
After reading this issue, I'm sure you'll agree we've achieved our goal. Yet perhaps not immediately obvious in the issue itself is that we achieved this goal because of Dr. Schumacher's persistent leadership and unwavering commitment to providing the community writ large with critical original research. The articles and the associated comments greatly advance our collective knowledge and understanding of green bonds and provide a foundation for future significant exploration.

Today's COVID-19 crisis makes these explorations more urgent and more essential than ever. As Michael Bloomberg writes in the current issue of *Bloomberg Green*, "governments around the world are debating how to mobilize unprecedented sums of money to stabilize national economies and counter the devastation wrought by the novel coronavirus. As they do, all are facing the choice between the old road and a new one. Between protecting jobs in old industries and creating jobs in new ones. Between burning coal and gas and harnessing renewable energy. Between damaging our health and improving it. And between worsening climate change and stopping it while building resiliency.

Our hope is that this issue will contribute to the debate and help investors choose the new road.

In closing, I'd like to thank Verger Capital Management LLC for sponsoring this issue. Verger is an investment adviser providing Outsourced Chief Investment Officer services to a select group of nonprofit institutions. Their sponsorship is further evidence of their commitment to invest in the lives of others.

Best wishes,



Angelo Calvello, PhD
Founder

Green Bonds: The Shape of Green Fixed-Income Investing to Come

Dr. Kim Schumacher
Lecturer in Sustainable Finance and ESG at the Tokyo Institute of Technology

Abstract

This paper serves as an introduction to the *Journal of Environmental Investing*'s issue (Vol. 10, No. 1, 2020) on climate and green bonds. Fixed income securities that integrate environmental, social, and governance (ESG) factors have become a crucial component of most sustainable investment and climate-related risk management strategies. Global green bond issuance has grown from USD 87.2 billion in 2016 to USD 257.7 billion in 2019. However, this issue is addressing some of the challenges of rapid market scaling. The first pertains to the labeling of green bonds. Albeit the term "green bond" becoming synonymous for the entire spectrum of ESG-aligned fixed income securities, there now exists a plethora of labels, names, and designations for green bonds, often resulting in confusion about what exactly constitutes a green bond. By providing the most comprehensive overview to date of all green bond variants, this issue explores the core attributes of green bonds, such as their potential returns from financial and nonfinancial angles, taxonomical and underlying conceptual considerations, and academic assessments of the market as a whole. In conclusion, this paper and the corresponding issue provide contemporary insights and an up-to-date snapshot of the evolving characteristics of climate and green bonds.

Keywords: *Sustainable Finance, ESG, Green Bonds, Climate Bonds, Taxonomy, Sustainability, SDGs, Responsible investment, Fixed Income*

JEL Classification: *G3; O16; Q01; Q2; Q3; Q4; Q54; Q56*

1. Introduction

So far, 2020 has proven to be a year of profound global turmoil, affecting all aspects of human life. From the socio-economic Covid-19 disruptions and protests against racial inequality to the continuously escalating climate crisis, humanity is at a veritable crossroads in terms of addressing and remedying past, present, and future risks to society and the planet. With the Paris Climate Agreement and the UN Sustainable Development Goals (SDGs), the global community has established ambitious yet critical targets to safeguard and improve the lives of present and future generations. In order to achieve these goals, numerous stakeholders, including law- and policy-makers, industry and civil society representatives, and academia, have been developing and conceptualizing appropriate tools and strategies.

Financial instruments, and the financial sector in general, have been identified as major levers in contributing to the fight against global warming and sustainable development. In recent years, terms such as sustainable investing, sustainable finance, and impact investing have entered the investor vocabulary, indicating that sustainability, climate, and socio-environmental issues are gaining in relevance among industry practitioners. Environmental, social, and governance (ESG) factors, climate-related risks, and nonfinancial performance metrics have transformed from marginal into material investment considerations. Investors are now turning their attention to the different approaches and vehicles at their disposal to integrate ESG factors or manage environmental and climate-related risks in their portfolios.

Fixed-income securities that use their proceeds toward the financing of ESG-aligned projects have proven particularly attractive among investors. Their volume has been increasing exponentially since their inception by the European Investment Bank (EIB) in 2007 and following their expansion by the International Finance Corporation (IFC) in 2010. A 2019 study examines the publicly reported allocations of green bond proceeds from 53 organizations to projects and assets throughout 96 countries from 2008 to 2017 (Tolliver et al. 2019). It found that the projects and assets financed with green bonds in this study sample are associated with over 108 million tonnes of carbon dioxide equivalent (tCO_2e) in greenhouse gas emission reductions and over 1,500 gigawatts in renewable energy capacity (Tolliver et al. 2019). Nowadays, the fixed-income securities category is represented throughout the entire investment chain, ranging from corporate bonds to municipal bonds and sovereign bonds. They seemingly offer a variety of advantages that render their issuance—as well as the measurement, reporting, and verification (MRV) of capital allocation and impact assessments—comparatively easier to accomplish than, for example, that of ESG-aligned funds or benchmark indexes.

For this special issue, we looked for articles that explore the extent to which sustainability-linked and ESG-aligned fixed-income securities can support the mainstreaming of responsible investment principles across the financial sector. We welcomed articles from practitioners, professionals, business leaders, regulators, and academics highlighting the transformative power of ESG-related bonds and the extent to which their often-unique characteristics have an impact on environmental investing as a whole.

Topics of particular interest and contemporary relevance have been: taxonomies; benchmarks; disclosure and reporting standards; impact measurement metrics; the roles of multilateral-development banks (MDBs) and development finance institutions (DFIs); public, private, and blended financing structures; the role of regulators; the role of stock exchanges; bond certification, ratings, and labels; classes of ESG-related bonds; and eligibility criteria. The final submissions analyze underexplored aspects and characteristics of ESG-aligned fixed-income securities and expand the dynamic conceptualizations of the latter. These will contribute to the growing body of academic literature on green and sustainability bonds.

Among the topics covered in their articles, the authors further investigate fundamental conditions that need to be fulfilled for fixed-income securities to be considered ESG-aligned, generate a tangible sustainability-related impact, and remain attuned with conventional market-level financial performance metrics. These are challenges facing many issuers of green bonds[1] and other sustainability-linked bond variants. By taking into account ESG factors, such as climate-related risks, green bonds have the potential to outperform their conventional peers because they are less exposed or vulnerable to negative ESG externalities.

In order to contextualize the articles of this special issue, it is important to outline the current understanding and developments around green bonds.

2. What Exactly Renders a Bond Green?

As mentioned above, the core concept of what is known today as a green bond emerged in 2007, when the EIB issued "Climate Awareness Bonds" (CABs). It bore the peculiar characteristic that its proceeds were earmarked and ring-fenced toward contributing to climate action in renewable energy and the energy efficiency sector (EIB 2020). The World Bank Group then incorporated a similar principle in their own sustainability-linked fixed-income product, the original "Green Bond." It was the first financial product that used the designation "green bond," and its first round was issued in 2010. All subsequent variants of green bonds then followed the core financial principles set out by the EIB's

[1] The term "green bond" will be utilized representatively for all ESG-aligned fixed-income securities throughout this article.

CABs and the IFC's Green Bonds. In theory, green bonds have higher yields and lower variance, and are more liquid, if compared with their closest brown bond neighbors (Bachelet et al. 2019). But a negative premium was dependent on the green bonds' being issued either by large institutional issuers or by private issuers whose bonds had external third-party verification (Bachelet et al. 2019). However, some issuers have been advocating for a "greenium" that investors should pay and that would cover the additional cost associated with *pre-issuance (ex-ante)* third-party and *post-issuance (ex-post)* impact monitoring and reporting (Weber and Saravade 2019). Still, Gianfrate and Peri (2019) observed that green bonds are actually more convenient than conventional bonds because the magnitude of the savings for issuers (in terms of interests paid) exceeds the costs of getting third-party certification or verification.

The global green bond market has seen rapid growth, with total issuance increasing from USD 87.2 billion in 2016 to USD 257.7 billion in 2019 (CBI 2017; 2019d). The United States, China, and France accounted for the majority of issuances according to the Climate Bonds Initiative (CBI) tracking figures (CBI 2017; 2019d). Supranational entities, notably MDBs and DFIs, also accounted for a significant share of issuance volume, standing at USD 13.7 billion in 2019, which represents 7% growth compared to 2018 (CBI 2019d). This solidified their precursory role in the market by facilitating new types of ESG-related bond types. A lot of this growth has also been catalyzed by stock exchanges with the first EIB CAB being listed at the Luxembourg Stock Exchange (LuxSE) in 2007 (Erhart 2018a). Many exchanges have been observed listing green bonds without any additional listing fees, as compared to vanilla bonds, and despite additional listing requirements in terms of verification and document screening (Erhart 2018a; 2018b).

Nonetheless, the overall size of the green bond market still pales in comparison to the conventional bond market, for which new bond issuance in 2019 totaled USD 6.86 trillion, up 17% from 2018 (S&P Global 2020). This solidified their precursory role in the market by facilitating new types of ESG-related bond types. However, these figures and greenwashing challenges, such as the inclusion of projects related to "clean coal" that were permitted for many Chinese green bonds, lead us to some of the key issues around standardization inconsistencies addressed in this *JEI* special issue (Weber and Saravade 2019).

Because rules and frameworks pertaining to domestic green securities inside China have at times differed substantially from international standards, significant dilemmas have arisen for investors interested in ESG-aligned portfolios (Weinland 2020). The main difference concerned coal-fired power generation, since Chinese green bond guidelines did not exclude investments in "ultra-super-critical" coal-fired power (CBI 2020a; 2020c). This approach starkly contrasts with the two predominant international standards, the CBI Standards and the ICMA (International Capital Markets Association) Green Bond

Principles, both of which exclude coal-fired power generation projects on the basis of their misalignment with emissions scenarios set by the Paris Climate Agreement and multiple other negative externalities linked to their operation, such as air pollution and mineral extraction (CBI 2020b; ICMA 2018b). This situation sometimes required trading platforms to make adjustments in order to account for these taxonomical divergences. For example, the LuxSE, which created the first dedicated Green Bond Exchange (LGX) in 2016, cross-listed Chinese green securities separately from regular ones on its platform. (LuxSE 2020). LuxSE indicated (among others) that the Green Bond Endorsed Project Catalogue by the People's Bank of China (PBOC), one of China's main financial regulators, "accepts retrofits of fossil fuel power stations, clean coal and coal efficiency improvements, and rail lines that mainly transport fossil fuels, which are not accepted under the Climate Bonds Initiative's eligibility taxonomy" (LuxSE 2020). Some studies found that these differences may affect the lender's investment assessment and decision on whether to provide financing to the issuer (Zhang 2020).

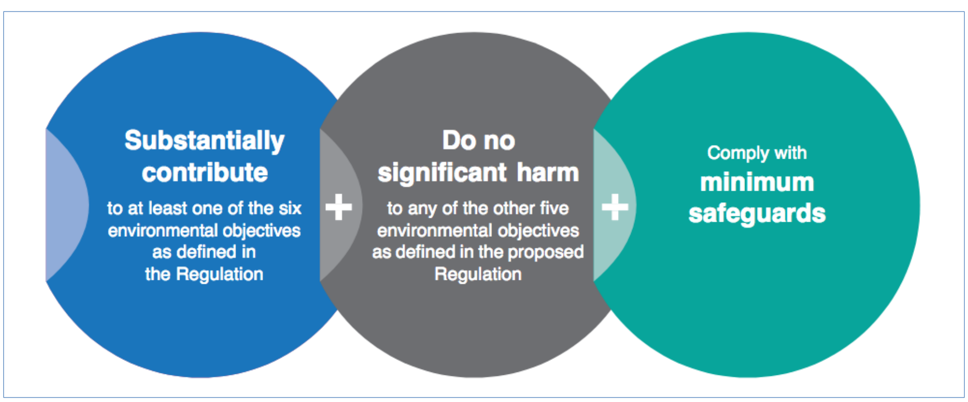
In a major apparent and imminent policy reversal, a draft for consultation of the 2020 edition of the PBOC's Green Bond Endorsed Projects Catalogue dropped fossil-fuel-related projects, including coal, from its taxonomy of eligible green projects (CBI 2020c). This development in China notwithstanding, the controversies around the inclusion of coal and other fossil-fuel-related projects are still continuing and touch directly on discussions surrounding greenwashing. Greenwashing in the ESG investing and sustainable finance industries alludes to the practice of marketing or distributing finance products or services that overstate their positive sustainability impacts, or understate their material environmental risks, or generally misrepresent their perceived ESG-related benefits. Reputational and economic considerations are the most frequent reasons for engaging in greenwashing. Several green bond products have been denounced as greenwashing attempts, notably a sustainability-linked bond by Italian energy conglomerate Enel (EF 2019a). In that instance, the greenwashing accusations made by large institutional investor Nuveen were not shared unequivocally; some researchers claimed that while certainly improvable, Enel's bond in question presented more comprehensive target-setting and incentives to reach the latter than conventional green bonds offered up to that moment (Dupré 2019). The controversies and discussions surrounding the inflation in green bond labels and designations were covered comprehensively by several commentators who observed that all of the innovation and experimentation in this area can lead to a simultaneous growth of greenwashing risks if no proper standards are fixed for the green bond market (Cripps 2019; Lee 2020; Deschryver and De Mariz 2020). Bonds issued by companies operating in carbon-intensive sectors, such as Enel, Repsol, Snam, and Teekay with their fossil-fuel-related activities, or Marfrig, a Brazilian meat producer, were seen as particularly critical. Most critics questioned the sincerity of their transition efforts and the general use of proceeds toward carbon reductions and other SDG-related improvements (Cripps 2019; Robinson-Tillett 2019; Lee 2020).

3. United We Stand, Divided We Fall: Initiatives to Reduce Greenwashing

In light of these persisting systemic risks—emanating from greenwashing and the general fluidity in defining what makes a project eligible to be considered green or ESG-aligned—multiple financial market regulators then attempted to provide clear guidelines on what types of activities could benefit from green bond proceeds. Prominent examples include the Japanese Ministry of Environment, which issued the first iteration of the Green Bond Guidelines in 2017, and the European Union (EU), which started a process at the end of 2016, with the creation of the High-Level Expert Group on Sustainable Finance (HLEG), to develop an overarching and comprehensive EU strategy on sustainable finance, including for green bonds (MOEJ 2017; EC 2018). The EU's efforts then culminated in concrete recommendations for the introduction of an EU Green Bond Standard (GBS), published in 2019 after prior preparatory work by a Technical Expert Group (TEG), a follow-up to the HLEG (EC 2020a; 2020d). The EU's GBS referenced the EU Taxonomy, a "classification system for sustainable economic activities—that will create a common language that investors can use everywhere when investing in projects and economic activities that have a substantial positive impact on the climate and the environment" (EC 2020b; 2020c).

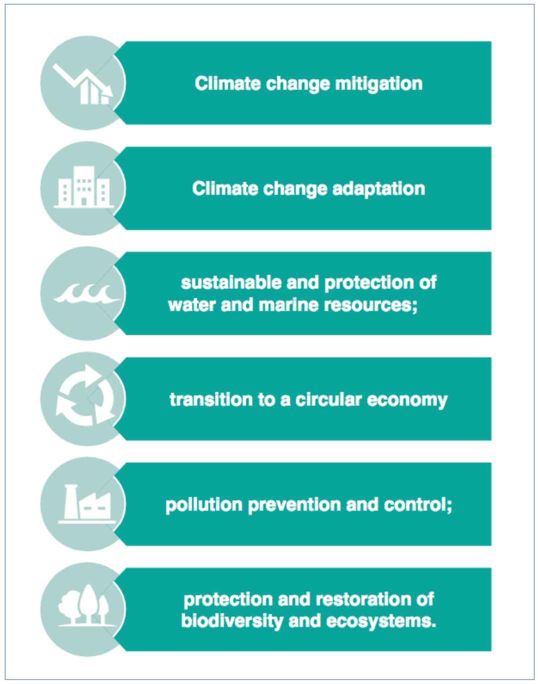
For projects to be eligible under the EU GBS, issuers need to demonstrate how the raised capital will actually be employed. While "use-of-proceeds" is not new, for the CBI and the ICMA pursued a similar approach in their respective guidelines and standards, the EU went a step further by tying any green-bond-related "use-of-proceeds" to projects and activities aligned with the Taxonomy (EC 2020c). This means that projects, in order to be eligible for inclusion in green bond financing, need to comply with several conditions (Figure 1) and environmental objectives (Figure 2).

Figure 1. EU Sustainable Finance Taxonomy—Performance Thresholds (referred to as 'technical screening criteria')



Source: EC 2020c.

Figure 2. EU Sustainable Finance Taxonomy—Six Environmental Objectives



Source: EC 2020c.

In climate change mitigation, the taxonomy also sets several sectoral criteria; it sets, for example (EC 2020b):

- The emissions intensity threshold of 100g CO_2e / kWh is proposed for electricity generation, heat production and the co-generation of heat and electricity. This threshold will be reduced every five years in line with political targets set out to achieve net-zero emissions by 2050.

- For passenger cars and light commercial vehicles:
  - Zero tailpipe emission vehicles (including hydrogen, fuel cell, electric). These are automatically eligible.
  - Vehicles with tailpipe emission intensity of max 50 g CO_2/km (WLTP) are eligible until 2025.
  - From 2026 onwards only vehicles with emission intensity of 0g CO_2/km (WLTP) are eligible.

The EU GBS and the corresponding EU Taxonomy represent thus far the most elaborate attempt at creating a uniform, and mandatory, set of rules and standards for green bonds. They are meant to provide investors with certainty around the ESG-alignment of the projects that respective green bond fund managers will invest in.

While standards regarding green fixed-income securities can increase the level of transparency in the ESG-investing and sustainable finance sectors, the fracturing of green bonds into continuously growing numbers of sub-groups and label variants hinders rather than supports broader awareness around green bonds.

Particular issues are the multiple label, denominations, and designations that have appeared for green bonds ever since their conceptual inception and practical implementation in 2007 by the EIB. The EIB marketed their first issuance of green bonds as "Climate Awareness Bonds" (CABs) in 2007, focusing mainly on climate-related projects (EIB 2020b). These were then complemented by "Sustainability Awareness Bonds" (SABs) in 2018, which responded to the EU's Action Plan on Sustainable Finance and have a stronger focus on the SDGs at large by aligning with the ICMA's Social Bond Principles and Sustainability Bond Guidelines (EIB 2018; 2019; 2020c). In 2018 and 2019, SAB project allocations were almost exclusively water-related; the majority of projects dealt with water supply, sewage, and wastewater collection and/or treatment (EIB 2018; 2019; 2020c).

However, the EIB-issued CABs and SABs constitute only two forms of currently marketed ESG-aligned fixed-income securities. Over the years, we have seen a plethora of green bond variants being launched. They all share commonalities in terms of "use-of-proceeds" frameworks and, in some form or shape, have to contribute to sustainability goals or integrate ESG factors to varying degrees (Table 1). These green bond variants often also follow or align with different guidelines or frameworks, which renders a general understanding of the underlying principles of green bonds unnecessarily complex (Table 1). This complexity risks exacerbating the challenges that green bonds still face in the market: first, protecting their environmental integrity, and second, enhancing their financial benefits (I4CE 2016). The increasing variety of bonds also corresponds to the regional risks that issuers anticipate in emerging markets and developing countries (Weber and Saravade 2019). While many sustainability and SDG-related projects would be carried out in these regions, some issuers remain cautious as to whether they can uphold investor expectations regarding transparency and disclosures to avoid any issues related to accountability. Hence, they see the diversification of bond types as a way of risk management (Weber and Saravade 2019).

Table 1. List of Green Bond Variants / Labels (in alphabetical order)

Bond Designation	Major Issuer(s)	First Issuance (Year)	Main Objective(s)	Key Eligible Projects	Main Frameworks/Guidelines
Benchmark Bonds (IDA, 2020)	International Development Association (IDA)	2020	SDGs	Projects and programs in eligible IDA countries as they advance the SDGs	Internal IDA/World Bank Guidelines
Blue Bonds (World Bank, 2018b)	The Republic of Seychelles	2018	Marine Resource Protection	Sustainable Fishing Practices and Marine Habitat Protection	Internal World Bank Green Bond Process Implementation Guidelines
Catastrophe/Disaster Bonds (World Bank, 2018a)	World Bank	2014	Climate Resilience and SDGs	Provide financial resources in the hands of public officials in the aftermath of climate disasters.	Internal World Bank Capital-at-Risk Notes Program Guidelines
Climate Action Bonds (Snam, 2019)	Snam	2019	SDGs	Energy transition and sustainable development projects	Snam Climate Action Bond Framework (Snam, 2020)
Climate Awareness Bonds (EIB, 2020b)	European Investment Bank (EIB)	2007	Climate Mitigation/ Adaptation	Renewable Energy and Energy Efficiency	Internal EIB Green Bond Framework ICMA GBPs (ICMA, 2018b) CBI Standards (CBI, 2019a)
Climate Bonds (CBI 2019a)	Climate Bonds Initiative[2]	2010	Climate Mitigation/ Adaptation	Renewable Energy, Sustainable Land Use, Water Resource Protection	ICMA GBPs CBI Standards
Climate Resilience Bond (EBRD, 2019a)	European Bank for Reconstruction and Development (EBRD)	2019	Climate Resilience	Infrastructure (e.g. water, energy, transport, communications & urban infrastructure); business & commerce; or agriculture & ecological systems.	CBI Climate Resilience Principles (CBI, 2019e)
Development Impact Bonds (UBS Optimus Foundation, 2019)	UBS Optimus Foundation	2018	ESG (focus on "S") and SDGs	Girls' education	National laws and regulations
ESG Bonds (BBVA, 2019)	Nomura Foundation[3] BBVA[2]	2019	ESG and SDGs	Projects is line with sustainability principles	ICMA GBPs and SBPs (ICMA, 2018a) CBI Standards
Environmental Bonds (NIB, 2019a)	Nordic Investment Bank (NIB)	2019	ESG (focus on "E")	Renewable Energy and Energy Efficiency; Clean Transport and Green Buildings	NIB Environmental Bond Framework (NIB, 2019b) ICMA GBPs
Environmental Sustainability Bonds (EBRD, 2019)	EBRD	2010	Climate Mitigation/ Adaptation	Climate Projects and Sustainable Resource Projects (Energy, Water, Pollution Prevention)	ICMA SBPs ICMA Sustainability Bond Guidelines
Forest Bonds (IFC, 2020a)	International Finance Corporation (IFC)/World Bank	2016	Forest Ecosystems	Reduction of Deforestation and Forest Degradation	UN-REDD and REDD+ Programme Frameworks
Green Bonds (IFC 2020d; Word Bank, 2019)	International Finance Corporation (IFC)/World Bank	2010	ESG and SDGs	Renewable Energy, Sustainable Land Use, Water Resource Protection	ICMA GBPs CBI Standards
Green Convertible Bonds (Neoen, 2020)	Neoen	2020	Climate mitigation and SDGs	Financing or refinancing of renewable energy production (solar PV, wind power) or storage activities	ICMA GBPs EU GBS (EC, 2020d)
Green Contingent Convertible Bonds (BBVA, 2020)	BBVA	2020	SDGs	Primarily energy efficiency, renewable energy, sustainable transportation, and waste and water management	BBVA SDGs Bond Framework (BBVA, 2018) ICMA GBPs

[2] The Climate Bonds Initiative (CBI) refers to Climate Bonds merely as a term equivalent green bonds (CBI, 2020).
[3] Nomura Foundation and BBVA refer to ESG bonds merely as a composite term that encompasses green bonds, social bonds, and sustainability bonds (Nomura Foundation, 2019; BBVA, 2019).

Green Transition Bonds (EBRD, 2019; 2020)	EBRD	2019	Climate Transition/ Mitigation	Manufacturing, food production and green buildings	ICMA GBPs
Pandemic Bonds (World Bank, 2017a)	World Bank (International Bank for Reconstruction & Development)	2017	ESG (focus on "S") and SDGs	Efforts against infectious diseases and containment of diseases	Covered perils: Flu, Filovirus, Coronavirus, Lassa Fever, Rift Valley Fever and Crimean Congo Hemorrhagic Fever
SDG Bonds (Theron, 2020)	African Development Bank (AfDB) and Nedbank South Africa	2020	SDGs	Environmentally friendly and climate-sensitive projects in areas such as renewable energy and affordable housing	ICMA Green/ Social/ Sustainability (GSS) Bond Principles & Voluntary Process Guidelines for Issuing GSS Use-of-Proceeds Bonds, certified by the CBI, or issued under the EU GBS
SDG/Sustainability-linked Bonds (Environmental Finance, 2019a)	Enel	2019	SDGs	SDG-related transition activities	ICMA Sustainability-Linked Bond Principles (ICMA, 2020d)
Social Bonds (IFC, 2020a)	International Finance Corporation (IFC)/World Bank	2017	ESG (focus on "S")	Under-served populations in emerging markets incl. women and low-income communities with limited access to essential services such as basic infrastructure, finance etc.	IFC Social Bond Process (IFC, 2020b) ICMA SBPs
Social Impact Bonds (Mair, 2017)	Social Finance Ltd. and Peterborough Community, UK	2010	ESG (focus on "S")	Preventive social programs with the aim of bringing medium- to long-term benefits to both local beneficiaries and regional governments.	National laws and regulations
Social Inclusion Bonds (CEB, 2018)	Council of Europe Development Bank	2017	ESG (focus on "S")	Support to micro, small and medium-sized enterprises (MSMEs) to strengthen job creation/preservation; social housing for vulnerable population groups; and education and vocational training.	Council of Europe Development Bank Social Inclusion Bond Framework (CEB, 2020)
Sustainability (Awareness) Bonds (EIB, 2018; 2020c)	EIB	2018	SDGs	Water Quality, Access and Sanitation and infrastructure projects in developing countries	ICMA SBPs ICMA Sustainability Bond Guidelines (ICMA, 2018a)
Sustainable Transition Bonds (Robinson-Tillett, 2019)	Marfrig	2019	SDGs	Improving the social and environmental standards of supply chains (Brazilian meat sector)	ICMA Sustainability Bond Guidelines
Sustainable Development Bonds (World Bank 2020a; 2020b)	World Bank (International Bank for Reconstruction and Development)	2017	SDGs	Gender Equality; Sustainable Cities; Climate Resilience; Ocean and Water Resources	ICMA SBPs ICMA Sustainability Bond Guidelines
Sustainable Growth Bonds (World Bank, 2017b)	World Bank (International Bank for Reconstruction and Development)	2017	SDGs	Gender Equality; Sustainable Cities; Climate Resilience; Ocean and Water Resources	ICMA SBPs ICMA Sustainability Bond Guidelines
Transition/Transformation Bonds (Cripps, 2019; Naumann, 2019; Lee, 2020; Pratsch, 2020)	Repsol and Teekay	2017 (Repsol) and 2019 (Teekay)	SDGs	Climate-related transition activities	ICMA Sustainability-Linked Bond Principles

Sustainable Growth Bonds (World Bank, 2017b)	World Bank (International Bank for Reconstruction and Development)	2017	SDGs	Gender Equality; Sustainable Cities; Climate Resilience; Ocean and Water Resources	ICMA SBPs ICMA Sustainability Bond Guidelines
Transition/Transformation Bonds (Cripps, 2019; Naumann, 2019; Lee, 2020; Pratsch, 2020)	Repsol and Teekay	2017 (Repsol) and 2019 (Teekay)	SDGs	Climate-related transition activities	ICMA Sustainability-Linked Bond Principles

Sources: See individual references.

As the extensive, albeit non-exhaustive, list in Table 1 shows, the green bond ecosystem is gradually becoming more multifaceted and the labels utilized by issuers are rapidly expanding to cover a growing number of SDG-related indicators or ESG factors at a more granular level. For example, green convertible bonds are the latest innovation in this bond segment. They have already gained prominence in areas of project finance for green energy infrastructure and green buildings (Fioretti 2019; Gregor, 2020).

In this context, new regulatory proposals such as the EU Taxonomy and EU GBS, as well as efforts by the International Standards Organization (ISO) Technical Committees 207 (Environmental Management) and 322 (Sustainable Finance), aim at creating uniform frameworks and standards that will reduce greenwashing and will increase transparency and the comparability of *ex-ante* project-related impact assessments and *ex-post* impact-related data collection. (ISO 2018; 2020). Post-issuance reporting is particularly important in measuring the veritable impacts of projects financed by green bond funds. Tolliver et al. (2019) concluded that many institutions still fail to publish reports that articulate environmental impact estimates of proceeds-recipient projects and assets. They stated that many post-issuance reports do not clearly identify the additionality of green bond impacts, which renders it difficult to derive the connections between SDGs and Nationally Determined Contributions (NDCs) oriented to environmental outcomes and green bond finance vehicles (Tolliver at al. 2019). These sentiments are echoed by Sartzetakis (2020), who states that bridging the informational gap between issuers and investors is probably the most important challenge for green bonds at the moment. Providing clear green criteria and a comprehensive monitoring process (for example, information on the projects' environmental impact) is crucial to the scaling of the green bond market.

Therefore, a lot of work remains: although a 2019 report found significant improvements over the past years by issuers providing use-of-proceeds or post-issuance impact reports, the scope and granularity of these reports need to be fundamentally improved (CBI 2019c). In order to draw proper conclusions about the material nonfinancial impacts of green bond-funded projects, the collected data requires further standardization and detail. Apart from the EU and the ISO, the industry-led ICMA has also proposed new harmonized frameworks on green and social bonds to enhance the usability of existing guidance on impact reporting and to avoid repetitions (ICMA 2020a; 2020b).While all of these initiatives are generally seen as steps in the right direction to counter greenwashing and stimulate sustainable investing, countries that still have non-negligible stakes in carbon-intensive industries are cautious because the Taxonomy's rigid sectoral thresholds would, for example, lead to the complete exclusion of coal, oil, and most gas projects and operations (CBI 2019b; EC 2020b; EC 2020c).

Japan, among others, has been particularly vocal since the country still relies heavily on coal for its domestic energy production, besides being a major exporter of coal-fired power-plant technology to other Asian countries (Schumacher et al. 2020; InfluenceMap 2020). In light of these facts, and despite having announced it will shut down about 100 inefficient coal plants by 2030, the Japanese Ministry of Energy, Trade and Industry (METI), in collaboration with several energy policy researchers, went on to propose a Climate Transition Finance Principle (Nikkei Asian Review 2020; Responsible Investor 2020). These principles act as a counterbalancing agent to the EU Taxonomy in that they explicitly permit the use of proceeds for transition actions toward the de- or low-carbonization of GHG-emitting industries and sectors (METI 2020). These views have also been supported by a number of studies; for example, Demary and Neligan (2019) argued in favor a more flexible and gradual approach when defining which economic activities are green and which are non-green. They advocate that businesses should, at least in part, be allowed to issue green bonds if they invest in technologies that reduce their CO_2-emissions significantly (Demary and Neligan 2019).

In addition to Japan, other countries have also proposed their own sustainable finance principles to define which activities fall under the sustainable finance moniker (CBI 2019b). Canada, like Japan, has also proposed the establishment of a "Transition Finance Taxonomy," complementing a regular EU-style green finance taxonomy (Canada Government 2019; CSA Group 2020). In south-east Asia, Malaysia has proposed a "Climate Change and Principle-based Taxonomy" that directly incorporates elements from the EU taxonomy, including the "do-no-significant-harm" principle (BNM 2019).

4. The Climate/Green Bonds Special Issue: Outline and Discussion

These examples illustrate the need for further structuring and clarifications concerning green bonds. Otherwise, numerous stakeholders and the general public will find it challenging to fully decipher the increasingly complex language and principles found across the green-bond spectrum. Academia, situated at the intersection of applied business-oriented research and the exploration of theoretical concepts in sustainable and environmental investing, plays an important role, both as a mediator between the scientific and business communities, and as an essential provider of ESG data.

This *JEI* special issue contains detailed case studies, literature reviews, and discussions that provide in-depth examinations of the green and climate bonds market and how certain aspects have evolved. They range from liquidity-level investigations around a specific type of forest sustainability bond in the first paper to the second paper's concept of greenium and whether market pricing mechanisms deliver an advantage to the cost of capital for green bonds. The next paper then provides an extensive review on the development of independent market-level sustainable finance taxonomy, while the final paper is a conceptual analysis of the core structures that underlie the green bond market.

To provide additional context and discussion, an expert opinion accompanies each article. These comment pieces, written by current industry practitioners, financial sector stakeholders, and academic experts, complement each article not only by discussing or challenging its methodologies and results but also by outlining potential avenues for further research and stakeholder engagement.

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Estimating Forest Sustainability Bond Prices for Natural Resource and Ecosystem Services Markets

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Abstract

Existing markets for natural resources commonly trade precious metals, energy, and minerals. More recently, the development of ecosystem service markets has begun, including for the resources of land carbon, species habitats, streams, watersheds, and wetlands. We introduce a sustainable forestry bond that is composed of wood products and ecosystem services. The security represents a specific forested land quality and quantity for the production of natural resources and ecosystem services. An investment decision is based on the Net Resource Value (*NRV*) of a series of cash flows produced from trees and benefits provisioned by the ecosystem services in a forest. This combination of inputs and outputs represents the value created over the lifetime of a forest project and is equal to the monetized difference between the forest natural resources and ecosystem service outputs and the capital invested to produce them. For investment decision making, an Average Internal Rate of Return or AIRR is calculated, which is Net Present Value-consistent (NPV-consistent).

A significant finding of adding all these ecosystem services is that they produce an increase in the cash flow to a traditional forest bond, which, in turn affects the security's Par value, and consequently the Return on Investment. Our results demonstrate that reforestation with a multiple harvest species maximizes direct-use benefits and provisions significant carbon sequestration benefits. However, land conversion to such a species can have long-term environmental effects that fundamentally change the structure of an ecosystem. To account for these environmental changes, we include two other ecosystem endpoints in the portfolio (i.e., waterfowl habitat and nitrate reduction). While forest and "green" bonds are traded today, our findings demonstrate that the return from an integrated portfolio that contains forest wood products (direct use) and ecosystem services (indirect uses) provides an investor with more investment choices.

I. **Introduction: Estimating Forest Sustainability Bond Prices for Natural Resource and Ecosystem Services Markets**

There is ample evidence of investor interest in forests, which provide a means to diversify financial investment portfolios and to securitize sustainable forests with green bonds (Erhart 2018; ECLAC 2017). For years, forest bonds have been used as a means to diversify an investment portfolio (Healy et al. 2005). On the other hand, green bonds for environmental sustainability, by preserving and developing forests, are a recent development (ECLAC, 2017; Madeira, 2016). Of the $6.5 billion ($US) invested toward capital during the years 2004–2015, investors directed 44% ($2.9 billion) of that capital toward sustainable forestry (Hamrick 2016). There are several green exchanges globally (Erhart 2018). In addition, there are evolving partnerships and quasi-markets in the United States. For example, the U.S. Department of Agriculture (USDA) supports conservation programs designed to sustain or restore ecosystem services (http://www.ers.usda.gov/topics/natural-resources-environment/conservation-programs/background.aspx, accessed April 15, 2016). These market-oriented conservation programs have increased in value from $0.5 billion in 1986 to just less than $5 billion annually since 2015. In *An Atlas of Ecosystem Markets in the United States,* Forest Trends' Ecosystem Marketplace reported that at least $2.8 billion is transacted every year through ecosystem markets in the United States (Bennett et al., 2016). The largest markets include land carbon, species habitats, streams, watersheds, and wetlands in many forms (Pindilli and Casey 2015). Carbon markets also exist at the state, regional, and international levels (Goulder 2013; Burtraw 2016).

There are applications of portfolio theory to estimate the *ROI* and risks involved in ecosystem services management (Boyd and Epanchin-Niell 2017; Sanchirico et al. 2008; Benitez et al. 2007; Benitez and Obersteiner 2006; Edwards et al. 2004). These examples demonstrate how a risk-return decision framework involves estimation of the economic return to a market commodity such as fish (Sanchirico et al. 2008) and the risk to an ecosystem service such as deforestation (Benitez et al. 2007).

Ecosystem processes and services are known to be interdependent at different spatial and temporal scales and can be positively or negatively correlated. Ecology, economics, and geography literatures acknowledge these interdependencies. Holling and Gunderson (2002) discuss interdependence between fast and slow ecological processes and the effects of human intervention on those processes. Geographers such as C. Raudsepp-Hearne et al. (2010) describe how ecosystem service bundles can have negative or positive effects on each other within an ecosystem. Ingram and Malamud-Roam (2015) explore the interdependence of short and long climate cycles on biophysical processes. Lastly, Boyd and Banzhaf (2007) define and describe the physical and economic processes that lead to ecosystem endpoints. Ecosystem endpoints have value to humans and can be considered end-use commodities in an economic framework. All of the above authors agree that ecosystem services are interdependent.

Although there are examples of direct-use returns (grayish) in conventional forest funds or indirect-use returns (greenish) for ecosystem services provisioned by forests, such as carbon sequestered and water quality and quantity in a watershed, trading occurs in separate markets. It is likely that wood products and ecosystem services occur in the same forest and similarly increase in value over time, which means they could be integrated into one security for public markets. A public market security listing on an exchange can be a combination of both assets that is based on the weighted sum of a traditional bond and a green bond for the same land (Bass et al. 2019). This approach for a sustainable forestry bond has two effects. First, it increases the yield of a traditional forest bond by including the return on investment from the green portion of asset value. Second, calculation of cash flows need only to account for investment and operating costs once rather than twice if the bonds were traded in separate markets or exchanges.

Market value is created from two component portfolios, each of which has its own rate of return and risk. Value creation for both wood products and ecosystem services have a correlation close to 1.0, whereas the correlation among ecosystem services can be negative or positive. The portfolio model developed here exploits this information to form a sustainable forestry bond. In addition to marketed products, a sustainable forestry bond should contain a second set of assets, namely ecosystem services such as waterfowl habitat, nitrate retention and carbon sequestration.

We develop the metrics for estimating the Average Internal Rate of Return (AIRR) and the current market price of a sustainable forestry bond of wood products (direct use) and multiple ecosystem services (indirect uses). Cash flows are estimated with and without a timber harvest, and with and without ecosystem services with land and forest management costs. Correlations among resources are estimated, which affect the outputs of ecosystem services depending on the land cover and existing land use (e.g., bottomland agriculture). Market value is created from two component portfolios, each of which has its own rate of return and risk. An investment decision is based on whether the AIRR of the forest exceeds the market or a required rate of return.

The example includes two types of forests and three ecosystem services in Tensas and Madison Parishes, Louisiana. Market (or appraised) values are employed for wood products and land and management costs and appraised values are estimated for ecosystem services. We assume an investor's objective is to maximize portfolio return or to minimize portfolio risk given a greenness preference. Application of alternative combinations of forest assets (treatments) that arise in the example can influence the investment choice in a market exchange. An investor has an initial amount of wealth to be invested in each of the two portfolios that, when combined, result in the sustainable forestry bond AIRR.

The paper is organized as follows: section II contains a derivation of the value created from a managed forest and is applied to a sustainable forestry bond investment decision (Marchioni and Magni 2018). Section III contains an application of a portfolio model for producing forest direct uses and provisioning indirect uses in the sustainable forestry bond. Section IV presents the results of the model application in two parishes in northern Louisiana (167,745 hectares), and section V is a discussion of the model, application, and avenues for future research.

II. **A Sustainable Forestry Bond and Portfolio Opportunity Set**

A publicly tradeable security in the form of a sustainable forestry bond is created based on the conversion of land to forests with the highest expected average return on investment (direct and indirect-use returns) at time *t* minus the expected opportunity cost of undertaking that conversion (Lubowski et al. 2008). Land in use $l, l = 1, \ldots, L$ will be reallocated use $j, j \neq l$, if it maximizes the economic return after conversion costs that are greater than the return to *l*; otherwise the land will remain in its current use at time *t*.

An investment decision is based on the net present value (*NPV*) of a series of cash flows produced from trees (v) and benefits (*b*) provisioned by the ecosystem services in a forest (*F*) at a discount rate (*r*). This combination of inputs and outputs represents the value created over the lifetime of the forest project and can be evaluated by calculating its *NPV*. By adding ecosystem services as an asset, we create a new component of value for the forest (Fenichel and Abbott, 2014). The value of the ecosystem services affects the forest *NPV* positively, which is relevant to an investment decision. Since we combine direct- and indirect-use assets, we label the combination a sustainable forestry bond to have a net resource value (*NRV*). The *NRV* is equal to the monetized difference between the forest natural resources and ecosystem service outputs and the capital invested to produce them. For investment decision making, the *NRV* is used to estimate an AIRR ($\bar{r}$), which is NPV-consistent (Magni, 2010).

A land asset scenario *s* produces an *NRV* for forest *F*. Each $s, s = 1, \ldots, S$ forest scenarios, produce direct-use benefits (b_v) and indirect-use ecosystems services (b_i) that are estimated via production functions for a land assessment unit *k* (Heal et al. 2005). The addition of ecosystem services as a land asset builds on the idea that a quantity change is a sustainability dividend (Bond et al. 2017). Quantities q_v and $q_i$are market goods produced and ecosystem services provisioned, respectively. The forest outputs have benefits and risks that arise from, among other things, colocation[1]. A market value for direct-use products $b_v, v = 1, \dots, \Upsilon$ and an indirect-use value $b_i, i = 1, \dots, B$ interdependent ecosystem services generate a monetized value for the two components of a scenario *s*.

The expected cash flows derived from wood and ecosystem service products and risks associated with the tradeoff between the assets in the portfolios. Estimation of the expected value $\mathbb{E}(v_k)$, for the direct-use asset depends on the land characteristics of location *k* for commodities revenue $v_k, v_k = 0, \dots \Upsilon_k$. Marketable commodities are a function of current prices and the quantity of the renewable resource harvested.

$$\mathbb{E}(v_k) = p_{sv}\left(-cp_k + b_v \cdot \left(1 + r_{v_n}\right)^{RI_k}\right) \tag{1}$$

where $\mathbb{E}(v_k)$ is the expected *NPV* for direct use of (a) rotation(s) of production, p_{sv} is the probability of timber harvested for scenario *s*, RI_k is a land use rotation interval of *t* years, $t = 0, \dots, n$, for *k* grid cells in a forest, $k = 1, \dots, K$, cp_k are the land, investment and management costs for *k* grid cells, $b_v = pw_k \cdot q_{V_k}$, b_v is the economic benefit from direct-use production, pw_k is the direct-use price for *k* grid cells, q_{V_k} is quantity produced, and r_{v_n} is the market discount rate.

Estimation of the expected value $\mathbb{E}(B_k)$, for the indirect-use asset also depends on the land characteristics of location *k* and the quantity of the renewable resource harvested. In addition, ecosystem services possess interdependencies that can be positively or negatively correlated in the *k*th cell of land. The spatial correlations affect the qualities and quantities of ecosystem services that are provisioned ultimately. Because a land assessment unit provisions a variety of ecosystem services the security is the weighted average of the expected benefits for the indirect use:

$$\mathbb{E}(B_k) = p_{sb_i}\left(\sum_{k=1}^{K}\sum_{i=0}^{I}(b_{ik}) \cdot \left(\left(1 + r_{B_n}\right)^{RI_k}\right)\right) \tag{2}$$

where $\mathbb{E}(B_k)$ is the expected forest *NPV* of the interdependent ecosystem service benefits in *k* for RI_k land use rotation(s) in *F*, B_k is an estimate of the gross conservation return (Murdoch et al. 2007), r_{B_n} is a green / social rate of discount, p_{sb_i} is the joint probability where $p_{sb_i} = p_s \cdot p(b_i|s)$, $p(b_i|s)$ is the conditional probability of obtaining a quantity provisioned for ecosystem service *i* given scenario *s*, and (b_{ik}) is the expected benefit from ecosystem service *i* in *k* in *F*. The appendix contains the method for calculating ecosystem service provision benefits. When treated as an asset for a forest harvest rotation time

1. Environmental risks such as wildfires occur at a low rate of approximately 1% annually. The majority of timber to a fire often can be salvaged (Healy et al. 2005).

period, $RI_k = n$, or the forest can remain intact in perpetuity, and $RI_k = \infty$. By adding ecosystem services provisioned in equation 2 to direct-use benefits in equation 1, the new combined value is denoted as the forest Net Resource Value NRV_F:

$$NRV_F \equiv \mathbb{E}(\upsilon_k) + \mathbb{E}(B_k) \tag{3}$$

NRV like Net Present Value can be considered a reliable tool for investment decisions, since it correctly measures value creation (Marchioni and Magni 2018). Application of the AIRR to the project, according to Marchioni and Magni (2018), is defined as the ratio of the overall return earned by the investor to the overall capital committed by the investor, or as the weighted mean of period rates associated with the capital stream:

$$\bar{r} = r^* + \left(\left(\frac{\sum_{t=1}^{n} \iota_t cp_{k_{t-1}} d_{t-1}}{\sum_{t=1}^{n} cp_{k_{t-1}} d_{t-1}}\right) - 1\right) \cdot (1 + r^*) \tag{4}$$

where $\bar{r}$ is the average internal rate of return, $cp_k = c_0 + \sum_{t=0}^{n} \frac{c_t}{(1+r)^t}$, c_0 is land and other initial investment, and c_t are operating and management costs for *k* grid cells, and $c_n = 0$. r_t is the return in *t*, $r_t = NRV_t / cp_{k_{t-1}}$, and $d_t = (1 + r)^{-t}$. The security AIRR has a direct use $\bar{r}_{\upsilon(s)}$, and an indirect use $\bar{r}_{B(s)}$. The AIRR is *NPV*-consistent and leads to the decision rule φ:

An investment project creates value if and only if $\varphi > r$ (Marchioni and Magni 2018).

If $\varphi = \bar{r}$, the following relationship exists:

$$NRV_F(1 + r) = cp_k(\bar{r} - r) \tag{5}$$

The decision rule and equation (5) can be reworked to be in terms of a capital base cp_k and an excess return can be estimated as:

$$\bar{r} - r > 0 \tag{6}$$

Estimation of $\bar{r}$ assumes that the investment is made in the initial year and remains invested for the project period. The period return rate is $ROI_t = \frac{\text{Operating Profit}}{\text{Investment Cost}}$ and the AIRR for an investment scenario $\bar{r}_s$ is (Marchioni and Magni 2018):

$$\bar{r}_s = r^* + \left(\left(\frac{\sum_{t=1}^{n} \sum_{k=1}^{K} (\upsilon_{k_t} + B_{k_t}) \cdot d_{t-1}}{\sum_{t=0}^{n} \frac{c_{n-1}}{(1+r)^{n-1}}}\right) - 1\right) \cdot (1 + r^*) \tag{7}$$

It is assumed that $\bar{r}_s$ is distributed normally (Laffont 1989).

We apply the AIRR over the *S* scenarios of multiple assets (wood and ecosystem services) for a range of treatments to populate a portfolio opportunity set. Treatments allow us to conduct sensitivity analysis and estimate the variance among the scenarios (e.g., the two components of the security can have different or equal AIRR's and discount rates). The objective of the investor is to maximize $\bar{r}_s$, which is a reliable measure of worth.

Security risk is a lack of perfect knowledge about inputs (e.g., resources, technology, regulations) and outcomes (e.g. revenues, fire disturbance, and ecosystem changes) for a time in the future. To measure the risk, we estimate the standard deviations for the direct-use component in a manner consistent with existing portfolio theory (Sharpe et al., 1999; Cubbage et al., 2014; Mei and Clutter 2010) and estimate the standard deviation for the indirect-use component from equation 8:

$$\sigma_{B_s} = \sqrt{\sigma^2_{b_{ik}} w^2_{b_{ik}} + \sigma^2_{b_{jk}} w^2_{b_{jk}} + 2 w_{b_{ik}} w_{b_{\zeta k}} COV_{b_{i\zeta k}}}\,, \quad k = 1, \dots, K \qquad (8)$$

where $w_{b_{ik}}$ is the proportion (weight) of investment in ecosystem service *i*, $w_{b_{\zeta k}}$ is the proportion (weight) of investment in ecosystem ζ, $COV_{b_{i\zeta k}}$ is the covariance of returns between ecosystem service *i* and ζ. The covariance is expressed as $COV_{b_{i\zeta k}} = \rho_{b_{i\zeta k}} \sigma_{ik} \sigma_{\zeta k}$, where $\rho_{b_{i\zeta k}}$ is the correlation between ecosystem service *i*, and ecosystem service ζ[2]. The covariance of the services in a scenario is important for understanding the interaction among services. A negative covariance is a reduction in scenario variance because expected returns move in opposite directions. This type of correlation is associated with a diversified scenario. On the other hand, assuming a positive covariance among ecosystem services would amplify a scenario standard deviation.

Like the sustainable forestry bond, portfolio construction is based completely on the AIRR and the standard deviation of the AIRR of the bond portfolio. In the portfolio analysis, the *S* scenarios are the investment choices for comparison to an existing baseline land use, such as bottomland agriculture (Boyd et al. 2015). The AIRR for a range of forest treatments is $\bar{r}_s$ composed of $\bar{r}_{v_s}$ and $\bar{r}_{B_s}$ divided by the investment cost. Depending on the investor's objectives for $\bar{r}_s$ and σ^2_s, the securities could be oriented more (less) toward market goods and less (more) toward provisioning of ecosystem services.

A key aspect of portfolio theory is the role of the statistical correlation between the direct- and indirect-use portfolios. The two assets are correlated because the ecosystem service

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[2]. $\rho_{b_{i\zeta k}} = \sum_{i,\zeta} p_{b_{ik} b_{\zeta k}} \left(\frac{b_{ik} - \mathbb{E}(b_{ik})}{\sigma_{ik}}\right)\left(\frac{b_{\zeta k} - \mathbb{E}(b_{\zeta k})}{\sigma_{\zeta k}}\right)$, where $i \neq \zeta, i = 1, \dots, I. \zeta = 1, \dots, I$, $p_{b_{ik} b_{\zeta k}}$ is the joint probability of b_{ik} and $b_{\zeta k}$ in *k* cells, and σ_{ik} and $\sigma_{\zeta k}$ are the standard deviations for ecosystem services *i* and ζ respectively.

benefits are a known externality affected by the market good. In a renewable resource case, a forest of trees produces timber as well as ecosystem services and is expected to have a positive correlation[3]. The correlations enter the analysis in the calculation of bond and portfolio risks. Each asset group is itself a portfolio and becomes an input to the opportunity set (Sigman 2005). The exception is NRV_0, the baseline, and is not included in the opportunity set. Thus, the risk is the variance of the direct use and indirect use provisioned, respectively:

$$\sigma_s^2 = f^2(\sigma_\upsilon)^2 + (1-f)^2(\sigma_B)^2 + 2f(1-f)\sigma_\upsilon\sigma_B\rho_{\upsilon B} \tag{9}$$

where σ_υ and σ_B are the standard deviations of the stochastic returns to direct-use production and ecosystem service provision of a scenario, and $\rho_{\upsilon B}$ is the correlation between direct-use production and ecosystem service provision. We consider a case of applying the spatial portfolio to assess the return of managed forest land. The portfolio contains timber and other wood products and ecosystem services via reforestation in Louisiana.

III. **Application: Sustainable Forestry Bond Pricing**

In this section, a variety of managed forests AIRR's are estimated for pricing a long-term sustainable forestry bond. The type of forest and its location will affect the intrinsic value of the investment for timber and ecosystem services. The process is for the investor to judge among scenarios of forest opportunities that maximizes $\bar{r}_s$. We compare a one species versus a multispecies forest as a 30-year sustainable forestry bond. Below, $\bar{r}_s$ and a current market price for a zero-coupon[4] and a traditional bond[5].

Demand for forest lands has been driven by changes to forest and timber market institutions, environmental policies and regulations, and incentives and tax measures for pension plans (Mei and Clutter 2010; Yao et al. 2016). Policies such as the Employee Retirement Income Security Act of 1974 have incentivized forestation (Mei and Clutter 2010; Binkley 2004). One outcome of the legislation is that forests and forest shares have become a growing part of land investment portfolios (Mei and Clutter 2010). The forest

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3. In a nonrenewable resource example, (e.g., fossil fuels) extraction and changes to ecosystem services are expected to have a negative correlation.
4. A zero-coupon bond is a bond that (1) pays no interest but instead is sold at a deep discount on its par-value, or (2) an interest paying bond that has been stripped of its coupon which is sold separately as a security in its own right. Bondholder's income is determined by the difference between the bond's redemption value on maturity and its purchase price (Business Dictionary 2020a).

5. A traditional bond is a bond issued with a number of coupons that must be presented to receive the periodic interest (Business Dictionary 2020b).

type will affect the terminal value of a forest investment security (Bass et al. 2019; Redmond and Cubbage 1988).

The investment is a multi-year decision. Alternatives may range between high production of wood products with multiple harvest cycles and an infinite planning horizon for preservation and no harvest. Although there have been references of the need to quantify the environmental benefits in this type of investment, they have been considered an externality (Rinaldi and Jonsson 2013; Cubbage et al. 2014; Frey et al. 2013; Binkley et al. 2006; Washburn and Binkley 1989). Only recently have green bonds and impact investing become available to public markets (Bass et al. 2019; Bennett et al. 2016). Although a variety of funds exist, the investment returns are dependent on various levels of quantification for generating revenues. Strategies include sales of timber, carbon offsets, other forest products, and land rights for permanent conservation (e.g., easements); and land leasing (Bass et al. 2019). But no method to estimate the within asset correlations among the indirect uses has been included.

A. ***Forest Production***

Location affects development and management efforts. Location quality is based on the size, age, condition, and configuration of Land Use and Land Cover (LULC) patches and can be represented as a distribution over the total number of these patches (Chivoiu et al. 2010). To be useful and traded in a market the areal unit must capture these landscape heterogeneities (Convertino and Valverde 2013).

Currently, a forest Return on Investment is based on the terminal value of the timber and other wood products (Cascio and Clutter 2008; Healy et al. 2005; Washburn and Binkley 1993; Redmond and Cubbage 1988). Investment analysis compares the asset (timber and wood products) value to a market or required rate of return r_F^*, (Cascio and Clutter 2008; Sun and Zhang 2001). In a market of this type, environmental assets are considered positive environmental externalities (Herbohn and Henderson 2002).

For timber, the forest yield in timber products is the stumpage price times the amount of wood removed (Straka et al. 2001). Two key elements affect the timber yield: site index and stocking. The site index describes the quality of land for growing trees (soil productivity). Site refers to a tree species; for example, pine or oak sites. Few species grow equally well on the same site. In our application, forest production estimates are for *Eucalyptus* and mixed hardwood trees. The capital gain is the result of the accumulation of the volume and quality of the trees (stock) that is distributed as a cash flow to investors (Healy et al. 2005). The quantity produced can be projected via a production function (Van Kooten and Bulte 2000). The yield of the forest is based on the annual cash flows over a period of years to a planned time horizon for harvest.

Ecosystem services are recognized as non-timber forest outputs. Designation of what is a direct or indirect use is defined by the Food and Agricultural Organization of the UN (Lange 2004). Estimation of the benefits of the ecosystem services is based on landscape qualities that have a range of biophysical characteristics and corresponding ecosystem services. The management scenarios and treatments provision the same three ecosystem services: carbon sequestration, nitrate retention, and enhanced habitat for waterfowl. However, the proportion of the benefits invested in each service varies.

*B. **Sustainable Forestry Bond Estimation***

Securitization for possible reforestation of forests in Tensas and Madison LA parishes in the Lower Mississippi Valley (LMV) is the region considered for the example. For accounting purposes, the forested lands are described within hydrologic units (Seaber et al. 1994). Hydrologic unit codes provide a geographic and hydrologic framework for water resources planning and include drainage, hydrography, culture, political and hydrologic unit boundaries. Analysis is conducted for reforestation of bottomland forests hydrologic units[6] in the LMV.

The LMV has experienced extensive loss and conversion of forests and wetlands in the past. The predominant land use is agriculture (the baseline), with pockets of bottomland hardwood forests (Barnett et al. 2016; Faulkner et al. 2011). Bottomland hardwood forests are forested lowland areas along streams and rivers that occur on alluvial floodplains (Barnett et al. 2016). The forested wetlands contained in Tensas and Madison Parishes provision flood attenuation, nutrient filtration, sediment retention, food production, groundwater recharge, wildlife habitat, carbon sequestration, recreational opportunities, cultural and aesthetic values.

The *NRV* is based on the stock and attributes of trees as well as the co-benefit service flows of the ecosystem services. Capital appreciation represents the change in the market price of the forest assets derived from the benefits of timber and ecosystem services. With the addition of an ecosystem services asset, an investor should expect an increase in the yield of the bond.

Equation 1 provides an estimate of the *NPV* of the timber and other wood production for one land-use rotation that is then used to determine $\bar{r}_{v_s}$ and σ_{v_s} for Madison and Tensas Parishes. Equation 2 provides the indirect-use component, $\bar{r}_{B_s}$ and σ_{B_s} for Madison and

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6. The hydrologic unit code is an eight-digit number that identifies each hydrologic unit. The code uniquely identifies each of the four levels-regional, subregional, accounting, and cataloging-of hydrologic classification within four two-digit fields (USGS 1999).

Tensas Parishes. The expected benefits are based on local values for carbon sequestration (*carbon*), waterfowl abundance (*wf*), and nitrate retention (*Nitrate*). In the indirect-use component, ecosystem services can be negative or positively correlated ranging between -1 and +1.

The market price of the production of the forest includes cash flows for direct, indirect or both uses (Sharpe et al. 1999):

$$P_{F(s)} = \sum_{t=0}^{T} \frac{NRV_{F(t)}}{(1+\bar{r}_s)^t} \tag{10}$$

where $P_{F(s)}$ is the current market price of a sustainable forestry bond for scenario *s*. The portfolio risk is measured by the standard deviation of the returns σ_s, which is the combined standard deviation of the wood products σ_υ and, standard deviation of the ecosystem services σ_B.

Traditional forest valuation approaches assume $\mathbb{E}(B_K) = 0$, so that the capital value and AIRR are derived from direct uses and compared to a required rate of return r_F^* for an investment decision. On the other hand, if $\mathbb{E}(B_k) > 0$, υ_k is altered by adding the indirect-use benefits to the security at no extra investment or operating cost. The addition of B_k to the forest security will increase the cash flow and rate of return, and consequently should alter the current security price. On the other hand, investment and operating costs are incurred for the indirect-use component for a forest with an infinite rotation period and no harvest.

The scenarios proposed for investment are available as two distinct types of bonds. First a zero-coupon bond is calculated. All bonds in this category should sell below par if the interest rate is greater than zero. Second, a traditional bond is calculated, which differs from a zero-coupon because the price of the bond depends upon the bond return and its annual coupon. $P_{F(s)}$ for a forest zero-coupon bond is:

$$P_{F(s)} = \frac{NRV_{F(T)}}{(1+\bar{r}_s)^T} \tag{11}$$

where $NRV_{F(T)}$ is the capital value at maturity (par value) for $t, t = (1, \ldots, T)$, time periods Alternatively, the $P_{F(s)}$ for a traditional bond with a required rate of return r_F^* is:

$$P_{F(s)} = \bar{r}_s \cdot \frac{1 - \frac{1}{(1+r_F^*)^n}}{r_F^*} + \frac{P_n}{(1+r_F^*)^n}, \tag{12}$$

where $\bar{r}_s$ is the coupon rate for timber and other wood products and / or ecosystem services.

C. An Example: Sustainable Forestry Bond

The LMV has had large-scale conservation efforts that have targeted the restoration and enhancement of ecosystem structure, functions, and services (Barnett et al. 2016; Chivoiu et al. 2010; Lower Mississippi Valley Joint Venture 2002). These efforts require patch- and landscape-level management, assessment, and monitoring to estimate the effects of changes in LULC. The study region is comprised of agriculture, restored riparian forest (mostly Wetland Reserve Program patches), water features, and mature bottomland hardwood forest. Concentrations of sediments and nutrients were obtained from USGS gage 07369500 within the Tensas River Basin, LA. The input parameter values for sediment and nutrient concentration are average values of available data from the period 01/01/1974 to 12/31/1999.

The analysis is undertaken with a data set that is constructed for the hypothetical example. Trees accumulate woody material (branches, bole, roots) over many years, a layer per period or year (Florida Forest Stewardship 2010). Growth is measured as the change in tree characteristics (weight, basal area, volume, etc.) over a specified amount of time. Different species gain value at different growth rates. For the purpose of exposition the direct-use component required rate of return is based on calculations from Cascio and Clutter (2008). Ecosystem service non-timber forest output quantities are estimated in an empirical model and Decision Support System (Kirilenko et al. 2007). The planning horizon in the example is 100 years for Madison and Tensas Parishes and covers 167,745 hectares in the Tensas River Basin. The hypothetical scenarios are as follows:

Forest scenario NRV_0: The baseline assumes no change in current LULC. It provides ecosystem services provisioned without new investment in forests and is the baseline compared to the managed forest alternatives.

Forest scenario NRV_1: Land conversion of 15% of current agricultural land split between the two parishes to fast growing Eucalyptus species. Trees are harvested every 12 years for biomass energy.

Forest scenario NRV_2: Land conversion of 15% of current agricultural land split between the two parishes to bottomland mixed forest with preference for landscape locations and hydrologic connectivity. Targeting variables include hydric soils, soybean production, low elevation, high hydrologic connectivity score, watersheds with currently high sediment and nutrient loads, near watershed outlet, and native Quercus/Carya species.

Table 1 contains the input values to calculate the scenarios in the opportunity set. There are two prices for carbon: a market price[7] and a social cost of carbon[8]. These two values bracket a reasonable price range for sequestration of LMV carbon. Forest costs include land purchase or rental, if applicable, and timber establishment and maintenance costs. Land cost for Madison Parish range between $1,675/ha and $4,586/ha and between $4,700/ha and $7,384/ha for Tensas Parish (2011). We assume that 50% of the reforested land comes from each Parish and that the land is valued at the average market price in each parish. Data input include area converted to forest, conditional probability of timber harvest output and price, rotation period, indirect-use value, discount rates, and conditional probability of quantity produced for an ecosystem service. The temporal risk of a wildfire has a probability less than 0.01 annually in the region based on the 2016 Madison and Tensas Parishes Hazard Mitigation Plans (Stephenson Disaster Management Institute 2016a; Stephenson Disaster Management Institute 2016b). We assume that $p_s\backslash geq$0.99.

Table 1. Input Values for Scenarios

	Scenario 1 (Eucalyptus)	**Scenario 2** (hardwood)
Wood Market Price ($/Ton)	$10.68[1]	$29.56[2]
Area in Hectares (ha)	9,632	9,632
Harvest for One Rotation (Tons/ha)	20[3]	207.6[4]
Rotation Period (Years)	12	100
Required Rate of Return (r_F^*)	0.058[5]	0.058[5]
Carbon Market Price ($/Ton)	$10.09[6]	$10.09[6]
Social Cost for Carbon ($/Ton)	$36.00[7]	$36.00[7]
Waterfowl ($/bird)	$7.90[8]	$7.90[8]
Value of Nitrate Reduction ($/acre ft)	$624.00[9]	$624.00[9]
Social Discount Rate	0.035[10]	0.035[10]

[1] For Eucalyptus we used a Pine pulpwood price of $10.68 per ton (2010; http://blog.forest2market.com/stumpage-market-trends-us-south-timber-prices)
[2] Hardwood sawtimber = $29.56 (2010; http://blog.forest2market.com/stumpage-market-trends-us-south-timber-prices)
[3] Eucalyptus harvest = 20 tons per hectare (accessed 8/2/2016; http://articles.extension.org/pages/28321/eucalyptus-as-a-short-rotation-woody-crop)
[4] Hardwood harvest = 207.6 tons per hectare (2010; http://blog.forest2market.com/stumpage-market-trends-us-south-harvest-type-tons-per-acre)
[5] (Cascio and Clutter 2008)
[6] (https://www.arb.ca.gov/cc/capandtrade/auction/november_2012/updated_nov_results.pdf)
[7] (https://www3.epa.gov/climatechange/Downloads/EPAactivities/social-cost-carbon.pdf)
[8] (Gascoigne et al. 2011)
[9] (Jenkins et al. 2010)
[10] (Moore et al. 2013)

7. https://www.arb.ca.gov/cc/capandtrade/auction/november_2012/updated_nov_results.pdf
8. https://www3.epa.gov/climatechange/Downloads/EPAactivities/social-cost-carbon.pdf

The indirect-use correlation matrix values $\rho_{B_{i\zeta k}}$ for the three ecosystem services are found in Table 2. These values are inputs to equation 8. They demonstrate that the integration of ecosystem services has both negative and positive correlations. Enhanced waterfowl habitat is negatively correlated with carbon sequestration, while improved water quality is positively correlated with carbon sequestration. Enhanced waterfowl habitat and improved water quality are negatively correlated, given their interaction with the carbon sequestration is expected.

Table 2. Ecosystem services correlation matrix for carbon sequestration (Carbon), enhanced waterfowl habitat (Waterfowl) and improved water quality (Nitrate Retention)

	Carbon	Waterfowl	Nitrate Retention
Carbon	1.00	- -	- -
Waterfowl	-0.41	1.00	- -
Nitrate Retention	0.98	-0.34	1.00

IV. **Results and Discussion**

The forest outputs and market values for each scenario are listed in Table 3. The output of timber and wood products and the economic value of that production vary by *s*. Among the scenarios the benefits from the forest are greatest for the Eucalyptus scenarios. This outcome is the result of the multiple harvests from Eucalyptus species as compared to the single harvest for the hardwood scenarios. The differences among the scenarios can be seen in the first three lines of Table 3.

Table 3. Quantity produced, discounted private benefits and Net Present Value with and without land cost for wood harvested in Madison and Tensas Parishes, LA for the period (negative values are in brackets)

Wood Benefits	Scenario 1 (Eucalyptus*)	Scenario 2 (Hardwood)
Wood Q(t) (per rotation)	192640	1999603
Total wood benefits (discounted)	$2,117,881.55	$210,417.30
Benefits per hectare ($/ha)	$219.88	$21.85
Management and Land Cost (discounted)	$89,990,442,74	$89,015,637.15
Costs per hectare ($/ha)	$9,342.86	$9,241.66
NPV (benefits-costs)	($87,872,561.18)	($88,805,219.85)
NPV (benefits-costs) ($/ha)	($9,122.98)	($9,219.81)

* Quantities for Eucalyptus are based on 8 forest rotations.

Adding in management costs decreases the value of the forest for the two Eucalyptus scenarios, however they still produce positive *NRV*s, while the hardwood forest is not economical. When land costs are included (last four lines of Table 3) all three scenarios are not economical. One way to increase an investor's rate of return would be to include the ecosystem service values as a second asset to a forest security.

Turning to the ecosystem service outputs in Table 4, an interesting outcome from the calculations is the expected quantity change in the services provisioned relative to scenario 0. The scenarios provision considerable additionality for improvements in water quality relative to scenario 0. Scenario 1 has a greater impact than scenario 2, if only marginally. The additionality constraint can have a significant impact on portfolio choice. Only scenario 2 provisions a significant amount of additional waterfowl over the baseline. This result eliminates scenario 1 from the opportunity set if additionality to ecosystem services relative to the baseline is required.

Table 4. Total quantity of ecosystem service produced by scenario over 100 years for Madison and Tensas Parishes, LA

	Scenario 0	Scenario 1	Scenario 2
Q ($carbon$) (Mg/ha)	214.94	260.44	247.12
Q (wf) (ducks/ha)	155.43	153.69	253.41
Q ($nitrate$) (kg/ha)	1026.72	10.03	14.93

In Table 5 the economic benefits from ecosystem services are presented as an increase to social well-being that becomes part of the *NRV*. Here the results demonstrate a similar pattern as in Table 4. Carbon sequestration favors the Eucalyptus alternatives over the baseline and scenario 2 because of the Eucalyptus's ability to sequester a great amount of carbon over a shorter time-period than the bottomland hardwood scenario. On the other hand, the opposite result occurs for the other two ecosystem services. As in Table 3 scenario 1 provides less value than the baseline, while for the other two ecosystem services scenario 2 is superior to the baseline and scenario 1.

	Table 5. (ecosystem benefits NPV)		
	Scenario	Scenario 1 (Eucalyptus)	Scenario 2 (Hardwood)
NPV without Costs	Social Carbon 36.00	$176,544,059.00	$124,856,254.00
	Private Carbon 10.09	$49,481,376.00	$24,994,434.00
	waterfowl	$(1,473,065.00)	$83,438,618.00
	water quality	$(1,790,832.00)	$313,323,350.00
NPV with Land and Management Costs	Social Carbon 36.00	$86,553,616.26	$35,840,616.85
	Private Carbon 10.09	$(40,509,066.74)	$(64,021,203.15)
	waterfowl	$(91,463,507.74)	$(5,577,019.15)
	water quality	$(91,781,274.74)	$224,307,712.85

The expected net benefits for the scenarios for three ecosystem services are listed in Table 5. Further inspection of Table 5 reveals a wide range of expected benefits for the scenarios. For carbon sequestration, the Eucalyptus scenarios capture more carbon than the hardwood alternative. On the other hand, the distribution of the expected benefits for *wf* and *nitrate* in scenario 2 are greater than the expected benefits for scenario 1. This is because the hardwood alternative provisions greater quality and quantity of ecosystem services of *wf* in the bottomlands and *nitrate* removal in the water supply. The lack of benefits for scenario 1 is exacerbated by the shorter rotation cycle that leads to fewer services provisioned in a less mature forest. In addition, the Eucalyptus trees' demand for water is greater than hardwoods'. Discounting increases these differences because the discount rate has a considerable impact in the later years of the forest lifetimes. Thus, investors can choose a bond for a bottomland hardwood forest that can be sold as timber and other wood products and that is worth more in the marketplace at the end of a rotation than a Eucalyptus forest. However, a Eucalyptus forest scenario could be chosen that possesses an excess return, $\bar{r}_s - r_F^* > 0$, that is equal to or greater than that of a hardwood forest (without indirect uses) if the positive carbon sequestration externality were included.

The correlation coefficient ρ_{vB} is among the scenarios that include the baseline ranges between 0.84 and 0.97 (Lubowski et al. 2008). The estimated correlations in Lubowski et al. (2008) are based on a panel data model that estimates the probability of the conversion of agricultural land to forest. At this point all the necessary input components are accessible to calculate the *NRV* and $\bar{r}_s$ for each s.

Table 6 lists the *NRV* and $\bar{r}_s$ for three distinct combinations of bottomland forest production and cost. They are (1) timber with up-front land costs and management costs, (2) ecosystem services with up-front land costs and management costs, (3) timber and ecosystem services with up-front land costs and management costs.

Table 6. Net Resource Value (*NRV*) and AIRRs ($\bar{r}_s$) for Tensas and Madison Parishes, LA with and without expected ecosystem services benefits (negative values are in brackets)

ROI	Scenario 1	Scenario 2
Timber with Costs	$(87,872,561.18)	$(88,805,219.85)
	-97.65%	-99.76%
Carbon with Costs		
Carbon ($36.00/ton)	$ 86,553,616.26	$35,840,616.85
	96.18%	40.26%
Carbon ($10.09/ton)	$(40,509,066.74)	$(64,021,203.15)
	-45.01%	-71.92%
Other Ecosystem Services with Costs	$(93,254,339.74)	$307,746,330.85
	-103.63%	345.72%
Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$83,289,719.26	$432,602,584.85
	92.55%	485.98%
Carbon ($10.09/ton)	$(43,772,963.74)	$332,740,764.85
	-48.64%	373.80%
Timber and Carbon with Costs		
Carbon ($36.00/ton)	$88,671,497.82	$36,051,034.15
	98.53%	40.50%
Carbon ($10.09/ton)	$(38,391,185.18)	$(63,810,785.85)
	-42.66%	-71.68%
Timber and Other Ecosystem Services with Costs	$(91,136,458.18)	$307,956,748.15
	-101.27%	345.96%
Timber, Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$85,407,600.82	$432,813,002.15
	94.91%	486.22%
Carbon ($10.09/ton)	$(41,655,082.18)	$332,951,182.15
	-46.29%	374.04%

Each scenario and treatment listed in Table 6 reveals some interesting outcomes for *NRV* and $\bar{r}_s$. Both scenarios have negative *NRV*s and $\bar{r}_s$ for forested products only because up-front land costs are much larger than wood revenue generated. Timber benefits and ecosystem service treatments with costs yield positive *NRV*s and $\bar{r}_s$ for scenario 2, but a negative outcome for scenario 1. Scenario 2 for timber with up-front land and management costs yields the lowest *NRV* and $\bar{r}_s$.

Particular scenario treatments show that the AIRR would exceed the required return of 5.8% per year (Casio and Clutter 2008). Twenty-seven percent (6 / 22) of the development plans have an excess positive return because $\bar{r}_s - r_F^* > 0$, and according to the decision criterion are worth the investment. There are four more treatments that are close to the required return r_F^*. The remainder of the opportunity set shows an AIRR improvement over the timber only treatments except for scenario 1, Timber and Other Ecosystem Services with Costs. This treatment shows that by not including carbon sequestration, the additional benefit from the other ecosystem services is small due to the short harvest rotation $\bar{r}_s - r_F^* = -1.01$. For the most part, the scenario treatments that include the indirect-use asset create a greater Return on Investment. The best performer is scenario 2, Timber, Carbon and Other Ecosystem Services with Costs and Carbon ($36.00/ton). The combination for this treatment takes the greatest advantage of the long-term growth in value for both asset components, i.e., $\bar{r}_s - r_F^* = 4.86$. The addition of the indirect-use asset increases returns and should be factored into the market price of a bond.

The means and standard deviations for the 2 scenarios and their treatments can be combined into a forest market with varying attributes over the opportunity set. The mean is an average of the expected returns from Table 6 while the standard deviation is calculated using the mean and calculating the sum of the squared deviations from this mean. The forest security opportunity set has an AIRR, median and standard deviation of -102.98%, -9.36% and 0.8862 for scenario 1 and 2249.12%, 204.47% and 2.356 for scenario 2.

Depending on investor preferences the proportion of a bond's direct and indirect-use components will vary. For example, an investor with a preference for a short rotation forest with the intent to maximize timber market products may favor a monoculture forest like Eucalyptus (scenario 1), which produce fewer and / or lower valued ecosystem services. In this case the weights of the assets in the security are skewed more toward market outputs. For example, a good investment hedge would be a Eucalyptus plantation with a 12-year rotation period (variations of scenarios 1). On the other hand, an investor who prefers greater amounts of ecosystem services could emphasize the indirect-use component so that the rotation could be as long as 100 years or in perpetuity. In this case a bottomland hardwood forest would be chosen because of the greater value of ecosystem services that would be produced over the longer rotation time (scenario 2).

The market prices for Tensas and Madison Parish, LA forest zero-coupon bonds can be found in Table 7 and are based on the AIRR for each treatment that has a positive *NRV* in Table 6. Current zero-coupon bond market prices are based on equation 11 and listed in Table 7 as offers in $1000 increments over a thirty-year period.

Table 7. $P_{F(s)}$ of a forest zero-coupon bond assuming an intrinsic (Par) value of $1000, and 30 years to maturity for Tensas and Madison Parishes, LA, with and without expected ecosystem services benefits Bond Pricing Assuming Par and Redemption are the same

	Scenario 1	**Scenario 2**
Timber with Costs	$1,342.29	$1,350.93
Carbon with Costs		
Carbon ($36.00/ton)	$750.39	$886.44
Carbon ($10.09/ton)	$1,144.94	$1,241.78
Other Ecosystem Services with Costs	$1,366.84	$360.73
Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$758.52	$240.84
Carbon ($10.09/ton)	$1,157.52	$332.55
Timber and Carbon with Costs		
Carbon ($36.00/ton)	$745.16	$885.81
Carbon ($10.09/ton)	$1,136.85	$1,240.89
Timber and Other Ecosystem Services with Costs	$1,357.13	$360.48
Timber, Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$753.23	$240.67
Carbon ($10.09/ton)	$1,149.34	$332.33

Entries in Table 7 include 12 treatments that are underpriced and 10 treatments that are over-priced. The 12 underpriced bonds have current market prices that vary over a wide range from $332.33 to $886.44. The 10 over-priced treatments current prices range from $1,157 to $1357.13. Table 7 shows a large current price discount that occurs when indirect uses are added.

Market prices for Tensas and Madison Parish forest with an annual coupon for a traditional bond (equation 12) are listed in Table 8. Bond pricing assumes Par and Redemption are the same with coupon payments (5.8%) over 30 years offered in $1000 increments. Bonds that sell above par are due to the fact that the AIRR (Table 6) is below the coupon rate, which makes the bond attractive. If the bond sells below par it is because the AIRR is above the market rate (coupon of 5.8%).

Table 8. $P_{F(s)}$ of a forest coupon bond assuming a Par value of $1000, $r_F^* = 5.8\%$, and 30 years to maturity for Tensas and Madison Parishes, LA with and without expected ecosystem services benefits

	Scenario 1	Scenario 2
Timber with Costs	$3,375.44	$3,391.15
Carbon with Costs		
Carbon ($36.00/ton)	$2,255.62	$2,522.36
Carbon ($10.09/ton)	$3,012.39	$3,191.56
Other Ecosystem Services with Costs	$3,420.06	$1,433.20
Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$2,271.78	$1,146.86
Carbon ($10.09/ton)	$3,035.80	$1,368.18
Timber and Carbon with Costs		
Carbon ($36.00/ton)	$2,245.22	$2,521.15
Carbon ($10.09/ton)	$2,997.33	$3,189.93
Timber and Other Ecosystem Services with Costs	$3,402.41	$1,432.64
Timber, Carbon and Other Ecosystem Services with Costs		
Carbon ($36.00/ton)	$2,261.28	$1,146.45
Carbon ($10.09/ton)	$3,020.59	$1,367.65

Table 8 displays the same trend as Table 7. The market price can vary widely among the scenarios, and even negative returns occur. The current price for a traditional bond is higher due to the yearly coupon rate. Entries in Table 8 are similar to Table 7 with 12 treatments that are underpriced and 10 treatments that are over-priced. Both scenarios have alternatives that pay a yearly return, which is above the market rate making them more attractive to the investor.

A zero-coupon sustainable forestry bond for many of the scenarios is sold at a low price due to the large AIRR's from the ecosystem services. However, if these bonds are oversubscribed (i.e. have increased demand) the price could rise over the original price, which could be a benefit for the seller of the bond as it lowers the return that must be paid. A traditional sustainable forestry bond sells above par in all cases due to the coupon rate of 5.8% being above the market rate of return (the 100-year AIRR). Because these bonds provide a yearly payout (i.e. coupon) they could be viewed as a safer alternative, but this depends upon investor preferences.

In addition to the type of bond offered, other factors influence the outcomes, such as length of rotation, discounting, harvest and perpetuity values, indirect uses, and land cost. Including carbon sequestration benefits and land acquisition cost has a major impact on the investment choice. If the objective is to sequester carbon emissions a Eucalyptus forest is the best alternative. On the other hand, if the objective is to maximize net benefits from other ecosystem services (i.e. waterfowl and nitrate retention) a hardwood forest is the best alternative.

Currently, a sustainable forestry bond includes the nonmarket effects of ecosystem services without wood products and a traditional forest bond includes wood products without ecosystem services. If the positive ecosystem services are not internalized into the calculated AIRR and subsequently not employed in calculating the price of a bond, returns from the wood products are negative. Alternatively, if ecosystem services are packaged as a separate asset and not included with the wood products, the returns, while positive (Table 6), do not account for the true value of the forest. As shown in Table 6 the best return is found when timber and ecosystem services are combined. Combining these two benefits into one asset internalizes the positive externalities of reforestation.

V. **Summary and Avenues for Future Research**

As ecosystem service markets thicken a sustainable forestry bond that can be traded is realizable in a market that incorporates direct use—harvestable timber—and indirect use—ecosystem services (Boyd et al. 2015). An investor in this type of forest market requires the quantification of the expected return and risk among ecosystem service assets and between direct- and indirect-use land portfolios. The concept of a market-based approach to long-term forest investments has been proposed as an investment security (Boyd and Epanchin-Niell 2017; Górriz-Mifsud et al. 2016; Binkley et al. 2006). However, a green bond for a market driven good such as timber does not produce a worthwhile return at current wood product market prices. Adding in the ecosystem service benefits does create a positive return, however the objective function is important in determining the size of the return.

Here we have developed a sustainable forestry bond that characterizes the investment as separable portfolios of direct and indirect uses that are integrated into one market product. The sustainable forestry bond demonstrates that a spatial portfolio model can be used to facilitate market functions and transactions. Investors expect a return of a specific sustainable forestry bond to exceed the required return, which affects what the investor is willing to pay for the security. The difference between $\bar{r}_S$ and r_F^* is used as an investment decision criterion.

A second use of the decision criterion is that it represents the degree to which a specific forest security is mispriced (Sharpe et al. 1999). This guideline is one way to assess whether a particular forest security is undervalued or overvalued and by how much.

Including the ecosystem services $\bar{r}_{B_S}$ does impact the total return of the security positively. Our results demonstrate that the benefits of ecosystem services are significant in the investment decision for the scenarios. The sustainable forestry bond is undervalued when $P_{F(s)}$ is less than P_n: or, if the expected return is less than the required rate of return, the forest security would be overvalued because $P_{F(s)}$ is higher than P_n. Some interesting differences are apparent in a comparison of Tables 7 and 8. In either case, the sustainable forestry bond shows that adding ecosystem services is a plus for renewable resources markets. The multiple harvest nature of eucalyptus in scenario 1 leads to a bond valuation that is near par at the higher social cost of carbon versus the lower cost. These features allow the market to include choices for the interest rate and forest rotation for timber harvest that can differ for the social time preference for ecological resources. Investors can make individual choices for weighting the security with more (less) direct or less (more) indirect uses. Adding the indirect-use asset is an attraction to investors because it allows an assessment of the wealth advantage that can be gained by internalizing the ecological assets (environmental externalities) into the security. Furthermore, the current prices for the zero-coupon and traditional bonds (Tables 7 and 8) reflect this outcome.

Adding the indirect-use asset produces an increase in the cash flow to the forest bond, which affects the Par value, and consequently the Return on Investment. In this analysis we assume that ecosystem services are time invariant, this may not be the case as a loss or benefit in ecosystem services produces a perpetual loss or benefit. Future research should investigate this arena and how it impacts market valuation through time.

Appendix: Decomposition of Ecosystem Services Production and Benefits

Conversion of land from a current land use such as agriculture to a forest includes changes in the values associated with both the direct and indirect uses of the land. Besides the change from a row crop to trees, it can be expected that a conversion will increase the sequestered carbon, reduce agrochemicals in surface and groundwater, and improve natural habitats for bird species (Nelson et al. 2009). Estimation of the benefits of these ecosystem services in equation 4 is based on landscapes that have multiple land-use, land-cover (LULC) classes, each with a range of biophysical characteristics and corresponding ecosystem services:

$$B_k = P_i \times Q_k$$

where $B_{k\sum_{t=0}^{n}\sum_{k=1}^{K}\sum_{i=1}^{I} b_{ikt}}$, b_{ikt} of ecosystem service i, $i = 0, \ldots, I$, produced in k grid cells at time t, $t = 0, \ldots, n$ years, $P_i = \sum_{i=1}^{I} p_i$, p_i is the price or indirect-use value of ecosystem i, $Q_k = \sum_{t=0}^{n}\sum_{k=1}^{K}\sum_{i=1}^{I} q_{ikt}$, Q_k is the total quantity of ecosystem services produced over the rotation period of t, q_{ikt} is the quantity of ecosystem service produced over time t in k cells and is based on the forest type and growth rate (http://www.sfrc.ufl.edu/extension/florida_forestry_information/forest_management/growth_and_yield.html accessed 5/31/16). Forest indirect-use values p_i for each service exist (Bennett and Carroll 2014)[9] and are traded currently (Forest Trends' Ecosystem Marketplace 2015, http://www.ecosystemmarketplace.com/wp-content/uploads/2016/01/Ecosystem-Marketplace-Market-Primer-2015-Final.pdf, accessed 5/9/16).

A forest scenario provides some or all the possible ecosystem services available in a forest as the benefits for the measured ecosystem services present and is denoted B_k. To compare the benefit of indirect uses for forest ecosystem services to an existing land use is to find:

$$P_i \Delta Q_k \quad \text{(A1)}$$

The indirect-use value for the forest is:

$$B_k = P_i \Delta Q_k = P_i(Q_k - Q_0) \quad \text{(A2)}$$

where B_k are the ecosystem services benefits, which is the difference between B_k with development and the ecosystems services benefits for the current land use, i.e., the baseline, ΔQ_{ik} is the change in quantity of ecosystem service i in k cells produced with development Q_{ik}, and Q_0 is the quantity of an ecosystem service produced in the baseline.

9. http://www.ecosystemmarketplace.com/marketwatch/carbon/north-america/
http://www.watershedconnect.org/programs/index.php.
http://www.ecosystemmarketplace.com/marketwatch/biodiversity/north-america/

The baseline produces interdependent ecosystem services (Sauer and Wossink 2013). B_k becomes the input to a land use security that can represent an indirect-use cash flow.

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A Comment on "Estimating Forest Sustainability Bond Prices for Natural Resource and Ecosystem Services Markets"

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Paper Summary and Overall Comments

This paper introduces a sustainable forestry bond composed of wood products and ecosystem services and investigates the project-based financial performance, such as NPV, associated with this bond. Results show that the bond produces an increase in the cash flow compared to a traditional forest bond that, in turn, affects the security's par value, and consequently impacts the return on investment (ROI). The results indicate that reforestation with multiple harvest species maximizes direct-use benefits and provisions of significant carbon sequestration benefits.

The paper tackles an interesting and relevant issue in today's business environment. However, I observe several noteworthy conceptual and technical concerns that limit the potential of the paper and should be addressed in follow-up studies. I discuss my concerns below, starting with the ones that I believe to be most relevant.

Main Concerns

- The main assumption of this study is that monoculture plantations add value through **indirect ecosystem services provisioned by forests**, such as carbon sequestered and water quality and quantity in a watershed. However, a report published at the Yale School of Forestry & Environmental Studies suggests that monoculture plantations that are quickly cut down "do little to tackle climate change or preserve biodiversity."[1] A study published in *Nature* by Lewis et al. (2019) suggests that 45% of promised reforestation will be monoculture plantations of fast-growing trees like acacia and eucalyptus. It is argued that such forests hold little more carbon than the land cleared to plant them and often decrease biodiversity rather than increase it. This argument is supported by Liu, Kuchma, and Krutovsky (2018). So, in my opinion, the analysis, results, and implications of this study are not sufficiently convincing at this stage, if this assumption is biased. Hence, I argue that the paper's contribution remains somewhat limited.
- This paper attempts to analyze the financial performance of a newly introduced forestry bond. However, the results, based on the hypothesized dataset, do not provide sufficient evidence of the practical implications for investors. Therefore, I would

1. https://e360.yale.edu/features/why-green-pledges-will-not-create-the-natural-forests-we-need.

encourage the authors to evaluate the forest bond's financial performance using IFC forest bond trading data in any future research. In addition, the price of a bond largely depends on the value of the income provided by its coupon payment relative to the broader interest rate on the secondary market. And the authors seem to neglect important market factors, inflation among others.

- The reference in the first paragraph of the Introduction that "For years, forest bonds have been used as a means to diversify an investment portfolio (Healy et al. 2005)" requires additional context. Despite the existence of forestry-related climate financial products, including under the 2008 launched UN-REDD (reduce emissions from deforestation and forest degradation in developing countries) programme, it should be noted that the first proper forest bond was issued in 2016. "On November 8, 2016, IFC opened trading on the London Stock Exchange to mark the listing of its innovative Forests Bond, a first-of-its-kind bond that gives investors the option of getting repaid in either carbon credits or cash."[2, 3]

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Biography

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2. https://redd-monitor.org/2019/07/09/ifcs-forest-bonds-quantitative-easing-for-sub-prime-redd-carbon-credits/.
3. https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/first-forests-bond-on-the-lse.

What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market

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Abstract

Whether green bonds deliver a cheaper cost of capital to issuers than vanilla bonds has been a contentious issue since the start of the green bond market. In the market's early days anecdotal statements from green bond issuers that their bonds were being oversubscribed, resulting in a pricing difference against equivalent vanilla bonds, led market participants to argue that green bonds provide a cheaper cost of capital (Harrison 2017b). However, this anecdotal evidence was unverifiable until the market matured to a size sufficiently large enough to provide comparable

bonds for analysis. The existence of a "greenium," a green bond premium over equivalent vanilla bonds, became a key research point for green bond analysts as the market matured (Harrison 2017b; Preclaw and Bakshi 2015). This analysis spread to sustainable finance research centers and bond trading desks and has now become a mainstay topic of green bond conferences and market events (Flammer 2018; Torsten and Packer 2017). Within academic circles, numerous papers have recently focused on looking directly at pricing differences in the U.S. green municipal-bond market (Baker et al. 2018; Larcker and Watts 2019). However, these discussions have yet to provide conclusive evidence for or against the presence of a substantial greenium. The academic debate remains focused on refining a standard methodological approach by which to detect any greenium. Developments such as the green halo effect (Basar and Krebbers, 2019), which blurs the added value of green bonds for issuers by blending it with the issuer's vanilla bonds, also make the academic search for a greenium insubstantial in relation to the green bond market's overall dynamics.

Drawing from the social sciences of finance, this paper contextualizes green bond pricing research by examining recent greenium discussions and the role of the Climate Bonds Initiative (Climate Bonds) in these discussions (Beunza, Hardie, MacKenzie 2006; Muniesa 2007). We reflect on the beginning of the first green bond pricing research at Climate Bonds and analyze how these early conversations have evolved among both academics and market participants. Drawing from literature review, quantitative pricing data, and qualitative data from semi structured interviews with market participants, we argue that the iterative nature of pricing discussions is a result of both pricing methodologies and market growth dynamics.

1. **Introduction: What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market**

Whether green bonds deliver a cheaper cost of capital has been a contentious issue since the start of the green bond market. This debate centers on whether there is a pricing difference between vanilla and green bonds. However, what pricing research coming out of financial institutions and universities misses is that the pricing debate has meaning only if it is contextualized in the conversations between issuers, investors, and other entities in the green bond market. In this paper, we attempt to provide this vital context for understanding pricing conversations in the green bond market. We are a multidisciplinary team consisting of an anthropologist, a climate finance researcher, and a green bond analyst, who have been involved in the green bond market for a cumulative total of 14 years. Here, we lay out the history of pricing analyses and debates in the green bond market. In this endeavor, we expand on the social science study of the "*technicality* of financial markets" and the performativity of prices (Beunza, Hardie, MacKenzie 2006, 721; Callon 2015; Muniesa 2007) by examining closely both the history of the quantitative analysis that produces a greenium as well as the social and market context around this topic.

2. **The Origin of Greenium**

In the market's early days, there were anecdotal statements from green bond issuers that their bonds were being oversubscribed, resulting in a pricing difference in relation to equivalent vanilla bonds and leading some market participants to argue that green bonds provide a cheaper cost of capital. However, until the market matured to a size large enough to amass enough comparable bonds for analysis, this anecdotal evidence had been unverifiable. The pricing difference search between vanilla and green bonds began with a white paper published by Barclays' analysts (Preclaw and Bakshi 2015). Two years later, the concept of the greenium arose from internal discussions at Climate Bonds. The earliest publication mentioning a greenium to our knowledge is a Climate Bonds' pricing paper for the organization's annual conference in March 2017 (Harrison 2017a).

Climate Bonds' Caroline Harrison coined the term in collaboration with colleagues. According to Harrison,

> *I met with Sean [CEO of Climate Bonds] in April 2016, he asked me whether I could find any evidence of green bonds pricing differently from vanilla bonds. He had heard market participants talking about green bonds pricing with lower yields than vanilla equivalents, and he thought it could be an interesting hook to encourage more issuers to print green bonds.*

Ordinarily, a bond issuer pays a yield slightly above the "market" to issue a new bond. This is known as a new issue premium, and the price of the bond is therefore slightly cheaper for the buyer. This is a normal feature of the new issue market. Around 2016, however, market talk was that green bonds were being priced with a new issue discount, that is, slightly more expensive than existing debt. This also occurs in the normal new issue market and is contingent on the strength of investor appetite. Investor appetite is dependent on multiple factors from macroeconomics, individual credit preferences, and concurrent bond issues on that day (Harrison 2017b).

In their early research, Harrison and the Climate Bonds team wanted to know whether this discount was consistently present in green bonds, or if the green label could influence pricing. This novel focus on pricing in the green bond market needed a name, and the name emerged through deliberation at Climate Bonds. In Harrison's words,

> *I had some conversations with Andrew Whiley, Head of Communications at Climate Bonds, about labeling this difference (real or perceived). This was around the time that the UK voted to leave Europe, and that process had been termed Brexit, which we liked, and which had been incorporated into the vernacular. . . . Andrew loved the greenium term and immediately began to use it in communications. We were thrilled when we noticed the term had been used by an independent third party.*

Focusing on the greenium, Harrison spent the first couple of months informally looking at spreads of green bonds in the secondary market. Most of the large green bonds were issued either by energy/utilities and financials or by supranational, sub-sovereign, and agency issuers (SSAs). She looked at EUR, GBP, and USD denominated bonds and compared them with vanilla bonds of the same issuer. Instinctively, the Climate Bonds team had not expected to find any differences, given that the bondholder would be facing the same entity irrespective of whether the bond was labeled green. SSA bonds were roughly trading in line, and for certain EUR denominated green-labeled corporate credits, spreads were tighter (Harrison 2017b). The logical explanation for this was the green label, along with the yield, also gained from moving further down the credit curve.

In 2017, Climate Bonds began to produce a market monitor, looking at the primary market performance of the largest bonds issued in three-month windows (Harrison 2017b; Harrison 2018). The reports began with a focus on bonds with a minimum size of USD 300 million, including only those denominated in EUR and USD to establish a critical mass of bonds for analysis. Metrics of analysis were evidence-based, offering insight into supply and demand dynamics of green bonds. Book building, spread compressions, and yield curves were analyzed to determine the presence of the greenium and the performance against matched indices in the immediate secondary market (pricing + 30 days). The reports later added comparisons to vanilla bond baskets and the amount of each green bond sold to investors declaring themselves as green.

The secondary market observations of the Climate Bonds' pricing report series are based on baskets of bonds sharing similar characteristics to the green bond in terms of credit rating, sector, maturity, seniority, and emerging/developing market. The indices used are the broad iBoxx indices in which green bonds currently sit. The motivation for these comparisons was to see how new green bonds perform against non-green bonds issued in the same three-month window, and to see how the new green bonds performed against the secondary markets.

3. **Growing Green Bond Market Pricing Analysis**

Alongside Harrison's and the Climate Bonds' work, the search for greenium initially started by looking for differences in yields for corporate green bonds compared with non-green corporate bonds (Climate Bonds Initiative and IFC 2017; Preclaw and Bakshi 2015). Recent studies that explore this pricing dynamic include Hachenberg and Schiereck (2018), Bachelet, Becchetti, and Manfredonia (2019), Kapraun and Scheins (2019), Wulandari et al., (2018) and Zerbib (2018). All of these studies focus on using the matched pair analysis method to compare the yields of green bonds with their closest equivalent non-green counterparts, some of which may be synthetic. This is also the approach taken in the Climate Bonds Initiative (2017 and 2018) pricing reports. Overall, there has been a wide variation in greenium results reported so far in the literature for corporate green bonds.

In searching for a greenium, bond pricing research needs consistent, reliable prices. Bonds are often priced using theoretical prices (sum of discounted cash flows), or using spread techniques, where bonds are set at a spread against a liquid benchmark and move in parallel. This does not strictly reflect market demand or activity for individual bonds. Since a sum total of green bonds were scarce in 2017, the Climate Bonds team was skeptical about the accuracy of data and reluctant to put too much emphasis on longitudinal studies in such a nascent market.

In the last two years, this relative paucity of data available for matched-pair analysis of corporate green bonds has led several green bond researchers to focus their analysis on the U.S. green municipal bond market. As of March 2020, total issuance in the U.S. green municipal market has reached $40.4 billion (Climate Bonds Initiative 2020). The U.S. green municipal bond market is unique in that it is largely tax exempt and has smaller green bonds issued more frequently, which enables more direct comparisons. One of the first analyses of this market was published by Karpf and Mandel (2018), whose dataset included 1,880 municipal bonds that were labeled green by Bloomberg, and which were compared with 36,000 conventional bonds by the same set of issuers from 2010 to 2016. Their results indicate no clear greenium until 2016, where they subsequently found a mean spread of 23 basis points (bp) (Karpf and Mandel 2018).

Karpf and Mandel's work was followed up by Baker et al. (2018), who performed an analysis of 2,083 municipal bonds defined as "green" by Bloomberg. Their comparison bond data was comprised of 643,299 conventional municipal bonds, also issued from 2010 to 2016. In this paper, their focus was on the primary market, and their regression analysis found an average greenium at issue of 6 bp. The bonds used for this analysis included taxable and tax credit muni bonds along with the tax-exempt bonds, so they took the step of adjusting the equivalent yields before doing the regression analysis, in contrast to Karpf and Mandel, who did not adjust their equivalent after-tax yields. As a result, Baker et al. assert that the reason that Karpf and Mandel failed to find a greenium in the early years was because "early green bonds were disproportionately taxable," and state that "our results suggest that this conclusion is incorrect" (Baker et al. 2018).

Further narrowing the focus to a sample of 640 pairs of matched green and non-green municipal bonds issued from 2013 to July 2018, Larcker and Watts (2019) found a nominal green discount of 0.45 bp, with the difference in price at issue being zero in 85% of the matched cases. They also found negligible greenium when their analysis was expanded to include neighboring bonds issued by the same issuers but at separate times. This work also found no significant difference in liquidity or institutional ownership levels and no pricing difference for certified green bonds. Overall, they state that "our results suggest that municipalities actually increase their borrowing costs by issuing Green bonds," and further, they claim that regression findings from previous works are "insufficient to effectively control for non-linearities and issuer-specific time variation which ultimately leads to spurious inferences" (Larcker and Watts 2019). One key aspect that these analyses have neglected is the potential change over time in the behavior of greenium in the municipal bond markets.

Building from these greenium analyses, a paper by Partridge and Medda (2020) performs a matched-pair analysis, but for 453 matched pairs of green and vanilla bonds issued from 2013 to 2018. The paired bonds in their sample were issued at the same time and under the same official statement, such that they have the same issuer, use of proceeds, issue date, maturity date, and coupon. This analysis looks at greenium in both the primary and secondary markets, and furthermore breaks down the pricing differences into yearly averages to detect trends in greenium as time progresses and the market grows. Partridge and Medda observe a greenium that grows to nearly 5 bp in the secondary market by 2018. While no statistically significant differences in greenium were observed in the primary market, they found that during 2017 and 2018, in the cases where paired bonds were issued, there are pricing differences.

All of these studies have relied on some form of regression and/or matched-pair analysis, but even the municipal bond studies still experience small sample sizes, largely due to the fact that the green municipal bond market in the U.S. only started in 2013, and its issuance has remained relatively low in comparison to the overall market. It may be that there is simply not enough data to be able to support the assertion of any greenium in the primary market yet, but this could change as the market grows. This could also be related to the finding of several studies (Partridge and Medda 2020) of evidence of a greenium in the secondary market, where there are many more data points than in the primary.

4. **Contextualizing Pricing Research in Market Talk**

The growing number of greenium analyses and debates among academics and green bond analysts since the start of Caroline Harrison's research coincides with continual market commentary on the existence of a greenium. Among green bond market participants, perspectives on a greenium rest on market positions. On the issuer side, green bond issuers claim to be beyond, and others claim to be at par. As the market has developed, commentary on the investment side has changed. Some investors are arguing that they are investing in green bonds at par with vanilla bonds, while others say that they give financial preference to green bonds.

A panel titled "Pricing deep dive: greenium, halos and trajectories" at the Climate Bonds Conference 2019, which focused on pricing discussions in the market, demonstrates the difference between academic pricing discussions and market participant debate (Climate Bonds Initiative 2019). This panel was made up of members of "bond syndicate and origination" at UniCredit, SEB, Credit Suisse, JP Morgan, and other market entities. Pricing dynamics in the green bond market were discussed at length, but in a very different and much more pragmatic manner than in the pricing research we have presented here.

The panel recognized the proliferation of the greenium conversation in both academic and market circles, with one participant noting that "the term greenium had been adopted to mean many different things." According to the participant, greenium has been used to describe bonds being priced underneath the issuer yield curb, while issuers have adopted the term to mean they shaved a couple of basis points off what they thought they would get from the market for an issuance. While the bond syndicate and origination heads were aware of and noted respectively assessed academic pricing research, their description of the decision making that goes into actual green bond deals differed greatly from the focused pricing description of academics. As one syndicate head noted, "[t]here is still a lot of art rather than science in syndicate pricing on desks." In constructing green bond transactions, syndicates bring in market feeling and conversation into their analysis, as opposed to the overall market analysis of academic research. In this vein, when asked whether there is a greenium in the green bond market, a panelist stated, "intuitively there should be a greenium." When pressed to elaborate on what this intuition is based on, the panelist argued that "the thing is, economics is not like physics, ultimately it's about people." In the green bond market, the process by which prices are put forth into the market is as much from current pricing analysis as it is from human relationships and discussion (Guyer 2009; Muniesa 2007). This pricing that aggregates in a potential yield curve is both "an epistemic and affective object" (Zaloom 2009). Economists and academics working on the greenium highlight its epistemic use, while the syndicate desk members on the Climate Bonds panel highlight its affective role in the green bond market itself (Çalışkan 2005). Prices are a synthesis of negotiations between people and institutions at distinct moments (Ferry 2016). The academic focus on pricing conversations is a result of the lens of economic analysis, while green bond prices themselves are generated by the motivations of the issuer, underwriters, verifiers, and investors involved in each issuance.

Along with the direct discussion on pricing, the panel also discussed the numerous side effects and complementary impacts of green bonds that complicate a singular search for a pricing difference. The green halo effect, the tendency of a green bond issue to positively impact both the bond and equity pricing of a green bond issuer, also complicates the quantification of a greenium (Basar and Krebbers 2019). As one bond syndicate head on the panel argued, "a green bond is of course a loudspeaker; it is the best way for me to communicate directly to the market on my sustainability." This communication impacts multiple relationships between an issuer and its market relationships to investors and underwriters, which in turn influences multiple prices. In this context, issuing a green bond is a performative act by an issuer, which, when recognized by investors and underwriters, can produce a greenium (Callon 2015; Beunza, Hardie and Mackenzie 2006). The existence of a green halo effect complicates the search for a greenium in that the halo extends to vanilla bond issuance as well (Basar and Krebbers 2019).

Reflecting on the weight of arguments and statements on green bond pricing from issuers, underwriters, and investors, Harrison from Climate Bonds argues that

> *this is the thing I cannot measure. . . . When issuers say this and there is no benchmark for comparison, I am skeptical. I trust the syndicate response because they are the ones doing this work . . . I buy what the syndicates say, but I cannot prove it either.*

With regard to green bond pricing dynamics, discussions from panels, such as the one at the Climate Bonds' Annual Conference, provide a reflection that is closest to direct-pricing decision making in the green bond market. The consensus of the panel that "intuitively there should be a greenium," illuminates how the concept of a greenium already exists for green bond dealmakers. Echoing this, from the results of investor surveys carried out by Climate Bonds, investors seem to overweigh green bonds in bond holdings regardless of a pricing difference (Almeida, Harrison, and Sette 2019).

The comments presented here from this conference panel are important not only in relation to academic greenium debates but also in relation to official statements from green bond market entities. While much more aggressive green bond buying seems to be the norm from off-the-record or Chatham House rules events, official statements are much more conservative. As Marilyn Ceci, Head of Green Bonds at JP Morgan, states in her official statement for this paper,

> *Green Bonds price on market. Generally, they price in line with traditional bonds, but occasionally demand outstrips supply and they can price a few basis points tighter.*

This statement needs to be taken at face value in signifying the type of institution JP Morgan is. In its green bond work, JP Morgan has been actively bringing new green bond issuers to market, and this added supply impacts the pricing dynamics of the market, but for its role as an underwriter, conservative stances are required.

5. **Conclusion**

The initial creation of the greenium through conversations at Climate Bonds and through Caroline Harrison's pricing research has generated both academic and market discussions, propelling critical reflection on what green bonds are and what characteristics they offer issuers, investors, and other market participants. The value of a greenium and the continuation of the academic debate in published papers on its existence has to be placed in the wider context we have traced throughout this paper if it is to have any relevant meaning beyond academic embroiling. The greenium's production is a consequence of market activity and subsequent academic analysis impacting these market dynamics (Mackenzie 2006; Zaloom 2009). Neither a greenium nor the green bond market is static—and as an increasing amount of academic study focuses on green bonds, this reality must be taken into account alongside attempts to analyze certain objects in the market, such as the existence of a greenium.

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Biographies

Caroline Harrison formally joined the Climate Bonds Initiative in April 2016 to work on research projects, including green bond pricing. Caroline has a fixed income background. She worked at ASSET4 Thomson Reuters to develop and market a model to classify the nonlisted portion of a bond portfolio according to ESG observations. Previously, Caroline spent four years in the Index and Portfolio Strategy team at Merrill Lynch and eight years as a Research Analyst at Morgan Stanley. Caroline has a BA in Italian and Business Studies from UCL.

Dr. Candace Partridge completed her doctorate at University College London, where her research focused on green bonds in the U.S. municipal bond market and ways to help finance more sustainable infrastructure. She has also done postdoctoral research on the economics of plastic waste management infrastructure, and her research continues to focus on the the intersection of sustainable urban infrastructure and climate finance.

Aneil Tripathy is a PhD Candidate in economic anthropology at Brandeis University, where his research focuses on the growth of climate finance and the green bond market. Aneil has been a visiting researcher at Cass Business School, University College London, and the Pentland Centre at Lancaster University. He has worked in climate finance for five years as a researcher, executive associate, and academic research consultant at the Climate Bonds Initiative, and as a consultant for the Clean Energy States Alliance. Aneil has training in environmental economics, ethnographic research, and systems thinking.

An Overview of Green Bonds Pricing Mechanisms

An Opinion on "What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market"

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A green bond is a "debt security that is issued to raise capital specifically to support climate-related or environmental projects" (World Bank, 2015). The green bond market grew rapidly from 2012 to 2019 (Figure 1), with US$3.4 billion of green bonds issued in 2012 and US$235 billion of green bonds issued in 2019. The price of a green bond depends on the rates of return of projects as well as on the ratings by issuers. That is why it is important to understand what projects are financed using green bonds and who the issuers are. Globally, green bonds are used mostly to finance renewable energy infrastructure and green buildings. Green bonds are issued primarily by the financial sector, including banks, in addition to governments.

Government policies supporting green bonds can also affect the pricing of green bonds. Some countries started to provide support for the issuance of green bonds. Such green-bond-supporting policies include subsidies or grants that reduce the issuing costs of green bonds by covering the external review costs, which are a mandatory requirement for labeling bonds as "green." According to Kidney (2017), the costs associated with external reviews represent some of the key barriers at the early stage of green bond issuance. Green bond grants, as well as other policies, potentially could affect the green bond prices. Policies supporting green bond issuance include the following categories according to the Climate Bond Initiative[1]:

- Green Bond Guidelines/Standards
- Tax incentives for issuers and investors
- Public issuance of green bonds
- Grant/Subsidy for green bond issuance
- Boosting demand
- Market development
- Improving the risk-return profile by supporting real sector investments

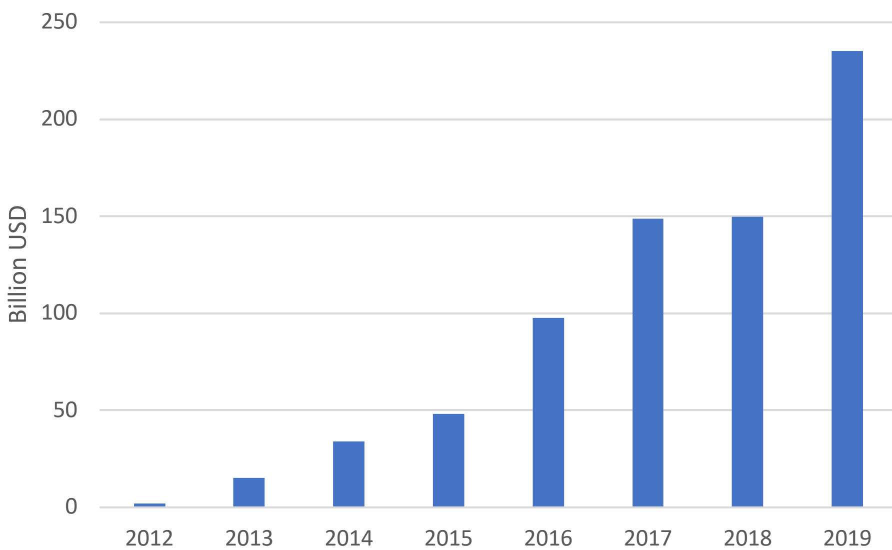
The paper "What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market" provides a review of empirical literature analyzing the difference in pricing between green bonds and conventional, non-green, bonds, as well as

1. https://www.climatebonds.net/policy/policy-areas.

practitioners' views on the pricing of green bonds. The paper would have benefited from further analysis into how future empirical studies could take into consideration practitioners' opinions. The authors of "What's in a Greenium: An Analysis of Pricing Methodologies and Discourse in the Green Bond Market" mention the policy implications of studying pricing mechanisms of green bonds. More in-depth research on the benefits of green bonds for issuers, such as lower yields, could ultimately help the promotion of green bonds.

Therefore, future empirical studies on the current topic are recommended in order to establish the role of government policies and practitioners' opinions on the pricing of green bonds.

Figure 1: Global Green Bond Issuance



Source:Author's own elaboration using data from Bloomberg terminal.

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Biography

Prior to her current position at the ADBI, **Dina Azhgaliyeva** worked as a Research Fellow in the energy economics division of the Energy Studies Institute, National University of Singapore. She was also a Research Fellow at the Henley Business School, University of Reading, performing empirical analysis of the impact of local content policy on extractive industries. From 2012 to 2015, Azhgaliyeva was an Economics Teaching Fellow at University College London. She also worked as a leading and chief specialist for the Tax Committee at the Ministry of Finance of Kazakhstan for five years. She holds a PhD, a master's degree, and a graduate diploma in economics, all from the University of Essex. She also holds qualifications in teaching from the Higher Education Academy and research career management from the Staff Educational and Development Association.

Defining Climate-Aligned Investment: An Analysis of Sustainable Finance Taxonomy Development

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Abstract

The green bond market has grown rapidly since its inception in 2007. Climate-aligned standards provide investors with the confidence that their investments deliver a measurable climate benefit. Serving as a benchmark, these standards demonstrate alignment with the Paris Agreement, against which green bond issuers can then report compliance. This paper draws on the authors' experiences as practitioners and researchers helping to develop the Climate Bonds Standard and the European Union's Sustainable Finance Taxonomy to analyze the methodological considerations that were vital to the development of both taxonomy systems. The first section positions the role of standards development within the context of the green bond market and is followed by an analysis of the factors that affect the Climate Bonds Standard criteria development process. This paper concludes with key takeaways and suggestions for areas of future research on climate-aligned standards development.

Keywords: climate-aligned, taxonomy, scalability, standards

1. **Introduction: Defining Climate-Aligned Investment: An Analysis of Sustainable Finance Taxonomy Development**

The global transition toward a low-carbon and climate-resilient economy requires common, science-based frameworks against which governments, the private sector, and individuals can determine whether activities contribute meaningfully to that transition. Developing a standardized language for determining what activities contribute to climate change mitigation and adaptation is a primary focus of international policymaking efforts to meet the Paris Agreement targets.

In March 2020, the EU Technical Expert Group (TEG) on Sustainable Finance released its final recommendations to the European Commission (the Commission) on the EU Taxonomy, outlining the technical screening criteria that determine whether an economic activity is environmentally sustainable. An increasing number of countries and jurisdictions are developing parallel climate-aligned investment guidelines that will help to determine the climate impacts of financial portfolios. Developing a better understanding of methodological considerations inherent within the taxonomy design process will enable policymakers to implement and improve on the sustainable finance taxonomy work that has been done at the EC level and previously by the Climate Bonds Initiative (Climate Bonds). Climate Bonds is a nongovernmental organization that has been developing the concept of a climate-aligned taxonomy through their Climate Bond Initiative Taxonomy (CBI Taxonomy) for over a decade (Kidney et al. 2009).

Although the EU Taxonomy and the CBI Taxonomy both focus on outlining what is eligible for sustainable and climate-aligned finance, the standards have been developed by organizations that are dramatically different in terms of size, capacity, and convening power. While these contextual factors may limit the comparability of the processes, the intention of this paper is simply to open the dialogue on what constitutes a good “standard-setting” process in the context of institutional realities and constraints.

In this paper, we start with a historical reflection on the development of sustainable finance standards before comparing taxonomy developments at both Climate Bonds and the Commission. We compare the overall processes of the two taxonomies before directly comparing how the expert groups were formed, the discussions were managed, and the decisions were made, as well as how public consultations, board approvals, and reviews occurred. By drawing on the first-hand and lived experiences of the authors, this paper highlights the different group and knowledge production dynamics that can arise from taxonomy development. We conclude with some key takeaways from both the CBI Taxonomy and the EU Taxonomy experiences in order to propose a set of guidelines for future taxonomy development.

2. **Background**

The bulk of climate-finance research, particularly within the green bond space, centers on the concept of pricing advantages available to green bond issuers (Kapraun and Scheins 2019; Bachelet, Becchetti, and Manfredonia 2019; Hachenberg and Schiereck 2018; Karpf and Mandel 2018; Larcker and Watts 2020; Partridge and Medda 2020; Zerbib 2019; Wulandari et al. 2018). A growing body of research is emerging on the role of policy frameworks in mobilizing climate finance (Edwards 2004; Lovell 2013; Lovell 2015). However, further investigation is needed into the methodological considerations that may affect the rules of a taxonomy if the field is to gain more credence within academic literature.

Social scientists have analyzed processes of standardization in markets through detailing the construction of devices (Lovell 2013; Mackenzie 2008; Riles 2011). These studies outline a method of study for standardization through tracing both the production of standards themselves as well as the organizational relationships. The proliferation of environmental standards is reinvigorating these academic discussions on the leveraging of scientific knowledge for markets and policymaking. As Paul Edwards notes in his reflection on standards as social technology, "[d]etecting climate change depends on global standards. . . . Stable scientific knowledge depends on the successful negotiation of such standards" (Edwards 2004, 827). As a method for transforming science into policy, the sustainable finance taxonomy process is in a unique position to build a bridge between policymakers and scientists in a way that has not been done before, through highlighting environmental and climate concerns (Linnenluecke, Smith, and McKnight 2016). This negotiation from science to industry standards allows investors, policymakers, and the public at large to comprehend the environmental and climate impacts of their decisions. Climate standards demonstrate the "the irreducible social and political dimensions of all technological systems," (Edwards 2004, 828). Climate standards in climate finance bring to the forefront questions of what a market is, how policymakers and government interact with finance, and what ultimately is the role of finance in society (Tripathy 2017; Silver 2017).

3. **Emergence of Standards for Sustainable Finance**

In the early years of the green bond market, the general consensus among market participants was that standards or any type of regulation on what projects were eligible to be included in green bond financing would stifle market growth and that scrutiny from investors or second party opinion providers was enough to maintain the integrity of the green bond market (Wood and Grace 2011).

When the European Investment Bank (EIB) and the World Bank issued the world's first green bonds, these institutions developed frameworks for disclosing details on projects, but they did not overtly define what eligible use of proceeds should be for green bonds. In their first green bond issuances, the EIB and World Bank each created frameworks. These two frameworks provided templates that could be used by future green bond issuers. They also helped policymakers align infrastructure portfolios with Paris Agreement targets. In a green bond market reflection from the EIB, the bank argues that "[p]olicy making is about clear indication of public priorities within those [market] alternatives" (European Investment Bank 2017). It was around 2013, with the experience of steady growth in the green bond market, that a philosophical rift widened among market participants. There were those who argued that a system of principles was necessary to guide the market. This was demonstrated by the development of the Green Bond Principles (GBPs), convened by the International Capital Markets Association (ICMA). As the market continued to grow at pace in 2013, the GBPs were established by a consortium of investment bank bond underwriters to provide conformity among green bond issuance (Bowman 2015, 208). At that time, and since, the GBPs have only included broad Use of Proceeds (UoP) categories for defining what is green (Kidney 2013). This approach was in contrast with the proponents of standardization who emphasized the importance of a common framework for transforming science into a sustainable finance taxonomy.

One market organization, the nonprofit Climate Bonds Initiative, ignored dismissals of standards and worked from its inception to establish a sustainable taxonomy to evaluate infrastructure financed by green bonds in relation to climate emissions scenarios (Kidney 2009). In 2012, the first CBI Taxonomy was published, with criteria for solar and wind being its initial foci (Pell 2013). Sean Kidney, co-founder and CEO of Climate Bonds, worked to establish the CBI Taxonomy to ensure that the green bond market was mobilized effectively to finance projects and assets that delivered climate change solutions. According to Kidney:

The idea initially was that if we change the planet quickly, we have to be clear on what we are going to do. We need a common global approach. . . . If we want investors to drive change, we need to have consensus. We need a strong enabling state to make the change, but we also need to make sure the changes are science driven. So, the whole idea of the standards was to create a science driven artefact to push change.

Through its consultations with academics focused on standards development, Climate Bonds began the process of creating a robust standard based on climate science in order to evaluate the UoP underpinning green bonds (McDermott, Noah, and Cashore 2008). While it's important to clarify the distinction between principles and standards—principles providing a framing of what is green, and standards establishing substantive criteria for evaluating green claims—in practice the two concepts work hand in hand. The

Climate Bonds Standard is made up of two parts: the overarching standard that applies to green bonds financing projects in any sector and sector criteria that have specific thresholds. These criteria are the technical requirements of the CBI Taxonomy. Together, the GBPs and the Climate Bonds Standard and CBI Taxonomy have become the cornerstones of green bond market policy frameworks today, encouraging other jurisdictions to develop similar guidance.

In 2015, the People's Bank of China (PBoC) and the National Development and Reform Commission (NDRC) each published their own guidelines for issuing green bonds in China. The CBI Taxonomy was used to develop these green bond market frameworks (Nan and Wang 2016). Similarly, in supporting efforts to protect the environment, the ASEAN Capital Markets Forum (ACMF) launched the ASEAN Green Bond Standards (ASEAN GBS)—based on the GBPs—to help in the allocation of resources toward climate-friendly investments in the region. Since its launch in November 2017, the ASEAN GBS has gained encouraging traction in the region, with three successful green bonds from Malaysia and Singapore carrying the ASEAN GBS label (ACMF 2017).

The latest move by the Commission to develop the EU Taxonomy, the PBoC's rule book, and the increasing usage of the CBI Taxonomy by green bond issuers, highlights the growing popularity of using a taxonomy to define what constitutes a low-carbon, climate-resilient economy. Although it would be ideal to compare the taxonomy development processes in China with those of the Commission and Climate Bonds, the authors can only access secondary and piecemeal information about the process in China. Further investigation in this area would be a welcome development. Thus, here we focus on our experiences with the Climate Bonds Standard and the EU Taxonomy.

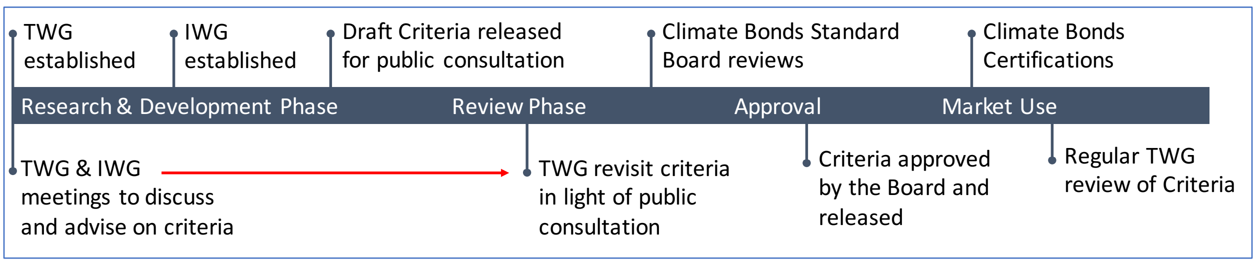
4. **Overall Processes of CBI Taxonomy and EU Taxonomy**

The processes underpinning the development of the CBI Taxonomy and the EU Taxonomy produce the frames through which both taxonomies interpret climate science for financial markets. The comparison here is particularly pertinent because the Commission process is based, in part, on Climate Bonds' experience (Financial Stability, Financial Services and Capital Markets Union 2019). Similarly, future taxonomy development work is likely to draw on both of these criteria. The International Organization for Standardization (ISO) is currently developing its own climate-aligned taxonomy, which is also expected to draw on both the Commission's and Climate Bonds' experiences (Gould 2018). The processes used are interesting to study both separately and comparatively because they are similar but have some significant structural and organizational differences, which may have affected the outcomes. Here we present both the CBI Taxonomy and EU Taxonomy processes separately and comparatively.

5. **CBI Taxonomy: Criteria Development Process**

Sector-specific criteria can be combined to create a taxonomy for sustainable finance. Since its inception in 2011, the CBI taxonomy has expanded in scope and published criteria for an increasing variety of sectors. The process for developing the standard and sector criteria begins with the establishment of the working groups and includes several phases (Figure 1).

Figure 1: The Process for Developing the CBI Taxonomy Overarching Standard and Sector Criteria



TWG: Technical Working Group. IWG: Industry Working Group
Source: Climate Bonds, 2018.

In the CBI Taxonomy process, discussions cover guiding principles for criteria, the scope of the criteria, and the metrics and thresholds for determining whether an investment is climate-aligned. Technical Working Groups (TWGs) and Industry Working Groups (IWGs) hold separate discussions on a bimonthly basis; these discussions are led by a technical consultant who is hired by Climate Bonds to lead the criteria development process based on their expertise. A TWG is composed of academic and technical experts in the specific area that criteria are being developed; they often work for universities, NGOs, consultancies, or intergovernmental agencies. An IWG is composed of potential green bond issuers, investors, verifiers, and other companies and entities involved in the infrastructure category.

Once the TWG and IWG have concluded their discussions and finalized draft criteria, those criteria are released for public consultation. The Climate Bonds Standards Board then gives the final approval for criteria to be used for Climate Bonds Certification. According to its design, this process is multi-stakeholder, grounded in the latest environmental and climate science, draws on expert input, and provides space for existing initiatives to be leveraged wherever appropriate to do so.

6. **EU Taxonomy: Criteria Development Process**

In response to growing interest and the development of numerous types of sustainable finance, the Commission launched a High-Level Expert Group (HLEG) on sustainable finance to provide recommendations for a comprehensive EU strategy on the subject as part of the Capital Markets Union (European Commission 2016). In January 2018, the HLEG published its final report, which contained eight key recommendations, other cross-cutting recommendations for financial institutions, sectoral recommendations, social recommendations, and broader environmental sustainability recommendations. The establishment and the maintenance of a common sustainable finance taxonomy at the EU level were the first two of the key recommendations made by the HLEG (Financial Stability, Financial Services and Capital Markets Union 2018a). In the May 2018 follow-up, the Commission established the EU TEG on Sustainable Finance, which was mandated to develop a sustainable finance taxonomy in its general assessment of sustainable finance (European Commission 2020a).

The HLEG essentially provided the mandate the Commission needed before it could prioritize developing a sustainable finance taxonomy. The Commission has a high level of convening power but must have a strong mandate before it can embark on a project as large as one establishing a sustainable finance taxonomy. The preliminary work and recommendations from the HLEG gave the TEG's work validity and momentum, which helped the TEG process to meet the tight timescales designated by the Commission.

The TEG took a divide and conquer approach to developing the taxonomy. TEG members were appointed to chair the development of criteria for economic sectors (energy, waste management, forestry, agriculture, transport, manufacturing, and adaptation and resilience). The chairs were supported by other TEG members and external experts who were screened and included through an additional EU Taxonomy (European Commission 2019). Similarly, Climate Bonds appoints a lead analyst from within the organization and hires a technical consultant to manage the development of each sector criteria.

EU Taxonomy discussions were organized according to a template that scoped sustainability issues, developed principles, and identified relevant legislation. The template also proposed indicators, thresholds, and trajectories for infrastructure sectors. These were provided as summary tables in the TEG's Technical Report. To design this development process, the TEG looked at what had been done before in sustainable finance to assess climate alignment, such as the CBI Taxonomy and the EIB's framework. The group also recognized the need for taxonomy development to be multi-stakeholder and grounded in the latest environmental and climate science.

The most striking difference between the EU and CBI taxonomies is the scale of the Commission's project and the simultaneous development of multiple criteria on a tight timeframe. In the CBI Taxonomy, criteria are developed independently of one another. Newer criteria development work builds on the principles and practices that emerge in older CBI Taxonomy criteria. In this sense, the CBI Taxonomy development has been more iterative than the EU Taxonomy.

From this outline of the criteria development process for both the Climate Bonds Standard and the EU Taxonomy, we now move to compare parts of these processes to recognize similarities, differences, and aspects that worked well, and to propose recommendations for future improvements. Here we discuss the formation of expert groups, management of discussions, decision-making structures, and the consultation phase for the TEG's and Climate Bonds' taxonomy developments.

7. **Multi-Stakeholder Input**

The credibility of a standard development process rests on the availability of technical and industry knowledge, and the ability to feed this information systematically into final agreements on sector criteria. Ensuring that there is a robust and sufficient representation of expertise from the relevant stakeholders can be accomplished through the formation of expert groups, but also during the public consultation when the criteria are circulated among a wider audience for feedback. This section outlines the key considerations taken by Climate Bonds and the Commission when forming expert groups and conducting public consultation.

How Are Climate Bonds' TWGs and IWGs Formed?

CBI Taxonomy criteria development draws on the organization's professional and industry networks to form TWGs and IWGs. Depending on the sector, Climate Bonds may also approach individuals or organizations that it has not previously had any connection with to see if they will participate in either a TWG or an IWG. Often receptive, these organizations or individuals see participation as an opportunity to apply sector-specific climate-change knowledge to a financial context and see the benefit of creating criteria for financial markets.

How Were the TEG Sector Working Groups Formed?

The Commission received 185 applications from 62 individuals and 123 organizations in response to its call for TEG membership applications (Financial Stability, Financial Services and Capital Markets Union 2018b). Some organizations proposed several individuals, leading to roughly 240 people who needed to be reviewed. A team of 15 reviewers from the EU's Directorate Generals (DGs), including the DG for Climate Action, DG for Environment, and DG for Financial Stability, Financial Services and Capital Markets Union, reviewed all applications. A minimum of two reviewers evaluated each applicant. The most important selection criteria in the review process were: (1) proven knowledge and expertise for one of the subtasks and (2) knowledge on the intersection between finance and the environment.

The Commission also considered the need for a balanced representation of relevant expertise and areas of interest, geographical distribution, gender distribution, and a sufficiently wide variety in the representation of financial and real economic actors and sectors. The selection process resulted in a group of individuals with 17 nationalities. Among the members, 15 out of 35 were women (European Commission 2018). Once sectors were assigned to the different co-chairs, a second call for external experts was made. These applicants were then screened by the TEG members co-chairing the respective sectors.

In both the TEG and Climate Bonds' TWGs and IWGs, expert groups are composed of a diverse and balanced representation of stakeholders. To form the TWGs and IWGs, Climate Bonds relied on professional networks and working relationships with the experts. These networks have grown over time as the organization has established itself in the green bond market and in climate finance at large. However, despite its strong position in the market, Climate Bonds does not have the convening power of the Commission as a political organization. In this sense, the Commission was able to encourage high-level stakeholder engagement and also leverage the expertise and resources available through the respective Directorate Generals. The efficiency with which the TEG criteria were developed was due to the convening power of the Commission. Similarly, the ability of the Commission to host TEG meetings and workshops throughout the consultation period helped facilitate a higher level of engagement and knowledge sharing.

This convening power is important to taxonomy development because the criteria attempt to convert scientific knowledge into industry-applicable rule sets that strike a balance between scientific rigor, ambition, and usability. The higher the convening power, the more likely it is that three things will be achieved: first, the right people for the criteria development will be recruited; second, enough experts will be recruited, both in terms of absolute numbers and diversity of experience, location, and gender; and finally, the members of the expert group will be committed to the objective and motivated to give time to achieving it.

Throughout the CBI and EU taxonomy development processes, the composition of expert groups is critical to the group's final output and the credibility of the criteria established. Organizations, such as the UK-based nonprofit InfluenceMap, track the presence and effect of lobbying and interest groups on the policy formation process. Its reports highlight the need to ensure that such expert groups are isolated from industry influences, which may be counterintuitive to the climate-agenda (InfluenceMap 2019). For the CBI Taxonomy, the availability of professional networks ensured that the TWGs and IWGs were populated by experts who would not compromise the organization's objectives. Similarly, the Commission's convening power was vital to ensuring that appropriate filtering could produce enough applicants with an adequate level of expertise and avoid industry influence.

8. **Discussion Management**

Discussions between Climate Bonds Standard's TWGs and IWGs are led by consultants through webinars and supported by presentations, a draft issues paper that develops into a final summary of the criteria, and a separate background document that provides details of the discussions. The issues paper outlines the role of decarbonization within and of the sector. The TWG and IWG then discuss principles, metrics, and thresholds over the consultation period. Climate Bonds has found it most productive to put in front of the TWG and IWG the proposals for criteria and thresholds, which can then be questioned and amended. Open discussions can cause scope creep and can make the process a bit overwhelming for the TWG and IWG in knowing where to start. It is always stressed that proposals are just that, and they can be fully rejected or completely reworked.

In the EU Taxonomy process, a predesigned template provided for all sectors guided the co-chairs. The template was completed over the course of the discussions and covered the climate impact of the sector, sector-specific principles for criteria design, proposed metrics, thresholds, and economic and social impacts. These templates accelerated discussions and kept TEG outcomes comparable across sectors.

One distinguishing feature between two taxonomy development processes was the use of the Statistical Office of the European Communities' NACE (Nomenclature des Activités Économiques dans la Communauté Européenne) codes to define the economic activities to which criteria would be developed. This helped to limit the scope of the TEG's work and was an important evolution from the process used by Climate Bonds, which prioritized sector criteria development based on climate change mitigation potential and demand from the green bond market.

One noticeable strength of the EC TEG process was that in addition to the webinars and teleconferences, the EU was able to facilitate in-person meetings between the TEG members and external experts in Brussels. While we cannot quantify the value of these meetings, it was clear that these interactions were vital for breaking communication barriers and building trust between individuals. From our lived experiences, it seems that consensus forming was more efficient when stakeholders were physically gathered together. As an NGO, Climate Bonds does not have the capacity to arrange and facilitate these in-person interactions, which has made it more difficult and time-consuming to reach a consensus between members.

9. **Public Consultation**

A public consultation helps ensure both the credibility and usability of taxonomies. The development of the CBI Taxonomy and the EU Taxonomy showed the importance of conducting a public consultation that allows stakeholders who were not directly involved in the process to feed into the final criteria. In both cases, efforts were made to ensure that the maximum number of people were aware that the criteria were being made available for public feedback (European Commission, 2020b).

10. **Decision Making**

Decision-making power at Climate Bonds rests with the TWG, and unanimity is required among TWG members. Consulted for its expertise, the TWG functions primarily to ensure that the criteria are scientifically and technically robust. The IWG is relied on to provide an industry perspective on the usability and feasibility of the criteria. The IWG does not have decision-making authority over the criteria, and consensus among the IWG members is not a requirement. This is because it is recognized that while the IWG has an important perspective to capture, in some cases, members may also have an incentive to weaken the criteria—for example, if they are a potential future issuer that may use the criteria for Climate Bond Certification. But the technical lead and researcher work to ensure that all considerations and perspectives are represented in the criteria.

Both Climate Bonds and the TEG sought to achieve consensus on the criteria from within the groups. Neither formally asked group members to vote for their approval of the final criteria, but chairs sought to address any objections and concerns raised by group members. Reaching consensus within the groups was found to be important because each group member represents a perspective from within the market and should not be viewed as an outlier opinion.

11. **Conclusion**

Over the last ten years, taxonomy development has expanded to different countries and to cover various activities and assets and projects. During this period, the process for producing criteria has evolved from both institutional learnings and trial-and-error. The EU Taxonomy managed to produce specific criteria for 67 economic activities across 8 economic sectors in under 18 months.

One of the factors that enabled the TEG to produce these criteria so efficiently was the use of the standardized template that focused the technical discussions on scoping the activity, setting sustainability objectives, and identifying suitable metrics. We recommend using a similar structure and template for future taxonomy-related discussions. Another important facet of the EC TEG approach was to use the EU NACE codes for guidance in selecting the economic sectors to develop criteria. This provided a systematic means to ensure that the most pertinent activities within a sector were addressed. Expert groups must represent a wide range of expertise from various industries, geographies, and types of institutions. In the absence of a widely recognized body that can utilize its convening power, an organization needs to leverage its existing networks while being mindful of the bias this may bring to the expert group.

The cohesion and success of these discussions depends on how well the group is able to align on the objectives of the taxonomy. The EU Taxonomy experiences highlight the importance of in-person meetings to facilitate dialogue and, when these are not possible, how online conferencing is crucial to maintaining discussions. Similarly, ensuring that stakeholders who are not directly involved in the process have the ability to feed in through public consultation processes is critical. Finally, establishing a process for decision making within the various steps of a taxonomy development process is also vital.

12. **Research Summary**

In this paper, we have identified steps within the climate-aligned taxonomy development process that policymakers and those tasked with developing future taxonomies will have to take. Expert groups should represent a wide range of interests and bodies of knowledge, and these different voices should be managed by an appointed head in order to keep discussions pointed to drafting coherent criteria. We hope that these comparisons between the CBI Taxonomy and the EU Taxonomy processes can provide insight and a structured approach for how to construct sustainable taxonomies that are functional for multiple stakeholder groups. From our experience, the robustness, credibility, and usability of the CBI Taxonomy and EU Taxonomy processes are heavily dependent on the composition of the groups and the quality of their discussions.

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Biographies

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Achieving Common Ground in the Development of Sustainable Finance Standards

A Comment on "Defining Climate-Aligned Investment: An Analysis of Standards Development for the Green Bond Market"

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Environmental and climate change have attracted increasing attention globally. The sustainable development of economy, society, and environment has become a consensus of the financial and nonfinancial institutions. In this context, the demand for sustainable financial products is strong, boosting the fast development of the green bond market. The main attribute of green bonds is that the green and climate-aligned projects they support can produce positive ecological, environmental, and climate benefits besides positive economic externalities and social values. However, there is still an urgent need to clarify the core notion of greenness. The definition and taxonomy of projects; the use and management of raised funds and proceeds; evaluation and certification; and information disclosure are the four key pillars that constitute the standard framework of green and climate bonds.

At the global scale, the disunity derived from different standards of the green and climate-aligned bonds represents a key bottleneck to the development of sustainable finance. The green and climate bond market currently lacks a top-level policy framework. The market is guided by multiple organizations with diverse political, economic, and technical backgrounds. The Climate Bond Initiative (CBI), European Commission (EC), and the International Capital Market Association (ICMA) play leading roles in the market standardization. In addition, rating agencies and stock exchanges also provide various definitions and standards regarding the development of green and climate-aligned bonds. Various inconsistent voices in the market lead to more barriers to implementing the green investment plan. Therefore, it is necessary to reach common ground in order to boost high-quality market development further.

A scientific, clear, and unified definition and classification of green-bond-supportable projects is an essential prerequisite to the prevention of greenwashing and to ensure sustainable development of the green bond market. *Climate bond* and *green bond* are the common expressions across green bond standards. Although they seem to be similar, differences still remain in specific connotations. For example, the scope of relevant projects defined by the Green Bond Principles is able to cover the majority of activities of issuers and investors related to environmental protection, pollution reduction, and climate change adaptation. In contrast, CBI's climate bond classification focuses more on climate change issues, covering a relatively narrower range of environmental activities, and with stricter technical requirements. However, fully understanding the different standards can be challenging to achieve for all the participants in the market. This difficulty may even lead to opportunistic issues such as greenwashing.

Sustainable finance now presents a trend of standardization beyond the borders of countries and continents. For example, from the EU Action Plan to the EU Taxonomy, the evolvement shows that the development of sustainable finance becomes more systematic, more institutionalized, and more mainstream. Similar advances are also observed in both developed and developing economies: for example, the United Kingdom issued the British Green Finance Strategy, Japan issued green bond guidelines, Indonesia issued the Sustainable Finance Initiative, the ASEAN Capital Markets Forum launched the ASEAN Green Bond Standard, India issued green bond listing disclosure requirements, and China worked on the development of a unified green bond standard on the basis of its original green bond guidelines.

The Climate Bonds Standard CBS V3.0 can be regarded as a step forward to confirm this trend. It is compatible with the recent EU Taxonomy; the standards of ASEAN, Japan, and India; and the Green Bond Principles of the ICMA. The overall structure of the CBS V3.0 adopts the four pillars structure that is consistent with the ICMA's Green Bond Principles, namely the use of raised funds, project evaluation and screening, fundraising and management, and information disclosure.

Globally, the pace of achieving common ground is accelerating and requires effective coordination among different organizations and institutions. During the process of discussion, decision making, and public consultation, it is important to encourage the technical group experts to collect and consider external opinions from various channels that reflect different perspectives and levels and thus enhance the credibility of the standards. The latest TEG report on the EU Taxonomy has taken an essential step toward addressing climate change and achieving common ground on sustainable development. The Taxonomy not only takes the shape of a glossary that defines Paris Agreement-aligned performance criteria over a set of economic activities but also absorbs the latest scientific and industry experience, since it has been developed after consultation with over 200 industry specialists and scientists. This mechanism enables the Taxonomy to respond dynamically to new developments in technology, science, and industry practice.

Challenges and opportunities continue to co-exist in the journey to reach common ground among sustainable finance standards. Different organizations have different strengths in convening capacity, authority, policymaking and implementation capacities, scientific research, market-making, and monitoring. The challenges arise out of coordination complexities between different organizations when attempting to help investors, issuers, project promoters, and policymakers understand whether an economic activity is within the scope of greenness, to guide and regulate fundraising and investment activities, or generally to navigate the transition to a low-carbon economy. Opportunities for the promoters of standards, investors, and issuers, as well as policymakers, also arise from the increases of standard scalability, efficiency in investment opportunity identification, and appraisal or reduction of transaction, regulation, and monitoring costs.

Biography

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A Multidisciplinary Literature Review of Academic Research on the Green Bond Market

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Abstract

Climate finance is the mobilization of public and private capital toward climate mitigation and adaptation. Green bonds are one of a growing number of financial products used to facilitate climate finance investments. The green bond market has grown rapidly since the European Investment Bank's inaugural issue in 2007. In November 2018, the total outstanding volume of green bond issues crossed the $500 billion threshold, with an additional $148 billion in green bonds issued since the beginning of 2019. As the bridge between scientists, policymakers, and the private sector, the field encompassing green bonds and other financial instruments could be critical to meeting the targets of the Paris Agreement under the United Nation's Framework Convention on Climate Change (UNFCCC). And as that happens, it will become increasingly clear that this field will require a vast array of expertise and perspectives. This paper adopts an interdisciplinary approach to map the burgeoning field of literature on green bonds and climate finance more broadly. We situate the green bond market within the development of climate finance by outlining the role that scientific research plays in developing green bond guidelines and standards. We examine this trend from an anthropological and economic-history approach, before delving into the policy research that is emerging in the climate finance and green bond field. This provides the context for an analysis of the rapidly growing body of legal research on the green bond market, including a reflection on the legal ramifications of a pricing difference between vanilla and green bonds. Finally, we propose areas for further research in each of our respective disciplines of anthropology, policy, and law.

Keywords: green bonds; climate finance; law; policy; anthropology

1. **Introduction: A Multidisciplinary Literature Review of Academic Research on the Green Bond Market**

The green bond market is expanding, and investors around the world are showing their appetite for the asset class. As green bonds and other environmental finance products continue to gain credence, the academic literature commenting on this field has also proliferated. This paper is intended to provide a mapping of existing academic climate finance discourse and highlight areas where further research is needed.

The climate finance and green bond debate is inherently interdisciplinary. In their paper, Linnenluecke et al. (2016) provide an overview of how the dynamics of sustainable finance bring together multiple disciplines. In a similar approach, this paper adopts a multidisciplinary approach, highlighting how different disciplines highlight different dimensions of climate finance. Anthropology provides an overview to interpret and connect developments in policy and law that are building the robustness of climate finance markets. As researchers and practitioners in the green bond market, we have attempted to review all published literature on green bonds from our respective disciplines: anthropology, policy, and law.

We begin by defining green bonds and situating the green bond market within the development of the wider environmental, green, and climate finance discourse. The demand from issuers has resulted in debates around a pricing difference, labeled a greenium, which has been studied by economists and market analysts. Pricing research is currently the mainstay of academic research on the green bond market. However, to deepen this understanding of the broader context of the green bond universe, we explore from an anthropological perspective how climate science is being translated into green bond guidance and action, and what the anthropological and sociological theory says on green bonds. This forms the basis for an examination of the political and legal research surrounding the green bonds market and climate finance in general.

2. **Defining Climate, Green, and Environmental Finance**

The concepts of green, climate, environmental, and sustainable finance are often used interchangeably. Climate finance is generally understood to be the financing of assets and activities that support climate change mitigation (and, arguably, climate change adaptation and resilience). Climate finance can be considered a subset of environmental finance, a growing field concerned with the financial implications of environmental change for industries and firms, and the need to transition to a sustainable economy (Linnenluecke et al. 2016). Similarly, Donovan and Bardalai (2017) propose that green finance "matches sources of funding to new capital and operating expenditures that generate measurable progress toward the achievement of a well-recognised environmental goal." These definitions can be expected to change as these fields evolve to include a wider range of sectors that can be "greened" and larger scope financial products (Bergedieck et al. 2017; Lindenberg 2014). The concept of a "well-recognised goal" is reflected in the ongoing development of classification systems used to determine the climate-alignment of assets and activities, for example the European Union Technical Expert Group on Sustainable Finance's (EU TEG) Taxonomy Technical Reports, commonly referred to as the EU Taxonomy (2020).

Concepts of sustainable, green, and climate finance have yet to be fully translated into law. The political agreement reached on December 18, 2019, between the European Parliament and the Council on a classification system for sustainable economic activities suggests that a binding regulation defining sustainable finance is underway in European Union law. Financial regulators in Europe have punctually released position papers on green finance products (for green bonds, see AMF [Autorité des Marchés Financiers] and AFM's [Autoriteit Financiële Markten] common position paper, 2019), while in the United States, sustainable finance was the subject of an early 2010 Securities and Exchange Commission (SEC 2010) guidance on climate-related disclosures (revised in 2018), without much normative progress since. It stands in stark contrast with China, which published its 2016 Guidelines for Establishing the Green Financial System. These guidelines clarify the definition of green finance, which refers to financial services provided for economic activities that are supportive of environmental improvement, climate change mitigation, and more efficient resource utilization (UN PAGE, 2016).

The field of environmental finance is derived from the fundamentals of environmental economics discourse. For example, Chesney (2016) builds on the concepts of carbon pricing (either through cap-and-trade or a carbon tax) by applying the Black-Scholes model to determine a "fair price" for carbon credits. Contemporary research on green bond policy represents a significant departure from the incentive-based regulation and carbon-pricing research that emerged in the early 1990s and 2000s. Rather than attempting to reveal or establish a carbon price, this new field of green bond policy research is primarily concerned with monetary policy and financial regulation that is targeted at financial actors, rather than on imposing an operational limit on corporates. However, the financial sector has begun to adopt a different approach to "environmental finance," which is more aligned with the definition provided by Donovan and Bardalai (2017).

As the subject of this issue, the development of financial products and, in particular, green bonds providing debt-finance to environmentally beneficial assets and activities marks a novel approach to dealing with the same problem. Research on the relationship between green bonds (and other green-finance products) and carbon prices is only starting to emerge, and there is evidence to suggest that carbon prices will support the growth of the green bond market (Heine et al.2019).

3. **Defining Green Bonds**

Green bonds are financial instruments that apply an environmental label to traditional bonds (commonly known as vanilla bonds), to signify that the proceeds will be used for financing green or climate-related products.[1] Green bonds are widely considered to be the flagbearer of the green finance agenda and are expected to deliver the volumes of capital necessary to make the transition to a sustainable economy.

To have an 80 percent chance of maintaining a 2°C limit, the IEA estimates an additional $36 trillion in clean energy investment is needed through 2050—or an average of $1 trillion more per year compared to a "business as usual" scenario over the next 36 years (Fulton and Capalino 2014, 2). The bond market is considered an important source of capital for meeting this target.

There are three ways in which a green bond can be labeled as such. Firstly, an issuer can self-label a financial product. In this case, the buyer of the financial product must rely on the reputation or trustworthiness of the issuer that the proceeds of the financial product are being used for expenditures that contribute to an environmental or climate-aligned objective.

Alternatively, the issuer can secure a Second Party Opinion (SPO) from an environmental consultancy or auditor who can confirm that the financial product being labeled as "green" meets the requirements of the International Capital Market Association (ICMA) Green Bond Principles (GBPs). The GBPs are voluntary process guidelines that recommend transparency and disclosure and promote integrity in the development of the green bond market by clarifying the approach for issuance of a green bond.

The GBPs have set a norm for reporting practices and proceeds management. However, the proliferation of the green bond market also brings into question whether the GBPs are robust enough to provide sufficient guidance on a bond's environmental credentials and safeguard against the risk of greenwashing.[2]

In response to this risk of greenwashing and to meet the need for increased consistency within the green bond market, a third method for labeling a product as "green," through the application of a "Taxonomy" has emerged. In this instance, issuers of a financial product hire third-party verifiers (who can be the same entities that provide SPOs), to assess the intended Use of Proceeds (UoP) of a financial instrument against a pre-defined standard. Bonds (or other financial instruments) showing that the assets or activities to be

[1] Other financial products such as loans can also be labeled as "green."
[2] Labeling or naming of an asset, activity, or financial product as providing an environmental benefit without the asset, activity, or financial product doing so.

financed will meet a technical or operational threshold that is aligned with Paris Agreement targets can be certified or labeled as compliant to a scheme. This method was pioneered by the Climate Bonds Initiative (Climate Bonds), which has developed the Climate Bonds Standard and Certification Scheme. The method has since been adopted by the People's Bank of China (through the Green Bond Catalogue) and is currently being adopted by the European Union Technical Expert Group on Sustainable Finance.

The taxonomic approach proposes that activities or asset-level thresholds can be developed based on climate-science to determine when that activity is providing a significant contribution to climate change mitigation. The concept of "labeling" a financial product raises numerous interdisciplinary questions on the value of labels in financial markets, the reliability and accuracy of such labels, and what an uptake in labeling activity represents in terms of market shifts. It is therefore necessary to maintain a multidisciplinary approach that draws on scientific, economic, financial, legal, policy, and anthropologic perspectives when examining the green bond market.

4. **The Market for Green Bonds**

The green bond market has grown rapidly from $11 billion in outstanding issuances in 2013, to $389 billion in 2018 (Climate Bonds Initiative 2018) and $723 billion at the start of January 2020 (Climate Bonds Initiative 2020a). In 2007 the European Investment Bank (EIB) issued the world's first green bond. After this beginning, the market grew quickly. According to JPMorgan Chase, "since the first green bond was issued in 2007 by the EIB, over $21 billion (USD equivalent) in green bonds have been issued, and $10 billion worth of green bonds have been issued in 2013 alone." The year 2014 ended with $36.6 billion issued by 73 institutions, bringing the market to a total of $53.2 billion outstanding green bonds (Olsen-Rong 2015). In 2015, $41.8 billion labeled green bonds were issued (Climate Bonds Initiative 2015). In 2016, large green bond issuances by New York City's Metropolitan Transportation Authority and by Apple, with a $1.5 billion issuance, continued to grow the market (Climate Bonds Initiative 2016). As this growth continues, the green bond market now stands as one of the key sectors of climate finance and environmental finance more broadly.

In 2017, Fiji and Nigeria both issued sovereign green bonds, showing that developing countries were beginning to look at capital markets to finance their climate-aligned infrastructure projects. Commercial Banks such as BDO Unibank in the Philippines, Thai Military Bank in Thailand, and OCBC NISP in Thailand have also issued green bonds in the last twelve months. The growth of the green bond market has led to more diversity in the type of issuers to offer green bonds, which includes development banks, sovereigns, municipalities, corporates, and financial institutions.

Green bonds can also be tagged or labeled green by other entities for grouping in benchmark indices and for exchange listings (ICMA 2018). The Bank of America Merrill Lynch Green Bond Index covers corporate, government, treasury, and securitized bonds, with a fixed minimum issue size of US$300 million, across a multi-currency benchmark. But this index has no explicit alignment with the GBPs or Climate Bonds certification scheme. Other green bond indices include the Barclays MSCI Green Bond Index, the S&P Green Bond Index/Green Project Bond Index, and the Solactive Green Bond Index. These indices all have varying methodologies for qualifying a bond as "green." The S&P Dow Jones' Green Bond index and the Solactive Green Bond index require bonds to be flagged "green" by Climate Bonds in order to qualify for listing. The Bloomberg Barclays MSCI Green Bond Index assesses bonds against six MSCI defined environmental categories. Unlike the Solactive and S&P indices, the latter also includes general-purpose bonds in which 90% of the bond is used for projects under the six categories. The methodological distinctions for green bond classification across the various indexes are in the different approaches for delineating the totality of the green bond market.

5. **Anthropological and Sociological Theory on Green Bonds**

Over the last twenty years, anthropological and sociological studies of finance have developed into a productive and innovative subfield branching the two social sciences (Beunza 2019; Graeber 2014; Hertz 1998; K. Ho 2009; LiPuma and Lee 2004; Welker and Wood 2011; Zaloom 2019). This research builds on studies by sociologists looking at economic activity's effects on society in the 1800s (Weber 1958; Simmel 1950), and from anthropologists studying systems of distribution and value in non-Western cultures (Malinowski 1978; Mauss 1967). The development of climate finance and the dramatic growth of the green bond market highlight elements of social change and the materiality of financial markets that have already been explored by social scientists in mainstream finance (Holmes 2014; Scott 2013; Smith 2014).

The rise of climate finance and green bond market practitioners marks a blending of multiple forms of expertise from outside finance to interpret environmental systems (Castree 2013), in a manner that is similar to the growth of Islamic finance (Maurer 2005; Rudnyckyj 2019). Green bond analysts are not only debt experts but also climate change experts (Mitchell 2002; Tripathy 2017). This blending of expertise reflects the embeddedness of financial markets in the social constructs of public and private or government, corporate, and household economic activity (Hann and Hart 2009; Polanyi 1944; Silver 2017).

Parallel to the development of climate finance markets, sociological and anthropological analysis began with reflections on carbon markets and the development of emissions trading schemes. Michel Callon and Donald Mackenzie have traced the construction of carbon credit markets (Bridge et al. 2019; Callon 2008; Mackenzie 2008). They contextualize the development of these markets as new manifestations of the rule of experts with added forms of knowledge to complement financial expertise (Demeritt 2006; Mitchell 2002).

The green bond market's cross-sectional functioning between private and public entities also furthers market studies in anthropology. As Felix Stein argues in *A Research Agenda for Economic Anthropology*, "for more than a decade, anthropologists approaching states and markets as fundamentally different have tended to describe their relationship with reference to neoliberalism" (Stein 2019, 25). The growth of the green bond market, a whole sector of the bond market, as a result of supranational entities challenges this division of the public and private in distinguishing states and markets. Climate finance enmeshes countries and markets with governments, corporations, and global law firms, interacting in the same field of the market directly (Lovell 2014).

Through markets such as those for green bonds, nature is accounted for in finance, or at least potentially accounted for. This process involves the translation of and accounting for climate change in financial activity. As Jaume Franquesa notes in his review of Aneil Tripathy's longitudinal study of the green bond market, green bonds "involve the complex cultural task of accounting for nature, translating it into the language of finance. The complications that this translation involves promote the creation of novel intermediate financial instruments, further introducing nature into the logics of finance" (Franquesa 2019, 84). The dynamic of climate finance extending the governance and purveyance of financial markets has also been noted by Sian Sullivan, particularly in relation to the green bond market (Sullivan 2018).

In their work, climate finance practitioners argue that the history of successful capital markets goes hand in hand with strong public sector policies (Bainbridge et al. 2018; Rutherford 2019). For them, with the growing political will for climate action, green investment offers an opportunity to strengthen both public and private sectors by providing a space of collaboration. Their view of the green bond market is inherently pluralistic and defies the categorization of the market as private or public, as they see the market as a space of collaboration between NGOs, governments, and corporations. Climate finance operates as what Michel Callon would recognize as an "anthropology of entanglement… [that] frees us from the irritating and sterile distinctions between state and market" (Callon 1998, 40). Research on climate, environmental finance and the green bond market highlights the relationship between finance and the physical and environmental effects of human society.

Climate finance engenders an innovative assemblage of understandings of nature and finance that impacts materiality through the construction of green infrastructure, funded by creative financial instruments (Rocky Mountain Institute 1998, 235). In the green bond market, nature is homogenized as green, and yet it is this homogenization that distinguishes green bonds from regular bonds. The value of a green bond comes from being different, as an innovative climate finance product, as well as from being similar in all practical aspects to a traditional bond. This sameness allows for the comparison between bonds to determine the added value of a bond issuance being green.

6. **The Translation of Climate Science into Finance**

As capital markets have begun to take notice of the opportunities present in the environmental and climate space, the risk of "greenwashing" financial products has become visible. This is particularly pressing because, according to Bergedieck et al. (2017), the labeling of "green finance" depends on the purpose of the borrower's or lender's capital. There have been numerous examples of green bonds that have been issued by entities whose main economic activity is counter-intuitive to the climate change mitigation agenda. For example, Repsol recently issued a "green bond," but this was poorly received by the green finance market because the firm's primary economic activity is the production of fossil fuels. This utilization of climate science to determine the upper limit of an asset or activity's operational emissions is intended to counter the risk of "greenwashing," an existential threat to the environmental and climate agenda that has existed for decades (Bigger 2017).

Climate science, through modeling and analyzing the environment with quantified assumptions, already involves a translation of information into guidance on economic activity (Lahsen 2005, 899). Taxonomies such as the EU Taxonomy and the Climate Bonds Taxonomy are based on existing models and policy directives. For example, the electricity generation thresholds of the current draft EU Taxonomy, are based on the EU's net-zero by 2050 target, a political target reflecting a science-based commitment to decarbonization of the economy.

7. **The Policy Significance of Green Bonds**

There is a growing body of frameworks and policies that countries around the world are implementing to enable green finance to flourish. Central banks, financial regulators, and ministries of finance and other government bodies are engaging in coordinated efforts to increase the financing of green assets, and simultaneously working to "green" the financial system (UK BEIS 2019).

Sovereigns are increasingly issuing sovereign green bonds to finance green infrastructure projects and improve climate resilience. At the time of this writing, twelve governments had issued a total of 19 green bonds (Climate Bonds Initiative 2020b). The countries that have issued sovereign green bonds have published Green Bond Frameworks outlining the specifics of the green bond, in line with the GBPs. The green bonds issued by Nigeria, the Netherlands, and Chile have also been certified by Climate Bonds (2020b). Such issuances have deepened the green bond market and exemplify its potential to decarbonize the global economy (OECD 2016).

As this sovereign green bond market grows, governments will need to improve the policy frameworks that surround it (Jun et. al. 2016; Clapp and Pillay 2017). Samuwai (2018) compares the climate finance readiness in 12 countries across the Asia-Pacific region. The study employs a multivariate model to examine the aggregate effect of policy and institutions, knowledge management and learning, and fiscal policy environment—all on a country's ability to attract climate finance.

The green bond discussion is complemented by a broader discussion on the need to embed climate and more extensive environmental and sustainability considerations into financial market activity. This field is primarily focused on understanding and addressing the risks that are presented by climate change. Climate change might lead to considerable losses in the financial and real economy owing to the stranding of assets, limited resource availability, fluctuations in prices, or the effects of policy choices, such as carbon pricing (Carbon Disclosure Project 2019). Similarly, at the sovereign level, Buhr et al. (2018), show that there is an increasing cost of capital faced by emerging countries that are most vulnerable to climate change.

Literature on the financial risks associated with climate change, and the macroprudential and financial tools available to policymakers to manage such risks, is growing. Since his landmark speech at Lloyd's of London in December 2015, Mark Carney, former governor of the Bank of England, has been leading the charge in creating a financial system that recognizes climate risk. In that speech, Carney lambasted the short-sighted, profit-seeking culture that led to the financial crisis and warned of the "tragedy of the horizon" (Carney 2015). He also discussed the ensuing establishment of the Task Force on Climate-related Financial Disclosures (TCFD), which has been instrumental to helping inform the financial market and policymakers about practices relating to climate risk disclosure (IAIS 2020).

The TCFD has sought to develop voluntary and consistent climate-related financial risk disclosures to be used by companies in providing information to investors, lenders, insurers, and other stakeholders. This has been a major step toward embedding awareness and action into the private sector. It expects that increasing transparency will make markets more efficient and economies more stable and resilient.

Prudential Regulation has become a core focus for climate finance. Campiglio (2015) and Liebreich & McCrone (2013) examine how macroprudential regulation affect environmental investments but can also be the key to unlocking them. Bolton et al. (2020) point to the role that central banks, regulators, and supervisors will play in addressing the risks that climate change poses to the financial system. Similarly, Dikau and Volz (2020) examine whether central banks have incorporated climate-related risks into their mandates. Matikainen et al. (2017) offer a variety of policy options for incorporating climate considerations into asset purchasing strategies, and Vaze et al. (2019) proposes policy levers available to central banks and financial regulators seeking to support climate-aligned investments and to reduce the climate-related risks facing the financial sector.

These studies have complemented the work of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), which was established to define and enhance the role of the financial system in managing risks and mobilizing capital "to support the transition toward a sustainable economy. . . . The Network's purpose is to help strengthen the global response required to meet the goals of the Paris Agreement and to enhance the role of the financial system to manage risks and to mobilize capital for green and low-carbon investments in the broader context of environmentally sustainable development." (NGFS 2019)

8. **Green Bond Market Governance in the Legal Literature**

The legal literature on green bonds acknowledges a divide between Western countries on the one hand and China and other Asian countries on the other. In China, green bonds markets are regulated through public provisions set by the regulators of the Chinese bond markets (Franklin 2017; V. H. Ho 2018). Indian guidelines issued by the Securities and Exchange Board of India (SEBI) are also deemed by legal authors to provide public governance for the green bond market (Faske 2018; Wang 2018). Conversely, Western countries' green bond regulations rest on private governance mechanisms (Park 2018).

Park (2018) mobilizes a substantial body of legal scholarship on Corporate Social Responsibility (CSR) and transnational law to describe how a plurality of private mechanisms (investment standards, certification schemes, ratings, and third-party assessments) enables Western green bond markets to function. Park assesses the degree of inclusiveness and prescriptiveness of private regulations (GBP, Climate Bonds green bond indices, certification schemes, and ratings). In doing so, he identifies green bond private governance's legitimacy issues. To address them, he advocates a hybrid legal framework combining public and private regulation through different legal techniques. Illustrating this hybrid system, Park suggests that public regulators could set a private standard default penalty: regulated entities are penalized unless they comply with the designated private standard (Park, 2018).

As a sub-element of green bond private governance, certification schemes received special attention from the legal literature. Cristina Banahan and Paul Rose demonstrate that green bond verifiers (GBVs) share many features with credit rating agencies (CRAs). According to them, GBVs and CRAs both act as intermediaries of information, operate on a license (be it granted by Climate Bonds or by a credit regulator), and are financed through an issuer-pays model (Rose 2018). Banahan adds a fourth similarity: GBVs' and CRAs' common reliance on reputation. She also identifies a difference: unlike GBVs, CRAs have been legally obliged to disclose their methodologies since the aftermath of the 2008 financial crisis (Banahan 2019). This overall likeliness between GBVs and CRAs raises questions about the ability of GBVs to avert CRAs' systemic failures that led to the 2008 financial crisis. Rose and Banahan advance solutions to tackle GBVs' systemic weaknesses. Rose suggests that Climate Bonds should entice non-profit GBVs. In addition, Climate Bonds should allow investors to sue GBVs in case of poor climate verification (Rose 2018). Banahan advocates the creation of a Green Bonds Standards Committee in the United States which would, among other functions, monitor GBVs and create litigation rules to hold them accountable for the quality of their verifications (Banahan 2019).

In addition to certification schemes, green bonds' private governance raises a diversified set of legal questions. Regarding investors' legal drivers, legal authors have suggested that investors' green mandates and/or their fiduciary duties—which, at times, require them to take into account climate risks—may constitute legal incentives for becoming a green bondholder (for example, Mercier 2017; Park 2018).

However, both types of governance regimes—the Western private and the Asian public ones—are imperfectly integrated into international climate finance law. According to Zahar, climate finance in international law is "the United Nations Framework Convention on Climate Change (UNFCCC)—induced transfer or finance from richer to poorer countries for climate change action (mainly mitigation and adaptation)" (Zahar 2017). To be qualified as climate finance under the UNFCCC, finance flows must abide by several criteria (for instance: being new and additional, adequate and predictable). These criteria are not addressed by existing green bond governance regimes. As a consequence, in the *2018 Biennial Assessment and Overview of Climate Finance Flows Technical Report* released by the UNFCCC Standing Committee on Finance, green bonds are not reported as climate finance enabling developed countries to meet their commitments under article 9.1 of the Paris Agreement ("Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation in continuation of their existing obligations under the Convention"), but only as a method for producing quantitative and qualitative information on capital stock and flows in order to track consistency with Article 2.1(c) (“Making finance flows consistent with a pathway toward low greenhouse gas emissions and climate-resilient development”).

The fact that green bond governance imperfectly fits international climate finance law does not strip it from all normative value. For instance, Park considers the Green Bond Principles a “policy dissemination tool,” because they help spread recommended standards templates (Park 2018). Faske has also emphasized the relation between green bonds and regulations implementing climate information disclosures (Faske 2018), on which a rich legal literature has preceded the rise of green bonds (for example, Watchman et al. 2007).

Despite the accomplishments of private governance in the green bond market, calls for improved green bond regulation are almost as old as the market itself (Baily 2015; Malecki 2015). In addition to the proposals already mentioned (hybrid governance, improved certification, and contractual structure), legal authors support clearer transparency and litigation rules. Some recommend the opening of class action litigation, and litigation on an environmental due diligence standard (for example, Trompeter 2017). Others endorse the implementation of tiered standards (that is, standards with different shades of green) (for example, Franklin 2016; Clapp 2018; Wang 2018) or advocate the use of blockchain for better enforcement of green bond regulations (Zhang et al. 2018).

9. **Pricing Research on Green Bonds**

The process of knowledge translation that has been linked to green bonds as green is now actively developing into a priced distinction within financial markets. Academic research on the green bond market has been most prolific within economics, where research focuses on pricing differences between green and vanilla bonds.

The search for a green bond discount or greenium initially started by looking for differences in yields for corporate green bonds compared with non-green corporate bonds (Preclaw and Bakshi 2015). Another paper in this issue of the *JEI* summarizes research trends and market conversations around green bond pricing (Harrison et al. 2020). Beyond economics, a greenium is also particularly significant for its potential legal ramifications.

10. **The Legal Consequences of a Greenium**

The legal literature on green bonds stresses that no green-bond-related litigation has occurred so far. However, the literature on climate litigation underlines that “the development of green financial products such as ‘green bonds’ or ‘green loans’ will inevitably lead to litigation” (Solana 2019).

The literature on green bonds highlights that the majority of litigation risks materialize if qualifying a bond as "green" triggers financial gains or losses. In the United States, bondholders are offered civil liability and private rights of action under the Security Act of 1933 on condition that they show *loss* and available remedies (Czerniecki and Saunders 2016; Breen and Campbell 2017; Franklin et al. 2017). In France, bondholders could also be offered civil liability under the article 1240 of the Civil Code if they demonstrate, among other conditions, the existence of a loss (Mercier 2017). The pricing effect of green bonds does have legal consequences. However, some of the litigation risks extend beyond the pricing question. Lawyers underscore the need for appropriate environmental due diligence to be carried on by the underwriter in the process of issuing a green bond. Besides the control by financial regulators over information accuracy in issuance prospectuses, competition law and marketing law can also potentially prove fertile grounds for litigation (Czerniecki and Saunders 2016; Breen and Campbell 2017; Franklin et al. 2017; Mercier 2017).

Pricing has another legal consequence: it enables a more sophisticated contractual structure. To date, the legal specificity of green bonds is generally limited to a green promise described in the issuance prospectuses or, more exceptionally, in the definitive contracts between the issuer and the bondholders. These promises have never been adjudicated. Very specifically, some Asian green bonds include a green commitment in the underwriting agreement—the agreement between the issuer and its investment bank (Franklin et al. 2017). Even though legal practitioners state that green bonds reflect the diversity of the legal forms—for example, use of proceeds bond, secured bond, convertible bond, and so on—in use on the bond market itself (Czerniecki and Saunders, 2016; Breen and Campbell, 2017; Franklin et al. 2017; Mercier 2017), they stress that a wide array of legal tools in use on the bond market could be employed for green bonds: ESG, use of proceeds and reporting covenants, green event of default, put option, and so on. However, these tools imply additional legal fees and additional risks for the issuer (Czerniecki and Saunders, 2016; Breen and Campbell 2017). Therefore, their usability relies upon a green bond pricing effect that would be important enough to offset the cost of these legal tools.

In turn, more sophisticated contractual features for green bonds could open additional venues for litigation. For instance, as the green bond contract may include provisions requiring "the issuer or the borrower to guarantee that the finance raised will be only used to fund specific projects," a "breach of these contractual obligations could lead investors and lenders to enforce early termination of rights that would trigger an acceleration of payments." (Solana 2019)

11. **Future Research Avenues**

In this paper, we have analyzed the development of the green bond market in the context of its significance for current research in anthropology, law, and policy. We conclude with an overview and reflection on relevant ongoing research programs.

11.1 ***Anthropology***

As the green bond market and climate finance continue to expand, and as environmental, social, governance, and climate risk assessments become embedded in mainstream finance, anthropologists and sociologists have crucial work to do in documenting the cultural and material impacts of these transitions.

These disciplines can provide a perspective on the lived reality of working in these financial markets that can allow us to comprehend the larger societal impacts of the accounting, legal regimes, market dynamics, and policy decisions that produce climate finance and the green bond market.

Currently, there are multiple initiatives within sociology and anthropology that look to be fruitful focal points for research on climate finance. The European Union's Horizon 2020 has funded two projects focused on analyzing both the dynamics of investment in fossil fuels as well as impact investing (European Commission 2017; 2019). Based at the University of St. Andrews and the University of Bologna, two teams of anthropologists are just beginning longitudinal studies of both brown and green finance.

Michel Callon states in *The Laws of Markets* that "the market must be constantly reformed and built up from scratch: it never ceases to emerge and re-emerge in the course of long and stormy negotiations in which the social sciences have no choice but to participate" (Callon 1998, 266). This reflection captures the transformation that we are experiencing in the growth of the green bond market and climate finance more broadly.

11.2. ***Policy***

A cohesive policy agenda for mobilizing trillions toward climate change mitigation and adaptation and for other sustainable development goals is evolving rapidly, partly as a response to financial reforms, but also out of a growing policy acknowledgement of the cost of climate change.

The COP 25 in Madrid failed to reach an agreement on the guidelines for implementing the carbon market established by article 6 of the Paris Agreement. This failure, in theory, leaves the State Parties to the Agreement no choice but to develop other climate finance instruments—like green bonds—in order to meet their climate finance obligations, such as the 100 billion dollars pledged by developed countries to developing countries for every year from 2020 onwards.

With this context considered, policy researchers should analyze how to best ensure that the world's financial system becomes more resilient while promoting climate-aligned investments. There is a growing suite of policy tools that can be used to incentivize investments in green bonds. The utility of these tools should be analyzed by policy researchers as the approaches are furthered by different public sector actors. These tools include

- Integrating climate risk into financial management by taking a precautionary approach.
- Understanding what climate risk is, through climate finance modeling and implementation of the TCFD recommendations (which should be expanded to other environmental areas).
- Accelerating taxonomy-aligned investment through
    - Green stimulus
    - Fiscal rules
    - Taxation
    - Private finance and credit guidance
    - Quantitative easing for green

11.3 ***Law***

Further legal research on green bonds could draw on the emerging field of climate finance law (Bowman 2015; Sarra 2018; Zahar 2017). From an environmental law perspective, legal scholars have already started exploring the role of the precaution principle in finance (Cullen 2018), legal aspects around environmental information disclosure (Epstein 2015) and the 2015 Paris Climate Agreement's provisions on adaptation financing (Di Leva 2017). From a financial law perspective, legal scholars and practitioners have begun to uncover legal issues raised by other green finance products, such as carbon allowances (Olawuyi 2016). In light of environmental issues, legal scholars reinterpreted central financial law concepts like fiduciary duty (Richardson 2013).

Building on these works, further legal research could focus on the following questions: How consistent are the environmental legal characteristics of green bonds with existing environmental law instruments? To what extent can green bonds contribute to environmental reforms of financial law? Combining environmental and financial laws, what would be the ideal legal form of environmentally concerned, publicly traded debt instruments?

12. **Conclusion**

In this paper, we have outlined academic research on the green bond market with a focus on current climate finance, green bond market perspectives, and research in anthropology, policy, and law. We hope that academics in these disciplines will expand on the research agendas we have outlined here.

For many practitioners in climate finance, the growth of the green bond market and other climate finance instruments support a hope that our global financial system and global environmental sustainability can be symbiotic. The development of the science, policies, legislation, and technologies, as well as business and financial models to make this transition happen, requires interdisciplinary research. This paper is intended to introduce this field and to serve as a starting point for future research in these areas.

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Comments on "A Multidisciplinary Literature Review of Academic Research on the Green Bond Market"

Kalyani Inampudi, ACSI, MBA, Imperial College Business School and ESADE Business School

Introduction

It was a great discussion on various research methodologies for green bonds. However, an in-depth discussion involving an anthropological perspective might have given additional flavor to this setting. Merely mentioning sociological and anthropological theories is not enough on its own. The exploration of its applicability and what key contributions anthropology has been bringing to the study of climate change are critical. To deepen the understanding from an anthropological perspective, the analysis of longitudinal studies of brown and green finance would have benefitted from additional clarity and further follow-up explanations.

A Comment on the Section "Defining Climate, Green, and Environmental Finance"

While climate finance is generally understood as the financing of assets and activities supporting climate change mitigation, the term climate finance in its current context is mostly aimed at financing or funding those technologies or activities that aim at reducing harmful emissions of greenhouse gases, and the atmospheric warming caused by the latter. It also indirectly aims at increasing the resilience of human and ecological systems to rapidly change negative climate change impacts.

Albeit the authors indicate that climate finance can be considered as a subset of environmental finance, in the current context the term *environmental finance* is mostly aimed toward financing and investing in the preservation of ecological systems and the environment, such as the management of solid waste, biodiversity issues (for example, landfills and hazardous waste, land remediation, and so on). Climate finance has mostly been distinguished from both ecology and ecological economics.

The authors did specify green and sustainable finance as important tools, as well as their importance, given the persisting urgency to fully transition to a sustainable economic model. However, in the upcoming EU policy and regulatory definitions, sustainable finance is referred to as any form of financial service integrating ESG (Environmental, Social, and Governance) criteria into business or investment-making decisions. Generally, this includes economic activities that ensure and improve economic efficiency and sustainability in the long term. Current activities that fall under green and sustainable finance include, among others, microfinance, funding for green bonds, sustainable projects (mainly those that overlap with project finance activities and follow the equator principles). In summary, it aims at gearing the whole financial system in a more sustainable direction.

A Comment on "Defining Green Bonds"

Climate bonds are fixed-income financial instruments that can be linked to climate change solutions, although not exclusively. They are most commonly issued by governments, investment banks, municipalities, or corporations.

While there is a need for $36 trillion of clean energy investments, the authors could have provided additional details such as the ratio of green bond capital to be raised in both developed and developing nations. According to recent scenarios, emissions and energy demand are both likely to double; hence it is crucial to calculate the break-even thresholds to estimate the minimum capital to raise and indicate the country-level or continental variances.

While it was quite interesting to know that private equity and venture capital can be sources of finance, it is also imperative to recognize other stakeholders in this value chain for the purpose of meeting the UNFCCC's annual $100 billion investment target. I would have stated that insurance companies, investment managers, pension funds, non-pension fund assets, foundations, and endowments all share equal responsibility to achieve these targets.

A Comment on "The Market for Green Bonds"

As of 2019, the United States, China, and France are leading national issuance rankings. According to the Climate Bonds Initiative, the 2019 volume was primarily driven by the wider European market, which accounted for 45% of global issuance. Asia-Pacific and North American markets followed at 25% and 23%, respectively. In 2019, the total amount of green bonds issued in Europe increased by 74% (or USD49.5 billion) year-on-year, reaching a total of USD116.7 billion.

It is evident that the overall market share for green bonds is increasing on a year-on-year basis. It might have been more helpful if the authors could have elucidated on the different stakeholders' contributions in this value chain through, for example, financial intermediaries, blended finance, and institutional investor-level fundraising. Additional insights regarding those classifications would have been quite helpful.

A Comment on "Anthropological and Sociological Theory on Green Bonds"

The review might have benefited from a few more lines on social theory and what level of input is required to help mitigate the challenges posed by climate change. Since the authors have referenced how anthropological studies have influenced green bonds, it would have been even more important to expand further on the different disciplinary methodologies and to what extent timescales have been involved. For example: What went right and wrong so far? On what timescales were those anthropological studies conducted?—meaning, were they shorter or greater than a decade ago, or did they cover much more extended periods?

Is it important to know if the data are quantitative, qualitative, or both? And what geographical locations have been of greater importance so far in helping the green bonds market mature? While it is great to know that the study of anthropology provides valuable insights for the scientific community, it is of higher relevance to establish metrics more directly linked to contemporary climate issues. These include the success rates of past adaption and mitigation measures, and also what lessons can be drawn from these so far. Explaining anthropological theories in this context would have generated substantial additionality.

A Comment on "The Translation of Climate Science into Finance"

Adhering to stricter legal frameworks, as well as business codes of conduct, is a key element in scaling climate finance. While the authors outlined the benefits of complying with existing industry product standards such as the Green Loan Principles of the Loan Market Association (LMA) and the sustainability bond guidelines of the International Capital Markets Association (ICMA), it would have been useful to also illustrate the role of external assurances where required, using appropriate benchmarks and adequate sustainable product definitions. These usually help to minimize greenwashing or reduce the risk of translating climate science into finance. However, the importance of extra due diligence and the participation of third-party verifiers for identification and evaluation purposes are also key aspects to be considered.

A Comment on "The Policy Significance of Green Bonds"

The authors have pointed out that having solid policies in place is seldom a barrier to the development and scaling of the green bonds market. However, additional coverage of the conflicting policies and practices in developing countries would have strengthened the paper, including how these policies have acted as a barrier so far, and what until now could have been done to improve this situation.

Readers might also have been interested to know that there are a variety of different climate-change-related risks which can cause asset stranding, including falling clean technology costs or new government regulations, such as carbon pricing (for example, carbon taxes). Policy frameworks are playing a vital role in decreasing these risks. Proper coordination between the ministries of finance and the ministries of environment during bond issuance can act as a catalyst to issuance growth.

The central role of the TCFD is valid, but it would have been nice to have more supporting studies on how this framework has positively impacted developing countries. This could be another topic for further green bond markets research.

A Comment on "Green Bond Market Governance in the Legal Literature"

In the discussion, while it is evident from Banahan (2019) that Green Bond Verifiers (GBVs) share many features with credit rating agencies (CRAs), it is imperative to understand how this situation could lead to conflicts of interest. Hence, this potential issue could be explored in more depth. Reputation across issuers is not equally distributed, with some studies highlighting the crucial role of issuers, who pay for the certifications (Becker and Milbourn 2011).

One of the main differences that has been highlighted was that CRAs are required to disclose methodologies' data assumptions to a certain extent and consistency in the application of ratings. In contrast, GBVs are not subject to such requirements, which could facilitate underlying potential conflicts of interest. The listed regulations made it imperative for CRAs to disclose their credit rating methodologies in response to the 2008–2009 financial crisis.

Green bonds are enjoying heavy growth and are now available in more than 20 countries. China, Brazil, and India have all released their respective policies and guidelines in this space. It is critical to evaluate how the standard-setting regimes, legal structures, and governance standards differ between jurisdictions, including those of the United States, European Union, and China, as these are leading in green bonds issuance.

Most of the countries have been developing or have developed their own regulatory structures for their respective green bond markets. However, for the sake of consistency, it would be preferable to have a certain degree of consistency between all of them. It is important to implement prominent guidelines such as the Green Bond Principles (GBP), established by ICMA, to help guide issuers in setting up credible green bonds. The GBP's suggested process guidelines seem to be, in my opinion, especially applicable to both GBVs and CRAs. The guidelines include the following steps:

- "Define criteria for a green project";
- "Define processes for evaluation and selection of the green project";
- "Have systems to trace the green bond proceeds"; and
- "Report, at least annually, on the use of the proceeds."

The authors should have elaborated more on transparency instruments, such as establishing a Green Standards Committee (GSC), as described by Banahan (2019), which could offer a great level of critical assurances to environment-focused investors by providing clarity, oversight, and accountability in the accreditation process. Moreover, it could have proven helpful to have a more in-depth look at how a GSC would oversee the market and provide assurances about verifiers not engaging in risky behavior, and how that could have helped prevent the 2008–2009 financial crisis.

In this context, I would like to mention the emergence of blockchain technologies, which could constitute an important tool in enabling green bonds to grow and increase their credibility and transparency. The authors' message of using blockchain in fostering these positive trends is not fully clear. More evidence and examples are needed to obtain a better understanding of how these novel technologies help enforce green bond regulations and enhance trust in green financial markets. These technologies are at an early stage of development, and it might prove hard to predict their future trajectories. Hence authors could have provided recommendations to help policymakers identify and recognize the potential behind these technologies.

A Comment on "Pricing Research on Green Bonds"

On average, the market for green bonds is still reasonably small in size compared to the one for vanilla bonds. This could make green bonds less liquid than other bonds with similar or identical credit ratings. A few additional lines from an issuer's perspective in relation to the potentially higher issuance costs would have proven useful, since these are primarily caused by labor-intensive reporting requirements that involve third-party verifiers. The additional procedural steps in the green bond issuance process can actually render them more expensive than conventional vanilla ones. For example, investment banks generally charge more to issue green bonds. New regulatory initiatives on the horizon, most notably in the EU, which is planning the introduction of green-bond-related issuance and reporting requirements, could lead to additional cost increases. At a global level, there is still a lack of clear guidance on what activities or projects increase the need for clear definitional frameworks for green bonds, similar to the EU's planned green taxonomy and green bond standards.

A Comment on "The Legal Consequences of a Greenium"

The authors have clearly stated the risk of greenwashing, especially via financial product offerings such as green bonds and green loans, which in some cases can lead to litigation. However, the other potential key risks of interest that were missing are "reputation risk" and "compliance risk." These represent material risks, notably if the issuer or borrower has failed to identify that the raised funds have been misallocated. Possible scenarios include, for example, insufficient evidence about how funded projects contributed toward positive environmental impacts or improperly tracked and inefficiently disclosed green bond proceeds. These shortcomings can damage the issuer's reputation and entail further legal proceedings with regard to the misrepresentation of risks and impacts.

It would have been interesting to see a more extensive exploration of whether green bonds can be considered as a separate asset class. There are a number of different approaches and standards being used to establish eligibility in the global labeled green bond market. At the moment, there are no mandatory green bond standards, and market actors are free to choose what and how these different approaches are applied, which can potentially turn into a systemic risk. This aspect could be explored in any further academic research on green bond markets.

A Comment on "Future Research Avenues and Anthropology"

While anthropology, law, and policy should remain key research areas on green bonds, another promising area would be archaeology. In my opinion, archaeologists help to understand the dynamics of how the earth and communities evolve or adapt after natural calamities, which often lead to material or structural post-disaster changes. The authors should consider this angle in their future research.

A Comment on "Policy"

The authors could have put additional emphasis on the importance for policymakers to clearly understand how to mobilize sufficient debt and equity capital to catalyze the transition toward low-carbon and climate-resilient economies.

A Comment on "Law"

While the authors' views expressed in this section are quite interesting, I am suggesting a further investigation into the following questions in any follow-up academic research:

- As there is currently only a limited scope on the legal enforcement of green integrity, especially in developing regions, what practices are in place to overcome this barrier?
- To what extent does the law facilitate or impede the avoidance of greenwashing?

Conclusion

Overall, the original article might have benefited from a more detailed explanation on how green bond principles support the identification of more granular criteria. Specifically, those criteria concerning the use of the bond proceeds as a way of helping to identify truly green projects and setting out these as a requirement rather than just as a voluntary principle.

Readers might also have benefited by understanding whether a global standard is possible or applicable. Or if more regionalized standards tailored for specific geographies will be more beneficial to countries. Will the upcoming EU standards have a ‘first mover advantage’ and transform into the *de facto* new global standard? For example, China has adopted its own approach, which could potentially pave the way for other countries, too, to implement their own standards. These green bond policy aspects require further research.

Finally, I would have loved to see the authors put more emphasis on the inherent weaknesses of green bonds, including the perceived lack of actual cost of capital advantages for the issuer, and whether these activities would have been financed anyway in the absence of the green bond label.

In conclusion, I recommend further discussions on the alternatives to green bonds and how to use green bonds’ proceeds more effectively, for example in the form of Green Asset Backed Securities (ABS) or Green Infrastructure Bonds, since both of these categories appear to be more narrowly defined and thus overall less susceptible to greenwashing.

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Biography

Kalyani Inampudi has a background in asset management and data analysis. Her experience includes deep data research and writing investment proposals. She has certifications from UNPRI, the CDSB via the TCFD Knowledge Hub, and the Associate

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