

What explains the emergence and diffusion of green bonds?

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Abstract

There is growing recognition that financing low-carbon energy and environmental transitions will require the innovation of new financial products. Yet current understanding of the conditions under which environment-focused financial innovations emerge and diffuse remains limited. This paper seeks to narrow this gap. Novel to the literature, we conceptualise financial innovation by synthesising insights from several conceptual frameworks previously used to understand technological innovation and sustainability transitions. Empirically, the paper focuses on the case of green bonds, which have been deployed to (re)finance a wide range of energy- and environment-related projects. Our analysis is based on a combination of semi-structured interviews, document analysis and observations from conferences. We show that many of the same processes, influences and dynamics identified in technology-inspired frameworks have played an important role in the upwards innovation trajectory of green bonds. These include: the activities of various intermediaries and entrepreneurs; a set of largely self-reinforcing processes such as learning and legitimation; and wider contextual developments creating a more favourable selection environment for sustainability-themed, fixed-income financial products. Our analysis additionally suggests that the scaling-up of green bonds depended on the specific design and implementation of the product itself and the growing involvement of emerging economies on the supply-side.

Key words: green bond, energy transition, innovation system, niche, multi-level perspective

Abbreviations: MDB = Multilateral development bank; MLP = Multi-level Perspective; SNM = Strategic Niche Management; TIS = Technological Innovation System.

1. Introduction

Financing the transition to a more sustainable, low-carbon economy will demand the rapid mobilisation of vast additional financial capital (Louche et al., 2019; McNerney & Bunn, 2019). For example, the IPCC (2018, pg.22) estimates that limiting global warming to 1.5 degrees Celsius will require approximately US\$2.4 trillion annual investment in the energy system until 2035. One way of accelerating financial flows to meet these needs is through financial innovation (Hofmann & Khatun, 2013; Zadek, 2019). Broadly speaking, this can be defined as ‘the act of creating and then popularizing new financial instruments, as well as new financial technologies, institutions, and markets’ that intend ‘to avoid or reduce environmental damage’ (Horbach, 2008, pg.163; Tufano, 2003, pg.310).

Yet very little is known about environment-oriented financial innovation. Our goal in this paper is to begin to remedy this shortcoming. To do so, we draw from, and combine, three frameworks which have previously largely been used to understand technological innovation and sustainability transitions: the Multi-Level Perspective (MLP), Strategic Niche Management (SNM) and Technological Innovation Systems (TIS) (Coenen & Díaz López, 2010; Jain et al., 2017; Markard et al., 2012). A particular advantage of these frameworks is that they provide insights into the agency, processes and dynamics through which newly-created innovations are successfully up-scaled, and progressively move from “niche” to increasingly “mainstream” markets (Dijk & Yarime, 2010).

Empirically, we focus on the case of green bonds¹. Representing the first significant effort at mobilizing debt for environmental purposes, green bonds are broadly defined as standard fixed-income products whose ‘proceeds will be exclusively applied towards new and existing green projects’ (ICMA, 2014, pg.2). Green bonds can be positioned as a form of impact investing in that they seek to generate a positive environmental impact² (Busch et al., 2016). Such bonds have been used to finance (and refinance) a range of projects such as renewable energy, energy-efficiency, green buildings and low-carbon transportation (Ng & Tao, 2016). The rationale for studying this specific financial product in the present context is two-fold. First, green bonds have emerged relatively recently, making it possible to trace their origins through interviews and document analysis. Second, while green bonds remain a small part (c.3%) of the overall bond market, they have arguably followed a “successful” innovation path. The product has diffused comparatively rapidly following innovation creation in the late-2000s, with considerable year-on-year growth in issuance since 2013. Our specific research goal in the present paper is to explain this upward innovation trajectory.

A unique contribution of the paper is to show that many of the same influences, processes and dynamics identified in technology-inspired frameworks have played an important role in the emergence and diffusion of green bonds. These include the entrepreneurial activities of various intermediaries who have nurtured, protected and championed the product; a set of largely self-reinforcing processes such as learning; and wider contextual developments which have created a more favourable selection environment for green bonds. By

¹ Bonds are a form of debt financing. Investors who purchase a bond receive an agreed interest rate, as well as their original investment once the bond reaches maturity.

² Unlike certain types of impact investing, investments in green bonds typically target a competitive rate of market return.

foregrounding these processes and influences, this paper highlights the value of frameworks such as TIS and the MLP in understanding low-carbon and sustainability transitions within the field of finance, a subject which has received very little attention in the existing literature. We also contribute policy-relevant insights by highlighting factors potentially relevant for accelerating the future innovation of environmental financial products and services.

Our study builds on, but also complements, a growing academic literature concerned with what is variously framed as climate, green or sustainable finance, as well as socially responsible investment (SRI). This work examines several overlapping themes. One stream of scholarship explores the nature, definition and magnitude of different forms of sustainability-themed finance, with studies reporting a significant (albeit uneven) growth in specific categories of SRI over the past decade (e.g. Haigh, 2012; Höchstädter & Scheck, 2015; Sandberg et al., 2008). Another stream of literature investigates various drivers, barriers and determinants (e.g. Criscuolo & Menon, 2015; Falcone & Sica, 2019; Gaddy et al., 2017; Hafner et al., 2020; Scholtens, 2005). A major focus of this work has been on identifying domestic factors which catalyse or constrain the amount of capital allocated to sustainable investments. A closely related body of literature explores the governance of sustainability-themed finance, documenting a role for both market (through self-regulatory codes, etc.), state (through support policies, etc.) and civil actors (through NGO campaigns, etc.) in the expansion of SRI (e.g. Ayling & Gunningham, 2017; Campiglio et al., 2018; Clementino & Perkins, 2020; Jackson et al., 2020; Slager & Chapple, 2016). Multiple studies also investigate the correlation between sustainable investment strategies and financial returns, with the majority finding a non-negative or positive relationship (e.g. Friede et al.,

2015; Khan et al., 2016; Revelli & Viviani, 2015; Trinks et al., 2018). Several contributions have additionally offered a critique of sustainable finance, for example, by questioning its substantive contribution to public climate and environmental goals (e.g. Bracking, 2015; Christophers, 2019; Sullivan, 2013).

The present paper advances on these past studies in three important respects. First, while the existing literature has gone some way in investigating the growth of sustainable finance, there has so far been limited exploration into the initial emergence and diffusion of new green financial products. Our study seeks to address this important germinal dynamic by examining the conditions under which environmental financial innovation takes place. Moreover, by focusing on a specific product (i.e. green bonds) and its characteristics, the paper improves on work which treats sustainable investment as a singular, homogenous category (e.g. Giamporcaro & Gond, 2016; Hafner et al., 2019; Louche et al., 2019). Second, taking a cue from a well-established body of work on technological change, we contribute to the existing literature by paying greater attention to temporal dynamics (e.g. Criscuolo & Menon, 2015; Falcone et al., 2018; Leete et al., 2013). More specifically, our study acknowledges the possibility that the factors impacting the initial development of a new financial product may differ from those important later-on as it diffuses more widely. And third, we take a “systems” approach, predicated on a structural and processual conception of sustainability transitions in finance. While we are not the first to invoke a systems perspective (e.g. Hafner et al., 2020; Oliver et al., 2019; Urban & Wójcik, 2019), our study advances on past ones by unpacking the various interrelated actors, processes and influences involved in the upward innovation trajectory of an environmental financial innovation.

In the next section (2), we review existing insights into green financial innovation. Section 3 presents the development of our hybrid framework. The research design is outlined in section 4. Section 5 presents results, while section 6 discusses our findings. Section 7 concludes.

2. Existing insights

The existing literature, much of it rooted in finance, economics and management, has largely theorised financial innovation within a framework of demand, supply and financial constraints (Merton, 1995; Silber, 1983). While instructive, this body of scholarship suffers from several shortcomings when it comes to understanding the innovation trajectory of environmental financial innovations. First, it has mainly been concerned with the initial creation (i.e. invention) of new innovations. Although an important topic, it is also one fraught with methodological challenges, particularly when it comes to analytically distinguishing the influence of supply and demand (Mowery & Rosenberg, 1979). Moreover, studies of innovation creation say relatively little about why certain products and services successfully diffuse, while others struggle to achieve market acceptance. Second, previous work has predominantly focused on non-environmental financial innovations (Tufano, 2003). Yet it is not entirely clear that lessons drawn from non-environmental financial innovations can always be applied to environment-themed ones – including those involved in financing low-carbon energy transitions.

Unfortunately, few studies have examined processes of green financial innovation. Dossa and Kaeufer (2014) draw attention to how external crises trigger the formation of positive ethical networks (PENs), comprising individuals with shared values who collaborate in creating new socially and/or environmentally-oriented products. Marcus et al. (2013) highlight how the growth of venture capital funding depended on various processes through which it was constructed as a 'legitimate' investment class. More broadly, Falcone et al. (2018) foreground the role of discursive storylines in the greening of financial systems, together with pressures emanating from both global and national actors. Other studies point to the role of entrepreneurs, service providers, governance devices, and government interventions in the uptake of environmentally-oriented investment products, services and strategies (Chelli & Gendron, 2013; Crifo et al. 2019; Déjean et al., 2004; Elbasha & Avetisyan, 2018; Giamporcaro & Gond, 2016; Knox-Hayes, 2009; Slager et al., 2012). In the only study to centrally focus on the emergence of the green bond market, Ivory et al. (2016) conceptualise its evolution in terms of four stages: 'incubation', 'early adopter', 'excitement' and 'mainstream'. However, while providing some valuable preliminary insights (e.g. about the importance of a supportive ecosystem), the piece stops short of providing a detailed, theoretically-grounded account of financial innovation.

3. Theorising environmental financial innovation

In order to theorise environmental financial innovation, this paper positions itself within a body of work which takes an evolutionary view of technological change. A central idea of this literature is that technological change proceeds along incremental trajectories within the boundaries set by technological paradigms. Earlier work emphasised the cognitive underpinnings of these path dependencies, pointing to routines, heuristics and shared

assumptions which influence engineers' beliefs about the nature of problems and the appropriate direction of technological search (Dosi, 1982; Nelson & Winter, 1977). Later work explicitly acknowledged the socially embedded nature of technological trajectories and paradigms, and how they are shaped and channelled by the wider socio-institutional context (comprising organizations, government regulations, values, etc.) (Freeman & Perez, 1988; Rip, 1995). Drawing on these ideas, Rip and Kemp (1998, pg.338) introduced the concept of the technological regime, defined as a 'rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems—all of them embedded in institutions and infrastructures.' By ordering, guiding and stabilising, regimes favour incremental technological change compatible with dominant socio-technical configurations. Conversely, more radical innovations may be locked-out by multiple interdependencies between technical and socio-institutional elements, implying significant switching costs and resistance by incumbent actors (Unruh, 2000).

The preceding discussion centred on (dynamic) stability begs the question of how innovations which depart from existing trajectories successfully emerge. These include environmentally oriented ones which are the focus of the present paper. It is within this context that we turn to three frameworks which have been used to understand paradigm shifts and sustainability transitions involving transformations from one socio-technical system (providing key societal functions such as housing, transportation and food) to another (Smith et al., 2010): the MLP, SNM and TIS. Previous applications of these frameworks have paid little attention to financial innovations or systems, with few exceptions. Falcone et al. (2018) invoke the MLP as a framework to conceptualize the

greening of the Italian financial system, paying particular attention to landscape level changes; Seyfang & Gilbert-Squires (2019) examine the relationship between transitions in the existing banking regime and the shift towards values-based banking practices in the UK; while Testa et al. (2019) situate crowdfunding as a socio-technical practice, using the MLP to theorise how it might contribute to the upscaling of new financial regimes. To the best of our knowledge, the present paper is unique in developing a hybrid conceptual framework – drawing from the MLP, SNM and TIS – which attempts to shed light onto the factors underpinning successful innovation paths for new green financial innovations.

The MLP is centrally concerned with system innovation. It distinguishes between different levels: niches (the site for novel innovations, see below), socio-technical regimes (which stabilise existing systems around a set of established technologies, practices, rules and networks) and landscapes (the highly structured and exogenous political, economic, social and cultural context) (Smith et al., 2010). Sustainability transitions are theorised to result from the dynamic interplay between these levels – including the development and upscaling of niches, landscape changes, and the internal destabilisation of regimes. As a precursor to the MLP, a central tenet of SNM is that radical innovations emerge in niches, understood as ‘protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures’ (Schot & Geels, 2008, pg.538).

Analytically, SNM identifies three key processes – learning, articulation of positive expectations, and development of social networks – hypothesised as necessary to enable novel innovations to become competitive and eventually replace existing ones. The TIS is rooted in a larger body of work on innovation systems, commonly defined as the actors, networks and institutions involved in inventing, diffusing and utilizing a new technology

(Carlsson & Stankiewicz, 1991). A central feature of TIS is its concern with systemic processes, known as functions, which are required in order for an innovation system to operate effectively (Bergek et al., 2008a).

We admit that combining and applying insights from the three frameworks to understand environmental financial innovation is not without its possible drawbacks. There could be differences between technological and financial innovations. Whilst not downplaying these possibilities, we note that the MLP and SNM have previously been applied to societal innovations, such as social enterprises (Hillman et al., 2018). Another potential drawback is complexity. Each respective framework foregrounds a distinctive set of influences, processes and dynamics. Moreover, there are differences between the frameworks, such as in their explanation regarding why certain innovations are successful (Coenen & Díaz López, 2010). However, to the extent that the MLP, SNM and TIS each shed light onto different, but complementary aspects of sustainability transitions, we believe that a combined analytical approach offers more promise for understanding green financial innovation than relying on a single framework (Raven & Walrave, 2018; Weber & Rohracher, 2012).

Dissecting the frameworks, we identify eight processes and influences which might explain why new environmental financial innovations become more widely adopted and are eventually able to compete in mainstream markets (see Table 1). Several of these, including legitimisation, actor networks, positive externalities and landscape changes, have been explicitly or implicitly identified in previous work concerned with sustainable investment (e.g. Déjean et al., 2004; Knox-Hayes, 2009; Pfeifer & Sullivan, 2008; Slager et al., 2012). We

include others, such as learning and the articulation of expectations, because they are central features of the respective frameworks.

<<INSERT TABLE 1 ABOUT HERE>>

As depicted in our conceptual framework (Figure 1), the various processes and influences are hypothesized to shape the innovation trajectory of newly created green financial innovations by impacting demand and supply. Many are the source of positive feedbacks – as indicated by the arrows (1-6) – which fuel further market growth. Others, such as entrepreneurs and intermediaries, play an important advocacy, mobilization and support role. The external landscape operates as an exogenous influence on supply and demand by modifying the selection environment (Falcone et al., 2018; Geels, 2011). Landscape changes potentially influence environmental regulation which we include in our framework given the preponderance of work on green technological change highlighting its central role in innovation diffusion (Jacobsson & Lauber, 2006; Nemet, 2009; Polzin, 2017).

<<INSERT FIGURE 1 ABOUT HERE>>

Through these processes and influences, we posit that environmental financial innovations will diffuse over time. Market growth may be slow during formative stages as actors engage in formative niche-building activities. However, it is likely to accelerate as niches are developed, replicated and eventually translated into wider markets (Bergek et al., 2008a).

4. Research design

The present paper employs a case study research design (Yin, 2009) – an approach frequently used in studies of (system) innovation (e.g. Geels & Raven, 2006; Kern et al, 2014; Seyfang & Gilbert-Squires, 2019). Our analysis focuses on the decade up to the end of 2016. The research data were obtained from: (1) twenty semi-structured elite interviews; (2) an extensive review of relevant articles, trade publications, and practitioner literature; and (3) observational insights from four conferences (e.g. *Green Bonds Europe*). Interviews were conducted between April 2015 and October 2016. To obtain a representative range of insights, and provide opportunities to verify perspectives (Berry, 2002), interviewees were sampled to capture the four primary actor groups within the market: issuers (i.e. suppliers of green bonds, denoted as IS below), investors (i.e. purchasers of bonds, IV below), underwriters (i.e. intermediaries who provide advisory, marketing and brokerage functions, and assume responsibility for selling newly-issued green bonds to investors, UW below) and other stakeholders (e.g. NGOs, OB below). Within this sample frame, specific interviewees were selected based on their knowledge of and involvement in the market itself, with this assessment guided by information drawn from the literature and conferences. While all interviewees were approached by email, conferences were invaluable for establishing contact with many elite actors, a crucial connection when later trying to gain access. Questions focused on respondents' views on key events, actors and influences involved in the development of the green bond market.

To identify literature, relevant search strings and keywords (“green bond”, “climate bond”, “renewable energy bond”, etc.) were used to retrieve articles on the financial product from the Nexus (formerly LexisNexus) database. The same search strings and keywords were used in the Google search engine to source additional articles (e.g. from trade journals) and “grey

literature” (e.g. reports); items gathered at conferences (e.g. market commentaries) were a further resource. We only included articles/documents which (a) were centrally focused on green bonds and (b) provided contextual information relevant to understanding the asset’s innovation trajectory. This resulted in a total of 827 relevant articles, and over 100 additional documents.

The case study analysis involved two interlinked components. The first involved constructing a historical narrative (Smith et al., 2014). The objective was to derive a timeline of key events and developments (e.g. pioneering issuances, regulatory interventions, etc.) in the evolution of green bonds. This involved iteratively examining and triangulating different sources of data until a reliable and stable chronological account was achieved. A second stage involved qualitative coding of our primary and secondary data (Saldaña, 2013). Here we sought to identify the actors, influences and processes underpinning the innovation trajectory of green bonds. Most of the codes were predefined, capturing categories within our conceptual framework (see Table 2 for empirical indicators used for the deductive coding). Codes for aspects which did not fit our framework (e.g. innovation characteristics) were derived inductively from the data. Attention was paid to how many sources referenced specific factors to evaluate their respective importance. Through this analytical approach – engaging with multiple sources, and cross-referencing and triangulating data – we sought to increase the rigour, reliability and credibility of our findings (Tracy, 2010).

<<INSERT TABLE 2 ABOUT HERE>>

5. Results

5.1 A history of green bond development

We divide the evolution of the green bond market into five phases – each one defined by distinctive developments (see also Figure 2).

<<INSERT FIGURE 2 ABOUT HERE>>

5.1.1 Creation and initial issuance (2006-2009)

The origins of green bonds can be traced to two multilateral development banks (MDBs). First, the European Investment Bank (EIB,) which issued its inaugural Climate Awareness Bond (CAB) in 2007. While not a conventional fixed-income bond, it nevertheless introduced the concept of earmarking of debt for environment-related investments³ (Romani and Murphy, 2008). The EIB's bond was followed in 2008 by the first officially labelled "green bond", issued by the World Bank in November 2008.

5.1.2 Slow initial development and the US\$1bn benchmark (2009-2013)

In the wake of the World Bank's (US\$294m) debut issuance, the market developed slowly, principally characterized by small-scale private placements by MDBs in domestic markets. In 2013 the market began to grow more quickly. Pivotal to accelerating market formation was the International Finance Corporation's (IFC) US\$1bn benchmark issuance in February of this year, purposely developed 'to strengthen this growing asset class' (Skoldeberg, 2013).

³ The idea of earmarking proceeds for public goods had previously been applied by the International Finance Facility for Immunisation (IFFm) in its "vaccine bond" issued in 2006.

5.1.3 Issuer diversification and standardization (2013-2014)

Following the IFC's bond, average issuance size increased in response to demand, encouraging further supply. Assisting this dynamic was a diversification of issuers away from a sole reliance on MDBs. The first municipal bond was issued by the state of Massachusetts in July 2013, followed by the city of Gothenburg in October. November saw the first issuances by corporates, with three issues in three days, including the biggest offer to date at €1.4bn by Électricité de France (EDF). Around this time, Zurich Insurance publicly committed US\$1bn to invest in green bonds, the first of many commitments by large institutional investors. Another critical development came in January 2014 with the creation of the Green Bond Principles⁴ (GBPs), a set of 'voluntary process guidelines that recommend transparency and disclosure, and promote integrity' in the market (ICMA, 2014).

5.1.4 Market take-off (2014-2015)

Following the release of the GBPs, there was a dramatic growth in the green bond market with issuances tripling to US\$37bn in 2014, a period described by Ivory et al. (2016) as the product's 'excitement phase'. This phase of market take-off constituted 'a bundle of firsts' (Coston et al., 2014, pg.8), with new green bond variations, such as Toyota's first asset-backed bond, and an expansion in the number and format of corporate offerings. Efforts to codify understanding of the new asset class also progressed in 2015, with Ceres' 'Statement

⁴ The GBPs define a set of good practices for issuing green bonds, covering use of proceeds, project evaluation and selection, management of proceeds and reporting.

of Investor Expectations for Green Bonds'⁵, updated GBPs, and the development of a 'Harmonized Framework for Impact Reporting' by various MDBs.

5.1.5 Geographic diversification (2015-2016)

The final stage in our chronology witnessed the proliferation of issuances by domestic actors in emerging economies. Beginning with South Korean and Taiwanese issuers in 2013 and 2014, respectively, this trend accelerated dramatically from late-2015 onwards. China has dominated issuance, accounting for over one quarter of green bonds issued in 2016 (CBI, 2016). During our study period, domestic actors also issued green bonds in Brazil, Costa Rica, Colombia, Mexico, Philippines, Turkey, and, most significantly in terms of scale, India. Latterly, national governments have joined the list of issuers, with Poland's green sovereign bond issuance in December 2016.

In the rest of this section, we examine the role of various processes and influences in explaining this innovation trajectory. Our analysis is organised into three sections based around actors, processes and landscape developments.

5.2 Explaining the green bond innovation trajectory

5.2.1 Entrepreneurs, intermediaries and networks

Our analysis identified the original creators of green bonds, MDBs, as central actors in the asset class's innovation path. The EIB and World Bank engaged in 'entrepreneurial

⁵ The Expectations sought to define some of the key features that investors looking to invest in green bonds expect from issuers.

experimentation' (Bergek et al., 2008a), pioneering prototypes of the new asset class which became the template for subsequent green issuers. These and other MDBs also played a vital supply-push role during the formative stages of green bonds, including by providing proof-of-concept through commercially successful issuances. Their involvement was critical. First, MBDs had a motive to act as willing entrepreneurs, in that most have mandates committing themselves to environmental-cum-climate action (UW2, pers. comm.). Second, the MDBs were capable entrepreneurs, with well-developed internal environmental criteria, evaluation resources and reporting capabilities required to issue green bonds. Indeed, one reason why the World Bank was approached by a Swedish Bank, SEB, to develop a fixed-income product was its existing infrastructure for environmental due diligence and monitoring, lacking amongst commercial banks at the time.

One consequence of their unique position is that MDBs were able to 'shield' (Smith & Raven, 2012) the nascent product from mainstream selection pressures emphasizing financial attributes (of credit risk and interest rate). By subsidising the additional costs associated with issuing green bonds (arising from due diligence, etc.), investors could purchase MDBs' green offerings without paying any market premium for doing so. Crucially, this pricing strategy was subsequently copied by other issuers, a practice which most interviewees stressed was essential to the asset class's successful innovation trajectory. Additionally, the MDBs have acted as product 'champions' (Klerkx & Aarts, 2013), publicly advocating the financial innovation amongst potential issuers, investors and others. They have also supported issuance in emerging economies (e.g. India) by, amongst other activities, issuing green bonds in "offshore" markets to directly finance the purchase of bonds issued by domestic corporates in local currencies (Shi, 2017).

A second entrepreneurial actor of considerable significance in understanding the green bond innovation trajectory is an environmental non-governmental organisation (ENGO), the London-based Climate Bonds Initiative (CBI). The CBI was established in 2009 ‘to foster the use of long-term debt to finance a rapid, global transition to low-carbon economy’⁶ (CBI, 2009). Ten interviewees cited the organization, and/or its charismatic CEO (Sean Kidney), as a key force guiding the market:

One of the things that Sean [Kidney] has been doing, I think quite effectively, is looking beyond where the market is now and engaging future potential issuers and market drivers (OB1, pers. comm.).

To enhance investor confidence in the environmental integrity of the nascent market, the NGO developed the first collective standard for green bonds, releasing its Climate Bonds Standard in 2011. The CBI has also provided system resources in the form of market intelligence, including data (e.g. on green bond issuance) and reports (e.g. on country developments). Yet, according to our analysis, of greater significance have been two further entrepreneurial roles. The first has been to create positive expectations – “hype” (van Lente et al., 2013) – around the new innovation. Through vehicles such as conference presentations, media interviews and publications, it has mobilized a discursive storyline emphasizing the urgency of addressing climate change, and the need to reallocate large volumes of capital to finance a low-carbon transition. This has been coupled with a forward-

⁶ Although nominally focused on “climate bonds”, aimed at financing climate migration and adaptation, many of the CBI’s activities have sought to support the wider green bond market.

facing narrative centred on the benefits from engaging with the asset class, the existence of considerable investment opportunities (e.g. in climate-resilient infrastructure), and the potential for significant market growth (e.g. see CBI, 2009, 2013, 2015).

A second critical role has been to act as a 'brokering' and 'bridging' intermediary (Klerkx & Leeuwis, 2009). The CBI has actively facilitated connections between issuers, investors, underwriters and other parties such as assurance providers (e.g. by providing introductions). In doing so, it has catalysed market transactions, and helped build a growing niche constituency. Moreover, through its own country green bond development programmes, the CBI has strategically engaged with potential market participants, industry associations and regulators in a range of countries. This role has been particularly important outside Europe and North America – and especially in emerging economies such as Brazil, China and India with limited previous domestic experience of sustainable and responsible investment (SRI) (Khouri, 2015). Here, the CBI has acted as a 'teacher' (Bomberg, 2007) by improving domestic understanding and shaping expectations around the new product (e.g. as a participant in multi-stakeholder fora such as the India Green Bonds Market Development Council), as well as supporting the development of system resources (e.g. domestic green bond guidelines).

Entrepreneurial action has also been evident on the part of bond underwriters (IS2, pers. comm.). The genesis of the first labelled green bond lay with an entrepreneur (Christopher Flensburg) from an underwriting bank (SEB), who approached the World Bank with the idea of developing a fixed-income product (Flensburg, 2010, pg.3). Likewise, underwriters were central actors in the development of the GBPs, which have acquired the status of the

leading international “standard” for green bond issuance. The GBPs originated at a conference, where two individuals from separate underwriting banks met before subsequently authoring the ‘Green Bond Framework’, an early draft of the Principles (Cripps, 2014). These were “handed over” to a trade body, the International Capital Markets Association (ICMA), which serves as the secretariat.

The GBPs had a catalytic impact on market formation by informing, steering and regulating market participants. Yet central to fully understanding the Principles’ impact is their role in the creation of an ‘innovation community’ (Fichter, 2009) around green bonds. By establishing a governing Executive Committee, comprising prominent investors, issuers and underwriters (particularly from Europe and North America), the GBPs formalized a vital social network (pers. comm. IV3). Nearly all interviewees stressed how this community was pivotal for the innovation’s success from 2014 onwards. The educational role of its members, and their collective ability to actively guide and drive the market, were particularly highlighted, with early participants working as ‘informal advisors’ (IS3, pers. comm.) to later entrants to the market:

Capital markets have acted as a catalyst of knowledge creation in effect. It is kind of a spiral process. You start with a single institution. Then the experience of this institution transfers to broader circles. And effectively what has been created is a kind of community or a number of communities of knowledge (IS2, pers. comm.).

Additionally, interviewees identified the dedication and personalities of the individuals within the network as key to market growth, with both authors witnessing the importance

of these attributes from attending industry conferences. Senior individuals from different actor groups – issuers, underwriters and investors – emerged as important champions of the product within, and moreover outside, their respective organizations. Their involvement has often had self-interested underpinnings, but also reflected a genuine expressive passion to foster the growth of a new, environmentally-oriented hybrid asset class.

Our analysis identified two further important sets of actors. One comprises various service providers, including verifiers and assurers (e.g. offering “second opinions” on the alignment of green bonds with the GBPs) and index providers (which identify a sub-set of green bonds which meet certain eligibility criteria). Included, too, are media companies which produce trade journals such as *Environmental Finance* and *Responsible Investor*. Such publications have been instrumental in disseminating knowledge (e.g. about ongoing market developments), experiences (e.g. via interviews with market participants) and positive expectations (e.g. through opinion pieces) about the emerging asset class (e.g. see Keglevich, 2016; Pell, 2013). Media companies have furthermore taken a lead in organizing industry conferences, which have been important sites for networking, and helped foster and renew collective visions for the green bond market.

Governments and regulators are another set of actors. While the creation of a green bond niche in Europe, North America and other developed countries was spearheaded by networks of market and civil actors, a more top-down, state-led approach has been evident in several emerging economies (Kumar, 2016). Nowhere is this more apparent than China. As part of a wider government-led initiative to foster the development of a domestic green financial system, the People’s Bank of China published a set of mandatory green bond

“guidelines” (covering financial issuers) in December 2015, followed by similar guidance by the National Development and Reform Commission (covering corporate issuers). The Indian state has adopted a broadly similar approach via official green bond guidelines released by a financial market regulator, the Securities and Exchange Board of India, in 2016.

5.2.2 Processes and positive feedbacks

An important challenge facing the newly-created asset class of green bonds is that, while resembling conventional bonds, the practice of using proceeds exclusively to fund environmental projects was nevertheless novel. Our analysis revealed that knowledge of the product amongst potential market participants was very limited early-on during its innovation trajectory, leading to slow growth of the market following the issuances by MDBs in the late-2000s (Hay, 2012). Most financial and corporate actors – who might otherwise be interested in environmentally-labelled transactions – had little understanding of green bonds, let alone how to issue them. Likewise, knowledge amongst many potential investors was also limited, with green bonds viewed as a largely “niche” product for ethically-oriented investors.

For these reasons learning was a key dynamic in market formation and overcoming the product’s ‘liability of newness’ (Zhang & White, 2016). On the supply side (i.e. issuance), learning has been necessary to develop the knowledge, skills and expertise required for project evaluation and selection, management of proceeds and reporting. On the demand side (i.e. investment), learning has been necessary for investors to understand the new asset class, including its distinguishing features and what qualifies as “green”.

Several attributes of the emerging innovation system for green bonds contributed to learning. One was the social network of issuers, investors and underwriters which took shape around the work of the GBPs. A recurrent theme emerging from the interviews was the willingness of network actors to share their knowledge, experiences and insights with other participants – even those traditionally regarded as competitors. As one observer noted, those involved ‘clearly have in mind the wider objective of what the market can do to address green issues’ (OB3, pers. comm.). One consequence of this co-operative innovation community is that understanding of the new product developed relatively quickly.

Another important aspect was standardization in the form of the GBPs. The Principles aggregated ‘the essentials of what bankers have learnt so far’ (Hay & Wilkie, 2014, pg.1). Specifically, they codified a procedural, market-friendly template of the ‘key components involved in launching a credible green bond’ (ICMA, 2014), which could readily be understood by potential issuers and investors alike. In doing so, the GBPs served an educative role, fostering learning and providing guidance:

They have been important, especially for newcomers. They start to understand exactly what a green bond is and what they should do and what are the norms (OB4, pers. comm.).

Opportunities for learning have been enhanced by the activities of NGOs, sustainable investment conferences, and growing media coverage.

As well as technical learning, our analysis identifies a role for more reflexive, conceptual learning (i.e. involving changes in underlying actor beliefs, goals and strategies) (Nilsson, 2005). One reason why new issuers, investors and underwriters were attracted to the green bond niche is increasing belief in the merits of engaging with the new asset. This has, to a greater or lesser extent, been the result of the discursive strategies of various innovation champions (Klerkx & Aarts, 2013) – chief amongst them, the CBI, and entrepreneurial issuers, underwriters and investors (e.g. World Bank, SEB and KFW). Proponents have created a legitimating narrative of co-benefits around green bonds, e.g. higher levels of market demand, improved reputation, and internal learning. They have also created positive expectations through a narrative emphasizing future market growth (Cripps, 2015; Keglevich, 2016). Crucially, these positive market expectations have been fulfilled, with year-on-year increases in green bond issuance since 2012.

This foregrounds another critical feature of the innovation trajectory: the existence of positive feedbacks. As the green bond market has grown, so it has become more attractive to issuers and investors, stimulating further growth (UW3, pers. comm). Early market formation by the MDBs was essential in creating these self-reinforcing dynamics. Issuances by these banks therefore had a powerful signalling effect, demonstrating the existence of genuine demand for the product. The International Finance Corporation's (IFC) US\$1bn benchmark transaction in February 2013 was cited by almost all interviewees as especially influential in this respect. Its heavy oversubscription (i.e. demand exceeding supply) and interest by mainstream investors proved that the wider investment community valued green bonds when provided at scale. Several respondents spoke on the nature of this offer:

It was the US\$1bn bond in 2013 by IFC that really caught everyone's attention. Because that type of scale, the fact that it sold so well, really gave an indication that the market was not just about the specialist ESG mandates, it is about the bigger group (OB1, pers. comm.).

Indeed, in the wake of this landmark issuance, the green bond market began to transform in two ways. The first is that average issuance size increased. This expanded the supply of green bonds and reduced one of the impediments which had previously limited demand for the product: issuance scale (Nicholls, 2012). Prior to the IFC's bond, issuances remained comparatively small, which served to 'exclude certain investors who have a minimum threshold size' in terms of bond size (IS3, pers. comm.). With larger tranches of issuances, a growing number of institutional investors (such as US pension funds) were attracted to the asset class, thereby stepping-up demand. Another transformation, accelerating significantly from 2013 onwards, was diversification. As more issuers entered the market, a greater diversity of product offerings arose, comprising bonds of varying levels of size, credit risk, yield, maturity and currency denomination. Significantly, this made green bonds better-suited to a wider universe of potential investors – including mainstream actors outside of the traditional ethical investment space – with specific product requirements. The Korea Export-Import Bank's first non-AAA, higher-yielding issuance of US\$500m was significant in this regard (Pell, 2013), with one underwriter suggesting that the bond, 'really pulled out of the woodwork more institutional investors who had interest in this if they could just get a little more yield' (UW4, pers. comm.). This trend has continued as more corporate, financial, municipal and sovereign actors have issued green bonds.

Our analysis also tentatively suggests that market involvement by an expanding number of high-profile actors created a context for imitative dynamics. On the demand-side, for example, one institutional investor noted how:

There is an element of peer pressure, if you will, and then there is an element of... with institutional investors, people like us do not want to be the first...I can give you a concrete example...I got a call from someone at a very large global insurance company, who kind of called me up and said hey, our board of directors has picked up on that commitment and has asked the question, 'what is this green bond thing, should we be doing anything?' (IV3, pers. comm.).

Self-reinforcing feedbacks have also come about from the proliferation of a complementary infrastructure of services and products which are the source of positive externalities.

Included here are collective standards such as the CBS, GBPs and domestic green bond guidelines, as well as quality assurance services provided by external providers (e.g. Cicero, Sustainalytics), which have been important in providing guidance, reducing uncertainties and facilitating market transactions.

Another complementary infrastructure comprises green bond indices⁷ (Bolger, 2014b).

Various interviewees noted how indices stimulated market growth by raising awareness of the asset class, rendering green bonds more commodity-like and making it easier for prospective investors to participate in the market niche. Moreover, much like the standards

⁷ The Solactive Green Bond Index was launched in March 2014. It has since been joined by indices from Barclays, S&P Dow Jones, and Bank of America Merrill Lynch.

on which several of the indices are partly based, indices helped to ‘put out publicly a line in the sand about what qualifies and what does not’ as a green bond (IV2, pers. comm.). In doing so, they have facilitated issuance and investment, including from institutional investors who only invest in bonds included in major indices (OECD, 2015, pg.6).

A further dynamic identified as shaping the innovation success of green bonds was their early legitimization and, equally importantly, the fact that they avoided subsequent de-legitimation. Contributing to the credibility of the new asset class was the involvement of MDBs which, amongst financial market participants, command a reputation for environmental integrity (UW5, pers. comm.). Concerns grew about the possibility of “sub-standard” issuance as private financial and corporate entities began to issue green bonds (Greene, 2015; Hay, 2014). Indeed, such worries have been instrumental in slowing growth of the market (McInerney & Bunn, 2019).

That the spectre of “greenwashing” has not been more impactful in undermining the integrity of the new asset class owes much to the GBPs. By mandating issuers to report on use of proceeds (i.e. the designated green projects (re)financed by the bond), the GBPs created a framework which allowed investors and other stakeholders to better evaluate the environmental credentials of product iterations (Park, 2018). This helped to mitigate against greenwashing to the extent that issuers may be less likely to issue a green bond with questionable environmental benefits.

The legitimacy of green bonds has also benefited from the involvement of mainstream actors, including well-known banks such as ABN AMRO, Crédit Agricole and HSBC. Issuance

by major, high-reputation corporates such as Apple, Unilever and Toyota had a similar effect. More generally, green bonds have received endorsement from trade bodies (e.g. ICMA), international organizations (e.g. OECD) and influential ENGOs (e.g. Ceres).

5.2.3 Landscape developments

While the above influences go a long way in explaining the positive innovation trajectory of green bonds, our analysis also points to the critical importance of wider contextual developments. One development has been rising societal, political and market concerns about climate and other environmental challenges, together with stakeholder demands to address these (Bolger, 2014a; van Renssen, 2014). Such landscape changes, which built up during the 1990s and 2000s, created growing market demand in Europe and North America for financial products which contributed to climate/environmental goals. Almost all interviewees therefore drew attention to how these dynamics had led to heightened interest in SRI, and impact investing in particular, which were crucial preconditions for green bonds.

This, in turn, created an opportunity for entrepreneurial actors to supply new financial innovations which met growing demand from investors in developed countries. The pioneering green bonds of the MDBs can be understood in these terms. The EIB's CAB was conceived to finance the European Union's (EU) public climate goals (specifically, its 2020 climate and energy targets); while the World Bank's inaugural bond was developed as a result of demand from Scandinavian institutional investors for a fixed-income, climate-focused product. Ongoing developments – the proliferation of public climate policies and heightened pressures on financial and corporate actors to demonstrate their legitimacy (see

below) – have only increased this demand over time (Pfeifer & Sullivan, 2008; Revelli, 2017).

Hence the innovation path of green bonds took place within a wider setting wherein selection pressures have increasingly emphasized climate/environmental considerations.

Landscape changes in developing countries, too, have meant climate/environmental considerations have assumed heightened salience. These include developments in international climate policy (e.g. the Paris Agreement); growing domestic recognition of the negative costs of environmental degradation; and the reframing of environmental regulation from a negative cost to a positive opportunity (Michaelowa & Michaelowa, 2015; Rogers, 2016). Within this context, domestic governments have adopted a range of increasingly ambitious climate- and environment-related policies, as exemplified by India's Solar Mission. It is also within this context that several governments, together with other actors (e.g. MDBs and industry associations), have enacted policy initiatives to catalyse the finance required to address the large capital requirements of meeting climate-cum-environmental goals (Kumar, 2016). In fact, developments in emerging and developed economies have been coupled, with issuers in the former incentivized to develop green bonds as a vehicle to gain access to growing amounts of capital dedicated to "green" in the latter (IS5, pers. comm.).

Another important contextual factor was the financial crisis of 2007-08. As attested by seven interviewees, its immediate impact was to slow growth of the green bond market by temporarily limiting demand for a product with a clear environmental focus. Yet two further consequences of the financial crisis later catalysed market development. First, the crisis led to a sustained critique of financial market actors, calling into question their practices,

purpose and legitimacy (IS1, pers. comm.). This made environmentally-themed financial products such as green bonds, which conveyed a “positive” storyline, more attractive to banks seeking opportunities for re-legitimation (c.f. Paterson, 2010). A second fall-out from the financial crisis was that it created a risk-averse investment climate. Against a backdrop of concerns over risk, capital preservation and economic stability, financial institutions allocated a growing share of their capital to the relative “safe haven” of fixed-income securities, and away from more volatile asset classes such as equities (Kidney, 2015). This provided an added stimulus to the bond market.

Within the frame of the MLP, these external developments can be interpreted as creating pressures on, and internal conflicts within, the current finance regime. Inconsistencies have emerged between the established rules and practices of financial actors emphasizing an exclusive focus on dominant financial conventions, on the one hand, and rising expectations to address climate-cum-environmental issues, on the other. As a result, a window of opportunity opened up for the creation and commercialization of a new innovation which allowed investors to visibly respond to growing climate/environmental demands by integrating sustainability issues into their fixed-income portfolios, or developing dedicated impact investment funds. More generally, green bonds were well-suited to a finance regime which placed enhanced emphasis on managing risk, with the added bonus that they could address legitimacy concerns by demonstrating an environmental contribution (Robinson-Tillett, 2015).

6. Discussion

We found evidence for all the processes and influences identified in our hypothesized framework (see Table 3 for a summary). Indeed, one important observation to be drawn is that conceptual frameworks developed to explain technological innovation and sustainability transitions can usefully inform understanding of green financial innovation (Naidoo, 2019). Many processes identified in the TIS – such as entrepreneurial actions and the creation of legitimacy – have also been influential in the formative and early-growth stages of green bonds. At a general level, the idea within SNM that new innovations emerge in niches, where they are shielded, nurtured and championed by various actors is broadly consistent with our empirical evidence. The fundamental conceptual tenet of the MLP, that system change is the product of a dynamic interplay between different levels, also conforms to the analytic story of green bonds. Specifically, a combination of landscape changes, tensions within the finance regime and niche developments have provided conditions conducive to the market diffusion of the product amongst an increasingly mainstream investor base.

<<INSERT TABLE 3 ABOUT HERE>>

Several features of the green bond innovation path have differed from the experience of environmental technologies from which our framework takes inspiration. One difference relates to scale-related effects. While scale economies have been widely implicated in the successful innovation trajectories of low-carbon energy technologies (Dijk & Yarime, 2010; Geels & Schot, 2007), we did not find that scale-related cost reductions had been a significant factor in the diffusion of green bonds. A further difference concerns environmental regulation. The widespread uptake of environmental technologies studied in

the literature, such as solar PV or electric vehicles, has often directly depended on price and/or quantity-based regulatory supports. This is because they have invariably not been cost-competitive with conventional alternatives (Kern et al., 2014; Nemet, 2009). Yet, because green bonds have been priced similarly to conventional bonds (Pell, 2013), effective market demand has not depended on environmental regulation. This said, environmental regulation has been important, but its influence has been more indirect. For example, by requiring actors in the “real economy” to reduce their emissions, environmental regulation has created a larger market for financial products which raise capital for low-carbon projects.

Finally, while this paper draws attention to the value of frameworks concerned with technological innovation and sustainability transitions, it is important to acknowledge two further aspects which are crucial to fully understanding the trajectory of green bonds. One is the innovation’s basic design and implementation. A central appeal of a green bond is that it is a hybrid – or “add-on” (Geels, 2002) – innovation which can be incorporated into, and be competitive within, the existing socio-technical regime for finance. It is not a truly radical innovation requiring a foundational shift in the selection environment and/or major changes to financial system architecture. Another critical feature of green bonds is their pricing. Issuers have not charged a price premium for green bonds, despite the higher costs of supply arising from environmental due diligence and reporting requirements (Nanji et al., 2014). The pricing model has allowed investors to gain exposure to environment-themed investments without sacrificing risk-weighted financial returns – thereby creating high levels of demand for green bonds. On the supply-side, too, there have been real or perceived offsetting benefits for issuers who have had to absorb the costs of issuing green bonds

(OECD, 2015; Rogers, 2016; Thomas, 2015). Such benefits have only been sufficient for a small share of potential issuers to engage with the asset class, resulting in a supply-constrained market. They have nevertheless helped to enrol a growing number of actors to supply green bonds.

Another critical aspect is spatial. The most recent wave of growth of the green bond market examined in this paper was sustained by processes of geographic diversification, with a rising share of issuances originating in emerging economies. Indeed, countries such as China and India can be interpreted as ‘fast followers’ (Mathews et al., 2011), with especially the former pursuing a concerted, state-led strategy to promote a domestic innovation system for green bonds. Work on TIS has recognized that innovation systems in different countries may be ‘spatially coupled’ (Binz et al., 2012) through ‘transnational linkages’ (Gosens & Lu, 2013). Likewise, there is acknowledgement that niches may be geographically distributed, with multiple, territorially-embedded experiments connected by boundary-spanning networks (Geels & Raven, 2006; Sengers & Raven, 2015). Our analysis concurs with these studies in highlighting the transnational nature of the innovation system for green bonds. It also draws attention to the role of transfer agents (e.g. the CBI) and spatially mobile system resources (e.g. the GBPs) in their diffusion and the development of transnationally integrated domestic niches (Zhang, 2019).

7. Conclusion and policy implications

Despite the importance of finance for energy, climate and sustainability transitions, surprisingly little is known about the innovation of new, environmentally oriented financial

products. A distinctive contribution of this paper is to begin narrowing this gap in current understanding. At an empirical level, we show that three sets of factors have been important in the emergence and diffusion of green bonds: (a) the strategic, goal-directed actions of intermediaries and entrepreneurs who shielded, nurtured and championed the green bond niche; (b) a group of largely self-reinforcing processes, such as learning, positive externalities and legitimation, which have increased the attractiveness of the new asset class; and (c) wider contextual developments creating a more favourable selection environment for fixed-income financial products which positively address climate and environmental goals.

In making these observations, we highlight the value of integrating different conceptual approaches in seeking to understand environmental financial innovation. Neither the MLP, SNM or TIS by themselves provide a framework to understand *both* (a) overall socio-technical system dynamics (i.e. involving interactions between landscape, regime and niches) *and* (b) innovation system dynamics (i.e. the activities required for the emergence and diffusion of specific innovations). Yet our paper suggests that they can be productively coupled in a way which can help us to identify and analyse key processes and influences underpinning successful innovation trajectories for new green financial products.

It ought to be noted that green bonds are just one example of an environmental financial innovation. An important task for future research is to examine other such financial innovations – including ones with different characteristics and/or innovation trajectories (McInerney & Bunn, 2019). This could help shed light on whether similar sets of processes, influences and dynamics underpin successful innovation trajectories in other contexts. What

is more, doing so might provide an opportunity to explore various blocking mechanisms (Crespi & Quatraro, 2013; Hekkert et al., 2007) or forms of regime resistance (Geels, 2007; Falcone et al., 2018), which impede environmental financial innovation.

Our paper has several policy implications. One is to underscore the importance of committed public actors (Johnstone & Newell, 2018). As demonstrated by the achievements of MDBs, publicly oriented actors can play an essential role in creating, demonstrating and commercializing new green financial products; including by drawing on in-house environment-related capabilities and shouldering the costs and risks associated with developing robust niches. Likewise, as evidenced by the growth of the green bond market in China, governments may be well-placed (under certain conditions at least) to catalyse supply and demand for new environmental financial innovations by enacting supporting policy frameworks.

Another policy implication is that non-state actors can have a major role in environmental financial innovation. The creation of a network of market participants was critical in the upscaling of the green bond niche, and expanding its constituents beyond MDBs on the supply-side, and the ethical investment community on the demand-side. Our analysis therefore points to a role for policy initiatives (e.g. workshops) aimed at supporting the formation of social networks around environmental financial innovations. Proponents of new financial products and policy-makers might also consider enrolling, supporting, or drawing insights from entrepreneurial “system builders” (Hughes, 1987) involved in the development of the green bond market. Of particular note, the CBI provides a model of a

pro-innovation NGO supplying a range of system resources (e.g. standards, technical assistance, etc.), lessons from which could usefully be replicated in other contexts.

A further policy-relevant observation concerns innovation design. Two features would appear to support market diffusion: (1) compatibility with established market conventions (i.e. financial innovations which do not require significant changes in existing socio-technical configurations); and (2) products which offer business benefits to sellers or buyers. Yet a note of caution: such “market friendly” environmental financial innovations might not necessarily be those which contribute most to the goals of low-carbon energy transitions or environmental sustainability (Bracking, 2015; Dupre et al., 2018).

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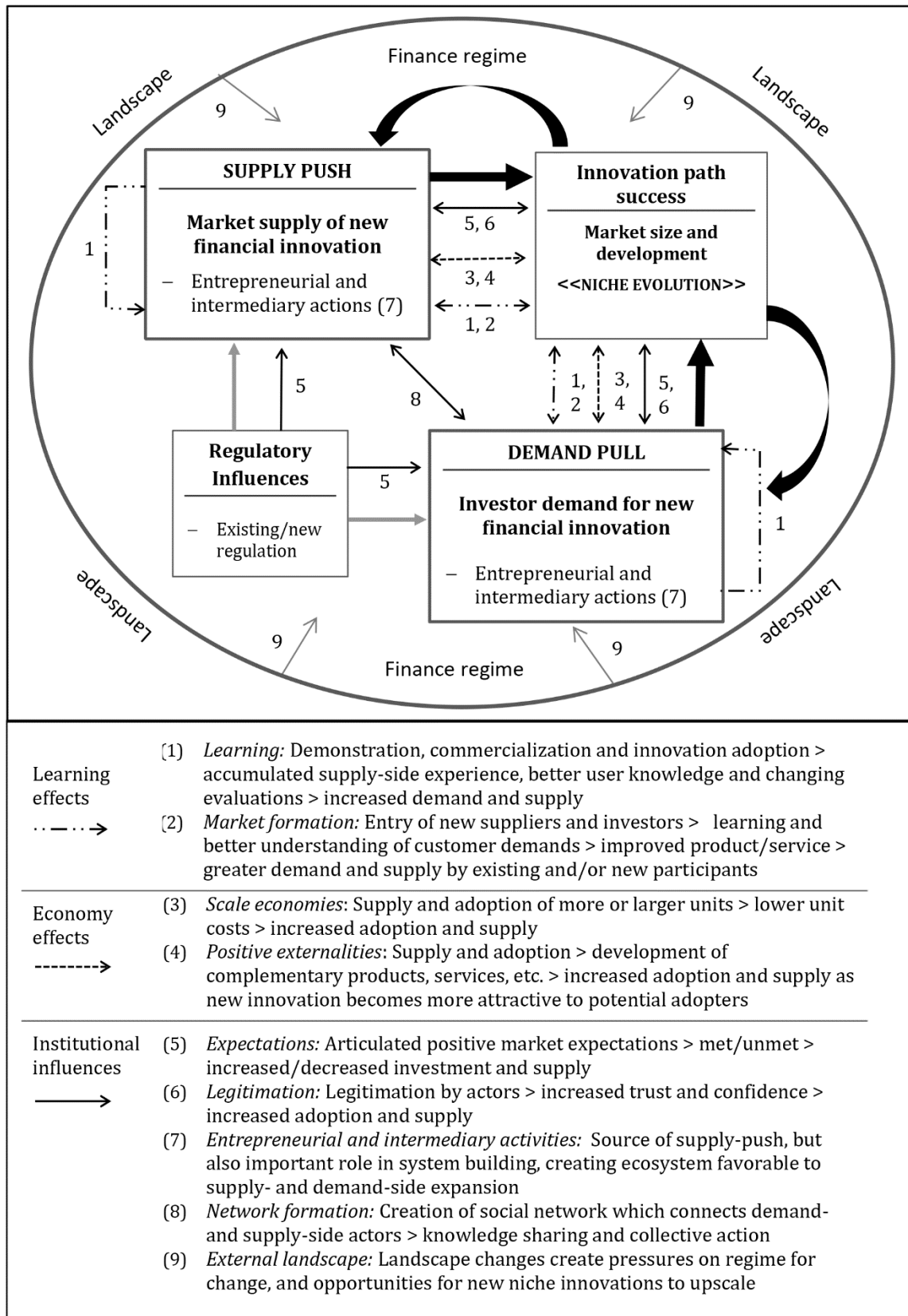
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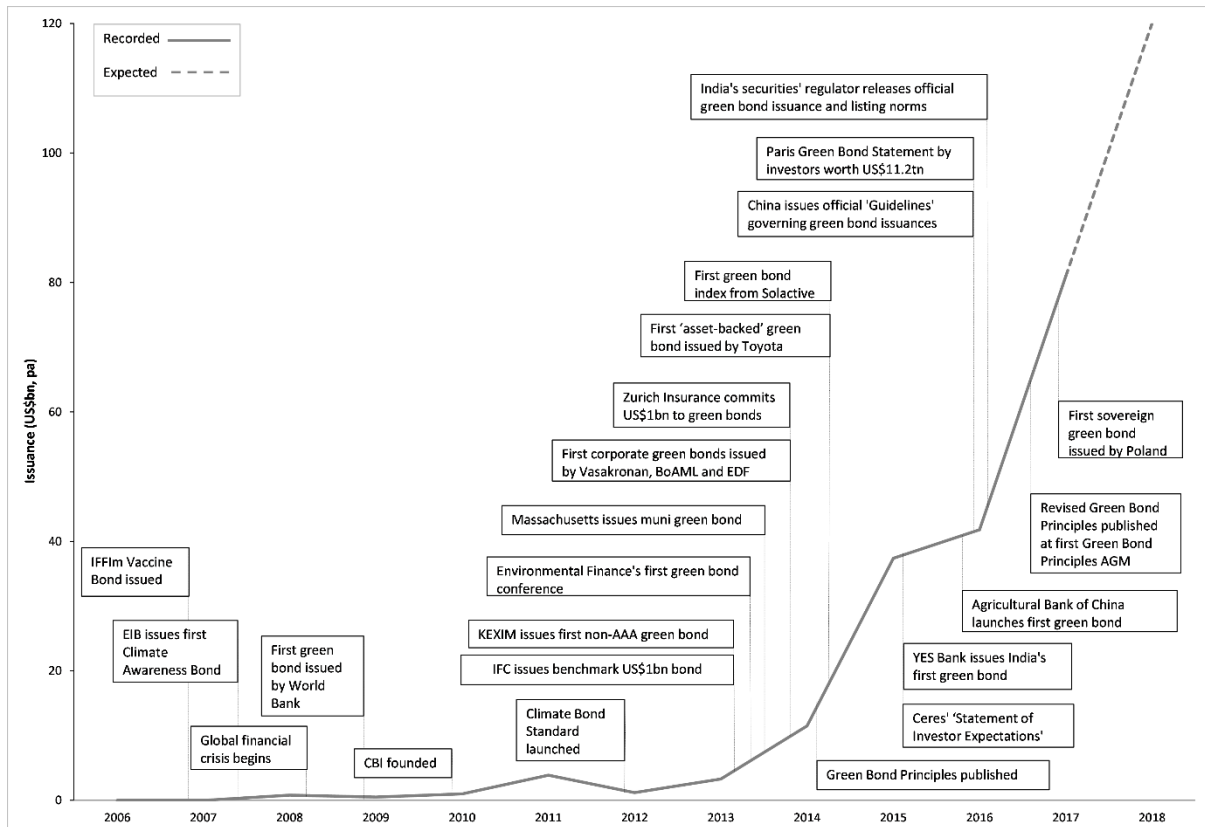
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Figure 1. Hypothesized conceptual framework of innovation path success



Source: Authors

Figure 2. Significant events in the emergence and growth of the green bond market



Source: Authors

Table 1. Hypothesized processes and influences involved in the successful innovation path for financial innovations

Process/influence	Description	Derived from
Learning	From a techno-economic perspective, learning (gained through own experience, but also from others) increases the commercial attractiveness of new financial innovations by reducing supply costs, improving performance, and fostering a better understanding of market preferences (e.g. what is expected from buyers in terms of an innovation’s environmental credentials). Work on niches has also emphasized the potential significance of more conceptual forms of learning, wherein actors change their underlying beliefs, resulting in changes in how they “see things”, (e.g. regarding the value of a new financial innovation). Conceptual learning may arise from interactive, collective engagement in networks (Geels, 2002; Schot & Geels, 2008).	TIS, SNM, MLP
Scale economies and positive externalities	Increased “output” scale on the supply-side and various positive externalities (e.g. development of a supporting infrastructure) provide feedbacks that encourage further market growth by lowering costs and increasing the attractiveness of the new innovation to potential adopters.	TIS, SNM, MLP
Market formation	Markets for novel financial innovations may be absent or poorly developed, necessitating the development of spaces (niches) wherein opportunities exist for experimentation, knowledge development and the articulation of customer demands (Bergek et al., 2008a). Niches are also potentially important in demonstrating the viability of novel products and the formation of constituencies supporting new innovations (Kemp et al., 1998).	TIS, SNM
Articulation of expectations	The elaboration of positive expectations (including “hype”) about the future of new financial innovations (e.g. their potential market growth, commercial returns or contribution to environmental goals) may influence wider beliefs about their economic and/or	TIS, SNM

	<p>cultural value and desirability. In doing so, they can help to gain attention (e.g. from potential market participants), attract investment and garner socio-political support for protection (e.g. from governments) (Coenen & Díaz López, 2010; Hekkert et al., 2007). Expectations may be especially influential where they are practically realized (Schot & Geels, 2008).</p>	
Legitimation	<p>Acting alone or as part of broader coalitions, innovation champions can actively seek to build support and social acceptance for a new financial product amongst potential suppliers, buyers, governments and the wider public. Over time, legitimation helps to build trust in unfamiliar innovations, together with their proponents (Bergek et al., 2008b; Zhang & White, 2016).</p>	TIS, SNM
Formation of actor networks	<p>Social networks facilitate sharing of information, knowledge and experience; and constitute a socio-political constituency backing new innovations (e.g. lobbying governments for support). Work has also stressed the function of networks in creating supportive system resources such as expertise and trust (Musiolik et al., 2012).</p>	TIS, SNM
Entrepreneurial and intermediary actions	<p>Entrepreneurs ‘turn the potential of new knowledge, networks, and markets into concrete actions to generate—and take advantage of—new business opportunities’ (Hekkert et al., 2007, pg.421). Active early on, and fulfilling experimentation and market formation activities, such actors provide a crucial supply-side push in innovation paths. Alongside entrepreneurs, recent SNM research stresses the key role of intermediaries (such as standard-setters) in scaling-up niche innovations.</p>	TIS, SNM
External landscape development	<p>Developments in the wider socio-technical landscape potentially create pressures for changes in the dominant regime which, here, comprises the financial system for mobilizing and exchanging funds. Destabilization can compel incumbent actors to adjust existing practices, and to adopt new innovations which are better aligned with revised expectations, rules and principles (Geels & Schot, 2007). In doing so,</p>	MLP

	they provide a window of opportunity for niche expansion, which entrepreneurs may exploit.	
Environmental regulation	Public environmental regulation may be important in fostering the invention, commercialization and diffusion of new environmentally-focused innovations (Nemet, 2009).	Work on eco-innovation

Source: Authors, based on multiple sources

Table 2. Operationalisation of key concepts

Concept	Confirmatory (empirical) indicators
Learning and knowledge development	Experience making it cheaper or easier for issuers to supply bonds; investors developing improved understanding of green bonds, or new beliefs about their value; evidence of knowledge sharing.
Scale economies and positive externalities	Falling internal costs of issuing green bonds with increased scale of issuance; market expansion giving rise to complementary services (e.g. assurance), reducing costs for issuers or investors.
Market formation	Creation of protected space; support (e.g. subsidies) making green bonds more competitive.
Articulation of expectations	Actions aimed at generating positive beliefs about market growth and/or benefits of market engagement; expectations translated into shared goals which are met.
Legitimation	Advocacy for, and engagement with, green bonds from influential constituencies (e.g. NGOs, leading banks, etc.).
Actor networks	Growth of networking and collaboration amongst different actors (e.g. issuers and investors); connections used to mobilize commitment and resources.
Entrepreneurial and intermediary actions	Experimentation by inventor-entrepreneurs; creation of system resources (e.g. standards).
External landscape development	Wider contextual conditions creating increased market opportunities for green bonds, either by valorizing them, or devaluing existing financial instruments.
Environmental regulation	Mentioned as a factor increasing supply and/or demand for green bonds.

Source: Authors, inspired by Kern et al. (2014)

Table 3. Summary of findings of processes and influences on green bond innovation trajectory

trajectory

Process/influence	Description
Learning and knowledge development	Technical learning by early issuers, underwriters and investors who subsequently shared their knowledge with later entrants. Standardization crucial in codifying what had been learnt. Some evidence of conceptual learning as participants' beliefs about need for, and value of, environment-themed products developed.
Scale economies Positive externalities	Scale mainly important because (a) larger issuances demonstrated the existence of investor demand and (b) greater product diversity made the product more attractive to major institutional investors. Issuance and investment induced complementary service and product creation, making further issuance and investment more attractive.
Articulation of expectations	Innovation champions defined what green bonds are and empowered the niche by positively framing green bonds and creating positive expectations about their growth. Investor commitments fulfilled positive expectations encouraging further market expansion.
Legitimation	Early involvement and support of MDBs lent legitimacy to product; with high-profile issuers and investors further enhancing credibility later on. Legitimacy additionally achieved through standardization via the GBPs, public green bond guidelines and indices.
Network formation	An innovation community formed around green bonds; engaged in information sharing, raising interest within the financial community, and system building activities (e.g. creation of standards).
Entrepreneurial and intermediary actions	Important entrepreneurial roles played by MDBs, underwriters and NGOs. Intermediaries influential by supplying system resources, connecting different stakeholders, and acting as transnational mobilisers of knowledge and assistance.
Market formation	MDBs and pro-active underwriters and investors played key role in nurturing and shielding early green bond niche. Product design critical with mutual benefits accrued by investors and issuers encouraging market participation.
Landscape	Wider developments shaped the evolution of the green bond market: (1) growing concerns over climate change/environment; and (2) the financial crisis.
Regulation	Public environmental regulation increased market for fixed-income products financing environmental/climate investments; also raised awareness amongst corporate and financial actors, leading them to both supply and demand green bonds.

Source: Authors, based on research findings