



Solving SME nature positive finance: A UK green innovation perspective

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ABSTRACT

This paper addresses two research questions: Why SME 'FinBio', the financing of SME nature positive biodiversity related activities, is crucial to tackling climate and environmental sustainability? How can SME finance markets deliver the required biodiversity innovation to meet the Kunming-Montreal agreement's global 30% of land and water protection by 2030 ('30by30') target? Examining the self-reported global green tech leading UK economy, an innovation investment diffusion (IID) model is used within an entrepreneurial finance ('entfin') ecosystem lens. This provides the framework for qualitative research involving 80 finance ecosystem interviews and 10 case study innovative ecological services. Using a two-step analytical approach thematic findings reveal an urgent need to establish science-based targets (SBTs) for biodiversity that complement climate action and enhance biodiversity protection and regeneration. We find that advanced ecological technology services can achieve this, but they require substantial public-private collaborations of finance and networking support to create the synergies to meet global climate and biodiversity targets.

1. Introduction

"If some companies and industries fail to adjust to this new world, they will fail to exist." (Carney, 2019).

Can financial institutions effectively integrate sustainability principles to accelerate progress towards global climate and biodiversity goals? Battiston et al. [1] argue that the financial instruments and profit orientation of financial institutions in developed markets mainly relate to the narrow environmental perspective of fossil fuel extraction and combustion. Are these institutions aware of their mispricing of climate risks or opportunities for revenue from environmentally sustainable investments [2]? The spectre of the existential threat to the global financial system of climate change and environmental degradation was starkly raised in Mark Carney's speech as Governor of the Bank of England in support of the international Network for Greening the Financial System (NGFS) [3]. This requires a coordinated approach to identifying the metrics for disclosing investor's exposure to both climate (Taskforce for Climate-related Financial Disclosures (TCFD) [4] and biodiversity risks (Taskforce for Nature-related Financial Disclosures (TNFD) [5], in order to develop action plans for environmentally sustainable finance [6]. Furthermore, Dasgupta's [7] UK Treasury report on the economics

of biodiversity highlighted the need for business to work with nature to secure a sustainable, prosperous future for the planet. Subsequent NGFS [8] and global TNFD [5] publications stress urgent need for holistic environmental action by considering the synergies between managing Earth's biosphere in a nature positive way and addressing climate change to deliver more efficient net zero solutions [9,10]. COP15 [11] reinforced this through support for the UN '30by30' call for the protection of 30% of Earth's land and water by 2030.

The challenge for the global financial system is therefore to go beyond assessing the cost of climate change and net zero mitigation to address the wider interactional environmental mitigation costs. However, recent literature remains climate and large business focused, with little or no consideration for the 'green' innovations that are required to meet global environmental targets [12]. For instance, Lamperti, et al., [13] find that climate risks can moderate the trade-off between productivity and financial failure of firms. Chabot and Bertrand [14] show that Scope 3 supply-chain greenhouse gas (GHG) emission by European financial institutions destabilises their financial health. Xie et al. [15] report that extreme weather is a catalyst for risk spillover in the green finance market, particularly for short-term investment. Apart from the financial institutions, with a global sample, Pankratz et al. [16] find that

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large corporates fail to assess and anticipate negative consequences of adverse climate change. Other related studies on biodiversity finance analyse the impact of corporate governance on climate change mitigation [17,18], financing pressure on large retailers to reduce GHG emissions [19], biodiversity conservation and tourism firm performance [20], impact of Kunming-Montreal declaration on stock prices [21] and country specific stock return due to biodiversity risk [22–24] among many others. But these studies are based on large corporate businesses which do not have similar (limited) resource constraints as small and medium-sized enterprises (SMEs).

Within the UK, the Government's Green Finance Strategies [25,26] proclaim the development of a global leading environmental green technology ('greentech') economy. The UK Green Finance Institute (GFI) and Infrastructure Bank offer broad environmental support, such as through the establishment of green bond schemes for electric vehicle (EV) and hydrogen power infrastructure and the development of natural capital markets in carbon, biodiversity and water [27]. However, as Owen et al. [12] argue, a persistent problem for green economic development is the focus of governments on large business and large-scale green infrastructural finance projects, whilst under investing in SMEs. The UK Green Finance Roadmap [28] offers no direction for SME green innovation finance and GFI [29] investment readiness toolkit guidance for nature-based projects and farming fails to support the broad range of SME 'green' nature positive ('FinBio') innovators [12]. This is an oversight, on two counts. First, SMEs represent almost all UK private businesses, over half of their employment and turnover, and also contribute to over half of GHG emissions [30]. Second, SMEs are agile innovators that, if effectively financed, can generate the rapid high growth ventures [31] to drive forward the global green economy [32]. Furthermore, Cowling and Liu [33] highlight that UK SMEs experience funding shortfalls for green innovation research and development (R&D) and also in adopting green practices and business models. Green practice adoption is further undermined by the lack of SME environmental reporting standards in the UK, resulting in a lack of awareness or willingness for green investment, despite the presence of government financial support schemes [34].

Thus, in this paper we address two research questions: first, why SME 'FinBio' is crucial to tackling environmental sustainability; second, how SME finance markets can deliver the required biodiversity innovation. SME FinBio [35] is defined as the operation of entrepreneurial finance markets to support (e.g. via investments, loans, grants, tax incentives and insurances) environmental, nature positive, impacts (i.e. environmental impact investment/finance).

Focusing on the UK, as a global leading green investment market, this study draws from 80 finance ecosystem interviews (2022–25), offering a wide range of insights (e.g. banks, corporate and equity investors, public and private support agencies and consultants) into current developments and operations in the UK green tech startup investment market. Additionally, 10 purposively selected case studies of UK SME early-stage innovative ecological services developing business to business (B2B) biodiversity-related measurement services are examined. These were selected to see how they can assist the finance markets to risk assess and finance nature positive business actions. We find that UK green innovation startup finance requires improvement to the SME finance stages escalator through increased collaboration between investors and entrepreneurs, and notably between large businesses as investors into SMEs as suppliers of their green innovation business solutions. The evolution of new types of specialist financial intermediaries, such as nature positive launchpads, accelerators and catapults can facilitate this process. They offer improved networking between stakeholders to generate improved SME market-based environmental solutions, thus reducing investor information asymmetries and enabling more rapid commercialization and scale-up.

Given the preceding discussions, we contribute a novel theory building perspective on the effective development of SME nature positive innovation finance and the role such innovation can play in

developing the wider nature positive finance market. First, we address a clear entrepreneurial finance research gap, extending beyond Harrer and Owen's [36] research into cleantech low carbon innovation measurement and investing, by improving understanding of how to increase environmental FinBio impact investing into green nature positive innovative SMEs. More specifically, we also examine the processes (rather than specific measurements), and incentives by which SME environmental impact assessment and reporting can take place to facilitate the operation of SME FinBio (further extending on Harrer and Owen [36]). Second, we combine a novel innovation investment diffusion (IID) model framework [37] with entrepreneurial finance ('entfin') theory within a UK ecosystem lens [38] to ensure a holistic research approach. This progresses beyond D'Orazio and Valente's [37] study of bank and public debt green investment into the purchase and adoption of green innovation by SMEs and larger businesses and organisations. Our study offers improved understanding of how information asymmetries between actors might be reduced along the green innovation entrepreneurial startup finance escalator, extending North et al.'s [39] early stage tech finance escalator operation within a green SME innovation context. Third, we extend the Flammer et al. [40] analysis of 33 biodiversity finance deals through pure private capital and blended financing globally. That study was limited by under-representative datasets and lack of harmonisation of a common framework across different countries. We overcome this limitation through in-depth analysis of one country, which can be replicated for other countries.

The remainder of this paper is organised as follows. Section 2 discusses the literature review and theoretical framework. We present the methodological approach including the sample and data collection and analyses in Section 3. In Section 4 we present the findings. Section 5 discusses the paper's contribution to building theory, policy recommendations, data limitations and guidance for advancing future research.

2. Literature review and theoretical framework

The problem with environmental ('green') innovation finance is complex and well documented (see e.g. [41]). Since the 1931 UK Macmillan report [42] there has been widespread agreement that a fundamental cause of innovation funding gaps is the heightened information asymmetries which exist between entrepreneurs and investors [43], which are most prevalent during the earlier stages of innovation due to the greater uncertainties of commercial viability [39]. For instance, prior research shows that the market value of R&D intensive firms depends on intangible assets which are difficult to assess by investors [44]. Moreover, Hu et al. [45] argue that it is difficult to convince investors in relation to risk of innovation failure and return on R&D investment. Green innovation is frequently 'deeptech' and disruptive, presenting additional investment assessment consideration and increased information asymmetries [36]. This is due to requirements for more capital-intensive hardware investment and longer periods of R&D (e.g. to build demonstrator plant and equipment), leading to extended payback horizons and what is referred to as a longer and deeper 'valley of death' - the seed investment period prior to establishing stable (profitable) commercial return [32,46]. There are also additional green innovation information asymmetries which relate to commercial market viability and acceptance, summarised by Harrer and Owen [36] for the UK and Kong et al. [47] for Chinese markets. These include poor policy mix [48] whereby conflicting counteracting government policies fail to deliver environmental improvements (e.g. removal of renewable energy subsidies and lack of regulations to support the greening of the UK construction sector) and more generally the lack of full socio-environmental return value (e.g. savings in national health costs) to green investors [49].

Increasing understanding of the complex combination of problems facing green investment decision making has led to calls for entrepreneurial finance ecosystem approaches [38,50,51] which include all

actors - entrepreneurs, investors and market supporters - that converge at the 'stakeholder triple nexus' to overcome information asymmetries and deliver green environmental impact investment [36]. However, whilst Harrer and Owen [36] focus on the need for improved signaling of the environmental impact value of innovations and greater cohesion in the institutional logics applied by different stakeholder groups in order to overcome information asymmetries they acknowledge, alongside NGFS [8], that environmental science-based targets (SBTs) are required to facilitate this. Without SBTs, the calculations for the market value of nature-based innovations remain problematic.

Whilst consensus exists that a fundamental measure of climate change mitigation is the reduction of greenhouse gases (e.g. expressed as tCO_2e – the weight in tonnage of CO_2 /GHG equivalent reduction), no magic bullet equivalent measure exists for biodiversity. Both the Network for Greening the Financial System [8] and the global Taskforce for Nature-related Financial Disclosures [5] call for ecological SBTs. They also recognize that simplified biodiversity proxy measures like habitat quality, exemplified by the UK Department for Environment, Food and Rural Affairs [52] metric to calculate Biodiversity Net Gain (BNG) in planning applications are insufficient. Providing an ecological baseline for habitat is inadequate for species assessment (see also [53]). Thus, whilst BNG is helpful in establishing a natural capital market such as habitat banking to facilitate biodiversity offsetting [54], what is additionally required is a set of measurements which relate to the various actions to mitigate the causation of environmental degradation and species loss which can then easily be risk assessed by businesses and financiers to calculate investment viability and cost.

In the absence of agreement on biodiversity SBTs, this paper addresses the wider vision of NGFS [8] and TNFD [5] for the finance sector to act as a driver of change to facilitate achieving net zero and nature positive impacts. A first step towards this, addressed in this paper, is to understand the framework of processes and dynamics by which private and public sector financiers can combine to generate the required levels of environmental impact investment to meet net zero and 30by30.

This paper addresses the research gap around facilitating SME green innovation and its adoption, with a focus on the financing of SME ecological innovation. Owen et al., [55] and Cowling and Liu [33] find that within a UK context SME green innovation is being stifled by a combination of economic and innovation uncertainty. This prevents both external investors from investing into SME green innovators and also established SMEs from investing in green innovations. Whilst these authors (ibid) argue for improved government intervention through targeted innovation and green product grants and subsidies (e.g. Innovate UK grants to SMEs and green energy and EV subsidies) and also offer strong support for Lerner's [31] private sector-led co-financing solutions for SME innovation, such as through government sponsored venture capital funds [56–58], there remains a gap in understanding the dynamic driver interactions between green impact investing, public policy and private market acceptance.

One way in which this can be examined and better explained is through combining the entfin ecosystem with innovation investment diffusion theoretical approaches. This provides a holistic research model framework of the key stakeholders within a given market – for example the lens of the contemporary UK green impact investment escalator of public and private investors and support and regulatory services [38,59] - with a structured approach to understanding how the risk-reward investment balance can be tipped in favour of green impact investing into and by SMEs. Here an important additional element to Harrer and Owen [36] is closer scrutiny on financial regulation and in particular the role

of environmental reporting. This needs to be considered within the realm of the rising sustainable environment, social and governance ('ESG') agenda which has led to increasing environmental reporting by UK and EU larger businesses and organisations, typically with over 500 employees in the UK [55]¹. This alongside the vanguard of SME self-reporting accreditation such as via 'B Corp' or ISO14001 provides evidence for where extra (non) financial aspects of business activity can contribute to the improved economic performance of SMEs, through for example, wider market credibility within business-to-business (B2B) supply-chains, public procurement, business-to-consumer (B2C) markets and local place-based (e.g. environmental) benefits [60].

Innovation investment diffusion (IID) theory considers the risk-reward ratio of innovation adoption and therefore the market viability of innovation. However, it fails to fully account and theorise for the early stage investment into entrepreneurial green innovations, and notably prior to their commercialisation. Ham's [61] review of innovation adoption theories demonstrates that the decision to adopt or reject is essentially an individual, entrepreneur [62] or organizational [63] decision-making diffusion process. This will be based upon a broadly structured stages model [64]. Such models include: entrepreneurial and organisational knowledge and learning and connected communication channels relating to the visibility of the innovation [64]; assimilation and assessment of innovation value, which requires individual mitigation of concerns – such as environmental perceptions and what others might think – [37,62] and organizational ease of adoption [65]; the decision to adopt or reject and further assessments over time whether to retain, refine or reject the innovation [62]. Ultimately, as both Rogers [64] and Davis [66] recognise, there are financial considerations regarding increased productivity and the ability of the innovation investment to pay back, which may be easier to calculate for shorter horizon payback for software adoption as opposed to more expensive hardware [64]. IID thus offers a structured approach to the appraisal of e.g. environmental innovation which is helpful to SME innovators and investors, but requires further green, early stage innovation development.

2.1. Establishing a UK green innovation investment diffusion model

D'Orazio and Valente [37] establish an econometric sequential green innovation diffusion model that demonstrates the value of public and private co-financing investment, as advocated by Mazzucato and Penna [67], for stimulating and encouraging green innovation. Whilst demonstrating the value of public policy intervention, the model [37, p.417] also considers the wider systems, providing "...a model that can be used as a tool to explore policies to foster environmental innovation diffusion." Critically, by adopting an innovation investment diffusion lens (e.g. UK FinBio startup innovation market), the model is able to consider influences on the demand-side behaviour of consumers and investors in innovation via learning and awareness, which may be impacted by policy interventions such as training, regulation and subsidies [68], which will interact with trade-off preferences relating to existing status (internal financial surplus, equipment and practices) and current or perceived future options [69]. Hence a novel interactional modelling takes place between the supply of innovation (e.g. novel green innovation like clean energy EVs) and consumer demand with regard to financial cost and trade-offs over time. Since Owen et al., [55] clearly articulate that the vast majority of SMEs and their investors are driven by financial motives, rather than green missions that supersede pure profit motives, two factors appear particularly pertinent. The first is the

¹ From 2024 The EU Corporate Sustainability Reporting Directive (CSRD) requires businesses with 250 or more employees and E40m plus annual turnover to provide environmental reporting. <https://www.europarl.europa.eu/news/en/press-room/20220620IPR33413/new-social-and-environmental-reporting-rules-for-large-companies>

push pressure of regulations (including environmental reporting) and market sentiment (customer preferences and credibility) and the second is the pull pressure of a stronger business finance case for improved markets and profitability. The model broadly supports the prior evidence on countercyclical investment patterns by state investment banks and the key role for state financial interventions to bolster innovation during recessionary periods of low financial availability, or for difficult to finance disruptive technologies [31,67,70] and therefore the need for targeted green grants, subsidies and public stimulated green investment [33,55]. These policies seem particularly pertinent during the 2022-25 research period's global economic crises and to assist more rapidly reaching net zero and nature positive targets through sustainable green innovation and adoption amongst SMEs.

This provides a framework for the paper's qualitative approach which seeks to explore the dynamics of SME green innovation investment and market diffusion within the contemporary UK cultural, regulatory and investment context. Notably, we develop D'Orazio and Valente's [37] model, to explore the early-stage equity investment market, specifically for nature positive ecological services. We extend the IID approach to examine investment diffusion in terms of the interactions of early stage pre commercialisation investment actors (equity investors, entrepreneurs and public policy and support) knowledge and experience that shape investment decisions – whereas prior work (ibid) has focused on debt finance and the purchase of commercialised innovations. An IID framework is constructed to qualitatively examine the operation of the UK green innovation SME finance market. The overriding research questions asks why SME 'FinBio' is crucial to tackling environmental sustainability and how SME finance markets can address this. To achieve this the paper tests two propositions:

Proposition 1. Net Zero and wider environmental market sustainability are interrelated and require joint action for the most efficient mitigation of environmental catastrophe costs [8].

Proposition 2. Financial markets can drive green innovation and investment for impact [5,8,10]. Specifically, this is tested through the entrepreneurial finance ('entfin') ecosystem lens which spans the three main actor domains in the UK sustainable triple nexus where founders and impact investors meet, intermediated by market supporters to deliver green innovation investment [36,55]. This framework provides understanding of how green innovation investment risk assessment and reporting takes place to facilitate SME FinBio and offers insights into market operational dynamics that can lead to greater SME environmental sustainability.

2.2. Investment ecosystem and domains

Our entfin investment ecosystem approach presents three main domains of interest which form propositions 2a,b,c and provide a more nuanced understanding of the roles and influences of different entfin actors on the IID.

First, the *entrepreneur/SME's* perceived need for green innovation development or adoption and the level of external finance required for this, versus an understanding of the environmental impact and payback period for investment.

Proposition 2a. The investment will be greater where there is clearer transparent understanding of the green innovation trade-off [55].

Second, the *financier's* willingness to invest or lend.

Proposition 2b. The financier will be more uncertain according to poorer economic climate, earlier stage innovation (along the finance escalator [39]) and earlier adoption and where disruptive, capital intensive and long horizon – which is typical of many green innovations [36].

Third, state regulation and financial intervention (e.g. finance, taxes,

subsidies).

Proposition 2c. Positive or negative impacts relate to the policy mix of regulations. Investment levels will improve with the increased certainty of financial support which apply to environmental awareness and reporting and investment (e.g. agrifood sector practices, larger business ESG reporting [48,59]).

The domains and their related components are set out in the green IID model, which provides the framework for the qualitative fieldwork research to establish the dynamics and process of interplay between domain actors (Fig. 1). This will assist the paper's unique contribution to understanding the most important dynamics and factors for theory building and policy development.

3. Methodology

A qualitative semi-structured interview approach is adopted [71,72]. This seeks to triangulate a broad base of evidence from across the three (UK) entfin ecosystem lens domains to test the propositions of our SME green IID model; SME finance demand-side, SME finance supply-side and intermediary public and private support services and their respective component factors, as set out in Table 1. This required three years of fieldwork (2022-25), initially involving a mapping of key actors through a review of contemporary literature, web material and key informant scoping interviews (with key government agencies, Table 1) in the UK SME green investment market, updating for example on Owen et al., [73] (2019, 2020 review of UK Beahurst data), Cowling and Liu [33] and O'Reilly et al. [46]. This approach ensured that the ecosystem domains were represented by the UK's leading green early-stage innovation investors, public and private support agencies and startup entrepreneurs in ecological services innovations (as detailed in Table 2).

3.1. Choice of interviews and case studies

Interviews were then purposively selected in order to gain wide representation and deep insight. Table 2 presents the wide range of UK entfin ecosystem actors interviewed, which covers: all of the main types of public and private early stage investors with an interest in green finance and nature tech; leading SME support intermediaries, including national SME/trade associations, financial and equity investment bodies and notable large businesses offering SME green innovation supply-chain finance; the ten UK SME ecological services innovators, selected by key finance (e.g. GAS) and support agency (e.g. UKCEH) recommendation for reaching formal equity finance stages and achieving market penetration.

A potential limitation of this approach is lack of representativeness, given the scale of the emerging green impact investment sector in the UK. For example, from the SME demand-side, Beahurst [74] reported 168 cleantech deals in 2021. Furthermore, Harrer and Owen [36] argue that this only covers the narrow MIT [75] definition of cleantech relating mainly to renewable energy and low carbon investments. Van der Schans et al., [76] drawing on the broader Mukherjee et al., [77] greentech finance literature review which includes nature tech and circular economy activities, found between 300-400 formally reported UK investment deals annually, worth £7.6bn between 2020-2024. However, as van der Schans et al., [76] highlight, the numbers of early-stage nature tech startups represent only a small proportion of these deals. More precisely, UK Centre for Ecology and Hydrology (UKCEH) - a UK (and global) leading research institute supporting nature tech that can assist biodiversity measurement - provided (in 2022) less than 10 examples of fundable startups addressing a range of measurement techniques ranging across advanced sensors, camera, acoustics and satellite innovations. This may be triangulated with the portfolio of Green Angel Syndicate, the UK's largest green angel investment network, which has 12 nature tech investments in its portfolio of over 50 early-stage UK greentech companies. Since the start of our study, it was

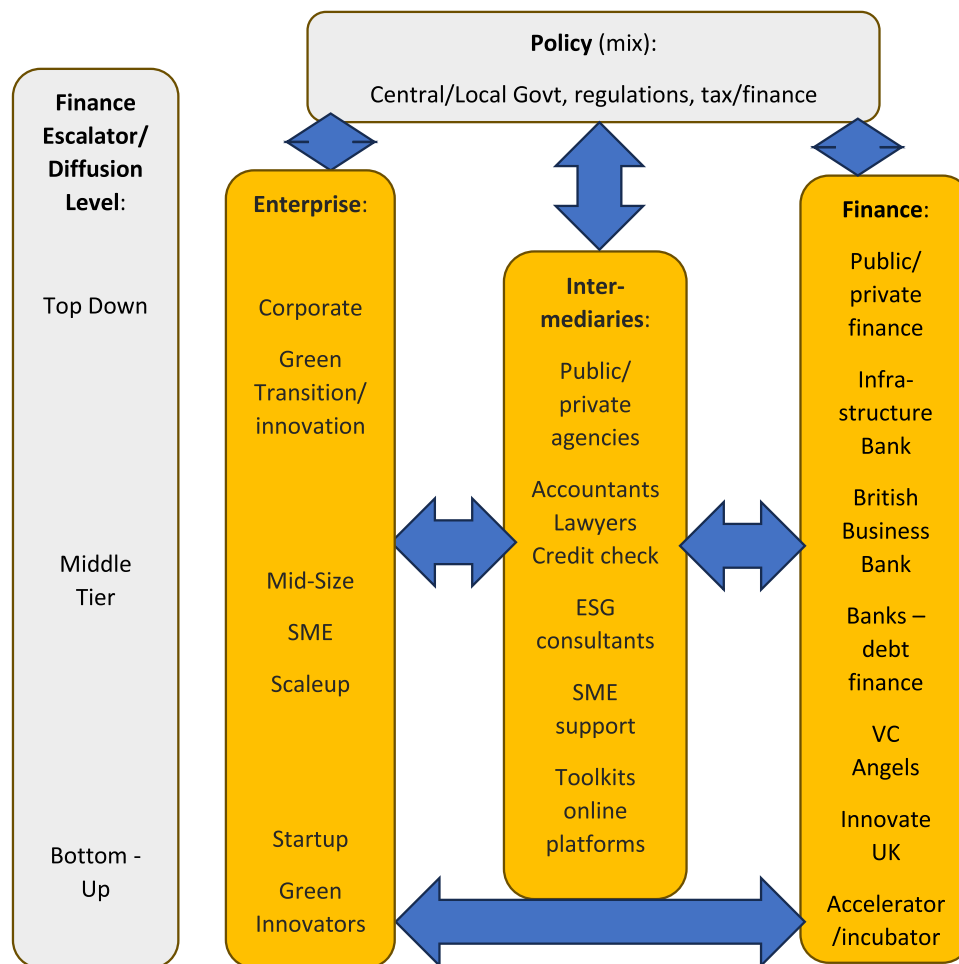


Fig. 1. Innovation investment diffusion (IID) model: UK Entfin ecosystem dynamics.
Note: Blue arrows represent interactions flows

Table 1
Components and structure for a green innovation investment diffusion model.

Component/ Domain- RQ	Demand side	Supply-side	Intermediary	Theories	Proposition	References
Financing Decision, IAs RQ 1, 2 Prop 1, 2	SME innovate or adopt	Invest or lend, market viability, scale, capital/ horizon	Public and private service, IA guidance	Innovation diffusion	Reduce IAs, viable market scale, capital/ horizon	Dorazio & Volante (2019), Owen et al (2022a)
Stages RQ 2 Prop 2b	Earlier/later/ established	Earlier or later	Incubator, accelerator, advisor	Finance Escalator	Reduced opacity by stage, time and capital/ horizon	North et al (2013); Owen et al (2018)
Resources RQ 2 Prop 2b	Smaller or larger size (emp/ turnover)	Informal, formal, institutional	Investment Readiness, awareness/ toolkit	Resource-based	Management team, skin the game, network	Owen et al (2019, 2022)
Behaviour RQ 2 Prop 2a	Mission proactive, reactor, laggard	Reputation, credibility, attractiveness	Accreditation, labelling, rating, nudge	Institutional logics, signalling	Sustainable impact oriented, regulated, unaware	Harrer & Owen (2022)
Policy RQ 2 Prop 2c	Inducement or coercion	Screening	Regulator, public good, innovation, market	Policy theory, ToC, mix	Financial inducement or taxation, regulation	Mazzucato & Penna (2016), Owen (2023), Owen & Vedanth- achari (2023)
Economic Cycle RQ 2 Prop 2b	Survival, growth/ development	Rationing and staging	Level of public/private funding, stability	Credit rationing	Degree of stability	Cowling and Liu (2023), Lee et al (2015)

Note: RQ denotes the main research question addressed and Prop denotes the propositions tested

noted by several UK VC and angel investors that AI is being increasingly incorporated into nature tech, but that the number of viable/investable hardware tech biodiversity measurement companies remains small. In

summary, the size of the UK green tech ecological services sector addressing biodiversity measurement that this study aims to explore is relatively small and niche within the broader UK green tech startup

Table 2

UK nature positive SME finance key informant interviews 2022–2025 and ecological service system case studies.

Key Informant	No.	Organisations Represented
Supply Finance	N=42	Investors
Venture studios/incubators	7	Bloom, C13, Zinc; public backed - CPC, SynbiCITE, SETSquared, ElevatorUK
Accelerators	3	Accelar, Bethnal Green Ventures, Sustainable Ventures
Business Angels	7	GAS x4, Minerva, Seedtribe/FiveThirteen, Cambridge Angels
Seed/VC	10	TfT, Regenerate, EFT, OnePlanet, Octopus, FuturePlanet, Ascension, ET Capital, SyndicateRoom, Farmhand Ventures
Venture Banks	1	Turquoise
Banks	7	NatWest, Barclays, Lloyds, HSBC, Triodos, ING, Oxbury
Public funds	7	CGF, LCIF, Welsh Angel Fund, WDB Tech Fund, BNIF, NEIRF, IUK Launchpads
Intermediaries	N=38	Market supporters
Trade Associations	7	UKBAA, WLB, WLC, CILT, BIFA, FSB, BVCA
Accountants	6	KPMG x4, SME accountants x2
Consultants	7	6x ESG consultants, BWB
Enterprise Agencies	1	Oxford Innovation (multiple locations in England)
Public agencies	9	BBB, WDA, Scottish Enterprise, Defra, IUK, DBT, LAsx3
Large Business supply-chain	8	National Trust, ABM Engineering, Worcester Bosch, Liberty, KPM, Heathrow, Network Rail, CEVA
Venture Demand	N=10	Ecosystem service innovation
Ecological Services Ventures	10	UK-based private independent SME innovators, supplying guidance/measurement/monitoring tech services e.g. for BNG or ELM – land management and green supply chains

Note: VC=Venture Capitalist; CPC=Connected Places Catapult; GAS=Green Angel Syndicate; TfT=The First Thirty; CGF=Clean Growth Fund; LCIF=Low Carbon Innovation Fund; WDB=Welsh Development Bank; BNIF=Big Nature Investment Fund; NEIRF=Natural Environment Investment Readiness Fund; IUK=Innovate UK; UKBAA=UK Business Angel Association; BVCA=British Venture Capital Association; WLB=West London Business; WLC=West London Chamber of Commerce; BIFA=British International Freight Association; FSB Federation of Small Business; BBB=British Business Bank; ESG=Environment Social and Governance; BWB=Bankers without Boundaries; LA=Local Authority; BNG=Biodiversity Net Gain; ELM= Environmental Land Management; KPM Marine.

sector.

From the UK SME green innovation finance supply-side, the two leading environmental impact angel networks – Green Angel Syndicate and combined Seedtribe and FiveThirteen (UK based women's investment networks) - both reported over 300 investor members in 2023). However, this study sought deep insight from experienced and currently active SME investors with a specific interest in nature tech. In practice our study does include representatives of these large angel networks and also some of the most active VCs and public sector early-stage green investors (e.g. Turquoise Bank and the Low Carbon Innovation Fund, and specialist accelerators like Sustainable Ventures, Zinc and Carbon 13, which are highlighted in Beauhurst data).

As stated, the 10 UK SME cases were purposively selected from biodiversity ecological services², via key agency recommendations, to examine a range of early stage and scaleup green nature tech innovations and their funding, drawn from across the UK and with different sector use focus, revenue stages and potential investment horizons (Table 3). Whilst our 10 UK based cases cannot claim representativeness of the potential range of ecological services innovations undertaken globally, they do cover the major ecological services activities raised by UK key informants such as UKCEH and GAS, and are sufficient to offer thematic saturation, based on the depth of interviewing and data triangulation discussed below [78].

The interviews addressed our key research questions (see Table 1) exploring through open questions [79] the: profile of actor and their organization; understanding of green investment markets (focusing on the UK); actions taken to overcome information asymmetries, relating to developing environmental impact assessments and screening and monitoring investments and lending portfolios; learning interactions between actors across domains to understand what works; the role of intermediary support actors for example in developing biodiversity indicators and ecological services market opportunities; the role of public policy regulations and financial support instruments; proposals for improving the operation of the SME green nature tech innovation finance market in the UK. Interviews conformed with UK university

research ethics codes, were undertaken face to face or online (e.g. Teams/Zoom), recorded (where permitted), transcribed, written up and factually cross-checked with participants [58]. Interviews typically lasted one hour and where possible follow-up interviews took place to facilitate longitudinal insights into the developmental investment learning processes taking place [73,80].

A qualitative abductive analytical process was undertaken following Tavory and Timmermans [81] methodology to progress from our green IID entfin UK ecosystem lens survey frame established by deduction from current literature (Table 1) to establish out research propositions and then assess the collected interview text, drawing out the emerging themes to form the qualitative reporting of findings. Table 4a summarises our abductive 3-level analytical process, presenting the 'Level 1' deductive research questions, propositions and related key questionnaire content. Essentially, the qualitative variables relate to the decision-making firm (or individual investor) or stakeholder organization as the unit of analysis (in line with similar qualitative research [82, 36]).

We then follow with a Gioia et al., [83] (see also Botelho et al., [82] who worked with Gioia to refine their inductive UK business angel investment analysis) two-step inductive qualitative analytical approach (Table 4a). In step 1 (Level 2), a cluster of emerging themes was drawn out manually by the research team (4 expert academic staff), using initial reflection on entfin groupings and investor stage types through interview content assessment, to form emerging operational dynamic themes from the interview scripts. These were cross-checked by the team members to avoid individual interpretive bias. This established the importance of bottom-up innovation investment diffusion activity to deliver the FinBio SBTs required by finance markets (Table 4b). In step two (Level 3), the process was repeated to explore the key themes arising around supporting the early-stage ecological services innovations, focusing on the 10 case studies.

4. Findings

4.1. Funding escalator spectrum

Our first round of inductive analysis revealed a broad high level thematic coding scheme (Table 4b) relating to the stage of the

² TNFD refers to 'ecosystem services', but the more precise term is 'ecological' for nature tech biodiversity measurement services.

Table 3

Ecological service case studies (interviewed 2022–25; * 2+ interviews).

Company name (founded)	Code	staff	Location	Description	Funding	Escalator Stage
Alo Mundus (2021)	E1	6	London	Urban tree planting monitoring	Accel, 2x grants £50k, 350k	Seed pilot, pre revenue
Chirrup (2022)	E2	4	South West	Acoustics bird song recording	£100k grant	Seed pilot, early revenue
Baker (2009)	E3	17	Midlands	Acoustics including soil/worms	£250k grant/self matched, need £500kVC	Scale/seed VC
KymaRail (2017)	E4	1	South West	Rail design enviro tech consultants	Self funded, needs grants/debt	Seed revenue
EnrichGeo (2022)	*E10	9	Midlands	GIS/geospatial and farm market solutions	Angel and self funded, seek £100k seed	Seed, pre revenue
Watr.Tech (2017)	*E5	12	East England	Water quality, flow monitoring	£750k accel/angel seed	Series A early revenue
BX-Earth (2013)	*E7	2	South East	Farm consultants, monitoring soil carbon	Supply-chain financed, seeking angel/VC	Seed
PES Tech (2017)	*E8	9	East England	Soil consultants, sensor monitoring microbial matter	Accel, grant, angel, VC, 2x seed rounds £2m+	Scale/ early revenue
Wildwood (2008)	E6	13	South West	B Corp Planning consultants BNG monitoring	Self financed	Established/ revenue
Nature Metrics (2013)	*E9	150+	East England	eDNA water and soil monitoring	Grant, angel, VC foundation, of £25m+	Scaleup/ revenue

Note: Yellow=grants; Orange=Business Angels; Blue=Venture Capital; Green=Accelerator

innovation and SME within the financing escalator – the ‘*funding escalator spectrum*’ – which related to both creator innovators or innovation adopters. Whilst our focus in this paper is on SME innovation creators, the green innovation investment diffusion (IID) model framework considers commercial market acceptance (‘salability’) as part of the assessment. In this way we are able to unpack and understand the influential processes, interactional dynamics and investment horizon considerations which impact on the different types of domain actors, including entrepreneurs, investors, market supporters and regulators and policymakers. Critically, this revealed the extent of connectivity between Net Zero and Biodiversity and most influential factors which determine green and nature positive investment. Within this framework the analysis presented in this paper focuses on 10 SME environmental ecological services innovators (Table 3), drawing from their external financing experiences and our wider market domain data from public and private green investors and related support agencies and potential business customers.

The funding escalator spectrum revealed three distinct strands of activity, presented here in terms of the domain actors and their key influences. This reveals that regulatory reporting processes – represented by regulatory reaction, versus self-reporting proactive change appear particularly critical to spurring action, given how slowly the less regulated private market has changed:

First, ‘*trickle down*’, was an expected process resulting from regulatory reporting by policymakers, large institutional financiers and large corporate businesses and organisations. Viewpoints of the different domain actors are instructive. Interviews revealed that UK policymakers are split both between central government departments and their delivery agencies and also between central and local government. Centrally, the Department for Business and Trade (DBT)³ set UK sustainable disclosure reporting standards taking into account International Financial Reporting Standards (IFRS), financial technical advice and Policy Implementation Committee (PIC) input from departments and regulators, including DBT, DEFRA, Department for Energy Security and Net Zero (DESNZ), Treasury, Bank of England and Financial Conduct Authority (FCA).

Thus far, UK Government focus has been on Net Zero reporting from large businesses with over 500 employees and £500m annual revenue. DBT (and DESNZ⁴) adopt light regulation and guidance for Net Zero, although these became more rigorous in 2024, following the International Sustainability Disclosure Standards Board reporting guidance,

including greater Scope 3 SME supply chain focus. Business guidance is Net Zero focused and mainly delivered through DBT’s financing agencies and the online Business Climate Hub [84] (now administered by DESNZ and Broadway Initiative). The Green Finance Institute and Infrastructure Bank focus on larger businesses and green projects, whilst IUK and BBB support SMEs and have developed climate focus since COP26 in 2021.

Conversely, DEFRA are the main department addressing biodiversity and 30by30, focusing on land-based activities such as agrifood through regulation and financing programmes such as Environmental Land Management Schemes (ELMS), Biodiversity Net Gain (BNG) planning requirements and with regulatory controls over utilities, mining and heavy industry, monitored by the Environment Agency. This split between NZ and biodiversity results in disjointed, incoherent policy, which is further complicated by the devolvement of environmental policy to underfunded and often under informed local government agencies such as local authorities and city region Mayors in London and Manchester [48]. DEFRA respondents were critical of the lack of SME guidance for Net Zero and particularly biodiversity by DBT agencies. Indeed, despite the increased presence of biodiversity and nature positive action to address climate change in the UK Green Finance Strategy [26], this message is not reaching, or impacting on most SMEs unless they are required to report to regulators or large business supply chains:

“Policymakers in the finance arena are aware that self-regulation of companies [SMEs] will lead to cost-effective, *not best environmental solutions*. DEFRA is feeding into this debate within government and arguing the case that Biodiversity and Nature are hugely interconnected with Climate Change.”

“There is a need for a single place for SMEs to access Net Zero and Nature Impact advice and support. We are trying to do for nature what it took 20 years to achieve for climate change.”

Local authorities and market supporters highlight both the increasing role that they are playing in managing the environment, notably through planning and the implementation of Biodiversity Net Gain (BNG) and also the lack of additional public funding and prevailing short-term perspective of the (European Regional Development Fund replacement) UK Shared Prosperity Fund (SPF).

“We will need to be smart in making connections and competing for funds and developing private funding leverage, such as through green bonds.”

“Local authorities lack guidance on BNG and how it might be used to raise revenue for green business solutions... The short-term [three-year programme] and underwhelming funding offered by the Shared Prosperity Funds replacing ERDF is constraining environmental actions.”

³ UK Sustainability Disclosure Standards - GOV.UK (www.gov.uk)

⁴ Formerly part of the combined Department for Business, Energy and Industrial Strategy (BEIS)

Table 4a
Abductive coding scheme development.

Level 1 Lit Review Deduction Model (Table 1) and Research Questions/Propositions	Level 2 Key Thematic Findings Induction: Investment Processes, Dynamics, Factors (Table 4)	Level 3 Clustered Sub-Themes Inducted Solutions for SME NP Innovators
Financing Decision, IAs RQ 1, RQ 2 How measure environmental impact for NZ, NP, CE Market scalability, return	Connectivity between NZ and NP: SBTs Market stability, scale, horizon	Environmental impact measures Biodiversity impact measurements NP servicing climate Defining MRV scale and impact, IP, enviro banks/credits
Stages RQ 2, Prop 2b Stage of green innovation development	Stage of innovation, TRL Funding escalator stage, seed, Series A, scaleup, revenue	Public co-funding for commercialisation and scaleup funding Disruptive hardware tech specialist investors
Resources RQ 2, Prop 2b Size of business Management team experience Support use and networking External financing requirements	Size of business, sustainability teams Support services, financial, non-financial Pitching ability and quality signalling Scale of funding, Supply-chain financing	SME innovation silos Collaborative tech venture solutions Sector materiality environmental impact Long horizon hardware grant/co-funds Corporate supply-chain funding AI originality, selective ML
Behaviour RQ 2, Prop 2a Green mission business model objectives Forms of environmental accreditation Financing preference, use	Investment time horizons, costs Reputation, stranded assets Voluntary reporting, B Corp Grant dependence, equity over debt for startups	Open innovation, collaborative stack research Lower tech practicality Green mission market leadership, voluntary accreditation Corporate solutions Green investment syndication
Policy RQ 2, Prop 2c Role of regulations and reporting Role of public funding	Funding escalator: Trickle down, Middle tier, Bottom-up Policy continuity, cohesion Regulations, reporting, BNG Public funding	NP business market awareness, toolkits Nature tech - policy relationship, regulations NP contribution to climate carbon sink Green procurement supply-chain, LA/support NP venture launchpads, studios, accelerators, sprint pilots, catapults
Economic Case/Cycle RQ 2, Prop 2b Impacts of macro-economic factors (e.g. COVID, Brexit, inflation) on markets and investment	Market uncertainty Access to finance and support resources	Economic efficiencies priorities Lower tech affordability Climate before NP Increased grant/co-funding Invest early to save environmental costs

Note: Following Tavory and Timmermans (2014) abductive qualitative analytical process

Second, ‘middle tier’ market supporters, financiers and businesses are characterized as those that are forced to react and adapt to regulations. UK private finance markets and larger environmental reporting businesses are mainly reactive to regulatory reporting pressures. For example, a large UK manufacturer which employed a sustainability team to manage climate change scope emissions had not extended this to consider biodiversity, because there was no regulatory requirement. Conversely, large businesses involved in regulated land management

activities (e.g. farming, heavy industry and water management) did at least consider biodiversity.

Mainstream financial services typically do not look beyond the mid-term. For example, commercial banks are mid-term lenders (3-7 years) and do not face long term investment consequences, whilst “...*accountants respond to client demand.*” This was evidenced by banks and accountants and large businesses that were adapting to regulatory pressures.

“Banking has moved rapidly in the last 5 years from climate as a niche consideration – where the bank had to handle public relations - of risk assessment, to a central factor for corporate lending. Risk space is the sharp end work of doing monetary deals and sustainability has moved up the list to become a major consideration.”

Environmental reporting is forcing change, not least because banks and accountants have to respond to both reporting clients’ demands and their own shareholders. There is also a trickle-down impact from large institutional investors like pension funds, which because of their longer-term investment horizons, are more concerned with potential stranded assets and material sector concerns around environmental degradation. This signals to middle tier financiers such as banks and VC to consider how they measure and report their portfolio environmental impacts to shareholder investors. However, as several finance respondents argued, this trickle down for biodiversity will be slow until there are Science Based Targets (SBTs):

““Biodiversity is the next frontier.... we need decision grade Science Based Targets.... and what does a 10x biodiversity investment look like?” It is just a matter of time for high street bankers, but requires a combination of institutional investor driver pressures and SBTs.

“Land use sector biodiversity may be considered, but it requires measures such as quality of harvest. There is a danger that simply subsuming biodiversity into Net Zero is insufficient.” This investment banker view highlights a drawback for private finance markets. They will make the connection between NZ and biodiversity, for example in assessing sectoral material impact to reduce carbon emissions, but not necessarily take into account sustainable biodiversity impacts without SBTs.

Since COP26, in 2021, UK high street banks have switched on to green lending, notably by offering preferential lending terms to support UK Government recommended Energy Technology List equipment investment. There has also been growing concern to support the agrifood sector where banks have high numbers of SME farmer clients. However, the speed of trickle-down impact has been slow and, as predicted, restricted to those sectors most obviously associated with NZ and land use.

In conclusion trickle-down has been slow and the development of nature positive finance has been determined mainly by regulatory pressures, which have only become more urgent and stringent since COP26 (2021) in relation to NZ and the COP15 (2022) 30by30 biodiversity decree. Within the private finance markets the other major drivers of change have been institutional investor longer horizon considerations to avoid investing in stranded assets, reputational concerns “...*no bank or business wants to be associated with something like China’s Scallop Apocalypse!*” which relate to customers and shareholders pressures and leading individual motivations, which drive e.g. VC fund managers and business leaders. This final observation links to the bottom-up approach revealed.

Third, ‘Bottom-Up’ refers to the activities of the SME green innovation investment market at the earlier stages of the finance escalator. To illustrate this, we focus on 10 purposively selected leading innovative UK SME environmental ecological services at different stages of their development to explore how their innovations relate to measuring environmental impacts, for customers and financial markets and how this has impacted on their own abilities to obtain external financing

Table 4b

First round high level 2 inductive coding scheme analysis.

Funding Escalator Spectrum	Process	Dynamic	Investors	Investment Horizon	Innovation Creation/ Adoption
Top trickle down	Regulation/proactive	Reporting and Scopes, credibility	Large investors, Supply-chains	Long-medium	Later creation, adoption
	Reporting larger organisations	Procurement, supply chains	Larger organisations, Investment Banks	Medium-Long	Adoption, some creation
Middle tier	Regulated/reactive	Reporting and Scopes, credibility	Bank lenders, HP, Insurance	Medium-short	Adoption
	SME self-reporting	Institutional Investors, credibility	VC and Crowdfunding	Medium	Creation, some adoption
Bottom-up	Regulation, sector specific	Larger reporting organisations	Supply chain finance	Medium	Adoption, some creation
	Self-reporting/ accredited	Funding pitch, market opportunity	Early investors Angels, Seed VC	Long-medium	Earlier Creation

(Table 3). It is important to reiterate that these cases represent what key informants (e.g. the leading research institutes UKCEH and Green Angel Syndicate as leading early-stage investors) considered to be amongst the UK's leading ecological services innovators. As such they potentially offer the best evidence of performance success markers (e.g. access to external finance, market penetration, delivering SBT measurement solutions).

The first observation is that these SMEs are typically young and small, either pre revenue, or trading through consultancy services which address a range of environmental domains (fresh and marine water,

land, climate and air, ecosystem habitat and nature) and measurements broadly developed by TNFD (Table 5). As such, they demonstrate niche solutions to measuring different elements of biodiversity and potential for establishing the required SBTs to guide the financial system. In many cases their services go well beyond the current requirements of the DEFRA 4.0 BNG metrics which focus on habitat grade to provide simple, cost-effective solutions. As one global pioneering eDNA genetic sampling company respondent suggested “...this is a case of government not keeping up with technology.”

“eDNA offers a wide range of water, soil and air biodiversity measurement which enables baseline and subsequent timeline checks for species richness [presence] and abundance... the science is advancing to enable greater understanding of ecosystem interactions and change over time... which are important in measuring the impacts of mitigation activities.”

Table 5

Emerging science based target measures for biodiversity (adapted TNFD, 2022, 2023).

Ecosystem Realm	Metrics	Data Key Sources	SME Ecological Case Service
Water	Water Domain		
Water flow	m3; people/business count	TNFD, UN SEEA, ICMA	Watr.Tech
Flood mitigation	flood frequency; people/building count; land loss km2	GRI, ICMA, UN SEEA	Watr.Tech
Purification	tpollutant removed; km2 area habitat covered	UN SEEA, Capital Coalitions	Watr.Tech
Water supply/ quality	m3, quality	UN SEEA	Watr.Tech
Land	Land Domain		
Soil erosion	tecosystem retained	UN SEEA	EnrichGeo
Soil waste	tpollution removed	UN SEEA	Wildwood
Pollination	km2 covered		
Cropping, grazing, wood	tprovision; km2	UN SEEA, Maes	EnrichGeo
Animal/plant	tbiomas	UN SEEA	PES
Climate services	Climate Domain		
Regulators	tGHGe reduction; tCO2e absorption	UN SEEA, ICMA, CDSB	Alo Mundus
Weather hazards	people/buildings affected	UN SEEA	EnrichGeo
Air filtration	tpollutant absorbed	UN SEEA	Nature Metrics
State of Nature	Ecosystem Domain		
Habitat	Habitat type, quality, change km2	EFRAG	EnrichGeo, Wildwood
Composition	eDNA species abundance, variety, counts, key species, change	EFRAG	NatureMetrics, Chirrup, Baker, PES
Function	energy store of plants, types of plant (Native key species)	EFRAG	Wildwood
Population	Numbers and breeding habitat	RSPB, EFRAG	Wildwood
Extinction risk	key species numbers and habitat change	EFRAG	NatureMetrics

Other respondents pointed to the added value of their specialist ecological services, such as acoustic, visual (cameras/drones, satellites) and water quality recording devices, which offer advantages of data validation, ease of use through postal collection and self-application, more accurate identification of specific rare, protected and apex species, real time measures and artificial intelligence (AI) big data algorithm analysis. Whilst some argued that “...you cannot always improve on boots on the ground”, all respondents (including a representative of an environmental research establishment) stated that these technologies were reducing survey costs through automation which reduced human error and provided better science-based baseline data and ability to replicate timeline tests and validity measurement proof of the impacts of mitigation measures. This was illustrated through examples of ‘polluter proof’ where for example water quality checks in catchment areas had proven that dog mess, not water utilities or farm run-off, had caused sewerage contamination during an extreme high water weather event and farm soil quality tests that demonstrate increased carbon lock-in from regenerative farming practices and their resultant improved crop yields. Whilst the majority of ecosystem work has been directed at farming and traditional polluting industries such as mining, construction and heavy industries, they are increasingly adopted into the initial stages of planning. A planning consultant mentioned that BNG meant that architects and developers were using ecologists at the outset to assess sites and assess ecological threats “...early assessments can prevent delays and significant costs at later stages of the planning process.” This was also the case for large infrastructure projects, such as the siting of wind farms and new road and rail developments. However, since COP15 there has also been increasing interest from larger reporting businesses that want to manage their land and premises in more environmentally sensitive ways. This was evidenced by a major bank developing a programme of staff and premises green space engagement with nature and support of urban nature programmes in their communities.

These findings clearly demonstrate that environmental regulation and reporting requirements in the UK are having a trickle-down supply-chain impact on the demand for innovative SME ecological services. There are also clear signs of market penetration of innovative ecological

services which progress beyond current regulatory requirements. They demonstrably enhance environmental management, notably by large companies and infrastructure projects in primary, transport, construction and heavy industry sectors, offering potential financial advantages relating to pollution attribution and control and more efficient environmental impact assessment. Having revealed how bottom-up innovation drivers can take place, we further explore how this relates to SME finance markets?

4.2. SME ecological services innovators as drivers of impact finance markets

As the findings demonstrate, environmental ecological services are addressing the critical SBT measurements that the finance markets require in order to assess the environmental impact of green innovations. As such, this second round of findings (Table 4a, Level 3) relates to the emerging themes around what can be learned from the fundraising experience of these critical SME FinBio innovators. Our questions focused, first on the SMEs' perceived market value in relation to potential market use, scale and barriers to adoption and second, on their financial market uses and (in-line with Harrer and Owen [36]) their experience in accessing external finance in terms of the environmental metrics that have been most effective for selection and monitoring. This portfolio screening and monitoring process was also examined with SME green innovation financiers and market supporters.

Nine out of ten of the interviewed SME ecological services had received early-stage external finance. Following the expected (revised) pecking order of innovation finance along the finance escalator [58,73], this typically initially came from government grants (6 cases, with one also seeking), with seed VC (5) and business angels (5) also more frequently present during seed and Series A pre and early revenue stage funding (Table 3). There was also a preference for self-funding rather than ceding equity share where revenue existed and a lack of bank or alternative venture debt finance use, reflecting its lack of availability due to the early-stage and high risk of the sample SMEs [39].

There was broad confirmation that disruptive, hardware tech green innovation is typically long horizon and remains difficult to fund [58], whilst many interviewees remain sceptical of software artificial intelligence (AI) solutions.

Deeper benchmarking analysis of our sample (drawing from Table 3 data) with recent UK data covering the period 2011–2024 [76] demonstrates similar alignment. For example, van der Schans et al. [76] found that the average time for UK Greentech to achieve first equity round funding from incorporation is 2.5 years, compared to 2.1 years for non Greentech. Furthermore, for Greentech hardware it is 2.8 years, compared with 2.2 years for Greentech software and services. For our ecological services cases the average time to first equity funding round is 2.3 years. The slightly lower length of time to funding in our sample may relate to their improved ability to demonstrate environmental impact [36] and is further explored. However, we are also able to see that two cases seeking equity for hardware development (for infrastructure and soil minoring) had been unsuccessful after 8 years of incorporation. Our sample is also broadly in line with van der Schans et al., [76] in terms of long horizon progression through finance escalator stages for Greentech hardware, since less than half (4/9) of our startups since 2009 have progressed beyond seed stage, despite an average age since incorporation of 6.7 years. However, our failure rate at just 2/10 cases no longer trading is lower than the 28% recorded by van der Schans et al. [76], which perhaps reflects the quality of the cases selected.

We find that biodiversity ecological services have a lengthy gestation time, particularly where they require hardware development "...which is expensive and often takes longer to refine and bring to market" and struggle to find and demonstrate their market niche. Longer established ecological services SME respondents noted "...there are new big data companies coming into the market, but they are looking for ways to utilize AI tech without understanding the market." Respondents felt that AI big data

machine learning should be applied to ecological services that are properly grounded in biodiversity, such as eDNA. Several of the interviewed cases had either developed proprietary tech services or were buying/licensing external services to assist their operations. These included for tree monitoring, soil quality and sound recording, but they were struggling to define their market role and impact, which was a deal breaker for investors.

Another major problem has been the lack of coherent regulatory support which has created market uncertainties [48]. For example, the construction sector presents many barriers to innovative SMEs. Notably, BNG has so far avoided reporting requirements for fauna species, thus far rendering many new monitoring services like eDNA, visual and acoustic, unnecessary, or at best restricted to niche rare species detection work. There is also a lack of collaboration between larger and smaller businesses. An infrastructure services design company mentioned that large operators like Network Rail are slow to adopt SME innovations and have potentially prohibitively expensive safety and security certification requirements. SMEs and particularly innovative startups have limited resources to develop or adopt innovations, which can hold them back. However, the findings also suggest that they are driven by highly motivated entrepreneurs who are willing to self-invest "...to demonstrate skin in the game", which along with grant, environmental and technical certification such as patents, send signals that investors do look for [85].

Additionally, innovative ecological services SMEs were more likely to be successful in accessing external finance where they collaborate to develop more effective market solutions. Examples included a water quality tech SME which was sharing its tech/hardware platform with other complementary specialist ecological service providers and the collaborative operation of eDNA tech. These technological SME aggregations ('stacking') are facilitating a more complete package of ecological services for large infrastructure projects globally, notably in Saudi Arabia (e.g. for water desalination plants and 'The Line' city construction).

However, the problem of longer horizon hardware investment, which stretches beyond the founder and initial grant and angel investment, is its high cost and risk [51]. For example "...prototype equipment development can cost several million pounds..." can lead to lengthy funding search delays [73]. Market supporters pointed to the small number of niche impact investors, their lack of understanding about green deeptech impacts, including circularity, and their need to determine the market scalability and exit timetabling and returns for potential investments [76]. Entrepreneurs and impact investors pointed to the "...need for clear regulatory certainty over time..." to support green innovation and development of biodiversity finance markets which go beyond the currently inadequate carbon markets to help tip the risk-reward balance in favour of investing. This would require, for example, the development of more sophisticated and secure BNG finance markets such as habitat banks which support land offsetting and ecological services (e.g. species measurement) required for long term (30 year) monitoring of land management and mitigation practices such as rewilding.

From the early-stage impact investor perspective - SME green innovation impact investors are nimble and receptive to developing their own screening and monitoring indicators to assist their impact investment screening selection and monitoring support processes [36]. Experienced green angel investors and fund managers revealed strong motivations to find and invest in "...real impact that can demonstrably make a difference." There was also some dismissal of ESGs and biodiversity in favour of NZ; "...the key is the 'E' in ESG, the rest is a confusing complication...we should be addressing climate change as our primary goal." For these investors biodiversity is important if it can demonstrate a clear connection with climate mitigation, such as through rewilding and offsetting innovations, or addresses a clear market need such as food security through for example pollination projects. However, assessing biodiversity and nature positive impacts is universally considered problematic. A

common approach is to assess each prospective investment on a case-by-case basis and to challenge the SME entrepreneurs to present e.g. UN SDGs as measures of sustainable impact, resulting in inconsistency; “... these are often far from satisfactory or sufficient.” The danger, which is clearly presented in these findings, is that green impact investors will support measurable carbon sink, rather than wider biodiversity impacts – particularly where proxy measures like BNG habitat persist.

4.3. The need for intermediary advisory services/toolkits, drawing on best practice

The rise of ESG consultants in recent years has been considerable, with for example, large UK financial institutions, including the British Business Bank, and large businesses initially employing private consultants and then establishing in-house sustainability teams. Small businesses and innovative startups remain under-resourced [86] and are benefiting from the increase in intermediary sustainability support services and online toolkits (e.g. carbon calculators). However, amongst the proliferation of sustainability accelerators [85], notably in London [87], most are concerned with NZ and health, few address biodiversity and there remains limited guidance for early-stage investors. However, there are signs of investor collaborations in the more mature UK markets like London and Cambridge and Scotland’s Glasgow-Edinburgh axis, where “investors know each other and are willing to share the costs and risks of green earlier stage investment.” Thus, whilst Harrer and Owen [36] found that UK VC investors used a mix of external tools (e.g. Cranetool, ENCORE) and proprietary black box solutions which were neither shared nor transparent, there are now signs of greater sharing of resources [88], driven by the examples of environmental screening and reporting of government backed funds like Clean Growth Fund and LCIF. Increasingly, we find evidence of collaboration between sustainable investors which serves the dual role of improving understanding and assessment of the sector and risk sharing brought about by syndication and public-private blended finance [77]. This involves enhanced angel networks and their climate funds and the combinations of government Catapult strategic and green sector development agencies, corporate and seed VC investors to develop entrepreneurial collaboration through tech-stacking venture builder studios and accelerators. This is considered the best way forward, as evidenced below.

Collaboration is embodied in the calls by market supporters for an improved investment matching service which enables entrepreneurs and investors to come together, perhaps developing on the increasingly popular venture studio approach, like Zinc (London), Carbon13 (Cambridge), Melting Pot (Edinburgh), and adopted by IUK through, for example, the Connected Places Catapult. These accelerators bring entrepreneurs, academic and industry mentor networks, corporate businesses and potential investors together to develop innovations to solve environmental problems in the market place [89]. A further application of this is to develop collaborative place-based environmental solutions which could involve innovative SME aggregating projects, for example, to enhance urban and industrial park green spaces. In the case of a highly successful eDNA SME specialist, investment had come through successful place-based demonstration with higher profit margin mining industries, rather than with agriculture. A similar approach to obtaining corporate investment had been taken by spin-out activity from Cambridge University’s construction sector monitoring [51]. Place-based examples could then form the catalyst for industry acceptance and increased environmental investment. Increasingly, it is clear that green innovation SMEs, particularly nature positive disruptors require opportunities to work with large corporate investors to sponsor and trial pilot work, sprint testing projects, such as operating through the Heathrow ‘Liftoff’ scheme and its development for example of the ‘Heathrow Honey’ SME pollination project.

5. Discussion, limitations and conclusions

The paper initially sought to establish why nature positive SME FinBio green innovation finance is important (Research Question 1). Our review of environmental finance and policy literature supported [Proposition 1](#) that Net Zero and wider environmental factors such as Biodiversity are interrelated. We demonstrate the value of nature to global resources (food, water) and health security and synergies between achieving Net Zero and 30by30, alongside widespread international acknowledgement since COP15 that improved Biodiversity conservation and adoption of sustainable regenerative practices will help achieve NZ.

Research Question 2 asked how finance markets can meet the global investment challenges of NZ and 30by30 targets. [Proposition 2](#) argued that finance markets can drive forward green investment (FinBio). Here our findings are more nuanced, demonstrating the value of our research framework in illuminating the combined roles of private investment, public policy and regulations and emerging financial intermediaries in developing FinBio. We constructed a novel research framework extending the innovation investment diffusion (IID) green finance policy model of D’Orazio and Valente [37] to examine the early equity investment market for FinBio innovation within the UK (a globally advanced green investment market). Incorporating an entrepreneurial finance (‘entfin’) ecosystem lens [51] enabled the paper to build theoretical understanding around the interactions of key actors. We reconceptualise North et al.’s [39] SME finance escalator for green technology ([Fig. 2](#)) and confirm the importance of Science Based Targets (SBTs) for FinBio as advancement on the low carbon signaling and financial intermediary framework of Harrer and Owen [36]. Crucially, our extended IID enables us to address policy mix [48] within an early green technology innovation context, demonstrating the need for holistic consistent policy support and priorities for action. Fundamentally, SME innovative ecological services (e.g. NatureMetrics) are highlighted as the catalysts for establishing SBTs which will advance FinBio markets. These SBTs will reduce information asymmetries and inform the required measurement, reporting and validation (‘MRV’) processes for policy and investors [38]. Furthermore, we reveal the key policy support mechanisms around vital emerging intermediary activities through accelerators, venture studios, angel networks, VC peer groups, corporate supply-chain investor networks that can facilitate green tech innovation collaborations and investment [36] for commercialisation and market scaling [51].

Critically, we find that (in the UK) NZ policy offers the first step towards business engagement with nature positive actions. However, even amongst specialist ecological services, impact investors and advisory services, clearer understanding of effective SBTs and MRV processes are required to deliver more efficient SME green innovation financing [90]. Nature positive actions remain undervalued, overshadowed by NZ, as highlighted by the UK’s disjointed short-term policy mix [48] and lack of public investment into nature positive [12]. Current UK emphasis on trickle-down regulatory environmental reporting requirements on larger businesses and financial institutions, relying on impacts into their in-scope SME supply-chains is reactive and too slow. There is requirement for improved business regulation and enforcement of environmental standards, progressing beyond proxy biodiversity measures such as carbon sequestration and Biodiversity Net Gain (BNG). Our IID research framework reveals two key green finance market drivers, SBTs and regulations and their respective operations and impacts on green innovation finance market diffusion. Whilst top-down regulations are operating through slow trickle-down supply-chain processes, SBTs and MRV processes are developing more rapidly through private, often SME bottom up, technological innovation [90]. Thus, we extend understanding of current theory, policy and practice by demonstrating the primary requirement for SBTs to develop the FinBio market. We also demonstrate that developing SBTs requires a framework combining appropriate environmental reporting regulations and

Stage/ Funder	Seed (£<50k)	Start-up (<£2m)	Early stage (<5m)	Scaleup (£5m+)
				VC
Private	Venture Builders Accelerators Crowdfunds	Seed VC Business Angels Crowdfunds Joint Venturing	Early VC Business Angels Venture Debt Corporate VC Co-funds (British Business Bank) VCT (EIS)	Venture Debt
				Bank & non-bank
				Corporate VC
				Private Equity (PE)
				Initial Public Offering (IPO)
Public (policy examples)	Grants (IUK, DEFRA) Launchpads (IUK, Universities) Venture Builders, Tech Stack (Catapults)	Grants (IUK, DESNZ) Co-funds (British Business Bank, IUK, DESNZ) Micro-loans (British Business Bank)	Venture Debt (British Business Investment)	Co-finance (British Patient Capital)
				Venture Debt (British Business Investment)

Note: Types of (formal) funder providing targeted green finance marked in green. DESNZ (Department for Energy Security and Net Zero); DEFRA (Department for Environment, Food and Rural Affairs); IPO (initial public offering); PE (private equity institutions and Family Offices); Non-Bank (alternative to traditional bank debt finance).

Fig. 2. UK early-stages green finance escalator.

Note: Types of (formal) funder providing targeted green finance marked in green. DESNZ (Department for Energy Security and Net Zero); DEFRA (Department for Environment, Food and Rural Affairs); IPO (initial public offering); PE (private equity institutions and Family Offices); Non-Bank (alternative to traditional bank debt finance).

targeted support for open, collaborative innovation (which extends internationally, [51]). Without this, the provision of public funding alone will not shift the dial towards the collective public-private environmental investment required to achieve NZ and '30by30' national or global targets.

More specifically, findings relating to Proposition 2a on the entrepreneurial take-up of green innovation are limited by the paper's primary data focus on early-stage SME innovators, but supported by the difficulties experienced by case study ecological innovators in their attempts to gain traction with investors [76] and commercial markets. Whilst the value of nature positive innovations remains unclear to the wider market place, take-up is limited to the few investors and customers that can afford the risk and have the motivation to adopt, such as wealthy mining companies and green infrastructure projects. Our study reveals the key drivers of investment present a mix of policy, economic and behavioural characteristics, relating to regulation, increased appreciation of the mitigation costs (e.g. of extreme climate events and catastrophic loss of biodiversity), fear of reputational damage and stranded assets, and large firm's ability to pay. Overall, in support of Dorazio and Valente's [37] model, we find that economic efficiency and viability is the overriding innovation diffusion driver, which therefore puts greatest emphasis on delivering SBTs that underpin market calculators (e.g. for carbon and potentially biodiversity).

From a policy perspective, resource-poor SMEs require coherent support policies which engage SMEs with information and investment support tools (e.g. carbon calculators and emerging biodiversity calculators being developed under the UK NERC IFB programme; Table 6). Where investment decisions remain less clear subsidized financing options, such as targeted grants (e.g. to support energy technology list low carbon equipment and nature positive actions such as industrial site greening or offsetting), are required to overcome information

asymmetries and adjust risk-reward in favour of investment [33]. The emerging UK agritech farming sector [59] demonstrates how state Environmental Land Management subsidies can support more sustainable land management and the adoption of innovative ecological services such as for improved soil nutrient measurement. However, where environmental policies are applied without long-term consistency they can be counter-productive [48].

Proposition 2b is strongly supported, with findings concurring with current entrepreneurial innovation finance theory that hardware technology, particularly disruptive green innovation remains difficult to fund (as benchmarked with van der Schans et al., [76]), since the information asymmetries, high cost of capital-intensive projects and long horizon payback timelines are too risky [32,51]. We also reveal that software AI solutions ecological services are also drawing scepticism from investors who are concerned that they do not have sufficient environmental grounding to deliver practical and marketable solutions.

From a policy perspective, given that SBTs offer the keys to unlock the MRV processes to create a more efficient green finance escalator [38], we would suggest following the guidance of van der Schans et al., [76] for public policy to focus on early-stage support services for venture building and supply chain finance to invest in SME ecological services innovations (see Table 6). Furthermore, where extensive capital investment is required for disruptive hardware technology governments should target larger scale (IUK) grants and public-private equity co-financing programmes, such as through new British Business Bank green innovation patient capital funds. This might take the form of a revamped UK Innovation Investment Fund [58] (Table 6).

There is strong evidence to support Proposition 2c and the role of public policy to create the stable regulatory and funding framework to encourage SME nature positive innovation and the formation of SBTs [5, 8]. This particularly relates to the role of facilitatory intermediary

Table 6
Specific UK green innovation policy instruments and support mechanisms.

Current Best Practice	Policy Recommendations
<i>Nurturing and coordinating early-stage green innovation finance</i> Innovation Knowledge Centres (7 IKCs) – support university green spinouts and utilise university training, equipment, knowledge transfer services for industrial sectors and verticals e.g. Imperial SynbiCite, Swansea SPECIFIC and Cambridge CSIC centres for engineering biology, cleantech and construction sectors. They can offer proof of concept grants and deliver international industry coordination and leadership. IUK Launchpads – offer regional sector specialist roadshow, including agritech, support and establishment of expertise and tech support programmes in local centres. Offer links to IUK Investor Partners. UKRI Nature Positive Accelerator – seed and early commercialisation collaboration between universities, private support services and green impact investors to improve green business models, understanding of environmental impact metrics and investment readiness <i>Scaling up green innovations</i> IUK Catapults – support later stage technology readiness level (TRL 5+) SME innovators to collaborate and link to corporate industry and infrastructure project initiatives. Connected Places and Digital catapults have combined to support digital biodiversity SME innovation sprint tests. UKRI Natural Environment Research Council – biodiversity calculator pilot for AI adoption to online B2B market solutions assessing innovation investment readiness and green innovation adoption cost calculation. Green procurement programmes (e.g. London and Partners, supported by Greater London Authority) – support SME innovators to access and solve large firm green supply-chain requirements. <i>Key UK Co-funding of green tech</i> Low Carbon Innovation Fund (established 2010) – British Business Bank £100m+ East of England regional fund for seed investment, assisted 80 SMEs Clean Growth Fund (established 2020) – DESNZ £101m series A+ cleantech fund, assisted 19 SMEs Big Nature Impact Fund and Natural Environment Investment Readiness Fund (2025) – DEFRA £30m fund Energy Entrepreneurs Fund (2012) – DESNZ £120m+ large scale grants for green energy ad industry efficiency. UK Treasury's Seed and Enterprise Investment Schemes (S/EIS) offer tax incentives for early stage investment.	<i>Early Seed stage</i> Develop more biodiversity tech research centres (Like UK Centre for Environment and Hydrology) with funding for specialist seed innovation companies. Provide more funding for IKC type research innovation translation into industry. Develop improved green breakthrough tech peer review, like Germany's Fraunhofer Institute – offering tech validation and SBT guidance. Agricultural areas (West of England, East Anglia, East Midlands, Wales, Scotland) local universities with agritech innovation capabilities – need coordinated expansion National and International collaboration arrangements are crucial to overcoming thin markets of knowledge and investment into biodiversity breakthrough sectors like eDNA, IoT sensors/AI and engineering biology. <i>Late Seed and Series A+ stages</i> Whilst Catapult centres have good UK-wide regional coverage (9 theme centres and 65 locations), with specialisms in energy and renewables, there is no specific UK biodiversity specialist catapult. Whilst DEFRA have produced online handbook materials to support SME biodiversity awareness across key sectors, a carbon calculator equivalent is needed for biodiversity. Private corporate green supply chain initiatives, such as Heathrow 'LiftOff' have introduced competitions for SME biodiversity innovators. There is scope for more public coordination programmes to increase SME green innovation access to corporate supply chains through accelerators and venture builders. <i>UK government specialist green tech co-funds</i> Whilst the UK has introduced specialist low carbon, clean tech funds, including the now closed UK Innovation Investment Fund (£330m), there is only a small amount of British Business Bank funding specifically allocated to cleantech funds (eg UKI2S) and very little public funding has been designated to SME biodiversity innovation. The UK needs a cohesive and clear green innovation funding route map across the emerging green innovation funding accelerator. Target long horizon green grant sector programmes. Extend S/EIS incentives in scale and investment horizon to encourage green patient capital.

services [36], such as public advisory programmes and online support tools (like DESNZ's Climate Hub and DEFRA's Nature Positive Handbook sector guides). Our findings also strongly support the need for clearly targeted SME green innovation finance initiatives [33,77] which blend public finance to leverage private investment [38] and can be more effectively linked along the green finance escalator [39] (Fig. 2). As Table 6 demonstrates, there is scope to further develop a range of UK public green innovation programmes, such as: IUK's green launchpads, regional venture building and Investor Partners programmes encouraging earlier stage private investment through co-funding (public grants and private equity); DEFRA's nature funds which offer a range of public finance support for nature positive innovations from early seed to scale-up; and specialist public-private co-finance programmes for greentech innovation like the Clean Growth Fund and East of England Low Carbon Innovation Fund (LCIF)(see [58]). Arguably, none of these UK public investment programmes has the scale of funding of the previous UKIIF [58], suggesting that a large new UK Greentech investment fund could be developed [76]. Finally, as Mazzucato and Semieniuk [32] suggest, there is a strong argument for an overarching government body (whether the Green Finance Institute or more likely the British Business Bank) to create a coordinated, sufficiently long-horizon and large-scale supply of finance and support programmes for SME green innovation (van der Schans et al., 2025).

Looking forwards, the novelty of this paper is that it is the first UK-wide, holistic study of the SME FinBio entfin early-stage ecosystem, providing a framework for future research and the formation of a process evidence base for how the UK public and private markets are coming together to deliver globally leading-edge nature positive finance market solutions. It does so by bringing together bottom-up early-stage innovators and their financiers (angels and seed VCs) with top-down larger corporate and institutional investors, including banks' SME investment arms (e.g. Barclays Eagle Labs) through venture builder accelerators. We observe that these operate at different stages in the early green tech finance escalator, from proof-of-concept ideas nurtured by e.g. London's Zinc accelerator, to the government sponsored Connected Places Catalyst green transport venture builder which aims to stack proven SME tech innovations using blockchain and AI into a special purpose (business) vehicle (SPV) to deliver specific green supply-chain transport solutions (e.g. delivering clean transport logistics on London's River Thames).

The evidence from the UK SME innovative ecological services case studies suggests that greater effort by the public and private sectors should be made to bring these tech innovations collaboratively together. Collectively, they can solve the SBTs that are required to ensure that the finance markets can correctly assess biodiversity risk. This can enable a progression from current proxy valuations, such as BNG, and the unfortunately persistent investor bias towards measurable carbon outcomes (carbon sink), and more rapidly support nature sufficiently to meet the joint challenges of Net Zero and '30by30'.

By showcasing the leading-edge early-stage SME green finance market development in the UK, our study offers important insights for international globally connected FinBio innovation solutions, such as through combinations of university, seed investor and business collaborations and international green innovation policy initiatives that establish technology, financing and market linkages [51]. However, our current research is limited to a (large) qualitative UK early-stage SME green ecological innovation investment market study. There is scope to develop our IID research framework internationally across mature and emerging green finance markets. Following Mukherjee et al. [77] there is also a need to develop improved SME green innovation finance market quantitative data collection and to deliver further insightful evidence from mixed method approaches that offer robust size data alongside qualitative SME green innovation case insights.

CRediT authorship contribution statement

Robyn Owen: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Suman Lodh:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Funding acquisition, Conceptualization. **Amy Burnett:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Data curation.

Declaration of competing interest

The authors declare that there are no conflicts of interest.

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Data availability

Data will be made available on request.

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