




# Past, present, and future of sustainable finance: insights from big data analytics through machine learning of scholarly research

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## Abstract

Sustainable finance is a rich field of research. Yet, existing reviews remain limited due to the piecemeal insights offered through a sub-set rather than the entire corpus of sustainable finance. To address this gap, this study aims to conduct a large-scale review that would provide a state-of-the-art overview of the performance and intellectual structure of sustainable finance. To do so, this study engages in a review of sustainable finance research using big data analytics through machine learning of scholarly research. In doing so, this study unpacks the most influential articles and top contributing journals, authors, institutions, and countries, as well as the methodological choices and research contexts for sustainable finance research. In addition, this study reveals insights into seven major themes of sustainable finance research, namely socially responsible investing, climate financing, green financing, impact investing, carbon financing, energy financing, and governance of sustainable financing and investing. To drive the field forward, this study proposes several suggestions for future sustainable finance research, which include developing and diffusing innovative sustainable financing instruments, magnifying and managing the profitability and returns of sustainable financing, making sustainable finance more sustainable, devising and unifying policies and frameworks for sustainable finance, tackling greenwashing of corporate sustainability reporting in sustainable finance, shining behavioral finance on sustainable finance, and leveraging the power of new-age technologies such as artificial intelligence, blockchain, internet of things, and machine learning for sustainable finance.

**Keywords** Sustainable finance · Sustainable development goals · Socially responsible investing · Climate financing · Green financing · Impact investing · Carbon financing · Energy financing · Governance · Big data analytics · Machine learning · Bibliometric analysis · Systematic literature review

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# 1 Introduction

As a universal call to action to end poverty, protect the planet, and improve the lives and prospects of everyone around the world, the 17 Sustainable Development Goals (SDGs) are a part of the 2030 Agenda for Sustainable Development that have been adopted by all United Nations Member States in 2015 and expected to be achieved by 2030 (United Nations, 2020). The United Nations estimates an investment in the range of \$5 trillion to \$7 trillion to achieve the SDGs (Craig, 2021). With the unprecedented outbreak of a global pandemic in 2020, the United Nations Development Programme (UNDP) launched the SDG Finance Taxonomy to provide a roadmap for manage the financing and transaction costs of projects that are aligned to the SDGs (Wang et al., 2020). The taxonomy also calls for private capital, finance instruments, and support from financial institutions to contribute toward achieving the SDGs. SDG 17, which is about partnership for goals, is earmarked as a lynchpin for meeting the finance needs required for activities dedicated to achieving the SDGs (MacDonald et al., 2019; Rizzello & Kabli, 2020).

Sustainable finance has emerged as an important concept at the intersection of finance and the SDGs. More than \$400 billion of new funds have been raised on capital markets in 2020, which includes \$357.5 billion from sustainability bonds and \$76.5 billion from green bonds (Refinitiv, 2020; United Nations, 2020). The definition of sustainable finance, however, is very broad, encompassing myriad dimensions of sustainable ways to attain finance and investment goals. The European Commission (2021) defines sustainable finance as an evolving process of considering environmental, social, and governance (ESG) factors in financial and investment decisions. However, this definition, which is limited to ESG factors, is very narrow. This calls for a broader and more encompassing definition that speaks to sustainability at large. In this regard, we propose that *sustainable finance should encompass all activities and factors that would make finance sustainable and contribute to sustainability*, a definition that we opine complements the myriad goals by different stakeholders, such as the European Commission's ESG and the United Nations' SDGs. Indeed, the attainment of sustainable policy objectives across numerous jurisdictions can be achieved through various ways such as climate finance, carbon and ESG disclosure, green bonds, and socially responsible investment (Alsaifi et al., 2020; Barua & Chiesa, 2019; Lokuwaduge & Heenetigala, 2017; Migliorelli, 2021; OECD, 2020; Widyawati, 2020), all of which can be covered under our umbrella definition of sustainable finance.

Considering the broad nature of sustainable finance and its importance for achieving the sustainability agenda, many studies have been undertaken to enhance the understanding and practice of sustainable finance. The recent review of sustainable finance by Cunha et al. (2021) exemplifies this observation, as the authors found that the extant literature on sustainable finance to be "excessively fragmented", which makes it difficult to "identify what constitutes the field and what differentiates it from traditional finance". However, their review, which shed light on the critical features of sustainable finance, the global initiatives for the promotion of sustainable finance, and the strategies and outcomes of the main players in sustainable finance, considered 166 articles only, though the field is in fact very much larger, as we demonstrate through the present review consisting of 936 articles. Noteworthy, no review, to date, has attempted to analyze the burgeoning field of sustainable finance without making excessive concessions, wherein overly stringent criteria are imposed to trim the corpus for review to a manageable size for review, as witness in the review by Cunha et al. (2021).

In this study, we aim to provide a state-of-the-art overview of sustainable finance research, taking into account all aspects and related articles in the field. That is to say, this study covers

the entire spectrum of sustainable finance, and thus, it is not limited to any single aspect of the concept, as in the case of past reviews such as climate finance (Giglio et al., 2020) and green finance (Malhotra & Thakur, 2020). Moreover, this study uses an objective and a powerful review method, namely bibliometric analysis, which is highly suitable for reviewing fields with a large corpus of articles using quantitative techniques (Donthu et al., 2021a; Pattnaik et al., 2020; Paul et al., 2021). Specifically, *bibliometric analysis exemplifies the use of big data analytics through machine learning of scholarly research* in two major ways, namely

- (1) the *search for big data* (bibliometrics) is carried out on an *artificial intelligence-powered scientific database* (Scopus), wherein the scientific database uses specified keywords for *supervised machine learning*, as a subset of artificial intelligence, to extract large amounts of bibliometric data relating to articles relevant to sustainable finance, and
- (2) the *analysis of big data* (bibliometrics), which is multi-faceted (e.g., journal, author, institution, country, keywords), multi-formatted (e.g., numbers, words), and large-scaled (e.g., thousands of data points across the multiple facets of 936 articles), is powered by *unsupervised machine learning*, as another subset of artificial intelligence, to *discover latent relationships* (e.g., interrelated keywords) and *the equivalent clusters of latent relationships* (e.g., major themes).

In this regard, this study significantly extends Cunha et al.'s (2021) review on sustainable finance to uncover the insights that they were not able to provide due to the inherent limitation of their manual and qualitative review of only a small corpus of the literature. Specifically, this study sheds light on the *performance analysis* and *science mapping* of the entire corpus of sustainable finance research using a bibliometric analysis, wherein the former unpacks the publication trend, the top articles and contributing journals, authors, institutions, and countries, and the methodological choices and research contexts, whereas the latter reveals the major themes and topics underpinning the intellectual structure of the field. In doing so, this study will contribute enriching insights that answer six research questions (RQs) that are typically reveal through bibliometric reviews (Donthu et al., 2021b, 2021c; Kumar et al., 2021a, 2021b, 2021c; Rao et al., 2021), and thus, provide a more accurate representation of the state of sustainable finance research as a whole as opposed to the piecemeal representation that emerges from a sample of the field, as in the case of Cunha et al. (2021):

**RQ1.** What is the publication trend for sustainable finance research?

**RQ2.** Which are the most influential articles and top contributing journals for sustainable finance research?

**RQ3.** Which are the top contributing authors, institutions, and countries for sustainable finance research?

**RQ4.** What methodological choices and research contexts exist for sustainable finance research?

**RQ5.** What are the major themes and topics for sustainable finance research?

**RQ6.** What are the future research directions for sustainable finance research?

The insights from this review can be used in several useful ways. First, both new and seasoned researchers in sustainable finance can gain an overview and up-to-date understanding of its publication trend to gauge its interest in the scientific community over time (RQ1). Second, prospective authors can identify key literature (articles, journals) (RQ2), potential collaborators (authors, institutions, countries) (RQ3), as well as methodologies and contexts (RQ4) for sustainable finance research through this review. The same applies for policy makers and industry practitioners who wish to identify experts for consultancy, key literature to inform decisions, as well as methodological and contextual guides for applied research. Third,

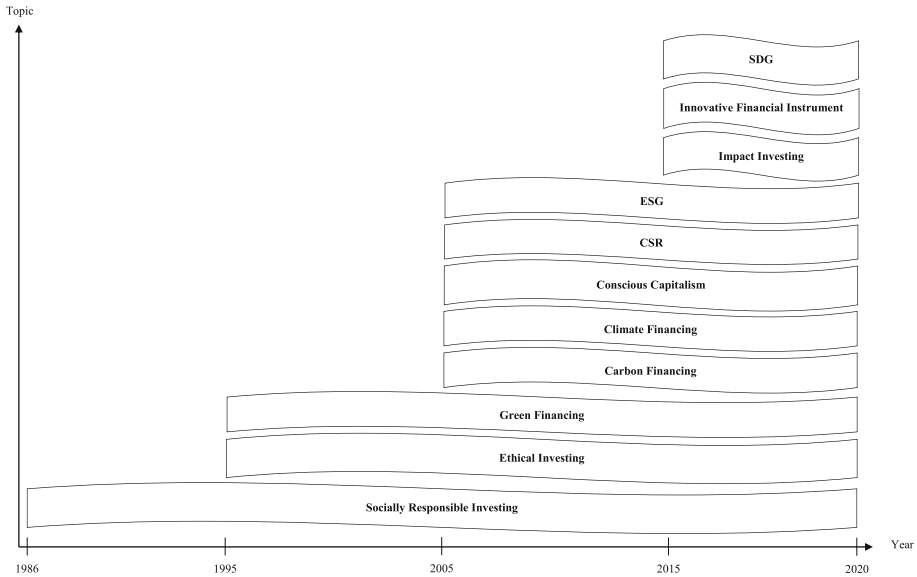
prospective authors can use the major themes and topics revealed through this review as a means to differentiate and position their contributions or novelty against existing streams of sustainable finance research (RQ5). Fourth and finally, prospective authors can gain inspiration from the curation of research directions herein to embark on new and potentially fruitful sustainable finance research (RQ6). These directions can also serve as a teaser into new knowledge that policy makers and industry practitioners can expect to see from the literature in the near future. These contributions, which are typically expected of well-done reviews, are in line with the authoritative guidelines for literature reviews of the field (e.g., Donthu et al., 2021a) and Paul et al., 2021).

The rest of this paper is organized as follows. The paper begins with an overview of sustainable finance. Next, the paper discloses the methodology and reports the findings of the review. Finally, the paper concludes with a future research agenda and a series of research questions for each major theme that can be used as a guide by prospective researchers to advance and fertilize the field of sustainable finance.

## 2 Sustainable finance

The literature on sustainable finance can be traced back to Ferris and Rykaczewski (1986), who addressed the concerns and benefits of social investing in portfolio management. Following this seminal article, the next decade of research (1986–1995) expanded the literature on the key success factors of socially responsible investing (Camey, 1994; Diltz, 1995). New research in the subsequent decade (1996–2005) extended understanding on socially responsible investing in terms of its performance against conventional funds (Guerard & John, 1997; Hutton et al., 1998; Statman, 2000) and the need to expand its scope to account for ethics (Wilson, 1997) and the environment (Heinkel et al., 2001) such as climate change and renewable energy (Van Der Laan & Lansbury, 2004). The later decade (2006–2015) sees the introduction and boom of new research such as carbon finance (Aglietta et al., 2015; Bredin et al., 2014; Purdon, 2015; Yenneti & Gamaralalage, 2012; Yeoh, 2008), climate finance (Brunner & Enting, 2014; Hogarth, 2012; Jakob et al., 2015; Vanderheiden, 2015), conscious capitalism (Sisodia, 2009, 2013; Wang, 2013a, 2013b), ESG-CSR and firm performance integration (Dorflleitner et al., 2015; Eccles & Viviers, 2011; Friede et al., 2015; Halbritter & Dorflleitner, 2015; Himick, 2011; Nielsen & Noergaard, 2011), and ethical investing (Bauer et al., 2007; Belghitar et al., 2014; Chow et al., 2014; Pender & Brocchetto, 2011; Richardson, 2009; Säve-Söderbergh, 2010; von Wallis & Klein, 2015; Watson, 2011). The most recent half decade (2015–2020) is characterized by research responding to the Paris agreement and the launch of the SDGs in 2015, with exponential growth in publications focusing on impact investing (Agrawal & Hockerts, 2019, 2021; Caseau & Grolleau, 2020; Lieberman, 2020; Robb & Sattell, 2016; Viviani & Maurel, 2019) innovative financial instruments such as social impact bonds (Carè et al., 2020; Giacomantonio, 2017; Rizzello & Kabli, 2020; Torre, et al., 2019), and ESG investing and firm performance (Alessandrini & Jondeau, 2020; Chen & Mussalli, 2020; Giese et al., 2019; Landi & Sciarelli, 2019; Schramade, 2016). The summary of the brief evolution of sustainable finance research is presented in Fig. 1, and will be investigated further in the later sections of this study.

Given the burgeoning research on sustainable finance, past researchers have also attempted to review the extant literature in the field. However, in most instances, such reviews were limited to a specific aspect of sustainable finance, and not sustainable finance as a whole. For example, using systematic reviews, researchers have consolidated the extant literature



**Fig. 1** Evolution of sustainable finance research. *CSR* Corporate social responsibility. *ESG* Environmental, social, and governance. *SDG* Sustainable development goals

pertaining to climate finance (Giglio et al., 2020), ESG (Daugaard, 2020; Widyawati, 2020), green finance (Malhotra & Thakur, 2020; Zhang, et al., 2019), impact investing (Clarkin & Cangioni, 2016), and socially responsible investing (Camilleri, 2020; Fabregat-Aibar et al., 2019; Rahman, et al., 2020; Revelli & Viviani, 2015; Viviers & Eccles, 2012), and using bibliometric analysis, researchers such as Bui et al. (2020) have revealed insights on sustainable corporate finance albeit from a small corpus of 227 articles. Apart from Cunha et al. (2021), which is the only and most recent review of sustainable finance prior to the present review, no other review has attempted to review the field as a whole. Yet, as mentioned previously, the review by Cunha et al. (2021) remains limited to a small corpus of 166 articles, and thus, providing a snapshot rather than a state-of-the-art overview of sustainable finance research, wherein the absence and need of the latter to provide a comprehensive stock take of the field motivates the present review, whose methodology will be disclosed in the next section.

### 3 Methodology

This study collects bibliometric data on sustainable finance research for its review. To do so, this study adopts and implements the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol, which consists of three major stages, namely *assembling*, *arranging*, and *assessing* of articles (Paul et al., 2021). The summary of the review procedure is illustrated in Fig. 2.

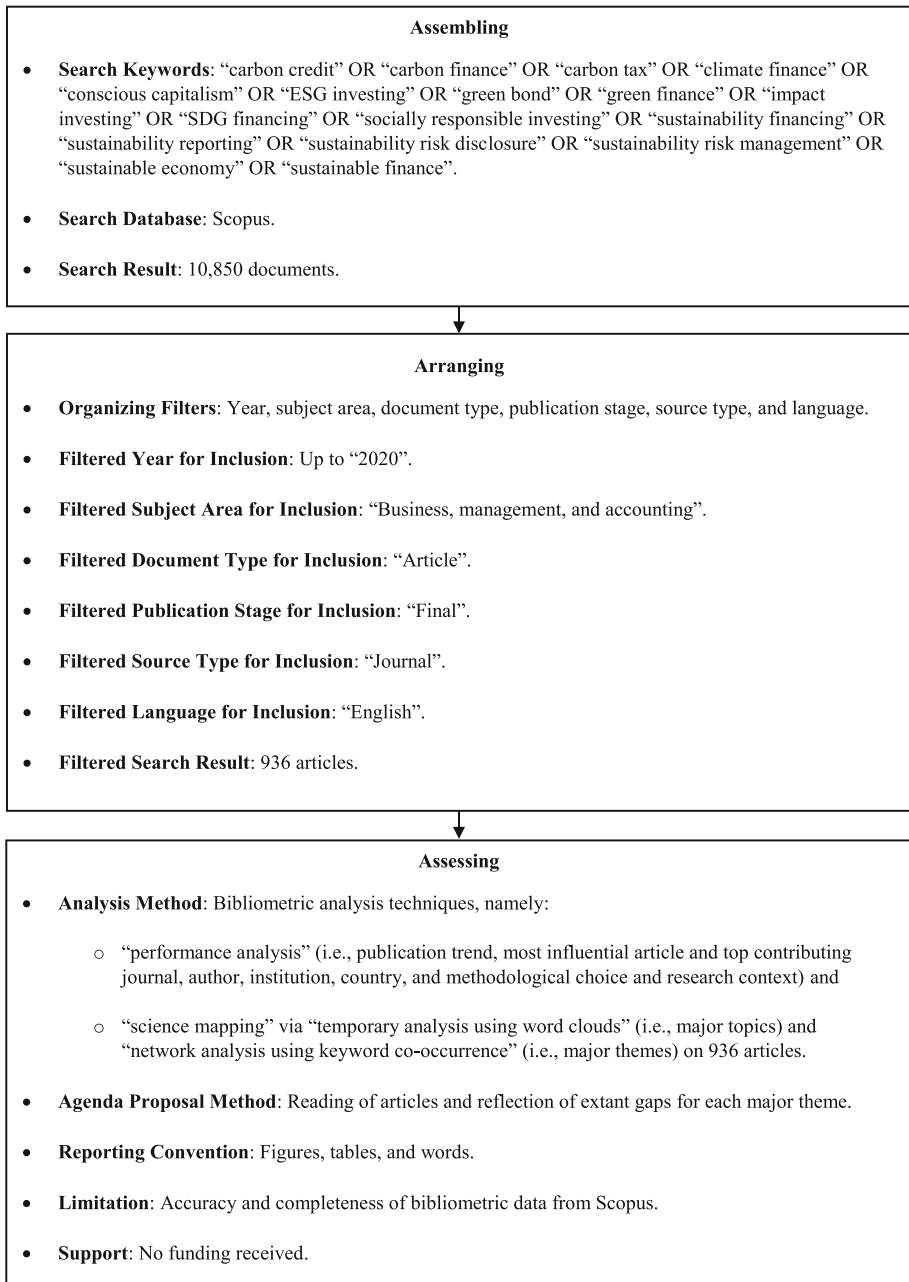


Fig. 2 Systematic review procedure using the SPAR-4-SLR protocol

### 3.1 Assembling

To *assemble* the corpus of articles on sustainable finance, this study identified its *search keywords* relating to sustainable finance from the preliminary review of relevant literature in the previous section and consulted 10 experts to ascertain the suitability of those keywords to represent sustainable finance. This led to a combination of 17 keywords that can be organized into the following search string:

“carbon credit” OR “carbon finance” OR “carbon tax” OR “climate finance” OR “conscious capitalism” OR “ESG investing” OR “green bond” OR “green finance” OR “impact investing” OR “SDG financing” OR “socially responsible investing” OR “sustainability financing” OR “sustainability reporting” OR “sustainability risk disclosure” OR “sustainability risk management” OR “sustainable economy” OR “sustainable finance”

Following the identification of search keywords, this study conducted a search for articles using the aforementioned search string in the “article title, abstract, and keywords” on Scopus, which is the largest high-quality *scientific database* of scholarly articles (Comerio & Strozzi, 2019; Norris & Oppenheim, 2007), and thus chosen over its alternative, Web of Science, which contains less articles for review than Scopus (Paul et al., 2021). In total, 10,850 documents were returned from the search.

### 3.2 Arranging

To *arrange* the corpus of 10,850 articles returned from the assembling stage, this study used the category (code) function in Scopus to review the search results according to *year*, *subject area*, *document type*, *publication stage*, *source type*, and *language*, wherein search results were filtered and limited to “2020”, “business, management, and accounting”, “article”, “final”, “journal”, and “English” in those categories, respectively. These filters were imposed in line with the recommendations of Paul et al. (2021) because 2020 represented the latest full year run; sustainable finance resides within business, management, and accounting; non-articles such as editorials and notes may not be peer reviewed and the inclusion of reviews can lead to double-barreled insights; in-press articles were discarded as they have not been finalized; non-journal sources such as book, book chapter, and conference proceeding were excluded as they may not have undergone rigorous peer review; and non-English articles were not included on the basis of our limited language proficiency in languages other than English. This led to a reduced corpus consisting of 1,530 articles.

Following that, we downloaded and read each article, and eliminated another 594 articles that mentioned the search keywords sparingly. That is to say, the aspects of sustainable finance did not take center stage in the investigation of those articles, resulting in their removal. This led to a final corpus of 936 articles for review, which was confirmed following a random cross-check using other databases such as Google Scholar and publishers website such as Elsevier, Emerald, Sage, Springer, and Taylor and Francis to avoid unintended exclusion of relevant studies in the field (Goyal et al., 2021; Harari et al., 2020; Lim et al., 2021).

### 3.3 Assessing

To *assess* the final corpus of 936 articles on sustainable finance, which is a relatively large corpus, this study adopts a bibliometric analysis approach for its review. In essence, a bibliometric analysis uses quantitative techniques to appraise scientific information of scholarly articles (Donthu et al., 2021a). Noteworthy, systematic reviews using bibliometrics are now a commonplace (Ellegaard & Wallin, 2015), including business in general (Baker et al., 2020; Donthu et al., 2021a; Zupic & Čater, 2015) and finance in particular (Durisin & Puzone, 2009; Linnenluecke et al., 2018; Xu et al., 2018) as a bibliometric analysis can mitigate the potential bias that avail in manual (e.g., error prone) and qualitative (i.e., subjectivity) reviews using quantitative (i.e., objectivity) tools (Broadus, 1987; Burton et al., 2020), especially when the corpus for review is large (high hundreds to thousands of articles) (Donthu et al., 2021a), as in the case of the present review (i.e., 936 articles). Following past reviews (Cobo et al., 2011; Donthu et al., 2020, 2021d; Khan et al., 2021), this study performs a bibliometric analysis using a *performance analysis* to delineate the publication trend, the top articles and contributing journals, authors, institutions, and countries, and the methodological choices and research contexts, and a *science mapping* via a temporal analysis using word clouds (Bastian et al., 2009; van Eck & Waltman, 2017) and a network analysis using keyword co-occurrence (Callon et al., 1983; Castriotta et al., 2019; Donthu et al., 2021a; Newman & Girvan, 2004; Pesta et al., 2018) in VOSviewer (van Eck & Waltman, 2017) to unpack the major themes and topics underpinning the intellectual structure of sustainable finance research. To advance insights in the field, this study curates a future research agenda based on our reading of the articles and reflection of extant gaps under each major theme. The next sections report the findings of the review, wherein narratives are supplemented by figures and tables.

## 4 Findings

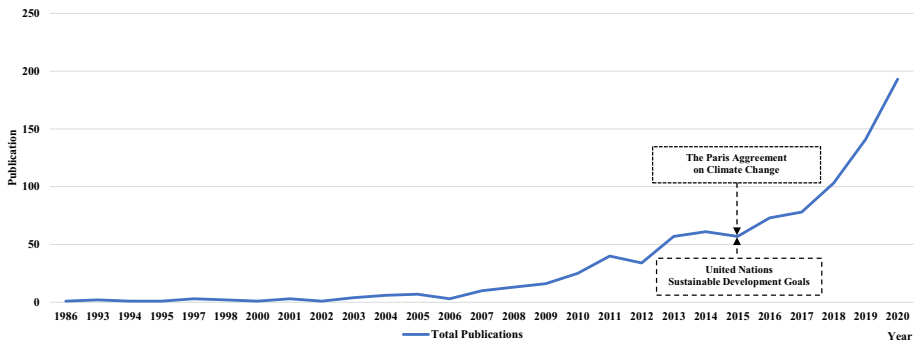
### 4.1 Performance analysis

Performance analysis is a bibliometric analysis technique that describes the performance of a research domain (Donthu et al., 2021a), and in this case, the field of sustainable finance. This analysis is akin to that of the profiling of participants in empirical studies albeit in a more rigorous way through the use of bibliometric metrics (Donthu et al., 2021a). In this study, a performance analysis is conducted to reveal (1) the publication trend, (2) the most influential articles, the top contributing (3) journals, (4) authors, (5) institutions, and (6) countries, and (7) the methodological choices and research contexts of sustainable finance research.

#### 4.1.1 Publication trend for sustainable finance research

The year-wise publication trend of sustainable finance research is presented in Fig. 3. The figure indicates that the first article on sustainable finance published in a journal indexed in Scopus appeared in 1986 (Ferris & Rykaczewski, 1986), and that publications in the field have grown over the last 35 years (1986–2020). With only a single publication in 1986 and single-digit publications in each ensuing year up to 2006, the field of sustainable finance has proliferated considerably in the next 15 years, with a record high of 193 publications in 2020. Noteworthy, an exponential increase in publications is witnessed from 2015 onwards, which is the year when the Paris agreement and the SDGs were signed by United Nations





**Fig. 3** Year-wise publication for sustainable finance research between 1986 and 2020

Member States. This is supported by a detailed scrutiny of the corpus, whereby close to 70% of articles were published between 2015 and 2020, thereby reaffirming 2015 as a landmark year for sustainable finance research.

#### 4.1.2 Most influential articles for sustainable finance research

The most influential articles for sustainable finance research in terms of citations are presented in Table 1. The table indicates that Dedusenko's (2017) article is the most cited article in the field, with an average of 43.67 citations per year and a total of 655 citations since its publication in 2006. This is followed by Viviers, Ractliffe, and Hand's (2011) and Roundy's (2019) articles in *Journal of Banking and Finance* and *Journal of Financial Economics*, which have been cited 500 and 431 times, respectively. Interestingly, the top three most-cited articles in the field are about impact investing, which highlights its prominence influence in the field. Noteworthy, the top 25 most-cited articles in the field have amassed a total of 5970 citations, which reflects the significant influence that sustainable finance research has had in the scientific community.

#### 4.1.3 Top contributing journals for sustainable finance research

The corpus of 936 articles on sustainable finance were published across 416 journals, with Table 2 indicating that the top 24 contributing journals with a minimum of five articles on sustainable finance have published 334 (35.68%) articles in the field. Specifically, the top three most prolific journals are *Sustainability*, *Journal of Business Ethics*, and *Journal of Sustainable Finance and Investment*, with 52, 47, and 42 articles, respectively. However, in terms of influence, *Journal of Business Ethics* leads the pack with 2712 citations, followed by *Journal of Banking and Finance* and *Climate Policy*, with 1422 and 458 citations, respectively. Noteworthy, most of the top contributing journals have an impact factor above one and they are rated favorably (3 and 4) in the Academic Journal Guide by the Chartered Association of Business Schools, which indicates that sustainable finance as an area of research has received attention from some of the best journals in the field.

**Table 1** Most influential articles for sustainable finance research

Author(s)	Article title	Source title	Year	TC	C/Y
Dedusenko E.A.	Impact investing trends in Russia and tourism	<i>Journal of Business Ethics</i>	2006	655	43.67
Viviers S., Ractliffe T., Hand D.	From philanthropy to impact investing: Shifting mindsets in South Africa	<i>Journal of Banking and Finance</i>	2008	500	38.46
Roundy P.T.	Regional differences in impact investment: A theory of impact investing ecosystems	<i>Journal of Financial Economics</i>	2011	431	43.10
Agrawal A., Hockerts K.	Impact investing strategy: Managing conflicts between impact investor and investee social enterprise	<i>Journal of Banking and Finance</i>	2011	383	38.30
Lehner O.M., Harrer T., Quast M.	Building institutional legitimacy in impact investing: Strategies and gaps in financial communication and discourse	<i>Financial Analysts Journal</i>	2005	354	22.13
Kimbu A.N., Tichaawa T.M.	Determinants of impact investing for tourism development in emerging destinations of sub-Saharan Africa	<i>Financial Analysts Journal</i>	2000	340	16.19
Lee M., Adbi A., Singh J.	Categorical cognition and outcome efficiency in impact investing decisions	<i>Journal of Financial and Quantitative Analysis</i>	2001	287	14.35
Novak P.K., Amicis L.D., Mozetič I.	Impact investing market on Twitter: Influential users and communities	<i>Journal of Corporate Finance</i>	2008	268	20.62
Jackson E.T.	Interrogating the theory of change: Evaluating impact investing where it matters most	<i>European Financial Management</i>	2007	260	18.57
Phillips S.D., Johnson B.	Inching to impact: The demand side of social impact investing	<i>Journal of Banking and Finance</i>	2008	236	18.15
Agrawal A., Hockerts K.	Impact investing: Review and research agenda	<i>Journal of Sustainable Finance and Investment</i>	2015	188	31.33
Viviani J.-L., Maurel C.	Performance of impact investing: A value creation approach	<i>Journal of Business Ethics</i>	2004	185	10.88
Jafri J.	When billions meet trillions: Impact investing and shadow banking in Pakistan	<i>Business Strategy and the Environment</i>	2010	180	16.36

**Table 1** (continued)

Author(s)	Article title	Source title	Year	TC	C/Y
Höchstädter A.K., Scheck B.	What's in a name: An analysis of impact investing understandings by academics and practitioners	<i>Journal of Management</i>	2010	172	15.64
Tekula R., Andersen K.	The role of government, nonprofit, and private facilitation of the impact investing marketplace	<i>Accounting, Organizations and Society</i>	1993	172	6.14
León T., Liern V., Pérez-Gladish B.	A multicriteria assessment model for countries' degree of preparedness for successful impact investing	<i>Journal of Business Ethics</i>	2007	159	11.36
Chen S., Harrison R.	Beyond profit vs. purpose: Transactional-relational practices in impact investing	<i>Journal of Management and Governance</i>	2004	152	8.94
Wood D., Thornley B., Grace K.	Institutional impact investing: Practice and policy	<i>Journal of Financial Research</i>	2005	151	9.44
Kappen J., Mitchell M., Chawla K.	Institutionalizing social impact investing: Implications for Islamic finance	<i>Journal of Financial Economics</i>	2012	145	16.11
Wong M.C.S., Yap R.C.Y.	Social impact investing for marginalized communities in Hong Kong: Cases and issues	<i>Journal of Banking and Finance</i>	2011	142	14.20
Jackson E.T.	Evaluating social impact bonds: Questions, challenges, innovations, and possibilities in measuring outcomes in impact investing	<i>Financial Management</i>	2012	130	14.44
Mendell M., Barbosa E.	Impact investing: A preliminary analysis of emergent primary and secondary exchange platforms	<i>Journal of Business Ethics</i>	2008	123	9.46
Espinosa S.	From philanthropy to impact investing: The case of Luxembourg	<i>Management Science</i>	2014	121	17.29
Urban B., George J.	An empirical study on measures relating to impact investing in South Africa	<i>Journal of Business Ethics</i>	2007	120	8.57
Lieberman D.	Impact investing 2.0—not just for do-gooders anymore	<i>Journal of Business Finance and Accounting</i>	2007	116	8.29

TC Total citations, C/Y Average citations per year

**Table 2** Top contributing journals for sustainable finance research

Journal	TP	TC	AJG	IF
<i>Sustainability</i>	52	173	NR	3.251
<i>Journal of Business Ethics</i>	47	2712	3	6.43
<i>Journal of Sustainable Finance and Investment</i>	42	448	1	1.87
<i>Climate Policy</i>	35	458	NR	5.085
<i>Journal of Portfolio Management</i>	16	55	3	0.709
<i>Ecological Economics</i>	11	233	3	5.389
<i>Climate and Development</i>	11	125	NR	4.28
<i>Journal of Banking and Finance</i>	10	1422	3	3.07
<i>Finance Research Letters</i>	10	93	2	5.596
<i>Journal of Cleaner Production</i>	9	54	2	9.297
<i>Research in International Business and Finance</i>	8	96	2	4.091
<i>World Development</i>	8	120	3	5.278
<i>California Management Review</i>	8	76	3	8.836
<i>Journal of Asset Management</i>	7	45	2	0.38
<i>Organization and Environment</i>	7	41	3	6.116
<i>Climatic Change</i>	7	55	NR	4.743
<i>Social Responsibility Journal</i>	7	39	1	3.5
<i>European Journal of Operational Research</i>	7	203	4	5.334
<i>Global Environmental Change</i>	6	128	3	9.523
<i>Corporate Social Responsibility and Environmental Management</i>	6	73	1	8.741
<i>Business Strategy and the Environment</i>	5	246	3	10.302
<i>Economic Modelling</i>	5	68	2	3.127
<i>Global Policy</i>	5	34	NR	2.084
<i>Energy Economics</i>	5	26	3	7.042

TP Total publication, TC Total citation, AJG Academic Journal Guide (AJG) 2021 by Chartered Association of Business Schools (i.e., lowest rating 1/2/3/4/4\* highest rating, NR No rating). IF Impact factor from Journal Citation Report (JCR) 2020 by Web of Science (WOS)

#### 4.1.4 Top contributing authors for sustainable finance research

The top contributing authors for sustainable finance research are presented in Table 3. The table indicates that Scholtens B. from University of Groningen, Netherlands and Cortez M.C. from University of Minho, Portugal are the two most prolific authors in the field with 10 articles each. This is followed by Richardson B.J. from University of British Columbia, United States and Dorfleitner G. from University of Regensburg, Germany with nine and eight articles, respectively. However, the most influential authors are S. Viviers from Stellenbosch University, South Africa and Hockerts K. from Copenhagen Business School, Denmark with 591 and 577 citations, respectively, though the latter ( $TC/TP = 144.28$ ;  $TC/TCP = 192.33$ ) yields a better average return of citations each year than the former ( $TC/TP$  and  $TC/TCP = 118.20$ ). Taken collectively, the top 25 contributing authors for sustainable finance research have contributed a total of 132 (14.10%) articles that have amassed 2127 citations in the field.

**Table 3** Top contributing authors for sustainable finance research

Author	Affiliation and country	TP	TCP	TC	TC/TP	TC/TCP	<i>h</i>
Scholtens B.	University of Groningen, Netherlands	10	7	14	1.40	2.00	2
Cortez M.C.	University of Minho, Portugal	10	7	11	1.10	1.57	1
Richardson B.J.	University of Tasmania, Australia	9	6	48	5.33	8.00	2
Dorffleitner G.	University of Regensburg, Germany	8	6	20	2.50	3.33	3
Pauw P.	German Development Institute, Germany	7	7	112	16.00	16.00	7
Taghizadeh-Hesary F.	Tokai University, Japan	6	4	9	1.50	2.25	2
S. Viviers	Stellenbosch University, South Africa	5	5	591	118.20	118.20	4
J. Timmons Roberts	Brown University, USA	5	5	84	16.80	16.80	5
Revelli C.	Kedge Business School, France	5	5	13	2.60	2.60	2
Utz S.	University of St. Gallen, Switzerland	5	5	10	2.00	2.00	2
C.Walkshäusl	University of Regensburg, Germany	5	2	3	0.60	1.50	1
Derwall J.	Maastricht University, Netherlands	5	2	2	0.40	1.00	1
Hockerts K.	Copenhagen Business School, Denmark	4	3	577	144.25	192.33	3
Geobey S.	University of Waterloo, Canada	4	4	143	35.75	35.75	3
Skovgaard J.	Lund University, Sweden	4	4	109	27.25	27.25	4
Pickering J.	University of Canberra, Australia	4	4	87	21.75	21.75	4
Michaelowa A.	University of Zurich, Switzerland	4	4	82	20.50	20.50	4
Stadelmann M.	University of Zurich, Switzerland	4	4	72	18.00	18.00	4
Urpelainen J.	Johns Hopkins University, USA	4	4	59	14.75	14.75	4

**Table 3** (continued)

Author	Affiliation and country	TP	TCP	TC	TC/TP	TC/TCP	<i>h</i>
Hourcade J.C.	Centre National de la Recherche Scientifique (CNRS), France	4	4	56	14.00	14.00	4
Nguyen M.	University of Regensburg, Germany	4	2	9	2.25	4.50	2
Yoshino N.	Keio University, Japan	4	3	7	1.75	2.33	2
Silva F.	University of Minho, Portugal	4	3	3	0.75	1.00	1
Kabir Hassan M.	University of New Orleans, USA	4	2	3	0.75	1.50	1
Ter Horst J.	Tilburg University, Netherlands	4	3	3	0.75	1.00	1

*TP* Total publication, *TCP* Total cited publication, *TC* Total citations, *TC/TP* Average citations per publication, *TC/TCP* Average citations per cited publication, *h* *h*-index

#### 4.1.5 Top contributing institutions for sustainable finance research

The top contributing institutions for sustainable finance research are presented in Table 4. The table indicates that the most prolific institution in the field is University of Regensburg, Germany with 15 articles, followed by University of Oxford, United Kingdom with 13 articles, and University of British Columbia, Australia and University of California, United States with 12 articles each. However, the most influential institution is Tilburg University, the Netherlands with 1050 citations, followed by University of Mino, Portugal and Maastricht University, the Netherlands with 846 and 698 citations, respectively. Taken collectively, the top 25 contributing institutions for sustainable finance research have contributed a total of 211 (22.54%) articles that have amassed 6439 citations in the field.

#### 4.1.6 Top contributing countries for sustainable finance research

The top contributing countries for sustainable finance research are presented in Table 5. The table indicates that the most prolific country is the United States with 242 articles, followed by the United Kingdom and Germany with 131 and 90 articles, respectively. The United States and the United Kingdom also emerge as the top two most influential countries, with 4,986 and 2,799 citations, respectively, and they are joined by the Netherlands, which is the third most influential country with 2,194 citations. However, Portugal yields the highest average citation of 78.27 for the 13 articles that authors from the country have contributed to the field. While American and European countries dominate the list of the top 25 contributing countries, there is notable representation from African countries such as South Africa, Asian countries such as China and India, and Oceanic countries such as Australia. Despite this representation, only 71 out of 936 articles have drawn samples from African and Asian countries, which shows that the majority of research on sustainable finance continue to be America and Europe focused. Nonetheless, upon detailed scrutiny, we observe that sustainable finance research

**Table 4** Top contributing institutions for sustainable finance research

Institution	TP	TCP	TC	TC/TP	TC/TCP	<i>h</i>
University of Regensburg	15	15	264	17.60	17.60	9
University of Oxford	13	11	264	20.31	24.00	7
University of British Columbia	12	11	428	35.67	38.91	7
University of California	12	11	381	31.75	34.64	6
University of Minho	11	9	846	76.91	94.00	5
University of Groningen	11	10	493	44.82	49.30	8
University of Zurich	10	6	104	10.40	17.33	5
Tilburg University	9	9	1050	116.67	116.67	6
Australian National University	9	6	98	10.89	16.33	4
Griffith University	9	7	86	9.56	12.29	4
German Development Institute	8	6	89	11.13	14.83	5
Harvard University	8	8	66	8.25	8.25	5
Columbia University	8	8	34	4.25	4.25	4
Maastricht University	7	6	698	99.71	116.33	5
York University	7	6	517	73.86	86.17	5
University of Rome	7	4	64	9.14	16.00	3
University of Cambridge	7	4	16	2.29	4.00	2
Pennsylvania State University	6	5	223	37.17	44.60	3
Stockholm Environment Institute	6	5	142	23.67	28.40	5
Carleton University	6	6	129	21.50	21.50	4
Brown University	6	6	116	19.33	19.33	6
University of Waterloo	6	4	102	17.00	25.50	4
Mercator Research Institute	6	6	87	14.50	14.50	5
Potsdam Institute for Climate Impact Research	6	6	79	13.17	13.17	5
University of Queensland	6	5	63	10.50	12.60	4

*TP* Total publication, *TCP* Total cited publication, *TC* Total citations, *TC/TP* Average citations per publication, *TC/TCP* Average citations per cited publication, *h* *h*-index

in African and Asian countries have begun to appear more prominently in the recent decade (2011–2020) (Fonta et al., 2018; Rajan et al., 2014; Urban & George, 2018; Viviers et al., 2011), which should and will likely to continue in the future.

#### 4.1.7 Methodological choices and research contexts for sustainable finance research

The methodological choices (i.e., research approach, research design, data collection technique, and data analysis tool) and research contexts (i.e., industry focus, research focus, and geographical focus) for sustainable finance research are presented in Table 6 across decades and over a cumulative period of 35 years (1986–2020).

Panel A of Table 6 depicts the preference of *research approach* for sustainable finance research. The qualitative approach tops the chart as the most preferred research approach across all decades, with 53% of articles in the field using this research approach. The quantitative approach is the next most preferred research approach, constituting 38% of articles,

**Table 5** Top contributing countries for sustainable finance research

Country	TP	TCP	TC	TC/TP	TC/TCP	<i>h</i>
United States	242	200	4986	20.60	24.93	35
United Kingdom	131	105	2799	21.37	26.66	26
Germany	90	76	1598	17.76	21.03	21
China	74	42	247	3.34	5.88	10
Australia	60	47	537	8.95	11.43	15
Canada	58	53	1892	32.62	35.70	22
Italy	45	32	260	5.78	8.13	9
Spain	44	34	428	9.73	12.59	11
Netherlands	43	36	2194	51.02	60.94	18
India	39	26	229	5.87	8.81	9
France	38	32	571	15.03	17.84	12
Switzerland	31	24	306	9.87	12.75	10
South Africa	30	19	161	5.37	8.47	7
Sweden	24	19	476	19.83	25.05	11
Belgium	20	16	447	22.35	27.94	8
Japan	19	11	138	7.26	12.55	6
Malaysia	19	13	63	3.32	4.85	4
Portugal	13	11	861	66.23	78.27	6
Austria	12	12	443	36.92	36.92	7
South Korea	12	7	174	14.50	24.86	5
Finland	8	5	131	16.38	26.20	4
Hong Kong	8	6	40	5.00	6.67	3
Norway	7	6	38	5.43	6.33	3
Saudi Arabia	7	7	22	3.14	3.14	3

*TP* Total publication, *TCP* Total cited publication, *TC* Total citations, *TC/TP* Average citations per publication, *TC/TCP* Average citations per cited publication, *h* *h*-index

whereas a mixed combination of the two approaches represents only 7.5% of articles in the corpus. Noteworthy, the share of the qualitative approach has been declining while the quantitative approach and the mixed approach have both gained increasing popularity over time, whereby the increased share of the quantitative approach being a reflection of the growing availability and accessibility of sustainable financial data, and the share of the mixed approach being a reflection of the increasing rigor required to publish sustainable finance research over time.

Panel B of Table 6 exhibits the preference of research design for sustainable finance research. The conceptual and empirical research designs were equally preferred in the field's early years (37.03%), though a stronger preference for empirical research designs and a declining preference for conceptual research designs occur over time. There is also a notable increase in review research designs as time passes, which indicates the growing maturity of sustainable finance research given that reviews are a stock take of mature fields of research (Donthu et al., 2021a). The same observation applies for the mixed research design, which is another point to substantial our previous inference that the expectation of rigor in sustainable



**Table 6** Methodological choice and research context for sustainable finance research

Panel and period	1986–1995 (%)	1996–2005 (%)	2006–2015 (%)	2016–2020 (%)	Overall (%)
<i>Panel A: Research approach</i>					
Qualitative	60	59.25	57.59	51.02	53.53
Quantitative	40	37.33	34.81	40.31	38.36
Mixed	0	3.7	7.59	7.65	7.48
<i>Panel B: Research design</i>					
Empirical	40	37.03	40.82	48.13	45.30
Conceptual	60	37.03	28.16	21.60	24.47
Review	0.00	3.70	7.91	8.84	8.33
Modelling	0.00	14.81	4.75	11.90	9.51
Mixed	0.00	11.11	21.84	20.07	20.30
<i>Panel C: Data collection technique</i>					
Case study	20	18.52	17.09	21.09	19.66
Interview	40	11.11	21.20	24.83	23.29
Archival	40	44.44	45.57	46.60	46.15
Survey	0.00	3.70	10.13	8.84	9.08
Laboratory	0.00	0.00	0.63	0.85	0.75
No data collected/reported	0.00	18.52	20.25	9.01	13.03
<i>Panel D: Data analysis technique</i>					
Descriptive	0.00	22.22	26.27	29.93	28.31
Regression	20	14.81	24.05	24.32	23.93
Other	20	0	12.03	9.18	9.94
No data analysis conducted/reported	60	62.9	37.66	36.90	38.03
<i>Panel E: Industry focus</i>					
Services	0.00	18.52	10.76	20.07	16.77
Manufacturing	20	3.70	3.16	4.42	4.06
Both	20	11.11	10.13	8.16	8.97
No specific industry	60	59.26	75.95	67.35	69.98
<i>Panel F: Research focus</i>					
Theory building	0	0.00	0.00	0.34	0.21
Theory verification	0	7.41	5.38	7.31	6.62
Application	100	92.59	94.62	92.35	93.16
<i>Panel G: Geographical focus</i>					
Single Country	100	22.22	22.15	22.11	22.54
Multi Country	0	11.11	6.01	12.07	9.94
Developing Country	0	0.00	7.91	13.10	10.90
Developed Country	100.00	100.00	92.09	86.90	89.10

finance research has increased over time. Nonetheless, interest in modeling research designs fluctuate and continue to remain relatively small.

Panel C of Table 6 illustrates the preference of data collection techniques for sustainable finance research. Noteworthy, archival data is the most preferred data collection technique across all time periods (46.15%), followed by interviews (23.29%) and case studies (19.66%). Surveys account for only 9.08%, whereas laboratory data makes up for only 0.75% of the corpus, which indicates that sustainable finance research have plenty of room to grow using a quantitative approach predicated on primary data. The rest of the 13.03% of the corpus do not utilize any data as they are mainly conceptual articles.

Panel D of Table 6 indicates the preference of data analysis techniques for sustainable finance researcher. Descriptive (28.31%) and regression (23.93%) techniques appear to be most preferred, with a large majority of studies not employing any specific data analysis techniques (38.03%). With regards to the former, we observe that research employing descriptive analysis typically offer basic descriptions of total, percentage, mean, median, and graphical representation of statistics, and advance descriptions using statistical analysis such as frequency analysis, *t*-test, and chi-square test, whereas research using regression analysis usually provide insights from ordinary least squares, logit, probit, panel, and vector-auto regression models. With regards to the latter, the nascent stage of sustainable finance in developing countries, which have yet to integrate sustainable finance in the economy and financial markets, could have led to a dearth of quantitative and statistical data for analysis, and thus, explaining why a large majority of studies do not employ any specific data analysis techniques. The rest of the 9.94% of the corpus have used other data analysis techniques such as CAPM modeling, Carhart modeling, data envelopment analysis, mathematical modeling, and variance-based techniques such as ANOVA, ANCOVA, MANOVA, and MANCOVA.

Panel E of Table 6 presents the industry focus of sustainable finance research. The panel indicates that research in the field have not been very focused to a specific industry as close to 70% of studies have not specified any industry of focus in their articles. Nonetheless, 30% of studies have adopted an industry focus, with services, especially financial services, being a highly popular industry due to the nature of sustainable finance (16.77%). Only 4% of studies have shown a preference for manufacturing, with a special focus given to energy and allied sectors due to the concepts of carbon, climate, and green financing. The rest of the corpus (9%) focus on both services and manufacturing, which have nonetheless been on a declining trend over time, indicating that the differences in each industry may be considerably challenging to be covered in a single study.

Panel F of Table 6 reveals the research focus of sustainable finance research in line with the classification by Gupta et al. (2009). The vast majority (93.2%) of studies in the field have focused on the application of existing concepts in the real-world settings, with few studies building (0.21%) and verifying (6.62%) theories, which signals immense room for theory development and testing to theorize phenomena on sustainable finance beyond the limited re-use of traditional theories such as agency theory, institutional theory, legitimacy theory, modern portfolio theory, resource dependency theory, and stakeholder theory.

Finally, Panel G of Table 6 shows the geographical focus of sustainable finance research. Though most studies have not focused on any specific country (67.52%), those studies that have are often seen focusing on a single country (22.54%) as opposed to multiple countries (9.94%), most of which are of a developed (89.10%) rather than a developing (10.90%) status.

## 4.2 Science mapping

Science mapping is an analysis that uncovers and provides a graphical representation of what knowledge exist and how they are interrelated in a domain (Donthu et al., 2021a), and in this case, sustainable finance research. The science mapping of sustainable finance research is carried out using two bibliometric analysis techniques in VOSviewer, namely a temporal analysis using word clouds to unpack the major topics characterizing sustainable finance research across each time period, and a network analysis using keyword co-occurrence to reveal the major themes underpinning the intellectual structure of sustainable finance research over the last 35 years (1986–2020).

### 4.2.1 Temporal analysis using word clouds for sustainable finance research

The corpus of articles on sustainable finance research was segmented into four time periods: 1986 to 1995, 1996 to 2005, 2006 to 2015, and 2016 to 2020. The major topics in each time period uncovered through a temporal analysis are illustrated through the word clouds in Figs. 4, 5, 6 and 7.

Figure 4 depicts the advent of “socially” “responsible” “investing” in the initial years of sustainable finance research between 1986 and 1995, wherein aspects such as “activities”, “beliefs”, “costs”, “personal” and “private” “portfolio”, “reputation” “management”,

Fig. 4 Sustainable finance research between 1986 and 1995



Fig. 5 Sustainable finance research between 1996 and 2005





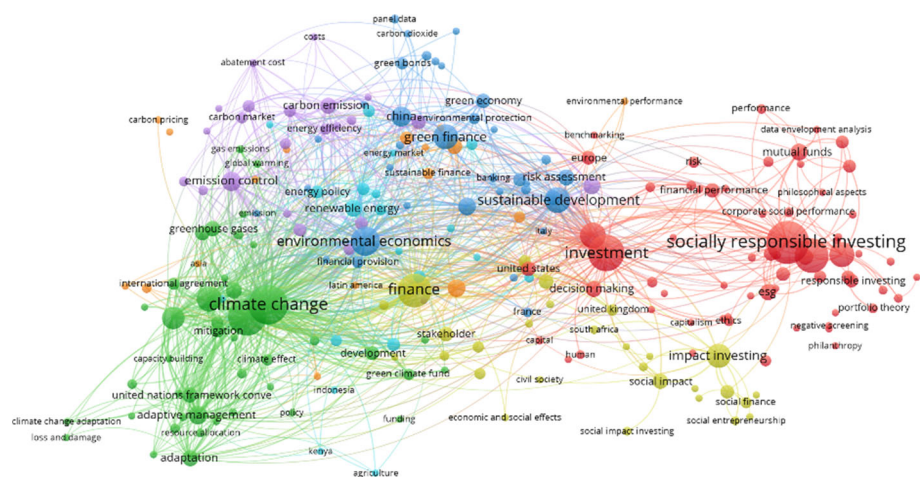
& Dorfleitner, 2015; Jackson, 2013a, 2013b; Mekonnen, 2014; Ryan, 2012; Viviers et al., 2011).

Finally, Fig. 7 indicates that “climate”, “green”, “impact”, and “social” finance and “investment” took center stage between 2016 and 2020 subsequent to the “Paris” agreement and the launch of the SDGs in 2015. Noteworthy, the “study” of sustainable finance in this five-year period has engaged and presented a “case” “analysis” and “evaluation” of the “bond”, “equity”, and “fund” “portfolio” manifested through the aforementioned sustainable finance concepts in tandem with the “adaptation”, “agreement”, “approach”, “change”, “governance”, “model”, “policy”, and “risk” involved, as well as the corresponding “evidence” of the “role” and “impact” of such “investments” among “corporate” “investors” toward “ESG” “performance” and “sustainable” “development”, including in “emerging” and “international” “markets” such as “energy” and “China”, respectively.

#### 4.2.2 Network analysis

Unlike the temporal analysis that employs word clouds and segments the corpus of articles on sustainable finance according to time periods to unpack the temporal evolution of topics in the field, the network analysis uses keyword co-occurrence on the entire corpus to unpack the major themes that characterize the intellectual structure of sustainable finance research since its inception in 1986 up to 2020. In this regard, the network analysis using keyword co-occurrence consolidates a wide range of topics according to thematic similarity, thereby shedding light on the major themes (or knowledge departments) in the field of sustainable finance. The major themes that emerged from the keyword co-occurrences in the network analysis of the entire corpus generated through VOSviewer are illustrated in Fig. 8, whereas the accompanying descriptive is presented in Table 7 and the interrelatedness between themes is reported in Table 8.

In total, the results of the network analysis of keyword co-occurrence presented in Fig. 8 and Table 7 reveal eight major themes pertaining to sustainable finance, namely socially



**Fig. 8** Keyword network of sustainable finance research. Red = socially responsible investing. Green = climate financing. Dark blue = green financing. Yellow = impact investing. Purple = carbon financing. Light blue = energy financing. Orange = governance of sustainable financing and investing. (Color figure online)

**Table 7** Major clusters and keywords for sustainable finance research

Keyword	TO	DC	EC	Keyword	TO	DC	EC
<i>Cluster 1: Socially responsible investing</i>				<i>Cluster 2: Climate financing</i>			
Socially responsible investing	175	120	0.59	Climate change	150	166	0.92
Investment	127	178	0.93	Climate finance	140	157	0.88
Corporate social responsibility	110	94	0.47	Environmental policy	59	126	0.77
Sustainability	65	147	0.81	Developing world	49	110	0.68
Socially responsible investment	61	76	0.37	Adaptive management	34	91	0.58
Mutual funds	27	48	0.30	Adaptation	26	66	0.42
Decision making	25	100	0.62	Developing Countries	25	82	0.54
ESG	25	47	0.23	United Nations Framework Convention on Climate Change	24	72	0.48
Corporate governance	23	34	0.19	Greenhouse gases	23	83	0.58
Financial performance	21	65	0.40	Paris agreement	21	54	0.38
<i>Cluster 3: Green financing</i>				<i>Cluster 4: Impact investing</i>			
Environmental economics	82	165	0.94	Finance	110	188	1.00
Sustainable development	64	143	0.80	Impact Investing	56	69	0.35
Green finance	60	95	0.60	Social Impact	22	55	0.31
China	39	98	0.63	Innovation	21	85	0.53
Financial system	32	02	0.66	Stakeholder	20	67	0.41
Risk assessment	26	87	0.56	Social Enterprise	18	30	0.18
Green economics	21	69	0.48	Strategic Approach	14	65	0.45
Sustainable development goals	21	69	0.45	United Kingdom	13	63	0.39
Market conditions	16	64	0.43	India	12	57	0.36
Financial provisions	14	69	0.43	Political Economy	12	39	0.29
<i>Cluster 5: Carbon financing</i>				<i>Cluster 6: Energy financing</i>			
Emission control	36	102	0.65	Renewable Energy	27	79	0.54
Financial market	28	89	0.56	Private Sector	17	76	0.50
Carbon emission	25	89	0.59	Energy Policy	17	68	0.50
Commerce	20	85	0.57	Alternative Energy	15	82	0.58
Clean development mechanism	17	58	0.42	Financial Services	15	70	0.49
Carbon finance	16	54	0.40	Fossil Fuel	14	65	0.49
Carbon	15	78	0.55	Economic Growth	13	65	0.49

**Table 7** (continued)

Keyword	TO	DC	EC	Keyword	TO	DC	EC
Emissions trading	15	60	0.43	Africa	13	48	0.34
Empirical analysis	13	71	0.49	Environmental Impact	12	71	0.52
Energy efficiency	13	62	0.45	Investment Incentive	10	57	0.39
<i>Cluster 7: Governance of sustainable financing and investing</i>							
Governance approach	30	108	0.67				
Economics	23	88	0.59				
Economic development	17	84	0.57				
Environmental management	13	63	0.45				
Sustainable finance	12	31	0.23				
Redd +	10	32	0.24				
Japan	6	44	0.34				
Environmental planning	6	33	0.26				
Environmental performance	6	32	0.26				
Latin America	6	28	0.23				

TO Total occurrence, DC Degree of centrality, EC Eigenvector centrality, Top keywords with TO  $\geq 6$  are presented for each cluster. Cluster = theme. Keyword = topic

**Table 8** Cluster-to-cluster links and cluster summary of sustainable finance research

From/To	Cluster 1 (%)	Cluster 2 (%)	Cluster 3 (%)	Cluster 4 (%)	Cluster 5 (%)	Cluster 6 (%)	Cluster 7 (%)
Cluster 1	<b>47.12</b>	9.89	13.71	10.38	7.05	6.65	5.19
Cluster 2	9.97	<b>39.34</b>	13.23	8.90	11.13	10.82	6.62
Cluster 3	16.66	15.96	<b>28.89</b>	10.35	12.24	8.68	7.22
Cluster 4	19.58	16.65	16.07	<b>27.78</b>	8.28	6.53	5.10
Cluster 5	12.48	19.54	17.82	7.77	<b>25.90</b>	9.97	6.51
Cluster 6	14.56	23.50	15.63	7.57	12.33	<b>21.94</b>	4.47
Cluster 7	16.79	21.23	19.23	8.75	11.91	6.60	<b>15.49</b>
%K	28.14	18.61	15.15	12.12	9.96	8.66	7.36
%L	42.75	42.43	35.19	22.67	24.17	19.54	13.22

%K = Percentage of total keywords in the network stemming from each cluster. %L = Percentage of total links (within and across clusters) in the network related to each cluster. The figures in bold represent the percentage of total links in the network within each cluster. Cluster 1 = socially responsible investing. Cluster 2 = climate financing. Cluster 3 = green financing. Cluster 4 = impact investing. Cluster 5 = carbon financing. Cluster 6 = energy financing. Cluster 7 = governance of sustainable financing and investing

responsible investing (first and red cluster), climate financing (second and green cluster), green financing (third and dark blue cluster), impact investing (fourth and yellow cluster), carbon financing (fifth and purple cluster), energy financing (sixth and light blue cluster), and governance of sustainable financing and investing (seventh and orange cluster).

The accompanying metrics in Table 7 shed light on the total occurrence (TO) of each keyword or topic, the degree of centrality (DC) measuring the number of connections for each keyword or topic, and the eigenvector centrality (EC) measuring the relative importance of each keyword or topic in terms of its connection to other keywords or topics, wherein keywords or topics with a high number of connections that are also connected to other keywords or topics with such characteristics will receive a higher EC score (Donthu et al., 2021a).

The nature of interrelatedness of each major theme is reported in Table 8, wherein two-way contributions are observed, though the contributions of one way may be notably more than the other way. For example, the table indicates that impact investing (fourth cluster) contributes 19.58% to socially responsible investing (first cluster), whereas the contribution of the opposite is 10.38%. Similarly, the table indicates that energy financing (sixth cluster) and governance of sustainable financing and investing (seventh cluster) contribute 23.50% and 21.23% to climate financing (second cluster), whereas the contributions of the opposite are 10.82% and 6.62%, respectively. Noteworthy, each keyword or topic can be primarily assigned to a major theme or cluster (Total %K = 100%), though their links (relationships) can span across themes or clusters (Total %L > 100%), thereby reflecting both the disciplinary and interdisciplinary nature of research on sustainable finance. The summaries of each major theme or cluster are presented next.

**Cluster 1 (red): socially responsible investing** The largest cluster pertains to socially responsible investing, comprising 28.14% of total keywords and 42.75% of total links in the network of sustainable finance research. The most popular keyword or topic in this cluster is “socially responsible investing”, which appears in 175 articles and is connected to another 120 keywords. Other popular keywords or topics in this cluster that are researched in conjunction with socially responsible investing include “investment”, “corporate social responsibility”, “sustainability”, “socially responsible investment”, “mutual funds”, “decision making”, “ESG”, “corporate governance”, and “financial performance”. Under this cluster, researchers have explained the performance of socially responsible funds and their outperformance over regular mutual funds (Jafri, 2019), the ethical requirements to fulfill social responsible investing (von Wallis & Klein, 2015), and how ESG scores can enhance investment decision making (Chow et al., 2014), among others.

**Cluster 2 (green): climate financing** The second largest cluster relates to climate financing, consisting of 18.61% of total keywords and 42.43% of total links in the network of sustainable finance research. The most popular keyword or topic on climate financing is “climate change”, which appears in 150 articles and is connected to another 166 keywords or topics. Other popular keywords or topics in this cluster that are researched in conjunction with climate financing include “environmental policy”, “developing world”, “adaptive management”, the “United Nations Framework Convention on Climate Change”, “greenhouse gases” and the “Paris Agreement”. Under this cluster, researchers have focused on the effects of climate change and the need for climate financing to mitigate greenhouse gases contributing to climate change in line with transnational agreements and frameworks (Dam & Scholtens, 2015; Gutiérrez & Gutiérrez, 2019; Ibrahim et al., 2016; Skovgaard, 2015), among others.



**Cluster 3 (dark blue): green financing** The third largest cluster pertains to green financing, containing 15.15% of total keywords and 35.19% of total links in the network of sustainable finance research. The most popular keyword or topic on green financing is “environmental economics”, which appears in 82 articles and is connected to another 165 keywords. Other popular keywords or topics in this cluster that are researched in conjunction with green financing include “sustainable development”, “China”, “financial system”, “risk assessment”, “green economies”, “sustainable development goals”, “market conditions”, and “financial provisions”. Under this cluster, researchers have highlighted the promise of environmental protection through green finance and policies (Tan et al., 2017), as well as the contributions of green bonds and hybrid innovative instruments toward achieving the sustainable development goals (Alessandrini & Jondeau, 2020; Muhamat et al., 2017; Vazquez & Chin, 2019), among others.

**Cluster 4 (yellow): impact investing** The fourth largest cluster relates to impact investing, encapsulating 12.12% of total keywords and 22.67% of total links in the network of sustainable finance research. The most popular keyword or topic in this cluster is “finance”, which appears in 110 articles and is connected to another 188 keywords, followed by “impact investing”, which appears in 56 articles and is connected to another 69 keywords. Other popular keywords or topics in this cluster that are researched in conjunction with impact investing include “social impact”, “innovation”, “stakeholder”, “social enterprise”, “strategic approach”, “United Kingdom”, “India”, and “political economy”. Under this cluster researchers have demonstrated how social enterprises and social entrepreneurship engage in social impact investments and innovations through social impact bonds and hybrid instruments (Abadie et al., 2013; Richardson, 2014; Roehrer & Kouadio, 2015), as well as business models for sustainability for impact investing and social impact bonds (Malhotra & Thakur, 2020), among others.

**Cluster 5 (purple): carbon financing** The fifth largest cluster pertains to carbon financing, including 9.96% of total keywords and 24.17% of total links in the network of sustainable finance research. The most popular keyword or topic on carbon financing is “emission control”, which appears in 36 articles and is connected to another 102 keywords or topics. Other popular keywords or topics in the cluster that are researched in conjunction with carbon financing include “financial market”, “carbon emission”, “commerce”, “clean development mechanism”, “carbon”, “emissions trading”, “empirical analysis”, and “energy efficiency”. Under this cluster, researchers discuss the feasibility and implementation of carbon finance (Pinsky et al., 2019), the carbon market crisis and clean development mechanism required for adapting funds and emissions trading (Harmeling & Kaloga, 2011) in international markets (Lesser et al., 2014), and the societal perceptions of socially responsible financing, including that emerging from carbon financing, for sustainable development (Escrig-Olmedo et al., 2013), among others.

**Cluster 6 (light blue): energy financing** The sixth largest cluster relates to energy financing, which is made up of 8.66% of total keywords and 19.54% of total links in the network of sustainable finance research. The most popular keyword or topic on energy financing is “renewable energy”, which appears in 27 articles and is connected to another 79 keywords. Other important keywords or topics in the cluster that are researched in conjunction with energy financing include “private sector”, “energy policy”, “alternative energy”, “financial services”, “fossil fuel”, “economic growth”, “Africa”, “environmental impact”, and “investment incentive”. Under this cluster, researchers have shed light on impact investment options

that include energy finance focusing on alternative and renewable energy (Geobey & Callahan, 2017; Marti, 2013), including in developing economies such as the Middle East (Sisodia et al., 2020), among others.

**Cluster 7 (orange): governance of sustainable financing and investing** The seventh largest cluster pertains to governance of sustainable financing and investing, which represents 7.36% of total keywords and 13.22% of total links in the network of sustainable finance research. The most popular keyword or topic in this cluster is “governance approach”, which appears in 30 articles and is connected to another 108 keywords. Other important keywords or topics in the cluster that are researched in conjunction with governance of sustainable financing and investing include “economics”, “economic development”, “environmental management”, “REDD+”, “Japan”, “environmental planning”, “environmental performance”, and “Latin America”. Under this cluster, researchers have focused on the alignment of global financial markets with the Paris agreement (Thomä et al., 2019), economic development through sustainable finance (Pinsky et al., 2020), and sustainable financing instruments for sustainable development (Zhang et al., 2020). For example, Thomä et al. (2019) explored a common set of accounting principles to be utilized for the alignment of equity and bond asset classes and multiple stakeholders towards the Paris agreement, whereas Pinsky et al. (2020) shed light on the governance process of REDD+ and performance-based mechanisms to incentive developing countries to engage in sustainable finance.

## 5 Forging the way forward

Sustainable finance has been and will continue to remain relevant for business schools, financial institutions, financial markets, and regulators. Noteworthy, both developed and developing countries are increasingly seen to be mandating SDG attainments through sustainable finance such as carbon, climate, and green financing (Dikau & Volz, 2021; Elavarasan et al., 2021; Taghizadeh-Hesary & Yoshino, 2019), whose importance are likely to magnify post the COVID-19 pandemic because of the setbacks that the pandemic has inflicted on the world’s progress toward the agenda of greater sustainability (United Nations, 2021). Besides that, financial markets are always on the lookout for innovative sustainable finance instruments that they can opportunistically leverage to meet economic demands whilst making impactful contributions toward sustainability and sustainable development, especially with regards to the attainment of the SDGs and the reduction of carbon footprint in accordance with the Paris agreement (Muganyi et al., 2021; Yu et al., 2021). Similarly, investors today are showing greater interest in ESG and socially responsible investment funds, giving directives to fund managers to screen and pursue funds for impact investing (Alda, 2020, 2021; Chen et al., 2021; Joliet & Titova, 2018; Yesuf & Aassouli, 2020). Taken collectively, a continuous stream of new insights is thus required to ignite and satisfy evolving demands for sustainable finance.

With the growth in the body of knowledge and the availability of data on transactions specific to sustainable finance, future researchers can expect to be in a much more privilege position as compared to past researchers when they examine the direct and indirect causes and effects of myriad aspects of sustainable finance, especially in terms of its performance and return (Chen & Ma, 2021; Kling et al., 2021; Tian & Lin, 2019; Yao et al., 2021; Zhang, 2021). Indeed, the growing interest in sustainable finance has been evidenced in this review through the notable increase in the number of related research articles over the years, as well

as the increased participation of investors and regulators in the field (Li et al., 2020; Schulz et al., 2020). More importantly, our reading of the articles and reflection of extant gaps under each major theme have led to several suggestions that should pave the way forward for future research to pollinate the field of sustainable finance in meaningful ways. Specifically, we observe that the major themes in the existing corpus have largely focused on the different types of sustainable finance (e.g., socially responsible investing, climate financing, green financing, impact investing, carbon financing, and energy financing), with the theme of governance being the noteworthy exception. While concepts such as green financing, carbon financing, and energy financing appear to be relatively similar at first glance, they can be differentiated through their research focus: green financing concentrates on increasing the financial flow (e.g., banking, micro-credit, insurance, and investment) across sectors (e.g., public, private, and not-for-profit) to sustainable development priorities more broadly, whereas carbon and energy financing focus on doing the same but for sustainable development priorities specific to carbon emission (e.g., greenhouse effects) and energy (e.g., renewable energy), respectively. We also realize that the major themes are interrelated and can therefore affect one another. In light of our learning of the field's composition and trajectory, we have deliberately decided to curate a future research agenda based on our reflection of the commonalities in the extant gaps and future research directions that we found from literature published within the last five years (2016–2020) that remain relatively underexplored, a summary of which we present in Table 9 and discuss in the next sections.

## 5.1 Developing and diffusing innovative sustainable financing instruments

The necessity for innovative financing instruments that can mobilize funds toward sustainable development has increased for both developed and developing economies as a result of the COVID-19 pandemic, an unprecedented global catastrophe that has reversed much of the world's progress in sustainability (United Nations, 2021). Though many researchers are addressing this need through studies on socially responsible investing, climate financing, green financing, impact investing, carbon financing, and energy financing, most results remain inconclusive as the field continues to provide limited insights on broad range of financial markets, especially emerging financial markets other than China (Ari & Koc, 2021; Sinha et al., 2021). Some researchers have reasoned that funding for sustainable finance and sustainable development continues to be developing, and thus, more empirical evidence in both established and emerging markets is needed (Clark et al., 2018). Noteworthy, venture capital investments play a pivotal role to propel innovation in sustainable financing and impact investing given the magnitude of funds that they make available, as seen through financial markets such as China, where government interventions and market forces have encouraged such investments in ways that lead to cleaner and sustainable environments (Chen et al., 2021). Moreover, the issuance of innovative sustainable financing instruments can assist firms in attaining stock liquidity (e.g., the issuance of green bonds affects stock prices positively), yet limited issuance of such instruments exist in emerging financial markets such as India (Tang & Zhang, 2020). More importantly, innovative sustainable financing instruments can only become popular in financial markets if they are supported by formal and information institutions as they play an important role to increase its supply as well as consumer and corporate investors' awareness, understanding, and demand of the benefits and costs of such financing and investing options in financial markets (Cui et al., 2020). Therefore, we propose five research questions to enrich understanding and prescription of innovative sustainable

**Table 9** Future research agenda for sustainable finance research

Future research	Research questions	Supporting source
Developing and diffusing Innovative sustainable financing instruments	<p>What value do innovative sustainable financing instruments offer, and how can such value be improved or sustained?</p> <p>To what extent are innovative sustainable financing instruments feasible for adoption and implementation in emerging markets, and what actions can be taken to improve feasibility?</p> <p>To what extent are innovative sustainable financing instruments linked with investors preference, and what actions can be taken to improve that link?</p> <p>To what extent are innovative sustainable financing instruments successful in meeting their objectives, and what actions can be taken to improve or sustain success?</p> <p>How can formal and informal institutions curate, influence, and shape innovative sustainable financing instruments?</p>	Clark et al. (2018), Chen et al. (2019), Tang and Zhang (2020) and Cui et al. (2020)
Magnifying and Managing the Profitability and Returns of Sustainable Financing	<p>What are the benefits, costs, opportunities, and threats of sustainable financing across markets?</p> <p>How can the benefits, costs, opportunities, threats, and ways forward for sustainable financing be conceptualized in and managed through an operational framework that accounts for and speaks to myriad stakeholders (investors, institutions, regulators)?</p>	Fu et al. (2020), Geczy et al. (2021), Kollenda (2021) and Cao et al. (2021)
Making Sustainable Finance more Sustainable	<p>To what extent does investing in sustainable funds lead to sustainable returns, and how can it be improved or sustained?</p> <p>To what extent does sustainable finance enable firms to avoid controversy related to ESG, and how can it be improved or sustained?</p> <p>To what extent are sustainable funds sustainable before, during, and after crises such as the COVID-19 pandemic?</p>	Popescu et al. (2021), Dorfleitner et al. (2021) and Quatrini (2021)

Table 9 (continued)

Future research	Research questions	Supporting source
Devising and Unifying Policies and Frameworks for Sustainable Finance	<p>What is the role and impact of regulators and financial institutions on sustainable finance (e.g., availability and performance of sustainable funds and instruments)?</p> <p>How can policies and frameworks for sustainable finance be developed and unified within and across markets?</p>	<p>Ng (2018), Taghizadeh-Hesary and Yoshino (2019), Elavarasan et al. (2021), Dikau and Volz (2021), Li et al. (2020) and Jan et al. (2021)</p>
Tackling Greenwashing of Corporate Sustainability Reporting in Sustainable Finance	<p>To what extent do firms engage in greenwashing of sustainability reports, and how can this be discouraged or mitigated?</p> <p>To what extent do firms engage in sustainable finance to manipulate traditional financial performance measures, and how can this be discouraged or mitigated?</p> <p>To what extent do firms engage in earnings manipulation with funds from sustainable financing, and how can this be discouraged or mitigated?</p> <p>In which markets do greenwashing of sustainability reports more or less prominent, and what can we learn from the latter and to what extent will it work for the former?</p>	<p>Garcia et al. (2017), Rezaee and Tuo (2017), Yu et al. (2020), Chen and Yang (2020), Huang (2020), Arouri et al. (2021), Uyar et al. (2020) and Sun and Zhang (2019)</p>
Shining Behavioral Finance on Sustainable Finance	<p>How do investors benefit from sustainable finance?</p> <p>How do investors perceive sustainable finance?</p> <p>What is the role of personality and behavioral biases of investors while selecting impact investing-based funds over conventional funds?</p>	<p>Dam and Scholtens (2015), Chatzitheodorou et al. (2019), Cerqueti (2021), Behl et al. (2021) and Bofinger (2021)</p>

Table 9 (continued)

Future research	Research questions	Supporting source
Leveraging the Power of New-age Technologies for Sustainable Finance	<p>How can artificial intelligence and machine learning be applied to screen credit applicants and monitor credit users of sustainable financing (e.g., financial distress prediction, credit scoring, corporate insolvency prediction, credit card anomalies detection, fraudulent financial statement detection)?</p> <p>How can blockchain and machine learning be applied to track and flag impact concerns or successes in the activities of sustainable financing (e.g., carbon, climate, and energy financing) on sustainability goals (e.g., SDGs)?</p> <p>How can big data analytics and machine learning be applied to acquire knowledge about public sentiments about sustainability issues, and how can sustainable finance providers automate the incorporation of that knowledge in the evaluation and provision of sustainable financing using sustainable alternatives powered by new-age technologies such as artificial intelligence and cloud computing?</p> <p>How can cybersecurity and machine learning be applied to create a safe, secure, and trusted marketplace for sustainable finance?</p> <p>How can machine learning be developed and deployed in ways that detect and prevent algorithmic bias for sustainable finance?</p> <p>How can new-age technologies such as artificial intelligence, blockchain, big data analytics, cloud computing, and machine learning be integrated in tandem with cybersecurity to achieve operational and impact excellence for sustainable finance, and how can the enablers and barriers to this integration be leveraged and resolved, respectively?</p> <p>How can firms leverage on new-age technologies such as artificial intelligence, blockchain, big data analytics, cloud computing, and machine learning develop or adapt sustainable financing operations and instruments in innovative, smart, and agile ways?</p>	Akter et al. (2020), Gupta et al. (2020) and Hassan and Abedin (2021)

financing instruments, which can be applied to the existing ones discovered through our review or to propel the development of newer ones moving forward:

- What value do innovative sustainable financing instruments offer, and how can such value be improved or sustained?
- To what extent are innovative sustainable financing instruments feasible for adoption and implementation in emerging markets, and what actions can be taken to improve feasibility?
- To what extent are innovative sustainable financing instruments linked with investors preference, and what actions can be taken to improve that link?
- To what extent are innovative sustainable financing instruments successful in meeting their objectives, and what actions can be taken to improve or sustain success?
- How can formal and informal institutions curate, influence, and shape innovative sustainable financing instruments?

## **5.2 Magnifying and managing the profitability and returns of sustainable financing**

The performance cost of sustainable financing can be managed through optimal adjustments of portfolios (Fu et al., 2020). However, the same may not be possible across all markets due to the limitations of available investment avenue sets and tied rewards with impact (Geczy et al., 2021). The intermediation cost is also higher for sustainable financing than traditional financing as on the one hand firms in low-income countries with social impact do not have access to funds (World Bank Enterprise Survey, 2017) while on the other hand many investors in high-income countries are unable to find the right cause to invest (Kollenda, 2021). Moreover, it was found that the finance cost of green bonds is no less than non-green bonds in China (Cao et al., 2021). Therefore, future research needs to offer new ways to manage the profitability and returns of sustainable financing in lucrative and sensible ways, as summarized through the following research questions:

- What are the benefits, costs, opportunities, and threats of sustainable financing across markets?
- How can the benefits, costs, opportunities, threats, and ways forward for sustainable financing be conceptualized in and managed through an operational framework that accounts for and speaks to myriad stakeholders (investors, institutions, regulators)?

## **5.3 Making sustainable finance more sustainable**

Assessing the sustainability of sustainable finance and rewards of impact investing is difficult. Investors also often demand non-financial performance metrics for such investments, with carbon footprints, exposure metrics, and ESG ratings gaining popularity despite their inherent limitations and shortcomings (Popescu et al., 2021). Dorfleitner et al. (2021) found most of socially responsible funds in the United States to be marred by persistent ESG controversies, which have led to calls by scholars such as Quatrini (2021) for mechanisms and strategies to address the existing flaws in the assessment of sustainable investments, which is both important and urgent to accelerate the world's recovery from the aftermath of the devastating effects of the COVID-19 pandemic on the progress of sustainability (United Nations, 2021). Therefore, we encourage future research to pursue three research questions that should make sustainable finance more sustainable:

- To what extent does investing in sustainable funds lead to sustainable returns, and how can it be improved or sustained?

- To what extent does sustainable finance enable firms to avoid controversy related to ESG, and how can it be improved or sustained?
- To what extent are sustainable funds sustainable before, during, and after crises such as the COVID-19 pandemic?

#### 5.4 Devising and unifying policies and frameworks for sustainable finance

Regulators and financial institutions are pushing forth the sustainable finance agenda to attain the SDGs across markets (Dikau & Volz, 2021; Elavarasan et al., 2021; Taghizadeh-Hesary & Yoshino, 2019). Past research has indicated that the integration of green financial systems in traditional financial system can lead to sustainability controls and cleaner production (Ng, 2018), and that the incorporation of green governance structures can assist in lower financing constraints (Li et al., 2020), which suggest that regulators and financial institutions need to set up sustainability performance policies and frameworks (Jan et al., 2021). Yet, myriad policies and frameworks exist within and across markets, wherein such inconsistencies or non-complementariness can hinder the potential of sustainable finance. Hence, it is important to understand the role of regulators and financial institutions in sustainable finance, and crucial to that understanding is the development and unifying of policies and frameworks that communicates a common and mutual language, which are noteworthy directions for future research that we summarized through the following research questions:

- What is the role and impact of regulators and financial institutions on sustainable finance (e.g., availability and performance of sustainable funds and instruments)?
- How can policies and frameworks for sustainable finance be developed and unified within and across markets?

#### 5.5 Tackling greenwashing of corporate sustainability reporting in sustainable finance

While earlier studies focused on the positive signals of ESG and impact investing on firm performance and concluded strong evidences of higher financial performance (Garcia et al., 2017; Rezaee & Tuo, 2017), recent studies have started questioning the quality of corporate sustainability reporting metrics and provided strong evidences of greenwashing of sustainability reports across markets (Arouri et al., 2021; Chen & Yang, 2020; Huang, 2020; Yu et al., 2020), with few studies rejecting greenwashing tendency of firms across sectors and markets (Uyar et al., 2020). Government regulations in the form of penalties and tax subsidies have nonetheless been evidenced to be effective to mitigate greenwashing in China (Sun & Zhang, 2019). Nonetheless, the evidence that avail remains inconclusive and limited, thereby suggesting potential for future research, especially across markets. Therefore, we propose the following research questions for future undertaking:

- To what extent do firms engage in greenwashing of sustainability reports, and how can this be discouraged or mitigated?
- To what extent do firms engage in sustainable finance to manipulate traditional financial performance measures, and how can this be discouraged or mitigated?
- To what extent do firms engage in earnings manipulation with funds from sustainable financing, and how can this be discouraged or mitigated?
- In which markets do greenwashing of sustainability reports more or less prominent, and what can we learn from the latter and to what extent will it work for the former?



## 5.6 Shining behavioral finance on sustainable finance

In the American and European stock markets, socially responsible investing is associated with large firms and abnormal returns (Mollet & Ziegler, 2014), with many socially responsible investors willing to forgo financial performance to pursue ethical or social objectives (Renneboog et al., 2008). Most scholars focus on the comparative performance between socially responsible funds and traditional funds along with associated screening and evaluation criteria (Chatzitheodorou et al., 2019), with studies showing better performance of socially responsible funds over traditional funds (Pedersen et al., 2020), higher market-to-book ratios and higher return on assets for socially responsible investors (Dam & Scholtens, 2015), and an opportunity to reduce systematic risk for investors (Cerqueti, 2021; Behl et al., 2021). However, little is known about the actual perceptions and behaviors toward sustainable finance, including that of and beyond socially responsible investing, which may be due to the lack of quantitative and survey social science-oriented research in sustainable finance. This is particularly important given that the outperformance of sustainable finance may not necessarily continue in the long run due to the external shocks such as the COVID-19 pandemic, the increasing awareness of greenwashing of sustainability reports, and the overpricing such stocks (Bofinger, 2021). In this regard, we call for additional research that seeks to shine a behavioral finance light in this direction through the following research questions:

- How do investors benefit from sustainable finance?
- How do investors perceive sustainable finance?
- What is the role of personality and behavioral biases of investors while selecting impact investing-based funds over conventional funds?

## 5.7 Leveraging the power of new-age technologies for sustainable finance

Last but not least, in our final reflection of this review, we stumbled upon the greatly astonishing state of sustainable finance, wherein the application and discussion of new-age technologies in sustainable finance research is almost virtually non-existent despite its omnipresence in other fields such as business sustainability (Sivarajah et al., 2020), sustainable automotive (Kamble et al., 2021) and humanitarian supply chain (Bag et al., 2020), sustainable logistics service quality (Gupta et al., 2021), and sustainability marketing (Bolton, 2021). In essence, new-age technologies refer to new technologies that emerge as new industrial revolutions surface, with technologies such as artificial intelligence, blockchain, internet of things, and machine learning being born out of the recent fourth industrial revolution (IR4.0) (Gupta et al., 2020). Noteworthy, IR4.0 is characterized as an era of digital transformation, which holds great potential for sustainability (Roblek et al., 2020). In fact, new solutions to get the world's progress on sustainability back on track has never been greater given that the COVID-19 pandemic has reversed years of existing progress (United Nations, 2021), and we opine that future research that explains how new-age technologies can be applied to sustainable finance can make significant contributions to the world's recovery and prosperity in the post-pandemic era, a contention that is supported by the central role that finance plays in funding digital transformation (Akter et al., 2020) and sustainability endeavors Cunha et al. (2021). In this regard, we call for new research that deliberately ignites and proliferates insights on the application of new-age technologies for sustainable finance through the following research questions:

- How can artificial intelligence and machine learning be applied to screen credit applicants and monitor credit users of sustainable financing (e.g., financial distress prediction,

credit scoring, corporate insolvency prediction, credit card anomalies detection, fraudulent financial statement detection)?

- How can blockchain and machine learning be applied to track and flag impact concerns or successes in the activities of sustainable financing (e.g., carbon, climate, and energy financing) on sustainability goals (e.g., SDGs)?
- How can big data analytics and machine learning be applied to acquire knowledge about public sentiments about sustainability issues, and how can sustainable finance providers automate the incorporation of that knowledge in the evaluation and provision of sustainable financing using sustainable alternatives powered by new-age technologies such as artificial intelligence and cloud computing?
- How can cybersecurity and machine learning be applied to create a safe, secure, and trusted marketplace for sustainable finance?
- How can machine learning be developed and deployed in ways that detect and prevent algorithmic bias for sustainable finance?
- How can new-age technologies such as artificial intelligence, blockchain, big data analytics, cloud computing, and machine learning be integrated in tandem with cybersecurity to achieve operational and impact excellence for sustainable finance, and how can the enablers and barriers to this integration be leveraged and resolved, respectively?
- How can firms leverage on new-age technologies such as artificial intelligence, blockchain, big data analytics, cloud computing, and machine learning develop or adapt sustainable financing operations and instruments in innovative, smart, and agile ways?

## 6 Conclusion

This study follows a systematic literature review approach using bibliometric analysis to shed light on the performance and science of sustainable finance research. This approach, which exemplifies the use of big data analytics through machine learning of scholarly research, is especially noteworthy given the astonishing absence of the application and discussion of new-age technologies in sustainable finance research. In doing so, this study contributes in a novel way by leveraging on the power of big data analytics through machine learning—and providing greater visibility to it in the process—to uncover the most influential articles and top contributing journals, authors, institutions, and countries, as well as the methodological choices and research contexts, and by revealing the temporal evolution of topics and the major themes underpinning the intellectual structure for sustainable finance research. To this end, we summarize five key takeaways and their equivalent implications from this state-of-the-art review of 936 articles on sustainable finance over the last 35 years (1986–2020).

First, the performance analysis indicates a consistent growth in publications in the field following the Paris agreement and the launch of the SDGs. Most publications came from authors and institutions in the United States and the United Kingdom as these countries have adopted sustainable finance frameworks and engaging in socially responsible investing much earlier than other developed and developing countries. In this regard, sustainable finance research should expand to underrepresented countries where sustainable finance is gaining momentum (e.g., Africa, Australia, Japan, Malaysia, and Singapore).

Second, the performance analysis also reveals that qualitative research is most prominent in sustainable finance due to the nascent stage of its adoption in most countries and thus the lack of cases and data points required for quantitative research, and that most researchers preferred archival data, with few opting to pursue experiments and surveys. In this regard, it

may be worthwhile for sustainable finance research to pursue the latter two data collection techniques that remain underutilized due to their potential to measure chronic and primed responses (Lim, 2015, 2021; Lim et al., 2019) among potential stakeholders of sustainable finance, thereby curating equally interesting cause-and-effect insights on its feasibility and market reaction prior to its start up or scale up.

Third, the performance analysis also shows that most studies are application oriented where the aim is to develop policies and frameworks for specific contexts rather than to build and test theories, that most studies focus on single country data where earlier studies concentrate on developed economies such as Europe, the United States, and the United Kingdom and more recent studies coming from emerging economies such as Asia, Africa, and Oceania, and that most studies are inclined toward the service sector, specifically financial services. Therefore, we encourage prospective researchers to proactively view these gaps as opportunities for making new and novel contributions to the enrich and extend understanding of sustainable finance.

Fourth, the science mapping through a temporal analysis reveals that sustainable finance research has contributed myriad insights overtime starting with a single focus on socially responsible investing (1986 onwards) and branching out progressively to other areas such as ethical and green financing and ethical investing (1995 onwards), carbon financing, climate financing, conscious capitalism, CSR, and ESG (2005 onwards), and more recently, impact investing, innovative financial instrument, and SDG (2015 onwards). Noteworthy, the field of sustainable finance will only grow larger in the future, with new innovative sustainable financing instruments being developed over time—as seen through the rise of carbon and climate financing—to shape and satisfy the demands of funding for sustainability and sustainability development.

Fifth, the science mapping through a network analysis of keyword co-occurrence unveils seven major themes that characterize the body of knowledge or the intellectual structure of sustainable finance research, namely socially responsible investing, climate financing, green financing, impact investing, carbon financing, energy financing, and governance of sustainable financing and investing. We observe that six out of seven major themes relate to the types of sustainable finance, with governance being a unique theme on its own. Noteworthy, our reading of the articles and reflection of the extant gaps under each major theme brought us to several underexplored or underrepresented issues that future research can take up to enrich the major themes in sustainable finance research, which include developing and diffusing innovative sustainable financing instruments, magnifying and managing the profitability and returns of sustainable financing, making sustainable finance more sustainable, devising and unifying policies and frameworks for sustainable finance, tackling greenwashing of corporate sustainability reporting in sustainable finance, shining behavioral finance on sustainable finance, and leveraging the power of new-age technologies for sustainable finance.

Notwithstanding the extant contributions from this seminal state-of-the-art review of sustainable finance research, we concede that our review remains limited in several ways. First, our review is limited to the accuracy and completeness of articles made available through the Scopus database. Nonetheless, we have taken due diligence to correct for erroneous entries and to cross-check against publisher websites and other databases to mitigate this limitation. Second, our review provides only a broad overview of the performance and intellectual structure of sustainable finance research. Though this is in line with the goal and value of systematic literature reviews using a bibliometric analysis, wherein large-scale reviews become pragmatically possible, we concede that this approach falls short of providing finer-grained insights into other deserving and interesting peculiarities such as the factors (independent, mediating, moderating, dependent) and relationships (positive, negative, linear, curvilinear)

that may entail in sustainable finance. In this regard, we encourage future reviews using alternative approaches such as a framework- or theory-based review on sustainable finance, though such reviews do not necessarily need to be large scale—they can be pursued on a smaller scale (e.g., tens to low hundreds of articles) so that the review remains pragmatic and manageable, as in the case of Cunha et al. (2021).

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