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How does finance impact the environment? A systematic literature review of state-of-the-art knowledge

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Declaration

I, Tora Lindheim, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..

Date…………………………………………

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Abstract

Financial systems have been expanding globally for many years, while their negative impact on the environment is becoming increasingly evident. Meanwhile, prevailing frameworks to examine the relationship between finance and the environment fail to account for risks financial systems pose to the environment (finance-to-environment risks). Therefore, financial institutions and markets, in turn, fail to account for finance-to-environment risks despite aims to do so. Thus, an enhanced understanding of these risks is crucial to improving environmental quality. This thesis investigates what is known about the finance-to-environment risks by conducting a systematic literature review on the environmental impacts of financial systems. The findings indicate that financial systems pose environmental risks through two main groups of mechanisms. First, financial systems pose risks to the environment through their functions to the overall economies and the improvement or worsening in performing these functions. Second, financial systems also pose risks to the environment through (a) economic growth, (b) foreign direct investment inflows, (c) technological innovation, and (d) energy consumption. While these mechanisms represent opportunities to alleviate environmental harm, most prevailing global trends of these mechanisms are to exacerbate environmental harm. This article uncovers knowledge gaps in the finance-to-environment literature and proposes three criteria to bridge these knowledge gaps: future research should (1) incorporate the multidimensionality of financial systems, (2) include aspects of inflows from and outflows to the biosphere, and (3) discuss both options of financial system reconfiguration and transformation. Bridging these knowledge gaps will help future research develop sound policy recommendations for enhanced environmental quality.

Keywords: financial systems; finance; environment; ecological macroeconomics; systematic review; environmental degradation

Table of Contents

1. Introduction

The prevailing frameworks to examine the relation between finance and the environment are dominated by an 'environment-to-finance' angle, focusing on examining the financial risks from environmental decline (Antoncic, 2019; Weber, 2014; World Economic Forum, 2020a). Far less attention has been paid to the risks that finance may pose to the environment (Crona et al., 2021). Financial systems—broadly defined as institutions and markets interacting to mobilize funds for investment and providing facilities to finance commercial activity (OECD, 2005)—are expanding rapidly.

The global financial sector has increased rapidly relative to the real economy, a relation referred to as the financial depth of financial systems (World Bank, n.d.-b). A deepening of the financial systems entails higher provision of financial services through financial institutions and markets (Čihák et al., 2012). The depth of financial institutions may be measured by the evolution of financial institutions' assets to gross domestic product (GDP) (Čihák et al., 2012). The total assets held by global financial institutions increased from 440.7 per cent of GDP in 2007 to 553 per cent of GDP in 2020 (Statista, 2022).[1] According to the McKinsey Global Institute (2021), financial institutions' assets amounted to $510 trillion globally in 2020.[2] The increasing depth of financial markets also reflects the expanding financial systems. Two measures of financial market depth are stock market capitalization to GDP (also called market value) and debt securities to GDP (Čihák et al., 2012). Stock market capitalization—the share price times the number of shares outstanding—of listed companies raised from 113.7 per cent of global GDP in 2007 to 133.8 per cent in 2020 (World Bank, n.d.-e), which in 2020 amounted to $93.69 trillion (World Bank, n.d.-f). In addition, total outstanding debt securities—debt instruments designed to be traded in financial markets—increased from 128.6 per cent of global GDP in 2015 to 163 per cent of global GDP in 2020,[3] amounting to $138.16 trillion in 2020 (BIS, n.d.; World Bank, n.d.-d). Altogether, these measures of financial depth amounted to $741.85 trillion in 2020. This number is striking when compared to the real economy (i.e., measured by GDP) and real estate measures (i.e., measured by nonfinancial assets), which

[1] Author's calculations based on assets in US$ from Statista (2022) and GDP in US$ from World Bank (n.d.-d).
[2] The global average calculated by the McKinsey Global Institute (2021) is an extrapolation derived from a weighted average of 10 countries based on GDP, this may be why the absolute numbers given by Statista (2022) differ slightly from the numbers by the McKinsey Global Institute.
[3] Author's calculations based on securities in US$ from the BIS (n.d.) and GDP in US$ from the World Bank (n.d.-d).

amounted to $84.75 trillion (World Bank, n.d.-d) and $520 trillion respectively in 2020 (McKinsey Global Institute, 2021).

A mounting body of literature points to economic growth (i.e., growth in the real economy) as a major driver of environmental degradation, including indicators of environmental pressure such as resource use (Krausmann et al., 2017; Wiedmann et al., 2015; 2020), carbon emissions (Hickel & Kallis, 2020; Jackson & Victor, 2019), and biodiversity loss (Marques et al., 2019; Otero et al., 2020). Yet, this literature lacks consistent documentation of the connection between growth in real economies and growth in financial systems (Victor & Jackson, 2020). Disentanglement of the link between the two could uncover interaction mechanisms between real economies, financial systems, and environmental degradation. Because financial systems play essential roles in the overall economy as allocators of capital, price-setters in trading and valuation, and influencers of corporate governance (Levine, 2005), expanding financial systems are expected to have a significant impact on the environment (Beck et al., 2000; Weber, 2014). Therefore, transformations of financial systems could facilitate the economic transformations needed to achieve the targets of the Paris Agreement and the Sustainability Development Goals (Crona et al., 2021; Pörtner et al., 2021).

The environment-to-finance angle (i.e., financial risks from environmental degradation) reflects the mainstream economics vision of the links between the environment and finance. According to Victor and Jackson (2020), such a worldview "[…] omits the crucial dependency of human economies on natural systems and the extent to which the capacity of these systems to provide sustainable prosperity for all is being undermined by economic activity" (p. 368). The field of ecological economics developed largely in response to this problem (Victor & Jackson, 2020). The subfield of ecological macroeconomics has progressed during the last decade (Rezai et al., 2013; Victor & Jackson, 2020), integrating the biosphere and the financial sector into modelling exercises (e.g., Boumans et al., 2002; Hardt & O'Neill, 2017). However, the understanding of the environmental impacts of financial systems (i.e., 'finance-to-environment' impacts) is still in its infancy. In an attempt to identify a research agenda for ecological macroeconomics, Victor and Jackson (2020) emphasize that there is a "[…] need to address not just the links between the real economy and planetary systems and not just the links between the real economy and the financial [system], but the complex interdependencies between all three embedded systems" (pp. 358-359). This paper contributes to this research gap by addressing the research question: *What is known about the risk that financial systems pose to the environment?* To answer this question, I conduct a systematic review of relevant literature and adopt an ecological macroeconomic lens to discuss the uncovered knowledge and knowledge gaps.

The study contributes to the development of Ecological Macroeconomics in line with the research agenda by Victor and Jackson (2020), which includes an enhanced representation of financial systems in ecological macroeconomic modelling. In order to gain insight from including these factors in such modelling, this paper argues that there is a need for an enhanced understanding of the mechanisms through which finance may impact the environment. Furthermore, adopting an ecological macroeconomic lens enriches the discussion of the results, bringing in the ecological macroeconomic concept of scale. Finally, this paper contributes by disentangling finance-to-environment impacts into separate mechanisms through which finance affects the environment and identifying knowledge gaps that need to be addressed to develop sound policy recommendations.

The remainder of this article comprises six sections. Section 2 provides an overview of financial system functions, components, and characteristics. Section 3 establishes the theoretical foundation of the paper. Section 4 explains the methods. Section 5 summarizes existing knowledge about the finance-to-environment relationship. Section 6 discusses the findings and knowledge gaps identified in the review and the implications and limitations of this study, while Section 7 concludes.

2. Background

To examine how financial systems can pose risks to environmental systems, it is crucial to understand what constitutes financial systems. Therefore, this section introduces background on key aspects of financial systems applied in the successive sections, namely financial system functions, components, and characteristics.

According to the Organisation for Economic Co-operation and Development (OECD), a financial system "consists of institutional units and markets that interact […] for the purpose of mobilizing funds for investment, and providing facilities, including payment systems, for the financing of commercial activity" (OECD, 2005). According to Levine (2005), financial systems have five main functions for the overall economy: (i) to produce information ex-ante about possible investments and allocate capital; (ii) to monitor investments and exert corporate governance after providing finance; (iii) to facilitate the trading, diversification, and risk management; (iv) mobilize and pool savings; and (v) to ease the exchange of goods and services (Table 1). A growing body of literature emphasizes *financial institutions* and *financial* *markets* as two major components of financial systems, noting that they significantly influence economic development, poverty alleviation, and economic stability (Levine, 2005).

2.1. Financial Institutions

Actors operating in financial markets can be called ‘financial actors’ or ‘financial institutions’ (Galaz et al., 2015). The term financial institutions imply that the actors deal with financial transactions, like investments, loans, and deposits. Such financial institutions include, for example, institutional investors, commercial banks, and investment banks. Institutional investors pool large sums of money to invest them in assets such as equities, bonds, and property. Such investors will be entitled to vote in a company and may influence the corporation's management (e.g., in a more or less environmentally friendly direction). Institutional investors include pension funds (e.g., Norwegian Governmental Pension Fund), insurance companies (e.g., Prudential), charities (e.g., Doctors Without Borders), educational establishments (e.g., Harvard University) (Galaz et al., 2015), and asset managers (e.g., BlackRock) (Galaz et al., 2018). A commercial bank (e.g., Danske Bank) provides various financial services, such as accepting deposits, making business and household loans, and offering basic investment products (Galaz et al., 2015). In defining their lending strategy, commercial banks determine which sectors and projects are eligible for lending and which are not (e.g., environmental, social, and governance factors may influence the creditworthiness of both companies and collateral value) (Schoenmaker & Schramade, 2019). This way, commercial banks influence corporate and individual behaviour. Unlike commercial banks, investment banks do not accept deposits from companies or individuals (Galaz et al., 2015). Instead, investment banks (e.g., Citigroup, Goldman Sachs, and Morgan Stanley) assist firms, governments, or individuals in raising capital by guaranteeing the security and may also provide other services such as helping in Mergers and Acquisitions (M&A) (Galaz et al., 2015). In their prospectuses for securities offerings or M&A advice, investment banks could incorporate both financial information and information about social, environmental, and governance factors (Schoenmaker & Schramade, 2019).

2.2. Financial Markets

Financial markets are arenas where people and entities can trade financial instruments (Galaz et al., 2015). They allow individuals and companies to invest and diversify their savings, and companies may raise money through these financial markets, bypassing traditional bank lending (Svirydzenka, 2016). Such financial markets include stock markets, bond markets, and derivative markets (Čihák et al., 2012). Financial instruments are paper or digital documents representing a tradable package of capital. There are two asset classes of financial instruments: equity-based and debt-based financial instruments. Equity-based financial instruments represent an ownership interest in an asset such as (common) stock or a partnership share. Debt-based financial instruments represent debt, including bonds and loans (Galaz et al., 2015). Both equity- and debt-based financial instruments are used to raise money, but they have diverse characteristics and are used by different actors.

According to Galaz et al. (2018), there is a significant difference between stock and debt concerning the financiers' influence on corporate governance (thereby also a company's effort to combat ecosystem and climate change). With debt, financiers (i.e., investors) can disclose their preference in the process of creating a loan (i.e., signalling discontent and pushing down prices by withholding capital from environmental laggards) or through covenants in the debt contract where violation may trigger a default. On the other hand, the stock ownership rights of stockholders (also known as shareholders) allow them to vote on strategic decisions and the election of top executives (Galaz et al., 2018). Scholars suggest three means that stockholders can use to achieve corporate influence: voting (Dam & Scholtens, 2013; Levine, 2005), direct engagement with management (Dimson et al., 2015), and divestment (or the threat of it) (Edmans, 2014). Hence, the role of stock can be considered more prominent than other finance types in the governance of companies (Edmans, 2014). However, stockholders face multiple barriers to exerting influence on corporate governance (Galaz et al., 2018; Levine, 2005). These barriers include the marginal economic role the ownership in the respective companies play for the identified stockholders' portfolios and the lack of incentives for exercising influence over individual companies because of associated costs (Galaz et al., 2018). Furthermore, additional barriers like coordination problems and free-rider dynamics may arise in the case of multiple large stockholders in one company (Dam & Scholtens, 2013; Edmans, 2014).

2.3. Financial Development

Financial development implies an improvement in financial system functions (Čihák et al., 2012). Čihák et al. (2012) identify four characteristics of financial institutions and markets to measure and benchmark financial systems: financial depth, financial access, financial efficiency, and financial stability (Table 1).[4] First, financial depth is a proxy of the overall extent of services a financial system provides. Second, financial access is the extent to which a population can access financial services. Third, financial efficiency measures the cost of intermediating credit. While efficiency measures for financial institutions include variables focused on measuring the cost of transactions, those of financial markets focus more on measuring transactions. Finally, financial stability is a part of the broader financial development process with proxies capturing the gap between growth and risk of crises or compare buffers (capitalization and returns) with the potential for risks (volatility of returns).[5]

Financial institutions and financial markets can contribute to these four characteristics, which Čihák et al. (2012) illustrate in a 4x2 matrix (Appendix B). Together with the overall financial system functions, financial system characteristics are useful to analyse the final sample of this research. These are presented together in Table 1.

Table 1
Overview of financial system functions and financial system characteristics.

Financial system functions (Levine, 2005)	Financial system characteristics (Čihák et al., 2012)
i. Produce information ex-ante about possible investments and allocate capital	a. *Depth*: the extent of financial services provided
ii. Monitor investments and exert corporate governance after providing finance	b. *Access*: the extent to which a population can access financial services
iii. Facilitate the trading, diversification, and management of risk	c. *Efficiency*: the cost of intermediating credit
iv. Mobilize and pool savings	d. *Stability*: the absence of system-wide crises
v. Ease the exchange of goods and services	

Note: Even if all financial systems provide financial system functions (listed to the left), they differ in how well it is done (Levine, 2005). The development of financial system characteristics (listed to the right), commonly referred to as financial development, implies an improvement of financial system functions (Čihák et al., 2012).

[4] The work by Čihák et al. (2012) is based on the research by Levine (2005) among others, and presents the Global Financial Development Database publicly available at http://www.worldbank.org/financialdevelopment and http://data.worldbank.org/data-catalog/global-financial-development.

[5] According to the World Bank (n.d.-c), periods of financial instability (i.e., absence of financial stability) best illustrates the true value of financial stability.

3. Theory

This section introduces key topics of ecological economics and justifies their relevance in linking finance and the environment supported by describing the development of global economies' physical scale (Section 3.1.). Furthermore, the key topics are linked to ecological macroeconomic knowledge, as well as knowledge gaps, which this research contributes to bridging (Section 3.2.). Together these sub-sections construct the theoretical foundation used to discuss the review results in Section 6.

3.1. Visioning a physical scale of human economies

Because most prevailing macroeconomic models lack a representation of the biophysical environment (Daly, 1985; Georgescu-Roegen, 1975; Stagl, 2014), they do not capture the economies' total dependency on planetary systems (Victor & Jackson, 2020). Ecological economics, however, provides an alternative pre-analytic vision, where human society is described as a metabolic organism embedded within the biosphere, with which it exchanges energy and materials (Daly, 1991). This human sub-system lives by absorbing recourses (i.e., inflows) from and sending back waste (i.e., outflows) to the biosphere. Therefore, attention is given to the physical scale of economies (i.e., economic metabolism) in relation to the biosphere (Daly, 1991; Victor & Jackson, 2020).[6] Changes in the physical scale can be monitored using measures of human pressure on the environment, such as ecological footprint, material footprint, greenhouse gas emissions, or other biophysical indicators (Røpke, 2016).

In ecological economics and sustainability science, there is a general agreement that the current scale of the economic metabolism exceeds safe limits and threatens to undermine human's life-support systems (Fanning et al., 2022; Rockström et al., 2009; Røpke, 2016; Steffen et al., 2015; The Club of Rome et al., 2022). This research suggests that several boundaries (also called 'planetary boundaries') have already been exceeded and that other boundaries will likely be surpassed soon because of human activities. Moreover, human impacts on the Earth system are amplified by a network of interactions (i.e., cascades and feedback mechanisms) between the planetary boundaries (Lade et al., 2020). Over the past decades, there have been dramatic changes in the scale of human economies, accelerating their adverse environmental impacts (Victor & Jackson, 2020). The global metabolism increased twelvefold in the past decade, from about seven billion tons of materials extracted and used per

[6] Ecological macroeconomics also care about the size of the economic metabolism in relation to the carrying capacity of the biosphere (Daly, 1991).

year in 1900 (Krausmann et al., 2009) to roughly 90 billion tons of materials in 2017 (Hickel et al., 2022).[7] This increase in material flows involved an accompanying rise in waste generation deposited on and under land, in water, and in the air (Victor & Jackson, 2020). The expanding human population occupying every inhabitable niche of the planet also spread the extensive loss of habitat as one of the leading causes of the 'sixth extinction' (Barnosky et al., 2011). Therefore, it is important to embed the economy within planetary systems, like in the ecological economic pre-analytical vision, to understand how to reduce waste generation and resource absorption to sustain human life-support systems and the wellbeing of all species.

3.2. Ecological Macroeconomics and Financial Systems

The initial ecological economic concern about economies' physical scale is inherently macroeconomic (Rezai & Stagl, 2016). However, it was not until recently that the term 'ecological macroeconomics' emerged more frequently in ecological economic literature.[8] There seems to be no mutually agreed definition of what it entails (Hardt & O'Neill, 2017). According to Jackson et al. (2014), the dilemma of remaining within planetary boundaries requires macroeconomic and microeconomic responses, yet ecological economic research has mostly focused "the unit of investigation on low-level, small-scale sub-systems of the economy" (Rezai & Stagl, 2016, p. 181). It has also primarily focused on the material and energy links between the biosphere and the macroeconomic aggregates defined by the system of national accounts: consumption, investment, wages, employment, and output (Victor & Jackson, 2020). These components encompass what is often called 'the real economy' while the additional complexity of financial systems is often absent from the analysis (Victor & Jackson, 2020).

There are at least two major themes covered in ecological economic research relevant to understanding financial systems' complexity. The first debate was advanced by forerunners of ecological economics already in the 1920s (i.e., Soddy, [1926] 1933) and concerns the nature of money. Adherents to an endogenous view of money supply suggest that loans issued by commercial banks feed into the overall broad money supply—which includes coins, banknotes, money market accounts, savings, bank and traveller's checks, and time deposits (World Bank, n.d.-a)—because commercial banks issue loans to borrowers without using existing assets such as money from other clients' savings accounts (Benes & Kumhof, 2012; Svartzman et al.,

[7] The national responsibility for ecological breakdown is unevenly distributed globally (Hickel et al., 2022).
[8] The concept of ecological macroeconomics can be traced back to Daly (1991) who called for a research agenda on 'environmental macroeconomics'. Jackson (2009) later spoke of the need for 'ecological macroeconomics', explicitly.

2020).[9] In practice, commercial banks increase borrowers deposit account by entering numbers equal to the loan amount into a computer (Godley & Lavoie, 2012; Wray, 2015). When loans are repaid, the money created by commercial banks is destroyed (Benes & Kumhof, 2012; Svartzman et al., 2020). This way, commercial banks can create money out of 'thin air' (Campiglio, 2016; Fontana & Sawyer, 2016; Rezai & Stagl, 2016; Svartzman et al., 2020). Therefore, endogenous money supply implies that money is created from within financial systems.[10]

While real wealth (e.g., real estate and physical supplies) decay over time, debt (with their associated resource use) does not. Therefore, it is convenient for individuals to exchange their wealth for money (Daly & Cobb Jr, 1989), which carries debt if issued by commercial banks (Mellor, 2010). However, if capital creation is coupled with resource use (Haberl et al., 2020), there is a limit to how much the future capital stock can grow. Therefore, scholars question whether the endogenous money supply should be limited to mitigate resource depletion and waste disposal (Ament, 2019; Daly & Cobb Jr, 1989; Soddy, [1926] 1933). Furthermore, while central banks change the interest rate to incentivize commercial banks to create more or less money, some scholars argue that commercial banks create money independently of interest rates (Ryan-Collins et al., 2012). In that case, central banks lack tools to influence the economy in times of financial instability (Campiglio, 2016): money supply varies independently of central banks' issuing of cash.

A second debate gained momentum after the collapse of the World's financial system in 2007-2008 (Urhammer & Røpke, 2013) concerning the connection between economies' 'real' and financial components. The financial crisis provoked critiques of excessive financial liberalization ('financialization') within ecological economics and beyond. These critiques argued that financialization leads to higher risk, more risk-taking behaviour, faster but unsustainable growth, and increased fragility (Rezai & Stagl, 2016). This way, the financial crisis stimulated research on the connection between the real and financial components of modern economies. Afterwards, ecological economists have examined financial systems' role in facilitating consumption through credit and debt creation (Rezai & Stagl, 2016).[11] Yet,

[9] The exogenous view of money supply entails that the supply of money is determined by forces outside financial systems and economies, most often by central banks (Svartzman et al., 2020).
[10] Endogenous money supply has been acknowledged by central bank economists as the principal money issuer in capitalist economies (e.g., McLeay et al., 2014).
[11] While credit is money that a person can borrow, debt is the money the person owes. Therefore, when a person use credit to borrow money, it creates debt.

financial systems perform additional functions, such as facilitating technological investments and distributing income and wealth (Rezai & Stagl, 2016). This will be examined further in Section 2.2. There have also been attempts to incorporate the behaviour of the financial sector in ecological macroeconomic modelling (Victor & Jackson, 2020). These models include characteristics such as endogenous money supply. Victor and Jackson (2020) emphasize a need for a comprehensive representation of financial systems in ecological macroeconomic modelling, including a broader range of financial institutions (see Section 2.1.).

4. Methods

To uncover what is known about the environmental impacts of financial systems, I conducted a systematic and replicable literature review proceeding in five phases (Figure 1). The first phase involved defining the purpose and scope of the review based on the research objectives (Section 1).

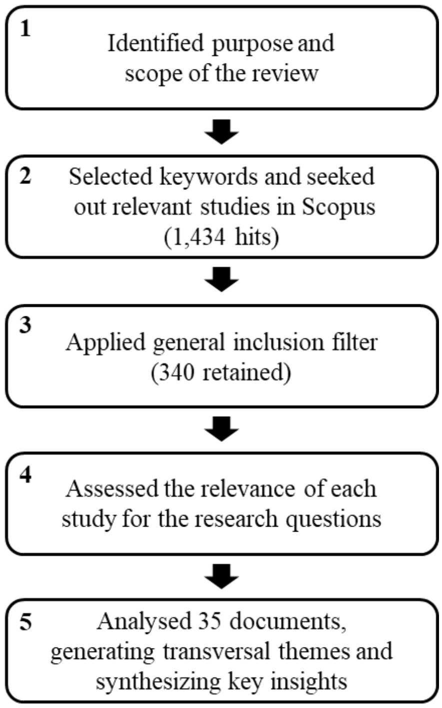

Figure 1
The systematic review process was divided in five phases. Adopted from on Bryman (2016, pp. 98-102) and Ziegler et al. (2022, p. 3)

In the second phase, I searched for relevant studies using the academic database Scopus (https://www.scopus.com). The Scopus search API supports varied Boolean syntax (e.g., 'AND', 'NOT', and 'OR') and field restriction (e.g., TITLE-ABS), unlike Google Scholar and Ecological Economics Journal.[12] Thereby, Scopus allowed filtering of the returned documents to those containing the selected terms in the title, abstract, or author keywords. A weakness of searching in specific fields is that not all documents have all fields, which may prevent some documents from appearing in the search results. However, as the alternative of searching in all fields returned 42,649 documents, it was not considered a feasible option. In line with the purpose and scope of the review, I selected several terms related to finance, the environment, and the interrelation between the two, such as 'financial institutions', 'earth systems', and 'impact'. In addition, I selected precise keywords such as 'financial system' and 'natural systems' over 'finance' and 'nature', respectively, because of the broad use of the two latter

[12] These only support a limited number of Boolean operators.

terms (see Table 2). This initial search gave 1,434 document results—a number still considered too high to be feasible for review due to time constraints.

Table 2

Overview keywords selected in the second phase

Finance	Environment	Interrelation
financial actors	biodiversity	change
financial institutions	climate	impact
financial market	earth systems	risk
financial services	ecosystem change	
financial system	ecological footprint	
money supply	environmental	
money creation	natural systems	
global debt	planetary systems	

Note*:* The columns represent different groups of keywords: keywords related to finance, the environment, and the interrelation between the two. The returned documents contained at least one word from each column.

In the third phase, I applied a general inclusion filter beyond the keywords based on language, impact, and newness (Table 3). First, I restricted the search to documents in English to be able to understand their contributions. Second, I used the Scimago Journal & Country Rank (https://www.scimagojr.com) to focus on medium- to high-impact journals, excluding papers published in journals with an average quantile score below Q2 in the period from 2010 to 2020.[13] I consider 'impact' an important criterion because it reflects the dissemination of knowledge among scholars (Ravenscroft et al., 2017). Third, I only included documents with the year of publication from 2015 to March 1st 2022, returning 813 documents. The choice of this time was motivated by three elements: (1) a key article from 2015 suggested limited research covering the finance-to-environment relationship (i.e., Galaz et al., 2015), (2) I expect most previous empirical published before 2015 to be cited in the papers published between 2015 and 2022, and (3) time constraints forced a further limitation of the sample. When I initially limited the time dimension from 2008 to 2022, the search still returned 1,206 documents. The number was lower, and I considered it more feasible when I changed the start year to 2015. The end date, namely March 1st, indicates when I conducted the search in Scopus and downloaded a database. Finally, I used Excel to exclude all documents with less than five citations for documents published between 2015 and 2019, while documents published between 2020 and 2022 were excluded if they had no citation. The first citation filter was

[13] At this point, I included books or conference proceedings without JSR quantile scores.

applied based on impact. Moreover, citations were considered quality-proof as scholars previously have read and cited the respective documents. In addition to the reasons for the first citation filter, the latter citation filter was applied despite the limited time since publication because this research's time constraint forced a further limitation of the scope. After applying additional inclusion criteria beyond keywords (Table 3), I retained 340 documents in phase three.

Table 3
Overview of general inclusion criteria beyond keywords and motivation of choice

Additional inclusion criteria	Motivation of choice
Language: English	Author's limited language skills.
Years: 2015-2022	(1) Galaz et al. (2015) highlight the limited research done before its publication, (2) the latest research is expected to cite research published before 2015, and (3) time constraints forced a further limitation of the sample.
JSR-quantile average: >= Q2	Impact of journals of publication.
2015-2019: citations>= 5	Impact of articles and quality-proof by peers.
2020-2022: citations>= 1	Quality-proof by peers and time constraints.

The fourth phase involved assessing the relevance of the 340 documents' abstracts to the research question by asking 1) *"Is a financial system component an important topic of the work?"*, and 2) *"Is the finance-to-environment relationship an important topic of the work?*". For a document to be retained for the fifth phase, it required the answers to both questions to be 'yes'. This reduced the number of articles to 36 documents. Finally, I excluded a book I could not attain (i.e., Silver, 2017), resulting in a final sample consisting of 35 documents (overview in Appendix A).

In the fifth phase, I analysed the 35 remaining documents building on the work by Levine (2005) and by Čihák et al. (2012). First, I mapped financial system functions and financial system characteristics examined in the sample (Table 1) and their associated environmental impact. The three first functions listed by Levine (2005) were identified to pose risks to the environment.[14] In addition, the review revealed that the development and instability in financial institutions and markets also pose environmental risks. Because sample studies examined the nexus between financial development and environmental quality using a variety of indicators and proxies, the 4x2 matrix by Čihák et al. (2012) helped match the indicators

[14] Similarly, Schoenmaker and Schramade (2019) have argued that three first financial system functions listed by Levine (2005) are most important to sustainable finance.

and proxies with financial system characteristics (Appendix B). Čihák et al. (2012) give examples of candidate indicators or proxies that can be used to measure the characteristics of financial systems. Therefore, I used these examples as a guiding principle when mapping financial mechanisms, which facilitated a comparison of the studies' results (Appendix C). For example, both private sector credit to GDP and broad money supply to GDP can be used as proxies to financial institution depth, while the turnover ratio for stock market is a proxy of financial market efficiency.[15] Some of the mechanisms proposed by the sample fall outside the classification of financial mechanism, these are: (a) economic growth, (b) foreign direct investment inflows, (c) technological innovation, and (d) energy consumption. Through these additional mechanisms, financial development indirectly poses risks to the environment. Together these financial mechanisms and additional mechanisms form the basis for Section 5.

5. Results

A sample of the representative mechanisms through which financial systems may impact the environment is provided in Table 4. The mechanisms are classified into two main categories: the mechanisms of financial systems (hereafter 'financial mechanism') that pose risks to the environment (Section 5.1.) and mechanisms through which financial development indirectly poses risks to the environment (Section 5.2.).

Table 4
Mechanisms through which financial systems pose risks to the environment

Mechanism		Description	Examples of environmental impact
Financial mechanisms posing risks to the environment			
(i)	Produce information and allocate capital	• Financial institutions may offer financial assistance to "green" projects and firms • By providing information, financial institutions may facilitate capital allocation (or hold back capital from) "green" projects and firms	• Cheap capital may facilitate firms to upgrade production technologies that cause less environmental degradation (Boufateh & Saadaoui, 2020) • Through loans household clients may purchase of automobiles, electrical and mechanical devices, and equipment, consequently increasing pollution-emitting activities (e.g., Khalid et al., 2021)
(ii)	Monitor investments and exert corporate governance after providing finance	• Financial institutions can, as capital providers, monitor and influence how the capital is used • Financial institutions may, as shareholders, influence corporate governance and thereby firms' environmental impact	• The Norwegian Governmental Pension Fund influenced corporate behaviour through (threats of) divestment (Galaz et al., 2015) • The World Bank International Finance Corporation influenced corporate behaviour through modification of their performance standards (Galaz et al., 2015)

[15] When indicators used in the studies were not present in the matrix, I used additional literature to place the indicators in the correct 'bin'.

			• There are financial Giants with considerable influence in companies shaping biomes (i.e., in the Amazon and boreal forest)--critical for the stability of the climate system—that are not using their potential to influence corporate governance (Galaz et al., 2018)
(iii)	Facilitate trading, diversification, and management of risk	• Finance is good at pricing the risk for trading and valuation • Such risk management can help deal with future uncertainties	• The European carbon market (i.e., EU ETS) is created to reduce the rate of climate change (Galaz et al., 2015) • "Green" financial instruments offer the opportunity to finance projects generating financial profits and alleviating environmental harm (Wang et al., 2021) • Even if the purpose of the ESG rating Morningstar Sustainability Rating for Funds is to provide information to investors by helping them compare funds based on sustainability, they fail to account for the deforestation risk of firm operation and trade (Crona et al., 2021)
(iv)	*Financial development and instability*		
	Financial institution development	• Development of financial institutions' depth, access, efficiency, and stability	• More cheap credit and long-term focus could facilitate capital allocation to environmentally beneficial purposes (e.g., Thampanya et al., 2021) • More cheap credit that is easy to get hold of could facilitate capital allocation to environmentally harmful purposes (e.g., Li et al., 2022)
	Financial institution instability	• Absence of stability in financial institutions	• Deleveraging process may constrain the take-off phases of green projects or firms' investments in more energy-efficient (Boufateh & Saadaoui, 2020)
	Financial market development	• Development of financial markets' depth, access, efficiency, and stability	• An expansion of EU ETS may reduce the risk of climate change (Galaz et al., 2015) • Larger stock markets may facilitate market discipline, obliging environmental laggards to conform to environmental standards, alleviating environmental degradation (Boufateh & Saadaoui, 2020) • The growing significance of financial markets in global agri-food value chains encourages new forms of distancing that make it complicated to link ecological and social cost externalization, making it more difficult to the responsibility for these costs (Clapp, 2015)
	Financial market instability	• Absence of stability in financial markets	• Price volatility may discourage farmers from making long-term investments, causing short-termism in decision-making which exacerbates environmental deterioration (Galaz et al., 2015)

			• The Asian Financial Crisis of 1997 paved the way for national policies supporting the rapid expansion of palm oil plantations in Indonesia, exacerbating environmental harm (Galaz et al., 2015)
Mechanisms through which financial systems indirectly pose risks to the environment			
(a)	Economic growth	• Increased income, i.e., gross domestic product (GDP), generated from final goods and services	• Economic growth escalates environmental degradation in the short run by supporting more production while decreasing environmental degradation in the long run by supporting the deployment and use of green and modern technologies (i.e., *Environmental Kuznets curve hypothesis*) (e.g., Ganda, 2019) • Alternatively, economic growth exacerbates environmental harm also in the long term (e.g., Mhadhbi et al., 2021) • Financial instability may decrease economic growth and reduce energy consumption in the short term, thereby alleviating environmental harm (Boufateh & Saadaoui, 2020)
(b)	Foreign direct investment (FDI) inflows	• The purchase of management interest in a firm operating in a different economy than that of the investor	• With FDI inflows, firms move pollution-intensive production to countries with less strict environmental regulations, exacerbating environmental degradation (i.e., *Pollution Haven Hypothesis*) (e.g., Anser et al., 2020) • Alternatively, with FDI inflows, firms transfer greener technology to host countries through FDI, alleviating environmental degradation (i.e., *Pollution Halo Hypothesis*) (e.g., Khan et al., 2021)
(c)	Technological innovation	• The adoption and exploitation of new technology among individuals, firms, and governments	• Technological innovation enhances environmental performance thanks to increased energy efficiency and other eco-friendly technological advancements (e.g., Rafique et al., 2020)
(d)	Energy consumption	• Use of energy in a society (i.e., both renewable and non-renewable)	• Decreasing energy consumption or replacing fossil fuel energy with renewable energy may alleviate environmental harm (e.g., Hove & Tursoy, 2019). • Increased energy consumption generated by fossil fuels may exacerbate environmental degradation (Ehigiamusoe et al., 2019).

Source: Author's classification based on Levine (2005), Čihák et al. (2012), and reviewed sample.

Note: ESG = Environmental, Social, and Governance. FDI = Foreign Direct Investment. "Green" projects and firms refer to projects and firms that are considered less environmentally damaging than the prevailing practices and firms. There is support for financial system functions and financial development both increasing and decreasing environmental degradation. Moreover, the reviewed studies suggest that financial development impacts the environment indirectly through the mechanism (a) to (d).

5.1. Financial mechanisms that pose risks to the environment

This review suggests that financial systems may impact the environment through their functions (cf. Levine, 2005) and changes in their characteristics (cf. Čihák et al., 2012). These financial mechanisms pose risks to the environment directly and/or indirectly, with the ability to alleviate and exacerbate environmental harm. The financial functions and their impact are classified into three categories:

> *Produce information and allocate capital:* Financial institutions can impact the environment by mitigating information asymmetry and allocating capital (Crona et al., 2021; Scholtens, 2017). On the one hand, by providing funds to support more sustainable firms, projects or technologies like the adoption of more energy-efficient and eco-innovative production methods, financial institutions have the potential to alleviate environmental harm (Qin et al., 2021). In addition, a well-functioning stock market can enable energy-efficient firms to quickly raise money to invest more in green energy technologies (Thampanya et al., 2021). But on the other hand, such capital can also facilitate increased industrial production, which stimulates energy supplies and consumption, as well as resources and waste upon which this process depends (e.g., Boufateh & Saadaoui, 2020; Sharma et al., 2021). Moreover, financial institutions may offer loans to household clients who purchase automobiles, electrical and mechanical devices, and equipment, consequently increasing pollution-emitting activities (e.g., Ganda, 2019; Khalid et al., 2021). Hence, through this mechanism, financial systems can affect the environment in both positive and negative ways depending on how they produce information and allocate capital.

> *Monitor investments and influence corporate governance:* Financial institutions can impact the environment through firms in which they invest, where they have the potential to take an influential role in controlling and directing corporate boards (Galaz et al., 2015). This way, financial institutions can prompt more environmentally friendly behaviour among firms and households (Galaz et al., 2015; Scholtens, 2017). Yet, shareholders may (decide) not to use this influence, thereby upholding the environmentally unfriendly practices of firms. This inaction may result from the multiple barriers introduced in Section 5.1. (Galaz et al., 2018), ignorance of the risks that corporate operations pose to the environment (Crona et al., 2021), or ignorance of the dangers of reputational damage (Boufateh & Saadaoui, 2020; Galaz et al., 2015).

Therefore, financial systems can affect the environment positively and negatively through this mechanism depending on how they monitor investments and influence corporate governance.

Facilitate trading, diversification, and risk management: Some scholars suggest that financial systems can manage risk and help deal with future uncertainties by pricing the risk for trading and valuation (Schoenmaker & Schramade, 2019). Two examples of risk management attempts are the European carbon market and 'green' financial instruments (Table 4). However, Crona et al. (2021) underline that the current characterization of sustainable finance initiatives such as 'green' financial instruments have significant shortcomings, raising the question of whether the succession of green equity and debt is enough to achieve a transition to a more sustainable future. Further, they highlight that the prevailing risk framework underlying sustainable finance fails to recognize the interconnected dynamics between economic activity, Earth system dynamics, and biosphere resilience.[16] This includes complex dynamics, such as tipping points and strong interactions resulting in cascading effects, which are all known drivers of systemic failure in complex systems (e.g., Helbing, 2013; Steffen et al., 2015). Furthermore, according to Crona et al. (2021), prevailing risk frameworks do not recognize (the many ways) that the investing companies may escalate the physical risks they are trying to assess and manage, contributing to the risk of systemic failure (Helbing, 2013). Therefore, Crona et al. (2021) argue that a cognitive disconnect between environmental and financial risk constrains sustainable finance initiatives (e.g., EU ETS, 'green' financial instruments, and ESG ratings) from fulfilling their potential.[17] Hence, financial systems have the potential to impact the environment positively by facilitating risk management. However, in the absence of sound risk frameworks, they may affect the environment negatively, even if the purpose is to enhance environmental quality.

[16] According to Schoenmaker and Schramade (2019), sustainable finance "looks at how finance (investing and lending) interacts with economic, social, and environmental issues" (p. 4).
[17] A positive trend in risk definitions in the financial sector over the past 3 decades (Antoncic, 2019) and shifting focus of risk discussion in World Economic Forum's annual reports (World Economic Forum, 2020b) make Crona et al. (2021) optimistic to the financial sector eventually close the "risk loop" in current risk frameworks.

Scholars propose that financial development (i.e., improvement of financial system functions) may enforce the mechanisms above (e.g., Qin et al., 2021; Wang et al., 2021).[18] Thus, financial development may both exacerbate and alleviate environmental harm through these financial mechanisms. Most of the reviewed studies (i.e., 30 out of 35) quantitatively investigate financial development's effect on the environment (Appendix D). However, many of these studies mainly adopt financial development indicators that capture financial institutions' and financial markets' depth but not access, efficiency, and stability. Thereby, they fail to capture the multidimensionality of financial development. Furthermore, they primarily adopt indicators of outflows from the economy to the biosphere (i.e., CO_2 and other GHG emissions), not indicators of inflows from the biosphere to the economy.[19] Therefore, my results from the sample only capture a small part of the finance-to-environment impacts.

While some studies suggest that overall financial development exacerbates environmental degradation (e.g., Nasir et al., 2021; Sharma et al., 2021), other studies suggest that overall financial development alleviates environmental degradation (e.g., Li et al., 2022; Rafique et al., 2020). This variety in the results could be attributed to different proxies and indicators used, econometric approaches employed (Nasir et al., 2021), choice of time periods (Ganda, 2019), and choice of countries (e.g., Ehigiamusoe et al., 2019; Thampanya et al., 2021).[20] Moreover, some of the studies adopt nonlinear approaches to examining the impact of financial development on the environment. These imply that the short-term environmental impact differs from the long-term environmental impact.

The studies in the sample find a U-shaped (Shahbaz et al., 2020) and inverted U-shaped relation (Zeeshan et al., 2021), as well as a non-U-shaped relationship (e.g., Hove & Tursoy, 2019; Qayyum et al., 2021) between financial development indicators or indicators of mechanism influenced by financial development and environmental harm indicators. An inverted U-shaped relationship implies that the environmental impact of financial development

[18] Some of the reviewed quantitative studies conduct causality and cointegrations tests (e.g., the tests of Granger, Dumitrescu and Hurlin, Wald, and the bound test) to check if they can identify causal relationships between the variables. While some studies detect unidirectional causalities running from the indicators of financial development to the environment supporting the claim that finance has an environmental impact, other studies detect bidirectional relations, unidirectional relations running the other way, or no causality at all (see Appendix D for overview). However, the most used of these tests, namely Granger causality test, has proven to be inadequate for resolving the question of directionality (see Haberl et al., 2020, p. 4). Therefore, the causality tests do not receive primary attention in this paper.

[19] A few exceptions use input indicators such as ecological footprint (i.e,.Khalid et al., 2021; Ngoc & Awan, 2021; Sharma et al., 2021).

[20] Differences between countries may be caused by dissimilar levels of financial and economic development (Ehigiamusoe et al., 2019; Guo et al., 2019) or income (Thampanya et al., 2021).

changes from an increasingly negative impact on the environment to a decreasing negative impact on the environment after a certain level of financial development, in line with predictions of the Environmental Kuznets Curve (explained in Section 5.2.). Some scholars have also highlighted the impact of financial instability on the environment, proposing that overall financial instability exacerbates environmental harm (e.g., Mahmood et al., 2018; Mohammed Saud et al., 2019). As financial development unfolds through financial institutions and financial markets (Čihák et al., 2012), I give some examples of the environmental impact of such development and instability in financial institutions and financial markets below:

Financial institution development and instability: Financial institution development (i.e., improvement of financial institutions' economic functions) could involve the increased provision of cheap credit and long-term focused capital allocation with fewer constraints for development projects, enabling more technological innovation and environmentally friendly upgrades (e.g., Boufateh & Saadaoui, 2020; Taher, 2020). Alternatively, they may also result in environmentally harmful purchases and upscaling traditional production and consumption (e.g., Li et al., 2022; Thampanya et al., 2021). The studies provide empirical evidence that financial institution development alleviates environmental degradation (Li et al., 2022; Tian et al., 2017), but most studies prove it exacerbates environmental degradation (e.g., Anser et al., 2020; Shahbaz et al., 2020). Hence, financial institution development can affect the environment positively and negatively depending on how financial institutions produce information, allocate capital, monitor, and influence corporate governance, and facilitate trading, diversification, and risk management.

In addition, some scholars stress that negative shocks in financial systems can cause a deleveraging process (i.e., the process of reducing one's debt level by rapidly selling one's assets) because it is the only way for financial institutions to preserve their balance sheets (Boufateh & Saadaoui, 2020). This may constrain the take-off phases of green projects—when financial support is vital—which may impede transitions to a low carbon economy (Boufateh & Saadaoui, 2020). A few studies detect an association between negative shocks in financial institution development and increasing environmental harm (Hove & Tursoy, 2019; Mohammed Saud et al., 2019). Yet, a different study finds that the negative shock in broad money is associated with exacerbation of environmental harm for high-income economies (Thampanya et al., 2021). In contrast, it is associated with alleviation of environmental harm for the overall panel of high-income and middle-income economies (Thampanya et al., 2021). Hence, negative shocks in financial institution development can affect the environment positively and negatively, potentially influenced by country characteristics.

Financial market development and instability: Financial market development (i.e., improvement of financial markets' economic functions) could involve that markets provide more funds to, for instance, clean and green innovation investments as the size and structure of financial markets rise (Li et al., 2022), thereby alleviating environmental harm. In addition, when markets grow more significant, transparent, and liquid, they may facilitate large investors to exert market discipline. With market sanctions, these investors could oblige environmental laggards to conform to environmental standards (Boufateh & Saadaoui, 2020). On the contrary, financial market development could also expand investment and consumer credit, increasing overall economic activities (Mahmood et al., 2018), thereby exacerbating environmental degradation. Moreover, the growing significance of financial markets in global value chains may encourage new forms of distancing, making it more difficult to allocate responsibility based on ecological and social costs (Clapp, 2015). The sample empirically supports that financial market development has environmental impacts (e.g., Mhadhbi et al., 2021; Nasir et al., 2021), concluding that financial market development may alleviate (e.g., Li et al., 2022; Thampanya et al., 2021) and exacerbate environmental harm (e.g., Ehigiamusoe et al., 2019; Guo et al., 2019). Some scholars also find that the environmental impact of financial markets is insignificant but suggest that the insignificance may result from a limited level of financial market development in sample countries (Zeeshan et al., 2021).

A few scholars also stress the environmental impacts of negative shocks in financial markets (i.e., financial market instability) (Thampanya et al., 2021) and how volatility in prices may become a barrier to long-term investments (Galaz et al., 2015). One study finds empirical evidence supporting that negative shocks in financial market depth exacerbate environmental degradation (Mhadhbi et al., 2021), while another study finds that the environmental impact depends on the income level of the economies (Thampanya et al., 2021).

5.2. Mechanisms through which finance indirectly poses risks to the environment

In addition to enforcing the mechanisms mentioned above, the sample proposes that financial development and financial instability (i.e., improvement and worsening of financial system functions) may have indirect environmental impacts through additional mechanisms.[21] The most prominent additional mechanisms[22] and their impacts are classified into four categories:

Economic growth: The relationship between economic growth and environmental harm has been under the scrutiny of a broad body of literature since 1972 debating whether economic growth may or may not decouple from its impacts on the environment (Haberl et al., 2020). Multiple sample studies adopt a hypothesis involving such decoupling, namely the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis suggests that the impact of economic growth on the environment will decrease (i.e., decoupling from economic growth) after reaching a certain threshold (e.g., Grossman & Krueger, 1995). Furthermore, the sample studies propose that financial development plays a crucial role in the EKC hypothesis by supporting and escalating more production—exacerbating environmental degradation—in the short run and supporting the deployment and use of green and modern technologies—alleviating environmental degradation—in the long run (Ganda, 2019; Mahmood et al., 2018).

Some of the sample studies prove that financial development and financial instability may impact the environment through economic growth by providing evidence that financial development influences economic growth (Li et al., 2022; Rafique et al., 2020) and that economic growth affects environmental impacts (e.g., Anser et al., 2020; Khalid et al., 2021). The sample's empirical results both support (e.g., Ganda, 2019; Mahmood et al., 2018) and debunk the EKC hypothesis (e.g., Anser et al., 2020; Qayyum et al., 2021). However, none of these studies that confirm the EKC hypothesis use so-called consumption-based accounting nor problematize their choice of territory-

[21] The sample literature also suggests that many of these mechanisms are interconnected through two-way causalities (e.g., Rafique et al., 2020). This interconnectedness makes it difficult to identify the sequences of the relationships. Below, I have used financial systems as the starting point of the sequence when synthesizing the main relationships.

[22] Other mechanisms that have received some attention are trade openness (e.g., Anser et al., 2020; Khalid et al., 2021), human capital (e.g., Ngoc & Awan, 2021; Sheraz et al., 2021), and industrial structure (e.g., Chen et al., 2021; Guo et al., 2019). In addition, Sheraz et al. (2021) also highlights the role of Globalization as a superior mechanism to financial development.

based emissions accounts.[23] Thereby, these studies fail to account for all the resources used or emissions emerging—independently of where in the world—along supply chains and required to meet national economies' final demand (Haberl et al., 2020). Therefore, according to the sample literature, financial development could cause both exacerbation and alleviation of environmental degradation in line with the EKC through economic growth. However, the studies' conclusions regarding the EKC hypothesis would potentially differ if they adopted a consumption-based indicator. Moreover, even some studies that detect an inverted U-shaped relationship find that economic growth exacerbates environmental harm (e.g., Mahmood et al., 2018; Shahbaz et al., 2020). This implies that the environmental impact of economic growth has not reached its peak and is still increasing in absolute terms (i.e., relative decoupling).[24]

The sample also provides empirical evidence for economic growth influencing financial development (Rafique et al., 2020). Furthermore, the sample supports that economic growth impacts the environment through other mechanisms presented in this section, namely energy consumption (Khalid et al., 2021; Sheraz et al., 2021) and technological innovation (Rafique et al., 2020). In addition, one study also proposes that financial instability can reduce economic growth and energy consumption, thereby decreasing environmental degradation, but provide no evidence for it (Boufateh & Saadaoui, 2020).

Foreign direct investments: According to the World Bank (n.d.-g), foreign direct investment (FDI) is the purchase to acquire a lasting management interest in a firm operating in an economy other than the investor. There are two predominant hypotheses related to the effect of FDI on the environment, the *Pollution Haven Hypothesis* (PHH), first introduced by Pethig (1976), and the *Pollution Halo Hypothesis* (also called FDI Halo Hypothesis), which builds on work by Grossman and Krueger (1995). A confirmation of PHH implies that firms will seek to avoid the cost of stringent environmental regulations by moving pollution-intensive production to countries with

[23] While the territory-based perspective accounts for resources used in or emissions emerging from a territory, consumption-based perspectives such as ecological footprint trace the environmental impacts embedded in goods and services beyond territorial borders (Haberl et al., 2020).
[24] Scholars distinguished between 'relative decoupling' and 'absolute decoupling'. While relative decoupling implies that GDP grows faster than environmental harm, absolute decouple would require that resource efficiency rise faster than GDP so that environmental harm may decline in absolute terms even when GDP grow (Otero et al., 2020). Most research debunk an absolute decoupling between economic growth and resource use taking place, especially at the global level (Haberl et al., 2020).

less strict environmental regulations, resulting in environmental degradation (Li et al., 2022). On the contrary, the Pollution Halo Hypothesis propose that firms transfer greener technology to the host countries, causing lower environmental degradation (Khan et al., 2021).

Sample literature proposes that financial development attracts foreign direct investment (FDI) because it is likely to improve investment procedures, decrease the need for financial risk mitigation, and increase capital accumulation (Rafique et al., 2020). The sample provides evidence that financial development influences FDI (Rafique et al., 2020; Vo & Zaman, 2020).[25] Moreover, the sample provides empirical results both supporting the PHH (e.g., Ganda, 2019; Vo & Zaman, 2020) and the Pollution Halo Hypothesis (e.g., Khan et al., 2021; Rafique et al., 2020). In line with the hypotheses, the sample has also found empirical evidence supporting that FDI may impact energy consumption (Vo & Zaman, 2020), technological innovation, and financial development (Rafique et al., 2020).

Technological innovation: Schumpeter (1942) argued that superior technological innovation enters an existing market through invention, innovation, and diffusion. In line with this theory, research and development (R&D) processes are employed to execute the invention and innovation phases. The diffusion phase occurs when individuals, firms, and governments adopt and exploit technological innovations. Some scholars argue that financial development increases technological innovation thanks to more capital allocated to R&D processes (Rafique et al., 2020). As mentioned above, this may involve a higher availability of cheap funds and resources for clean and green innovations (Li et al., 2022). Furthermore, scholars promote the idea that technological innovation is driven by economic growth (Khan et al., 2021) and a rise in FDI inflows (i.e., in line with the Pollution Halo Hypothesis) (Rafique et al., 2020).

Building on previous research and work by Weitzman (1997), scholars argue that technological innovation enhances environmental performance thanks to increased energy efficiency and other eco-friendly technological advancements (Rafique et al., 2020; Shahbaz et al., 2020). The sample provides empirical evidence supporting that technological innovation has alleviating effect on the environmental degradation (e.g.,

[25] Some studies apply FDI inflows as a proxy of financial development (e.g., Ganda, 2019). Because an increase in FDI inflows often is not a direct action by financial institutions or financial markets, it is treated as a separate mechanism here.

Qayyum et al., 2021; Rafique et al., 2020) but also provide two examples where R&D is associated with environmental pollution (Li et al., 2022; Ziołо et al., 2020). In addition, according to one study, technological innovation is also a driver of financial development, economic growth, and foreign direct investment (Rafique et al., 2020).

Energy consumption: By financing environmentally friendly projects like green technology and renewable energy projects, scholars suggest that financial development may enhance environmental quality by lowering fossil fuel and energy use (Khan et al., 2021). Scholars have also argued that expanding the financial sector may invite FDI and modern eco-friendly technology, increasing energy efficiency (Rafique et al., 2020). Moreover, some researchers have argued that when developing, the financial sector is likely to encourage its customers to rely more on energy (Nasir et al., 2021). Such consumption growth may occur through increased investments in machinery and equipment (Sheraz et al., 2021). The sample provides empirical support for a causal relationship between financial development and energy consumption (Vo & Zaman, 2020).

Most studies found that energy consumption exacerbates environmental degradation (e.g., Ehigiamusoe et al., 2019; Mohammed Saud et al., 2019). However, it alleviates environmental harm in a few country cases (Khalid et al., 2021; Qayyum et al., 2021). Other studies have identified that renewable energy consumption enhances environmental quality (Khalid et al., 2021; Qin et al., 2021). Scholars attribute this difference to the amount of renewable energy in the energy mix (e.g., Hove & Tursoy, 2019; Wang et al., 2021) and dissimilar financial systems (Khan et al., 2021). In addition, the sample provides evidence supporting that energy consumption leads to more financial development (Rafique et al., 2020), economic growth (Khalid et al., 2021; Sheraz et al., 2021), and FDI inflows (Rafique et al., 2020; Vo & Zaman, 2020).

To summarize, the literature is inconclusive regarding the accumulated environmental impact of financial systems, with both negative, positive, and insignificant impacts of financial systems on the environment reported. However, most of the examined mechanisms have been linked to higher environmental degradation, highlighting the risk they pose to the environment. Yet, the results present an incomplete picture of the reality as the literature unevenly examines financial system characteristics identified by Čihák et al. (2012) and indicators of inflows from and outflows to the biosphere. This will be discussed further in Section 6.

6. Discussion

Understanding the mechanisms through which financial systems impact the environment is crucial to achieving sound policy recommendations—which have been called for within ecological economics (Rezai & Stagl, 2016; Victor & Jackson, 2020). While this review helped identify mechanisms through which finance rose risks to the environment, it also uncovered critical knowledge gaps in finance-to-environment research (Section 6.1.). Furthermore, this research's analysis reveals that the reviewed literature lacks a discussion of finance's role in the physical scale of economies (Section 6.2.). This section discusses these aspects and the study's implications (Section 6.3.) and limitations (Section 6.4.).

6.1. Knowledge gaps in the finance-to-environment literature

The sample studies use different proxies and indicators, econometric methods (Nasir et al., 2021), time periods (Ganda, 2019), and countries (Ehigiamusoe et al., 2019; Guo et al., 2019). As mentioned in Section 5, these differences may explain the dissimilar results. Some scholars have scrutinised some of these differences, grouping their panels based on income level (Thampanya et al., 2021) and economic type (Obiora et al., 2020). Other scholars have also narrowed their scope down to countries with similar characteristics, such as similar geographical location (e.g., Khalid et al., 2021) and pace of economic growth (e.g., Li et al., 2022). Yet, because of their differences, these studies do not form a basis for identifying crucial elements to develop financial systems with low environmental impact or associated policy recommendations. Thus, this knowledge gap should be bridged by future research.

Moreover, even if the scholars claim to examine the environmental impact of financial development, few studies use sufficient indicators or proxies to reflect the multidimensionality of financial systems (ch. Čihák et al., 2012). For example, the studies have largely relied on single measures of financial institution depth as proxies for financial development, representing only one of two components and one of four characteristics of financial systems. Čihák et al. (2012) also problematize the predominant use of single and financial depth indicators.

Some studies use indices to capture the multidimensionality of financial development.[26, 27] However, most studies using indices do not disentangle the different aspects

[26] See the studies by Boufateh and Saadaoui (2020); Nasir et al. (2021); Ngoc and Awan (2021); Qayyum et al. (2021); Qin et al. (2021); Rafique et al. (2020); and Sheraz et al. (2021). The study by Nasir et al. (2021) stand out from the others as authors have decomposed the over metrics in eight sub-indices.

[27] The Financial Development Index is a database by Svirydzenka (2016) and International Monetary Fund (2019). It is based on the work by Čihák et al. (2012) and include three dimensions (financial access, financial

of financial development and still discuss financial development as a ‘simple’ phenomenon. As introduced in Section 4, this is problematic when financial development may occur along with many different characteristics. In addition, the review show that the environmental impact of financial development may be characterized by nonlinearity along the time horizon and the extent of the different impacts is likely to be asymmetric. Therefore, scholars should treat these various aspects with caution to disentangle financial mechanisms, the causes of the mechanisms’ different impacts, and identify means to maximize environmental quality.

Another knowledge gap is the limited use of indicators of inflows from the biosphere to economies. The quantitative studies in the sample mainly use indicators of the waste sent from economies to the biosphere, such as CO_2 and other GHG emissions. Only a few exceptions use inflow indicators such as ecological footprint (i.e., Khalid et al., 2021; Ngoc & Awan, 2021; Sharma et al., 2021). This reveals a lack of systematic investigation of finance’s role in influencing economies' resource absorption. Such an absence of inflows indicators is problematic because it results in an incomplete representation of financial systems’ impact on the physical scale of real economies. This incomplete representation could be fuelled by the dominant focus on combating climate change in the international environmental debate until recently (Zaccai & Adams, 2012), neglecting the importance of, for instance, biodiversity (see e.g., Steffen et al., 2015). However, other reasons for this neglect may be a lack of data availability and the complexity of biodiversity, making it easier to understand climate change than biodiversity loss (Zaccai & Adams, 2012). Even if data availability and complexity may explain this shortcoming, the reviewed studies fail to acknowledge it.

6.2. Finance’s role in economic metabolism

While the sample examines some topics relevant to forming a more sustainable future, discussions about finance’s role in relation to the physical scale of economies are scarce. Two exceptions are Crona et al. (2021) and Galaz et al. (2018), who link their discussions to, for example, planetary boundaries. Suppose the proposed inverted U-shaped relationship between financial development and environmental degradation indicators reflects the reality of most financial systems over time. When will the turn from increasing negative environmental impacts to decreasing negative environmental impacts occur? Will it happen in time to stay within the planetary boundaries? And will they ever reach a level below the planetary

depth, and financial efficiency) of each sub-sector (financial markets and financial institutions) and overall financial development. Thus, Svirydzenka (2016) argues it captures the multidimensionality of financial development to a higher degree than a single proxy.

boundaries? These questions are directly linked to the debate of whether economic growth will or will not decouple from environmental degradation (Haberl et al., 2020; Wiedenhofer et al., 2020), and whether it will happen soon (Haberl et al., 2020; Parrique et al., 2019) and fast enough to reach the Paris Agreement's targets (Hickel & Kallis, 2020). Because financial systems are drivers of economic growth, they deserve attention in this decoupling debate and maybe a decoupling debate of their own. However, the analysis shows that hardly any reviewed literature questions the continuous expansion of financial systems (or economic growth).[28] Similarly, the sample's discussions mostly evolve around further development of current financial systems, not whether a total system transformation is needed. This echoes a pro-growth approach to the growth dilemma (see e.g., Urhammer & Røpke, 2013).

The debate about the nature of money can also be linked to finance's role in economic metabolism. The preferred measure of financial institution depth (ch. Čihák et al., 2012), namely private credit to GDP, could, if issued by commercial banks, add to the debt level and the broad money supply, given that money is endogenous. While money holders will expect to be able to exchange money for goods and services when desired (Daly & Cobb Jr, 1989), the lender will depend on the debt and interests to be repaid. Suppose money is created within financial systems as debt (i.e., the money supply is, in fact, endogenous). Then, money and debt could grow unlimited. However, there is a limit to how much the future capital stock can grow as long as it is coupled with resource use (Haberl et al., 2020). This implies that at one point, the future stock cannot possibly match demand, which would damage the faith in the monetary system (Daly & Cobb Jr, 1989). Moreover, these phenomena can push the economic metabolism further beyond the planetary boundaries and into an unsafe space for humanity while creating more financial instability that governments have limited tools to tackle. Altogether, this demonstrates the importance of acknowledging all financial system characteristics. Moreover, it revives the concerns of early contributors to ecological economics, such as Soddy ([1926] 1933), suggesting that there should be a limit to how much debt can grow and that all lending should be covered with existing capital.

The review suggests that financial systems pose many environmental risks through complex interactions with real economies and the environment. Even if financial development can alleviate environmental harm through increased technological innovation and renewable

[28] This a similar finding to that of Haberl et al. (2020) who reviewed literature about decoupling of economic growth, resource use and GHG emissions. They find that most of the reviewed literature does not question the GDP growth paradigm.

energy consumption, other research suggests that rapidly growing global consumption has diminished or cancelled out any gains brought about by technological innovation (Haberl et al., 2020). Therefore, the help from technological innovation in decoupling growth (i.e., both expansion of financial systems and economic growth) is highly overdue. This also demonstrates that the review results give limited insight into finance's role in economic metabolism. Yet, the identified mechanisms through which financial systems can pose risks to the environment compose a valuable starting point for future research aiming to enhance finance-to-environment knowledge.

6.3. Implications of the study

This paper demonstrates the existence of multiple knowledge gaps in finance-to-environment literature. Further, it argues that bridging these knowledge gaps is essential for financial institutions to know how to exert unrealized influence, for governments to design regulations and incentive systems that prompt environmentally friendly behaviour (among financial actors and financial markets), and improve underlying risk frameworks. Moreover, at a point when time is limited,[29] the insufficient understanding of finance-to-environment risks is unsettling because it may result in environmentally unfavourable decision-making even among actors with good intentions (Crona et al., 2021). Therefore, new research is urgent, as well as its policy recommendations.

6.4. Future research

Future research should focus on three aspects to bridge knowledge gaps. First, research must incorporate and disentangle all financial system functions and characteristics or, as a minimum, be explicit about what functions and characteristics are not included. Second, future research should include both indicators of inflows from the biosphere to economies and indicators of outflows from economies to the biosphere. Together these indicators may better capture the dependency of economies on the biosphere and the diversity of environmental impacts that exist. Further, by systematically capturing and disentangling the multidimensionality of financial systems and the environment, future research can enhance the understanding of the environmental impact of prevailing financial system functions and characteristics and identify what makes some financial systems less environmentally harmful than others. This would facilitate the development of appropriate policy recommendations to improve environmental quality. Finally, future research would benefit from adopting a more

[29] See for example «World on course to breach global 1.5C warming threshold within five years» by Financial Times published on May 10th, 2022. Link: https://www.ft.com/content/6f73668d-ce55-4e23-a8a7-340e316f555c

critical perspective on the current financial systems that allow both discussions about reconfiguration options of financial systems as we know them and about whether a total transformation of the current financial systems is needed.

6.5. Limitations of the study

There are multiple limitations of this study that future research can tackle. There are four key shortcomings of this research related to the method. First, the research reviewed was limited to English, potentially excluding important contributions. Second, only peer-reviewed literature appeared in the final sample, which resulted from the choice of the academic database and filters.[30] Third, the limited time dimension of the search may also have excluded important contributions not referred to in the sample literature. Fourth, the citation filter used on documents from 2020 and 2022, because of impact, review expectations of the previous research, and time constraints (see Section 4), excluded 122 articles without citations. Among these, there could be important contributions published a short time before the search, thereby not having the time to be cited.

7. Conclusion

This review demonstrates that financial systems may impact and thereby pose risks to the environment through two groups of mechanisms: (1) financial mechanisms consisting of financial system functions and the improvement or worsening of how well financial systems perform these functions, and (2) additional mechanisms, through which financial systems indirectly pose risks to the environment, including economic growth, foreign direct investment inflows, technological innovation, and energy consumption. All reviewed studies validate a relationship between financial systems and the environment, but they are inconclusive about causal directions and signs of the relationship. Even if there is some evidence of financial development alleviating environmental degradation through increased technological innovation and renewable energy consumption, most of the evidence suggests that the risks that finance pose to the environment have resulted in the exacerbation of environmental harm. However, the current state-of-the-art knowledge about finance's risks to the environment is marked by significant knowledge gaps. To bridge the knowledge gaps and develop sound policy recommendations, this paper proposes that future research should (i) incorporate the multidimensionality of financial systems, (ii) include aspects of inflows from and outflows to

[30] Scopus did not return grey literature other than conference papers.

the biosphere, and (iii) discuss both options of financial system reconfiguration and transformation.

8. References

Ament, J. (2019). Toward an Ecological Monetary Theory. *Sustainability*, 11 (3). doi: 10.3390/su11030923.

Anser, M. K., Yousaf, Z., Zaman, K., Nassani, A. A., Alotaibi, S. M., Jambari, H., Khan, A. & Kabbani, A. (2020). Determination of resource curse hypothesis in mediation of financial development and clean energy sources: Go-for-green resource policies. *Resources Policy*, 66: 101640. doi: 10.1016/j.resourpol.2020.101640.

Antoncic, M. (2019). Why sustainability? Because risk evolves and risk management should too. *Journal of Risk Management in Financial Institutions*, 12 (3): 206-216.

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., Marshall, C., McGuire, J. L., Lindsey, E. L., Maguire, K. C., et al. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, 471 (7336): 51-57. doi: 10.1038/nature09678.

Beck, T., Levine, R. & Loayza, N. (2000). Finance and the sources of growth. *Journal of Financial Economics*, 58 (1): 261-300. doi: 10.1016/S0304-405X(00)00072-6.

Benes, J. & Kumhof, M. (2012). The Chicago Plan Revisited. *IMF Working Papers*, 2012 (202): A001. doi: 10.5089/9781475505528.001.A001.

BIS. (n.d.). *About debt securities statistics*. Available at: https://www.bis.org/statistics/about_securities_stats.htm (accessed: 05.06.2022).

Boufateh, T. & Saadaoui, Z. (2020). Do Asymmetric Financial Development Shocks Matter for CO2 Emissions in Africa? A Nonlinear Panel ARDL–PMG Approach. *Environmental Modeling & Assessment*, 25 (6): 809-830. doi: 10.1007/s10666-020-09722-w.

Boumans, R., Costanza, R., Farley, J., Wilson, M. A., Portela, R., Rotmans, J., Villa, F. & Grasso, M. (2002). Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. *Ecological Economics*, 41 (3): 529-560. doi: 10.1016/S0921-8009(02)00098-8.

Bryman, A. (2016). *Social research methods*. 5th ed. Oxford: Oxford University Press.

Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics*, 121: 220-230. doi: 10.1016/j.ecolecon.2015.03.020.

Chen, Y., Cheng, L., Lee, C.-C. & Wang, C.-s. (2021). The impact of regional banks on environmental pollution: Evidence from China's city commercial banks. *Energy Economics*, 102: 105492. doi: 10.1016/j.eneco.2021.105492.

Čihák, M., Demirgüç-Kunt, A., Feyen, E. & Levine, R. (2012). Benchmarking financial systems around the world. *World Bank policy research working paper* (6175).

Clapp, J. (2015). Distant agricultural landscapes. *Sustainability Science*, 10 (2): 305-316. doi: 10.1007/s11625-014-0278-0.

Crona, B., Folke, C. & Galaz, V. (2021). The Anthropocene reality of financial risk. *One Earth*, 4 (5): 618-628. doi: 10.1016/j.oneear.2021.04.016.

Daly, H. E. (1985). The Circular Flow of Exchange Value and the Linear Throughput of Matter-Energy: A Case of Misplaced Concreteness. *Review of Social Economy*, 43 (3): 279-297. doi: 10.1080/00346768500000032.

Daly, H. E. & Cobb Jr, J. B. (1989). Afterword: Money, Debt, and Wealth. In *For the Common Good: Redirecting the Economy toward Community, the Environment, and a Sustainable Future*, pp. 407-442. Boston: Beacon Press.

Daly, H. E. (1991). Elements of environmental macroeconomics. In Costanza, R. (ed.) *Ecological economics: The science and management of sustainability*, pp. 32-46. New York: Columbia University Press.

Dam, L. & Scholtens, B. (2013). Ownership Concentration and CSR Policy of European Multinational Enterprises. *Journal of Business Ethics*, 118 (1): 117-126. doi: 10.1007/s10551-012-1574-1.

Dimson, E., Karakaş, O. & Li, X. (2015). Active Ownership. *The Review of Financial Studies*, 28 (12): 3225-3268. doi: 10.1093/rfs/hhv044.

Edmans, A. (2014). Blockholders and Corporate Governance. *Annual Review of Financial Economics*, 6 (1): 23-50. doi: 10.1146/annurev-financial-110613-034455.

Ehigiamusoe, K. U., Guptan, V. & Lean, H. H. (2019). Impact of financial structure on environmental quality: evidence from panel and disaggregated data. *Energy Sources, Part B: Economics, Planning, and Policy*, 14 (10-12): 359-383. doi: 10.1080/15567249.2020.1727066.

Fanning, A. L., O'Neill, D. W., Hickel, J. & Roux, N. (2022). The social shortfall and ecological overshoot of nations. *Nature Sustainability*, 5 (1): 26-36. doi: 10.1038/s41893-021-00799-z.

Fontana, G. & Sawyer, M. (2016). Towards post-Keynesian ecological macroeconomics. *Ecological Economics*, 121: 186-195. doi: 10.1016/j.ecolecon.2015.03.017.

Galaz, V., Gars, J., Moberg, F., Nykvist, B. & Repinski, C. (2015). Why Ecologists Should Care about Financial Markets. *Trends in Ecology & Evolution*, 30 (10): 571-580. doi: 10.1016/j.tree.2015.06.015.

Galaz, V., Crona, B., Dauriach, A., Scholtens, B. & Steffen, W. (2018). Finance and the Earth system – Exploring the links between financial actors and non-linear changes in the climate system. *Global Environmental Change*, 53: 296-302. doi: 10.1016/j.gloenvcha.2018.09.008.

Ganda, F. (2019). The environmental impacts of financial development in OECD countries: a panel GMM approach. *Environmental Science and Pollution Research*, 26 (7): 6758-6772. doi: 10.1007/s11356-019-04143-z.

Georgescu-Roegen, N. (1975). Energy and Economic Myths. *Southern Economic Journal*, 41 (3): 347-381. doi: 10.2307/1056148.

Godley, W. & Lavoie, M. (2012). *Monetary economics: an integrated approach to credit, money, income, production and wealth*. Basingstoke: Palgrave Macmillan.

Grossman, G. M. & Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, 110 (2): 353-377. doi: 10.2307/2118443.

Guo, M., Hu, Y. & Yu, J. (2019). The role of financial development in the process of climate change: Evidence from different panel models in China. *Atmospheric Pollution Research*, 10 (5): 1375-1382. doi: 10.1016/j.apr.2019.03.006.

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Fishman, T., Hausknost, D., Krausmann, F., Leon-Gruchalski, B., et al. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. *Environmental Research Letters*, 15 (6): 065003. doi: 10.1088/1748-9326/ab842a.

Hardt, L. & O'Neill, D. W. (2017). Ecological Macroeconomic Models: Assessing Current Developments. *Ecological Economics*, 134: 198-211. doi: 10.1016/j.ecolecon.2016.12.027.

Helbing, D. (2013). Globally networked risks and how to respond. *Nature*, 497 (7447): 51-59. doi: 10.1038/nature12047.

Hickel, J. & Kallis, G. (2020). Is Green Growth Possible? *New Political Economy*, 25 (4): 469-486. doi: 10.1080/13563467.2019.1598964.

Hickel, J., O'Neill, D. W., Fanning, A. L. & Zoomkawala, H. (2022). National responsibility for ecological breakdown: a fair-shares assessment of resource use, 1970–2017. *The Lancet Planetary Health*, 6 (4): e342-e349. doi: 10.1016/S2542-5196(22)00044-4.

Hove, S. & Tursoy, T. (2019). An investigation of the environmental Kuznets curve in emerging economies. *Journal of Cleaner Production*, 236: 117628. doi: 10.1016/j.jclepro.2019.117628.

Jackson, T. (2009). *Prosperity Without Growth? The Transition to a Sustainable Economy*. London: Sustainable Development Commission.

Jackson, T., Drake, B., Victor, P., Kratena, K. & Sommer, M. (2014). Foundations for an Ecological Macroeconomics. Literature Review and Model Development. *WWWforEurope Working Paper No. 65*, WIFO Studies.

Jackson, T. & Victor, P. A. (2019). Unraveling the claims for (and against) green growth. *Science*, 366 (6468): 950. doi: 10.1126/science.aay0749.

Khalid, K., Usman, M. & Mehdi, M. A. (2021). The determinants of environmental quality in the SAARC region: a spatial heterogeneous panel data approach. *Environmental Science and Pollution Research*, 28 (6): 6422-6436. doi: 10.1007/s11356-020-10896-9.

Khan, H., Weili, L., Khan, I. & Oanh, L. t. K. (2021). Recent advances in energy usage and environmental degradation: Does quality institutions matter? A worldwide evidence. *Energy Reports*, 7: 1091-1103. doi: 10.1016/j.egyr.2021.01.085.

Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H. & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological economics*, 68 (10): 2696-2705.

Krausmann, F., Schandl, H., Eisenmenger, N., Giljum, S. & Jackson, T. (2017). Material Flow Accounting: Measuring Global Material Use for Sustainable Development. *Annual Review of Environment and Resources*, 42 (1): 647-675. doi: 10.1146/annurev-environ-102016-060726.

Lade, S. J., Steffen, W., de Vries, W., Carpenter, S. R., Donges, J. F., Gerten, D., Hoff, H., Newbold, T., Richardson, K. & Rockström, J. (2020). Human impacts on planetary boundaries amplified by Earth system interactions. *Nature Sustainability*, 3 (2): 119-128. doi: 10.1038/s41893-019-0454-4.

Levine, R. (2005). Finance and Growth: Theory and Evidence. In Aghion, P. & Durlauf, S. N. (eds) vol. 1 *Handbook of Economic Growth*, pp. 865-934: Elsevier.

Li, X., Ozturk, I., Majeed, M. T., Hafeez, M. & Ullah, S. (2022). Considering the asymmetric effect of financial deepening on environmental quality in BRICS economies: Policy options for the green economy. *Journal of Cleaner Production*, 331: 129909. doi: 10.1016/j.jclepro.2021.129909.

Mahmood, H., Alrasheed, A. S. & Furqan, M. (2018). Financial Market Development and Pollution Nexus in Saudi Arabia: Asymmetrical Analysis. *Energies*, 11 (12). doi: 10.3390/en11123462.

Marques, A., Martins, I. S., Kastner, T., Plutzar, C., Theurl, M. C., Eisenmenger, N., Huijbregts, M. A. J., Wood, R., Stadler, K., Bruckner, M., et al. (2019). Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nature Ecology & Evolution*, 3 (4): 628-637. doi: 10.1038/s41559-019-0824-3.

McKinsey Global Institute. (2021). *The rise and rise of the global balance sheet: How productively are we using our wealth?* Available at: https://www.mckinsey.com/industries/financial-services/our-insights/the-rise-and-rise-of-the-global-balance-sheet-how-productively-are-we-using-our-wealth (accessed: 23.05.2022).

McLeay, M., Radia, A. & Thomas, R. (2014). *Money creation in the modern economy*. London, UK: Bank of England Quarterly Bulletin.

Mellor, M. (2010). *The Future of Money: From Financial Crisis to Public Resource*. London, UK; New York, NY, USA: Pluto Press.

Mhadhbi, M., Gallali, M. I., Goutte, S. & Guesmi, K. (2021). On the asymmetric relationship between stock market development, energy efficiency and environmental quality: A nonlinear analysis. *International Review of Financial Analysis*, 77: 101840. doi: 10.1016/j.irfa.2021.101840.

Mohammed Saud, M. A., Guo, P., Haq, I. u., Pan, G. & Khan, A. (2019). Do government expenditure and financial development impede environmental degradation in Venezuela? *PLOS ONE*, 14 (1): e0210255. doi: 10.1371/journal.pone.0210255.

Nasir, M. A., Canh, N. P. & Lan Le, T. N. (2021). Environmental degradation & role of financialisation, economic development, industrialisation and trade liberalisation. *Journal of Environmental Management*, 277: 111471. doi: 10.1016/j.jenvman.2020.111471.

Ngoc, B. H. & Awan, A. (2021). Does financial development reinforce ecological footprint in Singapore? Evidence from ARDL and Bayesian analysis. *Environmental Science and Pollution Research*. doi: 10.1007/s11356-021-17565-5.

Obiora, S. C., Bamisile, O., Opoku-Mensah, E. & Kofi Frimpong, A. N. (2020). Impact of Banking and Financial Systems on Environmental Sustainability: An Overarching Study of Developing, Emerging, and Developed Economies. *Sustainability*, 12 (19). doi: 10.3390/su12198074.

OECD. (2005). *Financial system*. Glossary of Statistical Terms: OECD. Available at: https://stats.oecd.org/glossary/detail.asp?ID=6189 (accessed: 21.05.2022).

Otero, I., Farrell, K. N., Pueyo, S., Kallis, G., Kehoe, L., Haberl, H., Plutzar, C., Hobson, P., García-Márquez, J. & Rodríguez-Labajos, B. (2020). Biodiversity policy beyond economic growth. *Conservation Letters*: e12713. doi: 10.1111/conl.12713.

Parrique, T., Barth, J., Briens, F., Kuokkanen, A. & Spangenberg, J. (2019). Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability. *European Environmental Bureau*.

Pethig, R. (1976). Pollution, welfare, and environmental policy in the theory of Comparative Advantage. *Journal of Environmental Economics and Management*, 2 (3): 160-169. doi: 10.1016/0095-0696(76)90031-0.

Pörtner, H., Scholes, R., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W., et al. (2021). IPBES-IPCC co-sponsored workshop report on biodiversity and climate change; IPBES and IPCC. *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)*: 24. doi: 10.5281/zenodo.4782538.

Qayyum, M., Ali, M., Nizamani, M. M., Li, S., Yu, Y. & Jahanger, A. (2021). Nexus between Financial Development, Renewable Energy Consumption, Technological Innovations and CO2 Emissions: The Case of India. *Energies*, 14 (15). doi: 10.3390/en14154505.

Qin, L., Hou, Y., Miao, X., Zhang, X., Rahim, S. & Kirikkaleli, D. (2021). Revisiting financial development and renewable energy electricity role in attaining China's carbon neutrality target. *Journal of Environmental Management*, 297: 113335. doi: 10.1016/j.jenvman.2021.113335.

Rafique, M. Z., Li, Y., Larik, A. R. & Monaheng, M. P. (2020). The effects of FDI, technological innovation, and financial development on CO2 emissions: evidence from the BRICS countries. *Environmental Science and Pollution Research*, 27 (19): 23899-23913. doi: 10.1007/s11356-020-08715-2.

Ravenscroft, J., Liakata, M., Clare, A. & Duma, D. (2017). Measuring scientific impact beyond academia: An assessment of existing impact metrics and proposed improvements. *PLOS ONE,* 12 (3): e0173152. doi: 10.1371/journal.pone.0173152.

Rezai, A., Taylor, L. & Mechler, R. (2013). Ecological macroeconomics: An application to climate change. *Ecological Economics,* 85: 69-76. doi: 10.1016/j.ecolecon.2012.10.008.

Rezai, A. & Stagl, S. (2016). Ecological Macreconomics: Introduction and Review.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., et al. (2009). A safe operating space for humanity. *Nature*, 461 (7263): 472-475. doi: 10.1038/461472a.

Ryan-Collins, J., Greenham, T., Werner, R. & Jackson, A. (2012). *Where does money come from?: A Guide to the UK Monetary & Banking System*. 2nd ed. London: New Economics Foundation. Pg. London: New Economics Foundation.

Røpke, I. (2016). Complementary system perspectives in ecological macroeconomics — The example of transition investments during the crisis. *Ecological Economics,* 121: 237-245. doi: 10.1016/j.ecolecon.2015.03.018.

Schoenmaker, D. & Schramade, W. (2019). *Principles of sustainable finance*: Oxford University Press.

Scholtens, B. (2017). Why Finance Should Care about Ecology. *Trends in Ecology & Evolution*, 32 (7): 500-505. doi: 10.1016/j.tree.2017.03.013.

Schumpeter, J. A. (1942). *Capitalism, socialism and democracy*. London, UK: Routledge.

Shahbaz, M., Nasir, M. A., Hille, E. & Mahalik, M. K. (2020). UK's net-zero carbon emissions target: Investigating the potential role of economic growth, financial development, and R&D expenditures based on historical data (1870–2017). *Technological Forecasting and Social Change*, 161: 120255. doi: 10.1016/j.techfore.2020.120255.

Sharma, R., Sinha, A. & Kautish, P. (2021). Does financial development reinforce environmental footprints? Evidence from emerging Asian countries. *Environmental Science and Pollution Research*, 28 (8): 9067-9083. doi: 10.1007/s11356-020-11295-w.

Sheraz, M., Deyi, X., Ahmed, J., Ullah, S. & Ullah, A. (2021). Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from G20 countries. *Environmental Science and Pollution Research*, 28 (26): 35126-35144. doi: 10.1007/s11356-021-13116-0.

Silver, N. (2017). *Finance, Society and Sustainability How to Make the Financial System Work for the Economy, People and Planet*. London: Palgrave Macmillan.

Soddy, F. ([1926] 1933). *Wealth, virtual wealth and debt: the solution of the economic paradox*: George Allen and Unwin Ltd, London.

Stagl, S. (2014). Ecological macroeconomics: reflections on labour markets. *European Journal of Economics and Economic Policies: Intervention*, 11 (2): 171-181.

Statista. (2022). *Total assets of global financial institutions from 2002 to 2020 (in trillion U.S. dollars)*: Statista Research Department. Available at: https://www.statista.com/statistics/421060/global-financial-institutions-assets/ (accessed: 06.06.2022).

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., et al. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, 347 (6223): 1259855. doi: 10.1126/science.1259855.

Svartzman, R., Ament, J., Barmes, D., Erickson, J. D., Farley, J., Guay-Boutet, C. & Kosoy, N. (2020). Money, interest rates and accumulation on a finite planet: revisiting the 'monetary growth imperative'through institutionalist approaches. In Costanza, R., Erickson, J. D., Farley, J. & Kubiszewski, I. (eds) *Sustainable Wellbeing Futures: A Research and Action Agenda for Ecological Economics*, pp. 266-283: Edward Elgar Publishing.

Svirydzenka, K. (2016). *Introducing a new broad-based index of financial development*: International Monetary Fund Working Paper 16/5.

Taher, H. (2020). Financial Development and Economic Growth Impact on The Environmental Degradation in Lebanon. *International Journal of Energy Economics and Policy*, 10 (3): 311-316.

Thampanya, N., Wu, J. & Cowton, C. (2021). Carbon neutrality targets, optimal environmental management strategies & the role of financial development: New evidence incorporating non-linear effects and different income levels. *Journal of Environmental Management*, 297: 113352. doi: 10.1016/j.jenvman.2021.113352.

The Club of Rome, Potsdam Institute for Climate Impact Research, Stockholm Resilience Centre & Norwegian Business School. (2022). Earth for All: A Survival Guid for Humanity [Unpublished book].

Tian, Y., Chen, W. & Zhu, S. (2017). Does financial macroenvironment impact on carbon intensity: evidence from ARDL-ECM model in China. *Natural Hazards*, 88 (2): 759-777. doi: 10.1007/s11069-017-2925-0.

Urhammer, E. & Røpke, I. (2013). Macroeconomic narratives in a world of crises: An analysis of stories about solving the system crisis. *Ecological Economics*, 96: 62-70. doi: 10.1016/j.ecolecon.2013.10.002.

Victor, P. A. & Jackson, T. (2020). A Research Agenda for Ecological Macroeconomics. In Costanza, R., Erickson, J. D., Farley, J. & Kubiszewski, I. (eds) *Sustainable Wellbeing Futures: A Research and Action Agenda for Ecological Economics*, pp. 357-372: Edward Elgar Publishing.

Vo, X. V. & Zaman, K. (2020). Relationship between energy demand, financial development, and carbon emissions in a panel of 101 countries: "go the extra mile" for sustainable development. *Environmental Science and Pollution Research*, 27 (18): 23356-23363. doi: 10.1007/s11356-020-08933-8.

Wang, X., Huang, J., Xiang, Z. & Huang, J. (2021). Nexus Between Green Finance, Energy Efficiency, and Carbon Emission: Covid-19 Implications From BRICS Countries. *Frontiers in Energy Research*, 9. doi: 10.3389/fenrg.2021.786659.

Weber, O. (2014). The financial sector's impact on sustainable development. *Journal of Sustainable Finance & Investment*, 4 (1): 1-8. doi: 10.1080/20430795.2014.887345.

Weitzman, M. L. (1997). Sustainability and Technical Progress. *The Scandinavian Journal of Economics*, 99 (1): 1-13. doi: 10.1111/1467-9442.00043.

Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Streeck, J., Pichler, M., Mayer, A., Krausmann, F., Brockway, P., Schaffartzik, A., et al. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping. *Environmental Research Letters*, 15 (6): 063002. doi: 10.1088/1748-9326/ab8429.

Wiedmann, T., Lenzen, M., Keyßer, L. T. & Steinberger, J. K. (2020). Scientists' warning on affluence. *Nature Communications*, 11 (1): 3107. doi: 10.1038/s41467-020-16941-y.

Wiedmann, T. O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J. & Kanemoto, K. (2015). The material footprint of nations. *Proceedings of the National Academy of Sciences*, 112 (20): 6271. doi: 10.1073/pnas.1220362110.

World Bank. (n.d.-a). *Broad money (% of GDP)*. Available at: https://data.worldbank.org/indicator/FM.LBL.BMNY.GD.ZS.

World Bank. (n.d.-b). *Financial depth*. Key Terms Explained. Available at: https://www.worldbank.org/en/publication/gfdr/gfdr-2016/background/financial-depth (accessed: 01.05.2022).

World Bank. (n.d.-c). *Financial stability*. Global Financial Development Report. Available at: https://www.worldbank.org/en/publication/gfdr/gfdr-2016/background/financial-stability (accessed: 26.05.2022).

World Bank. (n.d.-d). *GDP (current US$)*. Available at: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

World Bank. (n.d.-e). *Market capitalization of listed domestic companies (% og GDP)*. Available at: https://data.worldbank.org/indicator/CM.MKT.LCAP.GD.ZS (accessed: 22.05.2022).

World Bank. (n.d.-f). *Market capitalization of listed domestic companies (current US$)*. Available at: https://data.worldbank.org/indicator/CM.MKT.LCAP.CD (accessed: 23.05.2022).

World Bank. (n.d.-g). *Metadata Glossary*. Available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/BX.KLT.DINV.WD.GD.ZS (accessed: 31.05.2022).

World Economic Forum. (2020a). *Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy*. Available at: https://www.weforum.org/reports/nature-risk-rising-why-the-crisis-engulfing-nature-matters-for-business-and-the-economy (accessed: 12.01.2022).

World Economic Forum. (2020b). *Toward Common Metrics and Consistent Reporting of Sustainable Value Creation*. Consultation Draft.

Wray, L. R. (2015). *Modern money theory: A primer on macroeconomics for sovereign monetary systems*. 2nd ed. Basingstoke: Palgrave Macmillan.

Zaccai, E. & Adams, W. M. (2012). How far are biodiversity loss and climate change similar as policy issues? *Environment, Development and Sustainability*, 14 (4): 557-571. doi: 10.1007/s10668-012-9344-x.

Zeeshan, M., Han, J., Rehman, A., Ullah, I. & Alam Afridi, F. E. (2021). Exploring determinants of financial system and environmental quality in high-income developed countries of the world: the demonstration of robust penal data estimation techniques. *Environmental Science and Pollution Research*, 28 (43): 61665-61680. doi: 10.1007/s11356-021-15105-9.

Ziegler, R., Balzac-Arroyo, J., Hölsgens, R., Holzgreve, S., Lyon, F., Spangenberg, J. H. & Thapa, P. P. (2022). Social innovation for biodiversity: A literature review and research challenges. *Ecological Economics*, 193: 107336. doi: 10.1016/j.ecolecon.2021.107336.

Zioło, M., Kluza, K., Kozuba, J., Kelemen, M., Niedzielski, P. & Zinczak, P. (2020). Patterns of Interdependence between Financial Development, Fiscal Instruments, and Environmental Degradation in Developed and Converging EU Countries. *International Journal of Environmental Research and Public Health*, 17 (12). doi: 10.3390/ijerph17124425.

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Appendix A. List of the articles in the final Sample

#	Author(s) and publication year	Type of study	Area/ Country	Conclusion regarding finance-to-environment relationship	Conclusion regarding other mechanisms' impact on the environment
1	Anser et al. (2020)	Quantitative	Saudi Arabia	Greater financial institution depth (here: PSC) increases carbon dioxide (CO_2) emissions and fossil fuel combustion. Greater financial market depth (here: M2) increases CO_2 and greenhouse gas (GHG) emissions.	Economic growth and electric power consumption increase CO_2 emissions. Greater foreign direct investment (FDI) inflows decrease CO_2 emissions. Enhanced trade openness increases GHG emissions and decreases CO_2 emissions.
2	Boufateh and Saadaoui (2020)	Quantitative	22 African countries	In the short term, a negative shock in overall financial development (here: FDIn) and financial institution development (here: FI) increases CO_2 emissions. In the long term, a positive shock in overall financial development (here: FDIn) and financial institution development (here: FI) decreases CO_2 emissions.	In the long term, economic growth decreases CO_2 emissions and energy consumption increased CO_2 emissions.
3	Chang et al. (2020)	Quantitative	18 countries with sophisticated financial markets	Greater financial market depth (here: MSCI stock index) increases CO_2 emissions from oil, while it decreases CO_2 emissions from coal marginally.	

4	Chen et al. (2021)	Quantitative	284 cities, China	Greater financial institution access (here: RBD) decreases sulphur dioxide (SO_2) emissions per capita. Moreover, greater financial institution access increases FDI inflows, technological innovation, and industrial structure upgrading.	Greater FDI inflows, technological innovation, and industrial structure upgrading decreases SO_2 emissions per capita.
5	Clapp (2015)	Qualitative		The growing significance of financial markets in global agrifood value chains encourages new forms of distancing. Such distancing makes it more difficult to link ecological and social cost externalization in the attempt to allocate responsibility to specific actors.	
6	Crona et al. (2021)	Qualitative		Even if financial institutions allocate capital based on desires to improve environmental quality it does not always serve its purpose entirely because the prevailing risk frameworks used in financial decision-making fails to account for physical risks such as deforestation associated to firms' operations and trade.	
7	Ehigiamusoe et al. (2019)	Quantitative	58 countries	Greater financial institutional depth (here: PCS, LL, and TCF) decreases CO_2 emissions. However, the country-specific effects show both significant positive and negative results for all variables in different countries.	Economic growth and greater energy consumption increase CO_2 emissions.
8	Galaz et al. (2015)	Qualitative		Financial markets, financial institutions, and financial instrument may impact the environment directly by influencing corporate behaviour and offering 'green' financial instruments. Moreover, financial markets may impact the environment indirectly by offering an arena for trading and	

				sending price signals. The rapidly increase in commodity derivatives, new actors (with other interests) operating in the financial markets globally, and use of trade algorithms may complicate long-term decision-making.	
9	Galaz et al. (2018)	Qualitative	Boreal forests	There are some financial institutions that are key stockholders of companies operating in the Amazon rainforest and boreal forests which have considerable influence that yet is unrealized. Stockholders like these may influence corporate governance through voting, direct engagement with management, and divestment (or the threat of it, but there are also barriers to such influence.	
10	Ganda (2019)	Quantitative	23 OECD countries	Greater financial institution depth both increases (here: PCS) and decreases (here: PCSB) CO_2 and GHG emissions.	Increased gross domestic product (GDP) per capita and FDI inflows increases CO_2 emissions.
11	Guo et al. (2019)	Quantitative	China: national and provincial levels	Greater financial institution depth both increases (here: PCS) and decreases (here: DBA) CO_2 emissions. Greater financial market depth both increases (here: ST) and decreases (here: MC) CO_2 emissions.	
12	Hove and Tursoy (2019)	Quantitative	24 emerging economies	Greater financial institution depth (here: TCF) increases CO_2 and nitrous oxide (NO_2) emissions.	Increased GDP per capita decreases CO_2 emissions and fossil fuel energy

					consumption but increases NO_2 emissions. Raised renewable energy consumption decreases CO_2 emissions and fossil fuel energy consumption increases CO_2 emissions. Greater industrial value-added increases CO_2 emissions and NO_2 emissions. Electric power consumption increases CO_2 emissions but decreases NO_2 emissions.
13	Khalid et al. (2021)	Quantitative	6 SAARC countries	In Bangladesh and Sri Lanka, overall financial development (here: FDIn) increases ecological footprint. In Nepal, overall financial development (here: FDIn) decreases ecological footprint.	In the panel and Nepal, enhanced trade openness increases ecological footprint. In Bhutan, increased energy consumption reduces ecological footprint. In all countries except Bangladesh, renewable energy consumption decreases ecological footprint.

14	Khan et al. (2021)	Quantitative	188 countries	Greater financial institution depth (here: PSC) increases CO_2 emissions.	Greater FDI inflows and renewable energy consumption, decreases CO_2 emissions. Enhances high-technology export increases CO_2 emissions.
15	Li et al. (2022)	Quantitative	BRICS countries	In the long term, overall financial development (here: FD), financial institution development (here: FIDIn), and financial market development (here: FMDIn) decreases CO_2 emissions Moreover, overall financial development (here: FD) may impact the environment through economic growth and research and development (R&D).	In the long term, GDP per capita and R&D increases CO_2 emissions.
16	Mahmood et al. (2018)	Quantitative	Saudi Arabia	In the long term, negative shocks in financial institution depth increases CO_2 emissions.	In the short term, a negative shock in energy consumption increases CO_2 emissions. In the long term, greater GDP per capita increases and has a U-shaped relationship with CO_2 emissions. Moreover, a negative shock in energy consumption decreases CO_2 emissions.

17	Mhadhbi et al. (2021)	Quantitative	19 emerging markets	In the short term, both positive (here: STPC) and negative shocks (here: MCPC) in financial market depth decreases CO_2 emissions per capita. In the long term, both positive (here: STPC and MCPC) and negative shocks (here: MCPC) in financial market depth increases CO_2 emissions per capita.	In short and long term, greater GDP per capita and energy consumption per capita increases CO_2 emissions.
18	Mohammed Saud et al. (2019)	Quantitative	Venezuela	Negative shocks in financial institution depth (here: PSC) increases CO_2 emissions.	In the short and long term, greater energy consumption increases CO_2 emissions.
19	Nasir et al. (2021)	Quantitative	Australia	In the long term, overall financial development (here: FDIn), development in financial institution access (here: FIA), financial institution efficiency (here: FIE), financial markets (here: FM), financial market depth (here: FMD), financial market access (here: FMA), and financial market efficiency (here: FME) increase CO_2 emissions per capita.	In the long term, greater GDP per capita, energy consumption, and trade openness increases CO_2 emissions per capita.
20	Ngoc and Awan (2021)	Quantitative	Singapore	Overall financial development (here: FDIn) increases ecological footprint.	Greater GDP per capita increases ecological footprint and greater human capital decreases ecological footprint.
21	Obiora et al. (2020)	Quantitative	45 countries: 15 of each economic type	In developing economies, greater financial institution efficiency (here: DR and RR) decreases total CO_2 emissions, CO_2 emissions by the power industry, CO_2 emissions by transportation sector, and CO_2 emissions by other combustion industries. Moreover, greater financial institution efficiency (here: DR) increases CO_2 emissions by buildings and CO_2 emissions by other sectors than power, buildings, and transportation.	

				Finally, greater financial institution depth (here: PCS and TCF) increases total CO_2 emissions, CO_2 emissions by the power industry, CO_2 emissions by transportation sector, CO_2 emissions by other combustion industries, and CO_2 emissions by other sectors than power, buildings, and transportation. In emerging economies, financial institution efficiency (here: DR) decreases total CO_2 emissions, CO_2 emissions by the power industry, CO_2 emissions by buildings, CO_2 emissions by transportation sector, CO_2 emissions by other combustion industries, and CO_2 emissions by other sectors than power, buildings, and transportation. Moreover, greater institution efficiency (here: RR) decreases CO2 emissions per capita. Further, greater financial institution depth (here: PCS and TCF) increases total CO_2 emissions, CO_2 emissions per capita, CO_2 emissions by the power industry, CO_2 emissions by buildings, CO_2 emissions by other combustion industries, and CO_2 emissions by other sectors than power, buildings, and transportation. Finally, greater financial institutional depth (here: PCS and TCF) and financial institution efficiency (here: LR) increases CO_2 emissions by transportation sector. In developed economies, greater financial efficiency (here: DR) and financial institution depth (here: PSC) decrease CO_2 emissions per capita. Moreover, greater financial efficiency (here: LR) decreases total CO_2 emissions, CO_2 emissions by the power industry, CO_2 emissions by buildings, CO_2 emissions by transportation sector, and CO_2 emissions by other sectors than power, buildings, and transportation. Finally, greater	

				financial institution depth (here: PSC) and financial institution efficiency (here: DR) increase total CO_2 emissions, CO_2 emissions by the power industry, CO_2 emissions by buildings, and CO_2 emissions by other sectors than power, buildings, and transportation.	
22	Qayyum et al. (2021)	Quantitative	India	In the short and long term, overall financial development (here: FDIn) increases CO_2 emissions per capita.	In short and long run, GDP per capita increases CO_2 emissions per capita. Technological innovation and renewable energy consumption decreases CO_2 emissions per capita.
23	Qin et al. (2021)	Quantitative	China	Overall financial development (here: FDIn) decreases CO_2 emissions, while increases financial risk increases CO_2 emissions.	Greater renewable energy electricity consumption and human capital decreases CO_2 emissions.
24	Rafique et al. (2020)	Quantitative	BRICS countries	Overall financial development (here: FDIn) decreases CO_2 emissions Overall financial development may impact the environment through economic growth, FDI, technological innovation, and energy consumption per capita.	In long term, economic growth, energy consumption per capita, and trade openness increases CO_2 emissions. In contrary, greater FDI inflows and technological innovation decreases CO_2 emissions.
25	Scholtens (2017)	Review		Ecology is important for finance and an alignment of finance and ecology would benefit society. Such an alignment requires financial institutions to acknowledge the environmental impact of finance and the financial impact	

				of the environment, and that financial institutions are held responsible for their impacts.	
26	Shahbaz et al. (2020)	Quantitative	UK	Greater financial institution depth (here: M2) increases CO_2 emissions.	In the short term, economic growth, energy consumption and R&D increase CO_2 emissions. In the long term, economic growth and greater energy consumption still increase CO_2 emissions but R&D decreases CO_2 emissions marginally.
27	Sharma et al. (2021)	Quantitative	8 South and Southeast Asian countries	In the long term, overall financial development increases ecological footprint, carbon footprint, and land footprint.	In the long term, economic growth, greater energy consumption, and trade expansion increase ecological footprint, carbon footprint and land footprint.
28	Sheraz et al. (2021)	Quantitative	developed and developing G20 countries (excluding the EU)	Overall financial development (here: FDIn) decreases CO_2 emissions per capita.	Economic growth and increased energy consumption per capita increase CO_2 emissions per capita.
29	Taher (2020)	Quantitative	Lebanon	Greater financial institution depth (here: PSC) increases CO_2 emissions.	Greater GDP per capita and fossil energy consumption increase CO_2 emissions, but trade openness decreases CO_2 emissions.

30	Thampany a et al. (2021)	Quantitative	61 high- and middle-income countries	In the long term, independently of economic type, a negative shock in financial institution depth (here: M2) increases CO_2 emissions per capita. In contrary, a positive shock in financial institution depth (here: M2) decreases CO_2 emissions per capita. Moreover, a positive shock in financial market depth (here: MC) decreases CO_2 emissions per capita, while a negative shock increases CO_2 emissions per capita. In the long term, there effects in high-income and middle-income economies, but they differ. In high-income economies, a positive shock in financial institution depth (here: M2) decreases CO_2 emissions per capita and a negative shock in financial institution depth (here: M2) increases CO_2 emissions per capita. Moreover, a negative shock in financial market depth (here: MC) decreases CO_2 emissions per capita. In contrary, a positive shock in financial market depth (here: MC) increases CO_2 emissions per capita in middle-income countries.	In all economies, greater energy consumption and economic growth increases CO_2 emissions per capita. Greater FDI inflows decreases CO_2 emissions per capita, confirming the pollution **halo** hypothesis. In the long term, the effect varies between high-income and middle-income economies. In high-income economies, greater GDP per capita and FDI inflows decrease CO_2 emissions, confirming the pollution **halo** hypothesis. In middle-income economies, greater FDI inflows increase CO_2 emissions per capita, confirming the pollution **haven** hypothesis.
31	Tian et al. (2017)	Quantitative	China	Greater financial institution depth (here: PSCB) and financial market efficiency (here: TR) decrease carbon intensity.	
32	Vo and Zaman (2020)	Quantitative	101 countries	Greater financial institution depth (here: M2) decreases CO_2 emissions per capita.	Greater FDI inflows increases CO_2 emissions per capita, confirming the pollution **haven** hypothesis.

				Financial institution depth may impact the environment through economic growth and FDI.	
33	Wang et al. (2021)	Quantitative	BRICS countries	Green finance (here: GFI) decreases CO_2 emissions, but the relationship varies on different quantiles and the coefficient of green finance is relatively small.	Greater GDP per capita, FDI inflows, energy consumption, and trade openness increase CO_2 emissions. Greater renewable energy consumption and R&D decrease CO_2 emissions.
34	Zeeshan et al. (2021)	Quantitative	20 high-income developed countries	Greater financial institution debt (here: PSC, LL, and TDF) increases a composite index of CO_2, SO_2, N_2O, and CH_4 emissions.	Greater GDP per capita and energy consumption increase a composite index of CO_2, SO_2, N_2O, and CH_4 emissions but only marginally.
35	Zioło et al. (2020)	Quantitative	Two groups of EU countries: converging economies from Central and Eastern Europe and the largest developed economies of Western Europe	Greater risk of financial institutional instability (here: DTE and ATE) increases GHG emissions, while greater financial market depth (here: PDS) decreases GHG emissions.	Greater R&D increases GHG emissions.

Note: PSC shows private sector credit to GDP, which is domestic private credit to the real sector by deposit money banks to GDP. FDIn shows Financial Development Index, which is an index developed by Svirydzenka (2016) and International Monetary Fund (2019) based on the work by Čihák et al. (2012). FI shows a financial institution development sub-index of FDIn. FDI shows a financial institutional depth sub-index of FDIn. FIA shows a financial institution access sub-index of FDIn. FIE shows a financial institution efficiency sub-index of FDIn. FM shows a financial market development sub-index of FDIn. FMD shows a financial markets depth sub-index of FDIn. FMA shows a financial markets access sub-index of FDIn. FME shows a financial markets efficiency sub-index of FDIn. FD shows the financial deepening index by Li et al. (2022). FIDIn shows the financial institutional deepening index by Li et al. (2022) which is constructed from three sub-indices: financial institution depth, financial institution efficiency, and financial institution access. FMDIn shows the financial market deepening index by Li et al. (2022) which is constructed from three sub-indices: financial market depth, financial market efficiency, and financial market access. FDIn1 shows a self-constructed financial development index by Sharma et al. (2021), consisting of broad money supply to GDP, domestic credit given by the financial sector to GDP, domestic credit to the private sector relative to GDP, and government's liquid liabilities (% of broad money). FRIn shows financial risk index. MSCI shows MSCI stock index. RBD shows regional bank development. LL shows liquid liabilities to GDP. MC shows stock market capitalization to GDP and is defined as the value of listed shares to GDP. MCPC shows stock market capitalization per capita; TCF shows total domestic credit provided by financial institution to private and public sectors relative to GDP. ST shows stocks traded to GDP and measures stock market liquidity that promotes more efficient resource allocation and reduces disincentive to investment (Ehigiamusoe et al., 2019). STPC shows stocks traded per capita. TR shows turnover ratio for stock market and measures the value of trades of domestic shares in the domestic market divided by market capitalization (Ehigiamusoe et al., 2019). DBA shows the sum of deposit and loan balances of financial institutions to GDP. LR shows lending rate. DR show deposit rate. RR shows real interest rate. CBL show commercial bank lending (CBL). IFIN shows financial product innovation degree (see Tian et al., 2017). GFI shows a green finance index including based on green credit, green securities, and green investment (see Wang et al., 2021). PDS shows outstanding domestic private debt securities to GDP. DTE shows financial sector leverage (debt to equity) (see Zioło et al., 2020). ATE shows banking leverage (assets-to-equity multiple) (see Zioło et al., 2020).

Appendix B. 4x2 Matrix of Financial System Characteristics with examples of candidate variables

	Financial institutions	Financial markets
Depth	• **Private sector credit to GDP** • Financial institutions' assets to GDP • M2 to GDP • Deposits to GDP • Gross value-added of the financial sector to GDP	• **Stock market capitalization plus outstanding domestic private debt securities to GDP** • Private debt securities to GDP • Public debt securities to GDP • International debt securities to GDP • Stock market capitalization to GDP • Stocks traded to GDP
Access	• **Account per thousand adults** (commercial banks) • Branches per 100,000 adults (commercial banks) • % of people with a bank account • % of firms with line of credit (all firms) • % of firms with line of credit (small firms)	• **Percent of market capitalization outside of top 10 largest companies** • Percent of value traded outside of top 10 traded companies • Government bond yields (3 months and 10 years) • Ratio of domestic to total debt securities • Ratio of private to total debt securities (domestic) • Ratio of new corporate bond issues to GDP
Effi-ciency	• **Net interest margin** • Lending-deposits spread • Non-interest income to total income • Overhead costs (% of total assets) • Profitability (return on assets, return on equity) • Boone indicator (or Herfindahl or H-statistics)	• **Turnover ratio** (turnover/capitalization) for stock market • Price synchronicity (co-movement) • Private information trading • Price impact • Liquidity/transaction costs • Quoted bid-ask spread for government bonds • Turnover of bonds (private, public) on securities exchange • Settlement efficiency
Stability	• **Z-score** (or distance to default) • Capital adequacy ratios • Asset quality ratios • Liquidity ratios • Other (net foreign exchange position to capital etc.)	• **Volatility** (standard deviation/average) of stock price index, sovereign bond index • Skewness of the index (stock price, sovereign bond) • Vulnerability to earnings manipulation • Price/earnings ratio • Duration • Ratio of short-term to total bonds (domestic, international) • Correlation with major bond returns (German, US)

Source: Adopted from Čihák et al. (2012, p. 9)

Note: Čihák et al. (2012) have created this stylized table based on their literature review. They highlight variables suggested for benchmarking financial system characteristics in bold. The authors further note the following regarding the data in the table: “Private sector credit to GDP is domestic private credit to the real sector by deposit money banks to GDP. Accounts per thousand adults (commercial banks) is the number of depositors with commercial banks per 1,000 adults. For each type of institution, this is calculated as the (reported number of depositors)*1,000/adult population in the reporting country. The net interest margin is the accounting value of bank's net interest revenue as a share of its average interest-bearing (total earning) assets. The Z-score (or distance to default) is (ROA+equity/assets)/sd(ROA), where ROA is average annual return on end-year assets and sd(ROA) is the standard deviation of ROA. Stock market capitalization plus outstanding domestic private debt securities to GDP is defined as the value of listed shares to GDP plus amount of outstanding domestic private debt securities to GDP. Percent of market capitalization outside of top 10 largest companies is the market capitalization out of top ten largest companies to total market capitalization. Turnover ratio (turnover/capitalization) for stock market is the ratio of the value of total shares traded to market capitalization. Volatility (standard deviation / average) of stock price index is the standard deviation of the sovereign bond index divided by the annual average of that index.” (Čihák et al., 2012, p. 9)

Appendix C. Summary of quantitative studies

#	Author(s) and publication year	Area/ Country	Time period	Financial indicators/ proxies	Environmental indicators/ proxies	Conclusion regarding finance-to-environment relationship	Other relevant mechanisms examined	Conclusion regarding other mechanisms	Relevant causalities detected	Relevant asymmetrical, U-shaped relationships and hypothesis confirmed
1	Anser et al. (2020)	Saudi Arabia	1975-2018	PSC; M2	CO2; FFUEL; GHG	PSC↑CO2↑ PSC↑FFUEL↑ M2↑CO2↑ M2↑GHG↑	GDPPC; FDI; EC; EPC; TOP	GDPPC↑CO2↑ FDI↑CO2↓ EPC↑CO2↑ TOP↑CO2↓ TOP↑GHG↑	PSC→CO2 PSC→FFUEL M2→FFUEL FDI→CO2, FFUEL	GDPPCYFFUEL *Pollution Halo Hypothesis confirmed*
2	Boufateh and Saadaoui (2020)	22 African countries	1980-2014	FDIn; FI; FM	CO2	S/T: FDIn↓CO2↑ S/T: FI↓CO2↑ L/T: FDIn↑CO2↓ L/T: FI↑ CO2↓	GDP; EC	L/T: GDP↑CO2↓ EC↑CO2↑	*Causality not tested*	S/T: EKC not supported L/T: GDPΩCO2
3	Chang et al. (2020)	18 countries with sophisticated financial markets	1971-2001	MSCI	CO2coal; CO2oil; CO2gas	MSCI↑CO2oil↑ MSCI↑CO2coal↓ (marginal)			MSCI→CO2coal MSCI→CO2oil	
4	Chen et al. (2021)	284 cities, China	1998-2018	RBD	SO2PC	RBD↑SO2PC↓	FDI; TI; ISU	RBD↑FDI↑ RBD↑TI↑ FDI↑SO2PC↓ TI↑SO2PC↓ RBD↑ISU↑ ISU↑SO2↓	*Causality not tested, but they use instrumented variable (IV) to deal with any endogeneity problem*	*Pollution Halo Hypothesis confirmed*

7	Ehigiamusoe et al. (2019)	58 countries	1991-2015	PSC; LL; TCF; MC; ST; TR	CO2	PCS↑CO2↓ LL↑CO2↓ TCF↑CO2↓ *Country-specific effects show both significant positive and negative results for all variables in different countries.*	GDP; EC	GDP↑CO2↑ EC↑CO2↑	*Causality not tested*	*Insignificant nonlinear results suggest linear model is better fit*
10	Ganda (2019)	23 OECD countries	2001-2012	PSC; PSCB	CO2; GHG	PCS↑CO2↑ PCS↑GHG↑ PCSB↑CO2↓ PCSB↑GHG↓	GDPPC; FDI	FDI↑CO2↑ GDPPC↑CO2↑	*Causality not tested*	GDPPCΩCO2 GDPPCΩGHG *Pollution Haven Hypothesis confirmed*
11	Guo et al. (2019)	China: national and provincial levels	1997-2015	PSC ; DBA; ST; MC	CO2	PCS↑CO2↑ DBA↑CO2↓ ST↑CO2↑ MC↑CO2↓	IS		*Causality not tested*	
12	Hove and Tursoy (2019)	24 emerging economies	2000-2017	TCF	CO2; FFC; NOE	TCF↑CO2↑ TCF↑NOE↑	GDPPC; GDP2; REC; EPC; IVA	GDPPC↑CO2↓ GDPPC↑FFC↓ GDPPC↑NOE↑ REC↑CO2↓ REC↑FFC↓ IVA↑CO2↑ IVA↑NOE↑ EPC↑CO2↑ EPC↑NOE↓	*Causality not tested*	GDPPCYCO2 GDPPCYFFC GDPPCΩNOE (marginal) *Debunks EKC hypothesis for emerging economies globally*

13	Khalid et al. (2021)	6 SAARC countries	1997-2015	FDIn	EFP	Panel: *FDIn insignificant* Country-specific: Bangladesh & Sri Lanka: FDIn↑EFP↑ Nepal: FDIn↑EFP↓	GDP; EC; REC; TOP	Panel: TOP↑EFP↑ Country-specific effects: Nepal: TOP↑EFP↑ Bhutan: EC↑EFP↓ All countries except Bangladesh: REC↑EFP↓	GDP→FDIn GDP→EFP GDP→REC GDP→TOP EC→EFP EC→TOP EC↔GDP REC→EFP TOP↔EFP	
14	Khan et al. (2021)	188 countries	2002-2018	PSC	CO2	PCS↑CO2↑	GDPPC; FDI; TE; REC; EC;	FDI↑CO2↓ REC↑CO2↓ TE↑CO2↑	*Causality not tested*	*Pollution Halo Hypothesis confirmed*
15	Li et al. (2022)	BRICS countries	1990-2019	FD; FIDIn; FMDIn	CO2	S/T: *mixed and mostly insignificant effects* Linear model & L/T: FD↑CO2↓ FIDIn↑CO2↑ FMDIn↑CO2↑ Non-linear model & L/T: FD↑CO2↓ FIDIn↑CO2↓ FMDIn↑CO2↓	GDPPC; RD	S/T: *mixed and mostly insignificant effects* All models & L/T: GDPPC↑CO2↑ RD↑CO2↑	Symmetric causalities: FD↔CO2 FMDIn↔CO2 FD→GDPPC RD→CO2 Asymmetric causalities: FD_POS→CO2 FD_NEG→CO2 FIDIn_POS→CO2 FMDIn_POS→CO2 RD→CO2 FD_NEG→RD FIDIn_POS→GDP RD→FIDIn_POS	

16	Mahmood et al. (2018)	Saudi Arabia	1971-2014	PSC	CO2	L/T: PSC↓CO2↑	GDPPC; GDP2; EC	S/T: EC↓CO2↓ L/T: GDPPC↑CO2↑ EC↓CO2↓	*Causality not tested*	*Asymmetric effects of PSC and EC on CO2* L/T GDPPCΩCO2 *EKC Hypothesis confirmed*
17	Mhadhbi et al. (2021)	19 emerging markets	1995-2014	MCPC; STPC	CO2PC	Linear model, S/T: STPC↑CO2PC↓ Linear model, L/T: MCPC↑CO2PC↑ STPC↑CO2PC↑ Nonlinear model, S/T: MCPC↓CO2PC↓ STPC↑CO2PC↓ Nonlinear model, L/T: MCPC↓CO2PC↑ MCPC↑CO2PC↑ STPC↑CO2PC↑	GDPPC; EC	All models, S/T & L/T: GDPPC↑CO2↑ ECPC↑CO2↑	Linear causalities: MCPC↔CO2PC STPC↔CO2PC GDPPC↔CO2PC ECPC↔CO2PC Nonlinear causalities: MCPC_NEG→CO2PC STPC_POS→CO2PC STPC_NEG→CO2PC	*Asymmetric effects of MCPC and STPC* *Debunks EKC hypothesis*
18	Mohammed Saud et al. (2019)	Venezuela	2017-2013	PSC	CO2	L/T: PSC↓CO2↑	GDPPC; GDP2; EC	S/T & L/T: EC↑CO2↑	S/T: CO2→PSC CO2→GDPPC CO2→EC GDPPC→PSC EC→GDP PSC↔EC	GDPPCΩCO2

									L/T: PSC→CO2 GDPPC↔EC EC→CO2 GDPPC→EC	
19	Nasir et al. (2021)	Australia	1980-2014	FDIn; FI; FID; FIA; FIE; FM; FMD; FMA; FME	CO2PC	L/T: FDIn↑CO2PC↑ FIA↑CO2PC↑ FIE↑CO2PC↑ FM↑CO2PC↑ FMD↑CO2PC↑ FMA↑CO2PC↑ FME↑CO2PC↑	GDPPC; GDP2; EC; TOP; IVAPC	L/T: GDPPC↑CO2PC↑ EC↑CO2PC↑ TOP↑CO2PC↑	FMA↔CO2PC GDPPC↔CO2PC EC↔CO2PC IVAPC↔CO2PC	GDPPCYCO2PC *Debunks EKC hypothesis*
20	Ngoc and Awan (2021)	Singapore	1980-2016	FDIn	EFP	FDIn↑EFP↑	GDPPC; HC	GDPC↑EFP↑ HC↑EFP↓	EFP→FDIn GDPPC↔EFP HC↔EFP GDPPC→FDIn HC→FDIn HC→GDPPC	
21	Obiora et al. (2020)	45 countries: 15 of each economic type	1990-2017	LR, DR, RR, PSC, TCF	CO2; CO2PC; CO2Pi; CO2B; CO2T; CO2OCI; CO2OS	Developing economies: DR, RR↑ CO2, CO2Pi, CO2T, CO2OCI↓ DR↑CO2B, CO2OS↑ PCS, TCF↑ CO2, CO2Pi, CO2T, CO2OCI, CO2OS↑			*Causality not tested*	

						Emerging economies: DR ↑ TCO2, CO2Pi, CO2B, CO2T, CO2OCI, CO2OS↓ RR↑ CO2PC↓ PSC, TCF↑ CO2, CO2PC, CO2Pi, CO2B, CO2OCI, CO2OS↑ LR, PSC, TCF↑ CO2T↑ Developed economies: LR↑ TCO2, CO2Pi, CO2B, CO2T, CO2OS↓ DR, PSC↑ CO2Pc↓ DR, PSC↑ TCO2, CO2Pi, CO2B, CO2Pi, CO2OS ↑				
22	Qayyum et al. (2021)	India	1980-2019	FDIn	CO2PC	S/T and L/T: FDIn↑CO2PC↑	GDPPC; REC; TI	S/T and L/T: GDPPC↑CO2PC↑ TI↑CO2PC↓ REC↑CO2PC↓	GDP→CO2 GDP→REC TI→CO2 TI→REC REC→CO2 REC→GDP	*Debunks EKC hypothesis*

23	Qin et al. (2021)	China	1988-2018	FDIn; FRIn	CO_2	FDIn↑CO_2↓ FRIn↑CO_2↑	GDP; REE; HC	REE↑CO_2↓ HC↑CO_2↓	S/T, M/T, & L/T: FDIn→CO_2 FRIn→CO_2 GDP→CO_2 REE→CO_2 HC→CO_2	
24	Rafique et al. (2020)	BRICS countries	1990-2017	FDIn	CO_2PC	L/T: FDIn↑CO_2↓	GDP; FDI; TI; ECPC	L/T: FDI↑CO_2↓ GDP↑CO_2↑ TI↑CO_2↓ ECPC↑CO_2↑ TOP↑CO_2↑	FDIn↔CO_2PC FDIn↔GDP FDIn↔FDI FDIn↔TI GDP↔CO_2 GDP↔TI GDP↔TOP FDI↔ECPC CO_2→FDI TI↔CO_2 TI→FDI TOP↔CO_2 TI↔TOP TI↔ECPC	*Pollution Halo Hypothesis confirmed*
26	Shahbaz et al. (2020)	UK	1870-2017	M2	CO_2	M2↑ CO_2↑	GDP; GDP2; EC; RD; RD2	S/T: GDP↑ CO_2↑ EC↑ CO_2↑ RD↑ CO_2↑ L/T: GDP↑ CO_2↑	M2→CO_2	M2 Y CO_2 GDP Ω CO_2 *EKC Hypothesis confirmed* RD Ω CO_2

								EC↑ CO_2↑ RD↑ CO_2↓		
27	Sharma et al. (2021)	8 South and Southeast Asian countries	1990-2015	FDIn1	EFP; CFP; LFP	L/T: FDIn1↑ EFP, CFP, LFP↑	GDP; EC; TX	L/T: GDP↑ EFP, CFP, LFP↑ EC↑ EFP, CFP, LFP↑ TX↑ EFP, CFP, LFP↑	Direct causality: FDIn1→ CFP, LFP Indirect causality: FDIn1→ EFP	
28	Sheraz et al. (2021)	developed and developing G20 countries (excluding the EU)	1986-2018	FDIn	CO2PC	FDIn↑CO2PC↓	GDP; ECPC; HC	GDP↑CO2PC↑ ECPC↑CO2PC↑	CO2PC→FDIn ECPC→FDIn HC→FDIn GDP→FDIn GDP↔ECPC CO2PC→GDP ECP→CO2PC HC→GDP	
29	Taher (2020)	Lebanon	1988-2018	PSC	CO_2	PSC↑ CO_2↑	GDPPC; FEC; TOP	GDPPC↑ CO_2↑ FEC↑ CO_2↑ TOP↑ CO_2↓	*Causality not tested*	
30	Thampanya et al. (2021)	61 high- and middle-income countries	1990-2018	M2; MC	CO2PC	Nonlinear model & L/T High-income economies: M2↑CO2PC↓ M2↓CO2PC↑ MC↓CO2PC↓ Middle-income economies: MC ↑CO2PC↑	GDPPC; FDI; EC	All models: EC↑CO2PC↑ Nonlinear model & L/T High-income economies: GDPPC↑CO2PC↓ FDI↑CO2PC↓	All economies: M2↔CO2PC MC↔CO2PC GDPPC↔CO2PC CO2PC→FDI EC↔CO2PC	*Pollution Halo Hypothesis confirmed in overall sample* *Pollution Halo Hypothesis confirmed in high-income economies* *Pollution Haven Hypothesis confirmed in middle-income economies*

						All economies: M2↑CO2PC↑ M2↓CO2PC↓ MC ↑CO2PC↓ MC↓CO2PC↑		Middle-income economies: FDI↑CO2PC↑ All economies: GDPPC↑CO2PC↑ FDI↑CO2PC↓		
31	Tian et al. (2017)	China	1992-2014	PSCB; IFIN; TR	CI	PSCB↑CI↓ IFIN↑CI↓ TR↑CI↓	FDI		PSCB↔CI	
32	Vo and Zaman (2020)	101 countries	1995-2018	M2	CO2PC	M2↑CO2PC↓	GDPPC; FDI; EC	FDI↓CO2PC↑	M2→FDI M2→GDPPC CO2PC→M2 EC→M2 FDI↔EC	GDPPCΩCO2
33	Wang et al. (2021)	BRICS countries	2000-2018	GFI	CO2	GFI↑CO2↓	GDPPC; FDI; EC; REC; RD; TOP	GDPPC↑CO2↑ FDI↑CO2↑ EC↑CO2↑ REC↑CO2↓ RD↑CO2↓ TOP↑CO2↑	*Causality is tested but not commented or displayed in the paper*	*Pollution Haven Hypothesis confirmed*
34	Zeeshan et al. (2021)	20 high-income developed countries	2001-2018	PSC; LL; TDF; MC; ST; TR	EMS	PSC↑EMS↓ LL↑EMS↓ TDF↑EMS↓	GDPPC; EC	GDPPC↑EMS↑ EC↑EMS↑ (only marginal)	*Causality not tested*	PSCΩEMS LLΩEMS TDFΩEMS
35	Zioło et al. (2020)	Two EU groups: converging economies from Central and Eastern	2008-2017	PSC; DTE; ATE; PDS;	GHG	DTE↑GHG↑ ATE↑GHG↑ PDS↑GHG↓	RD	RD↑GHG↑	*Causality not tested*	

		Europe and the largest developed economies of Western Europe								

Note: OECD is an acronym for the Organisation for Economic Co-operation and Development. SAARC is an acronym for the South Asian Association for Regional Cooperation. BRICS is an acronym for Brazil, Russia, India, China, and South Africa. PSC shows private sector credit to GDP by any financial institution. PSCB shows private sector credit to GDP, which is domestic private credit to the real sector by deposit money banks to GDP. FDIn shows Financial Development Index, which is an index developed by Svirydzenka (2016) and International Monetary Fund (2019) based on the work by Čihák et al. (2012). FI shows a financial institution development sub-index of FDIn. FDI shows a financial institutional depth sub-index of FDIn. FIA shows a financial institution access sub-index of FDIn. FIE shows a financial institution efficiency sub-index of FDIn. FM shows a financial market development sub-index of FDIn. FMD shows a financial markets depth sub-index of FDIn. FMA shows a financial markets access sub-index of FDIn. FME shows a financial markets efficiency sub-index of FDIn. FD shows the financial deepening index by Li et al. (2022). FIDIn shows the financial institutional deepening index by Li et al. (2022) which is constructed from three sub-indices: financial institution depth, financial institution efficiency, and financial institution access. FMDIn shows the financial market deepening index by Li et al. (2022) which is constructed from three sub-indices: financial market depth, financial market efficiency, and financial market access. FDIn1 shows a self-constructed financial development index by Sharma et al. (2021), consisting of broad money supply to GDP, domestic credit given by the financial sector to GDP, domestic credit to the private sector relative to GDP, and government's liquid liabilities (% of broad money). FRIn shows financial risk index. MSCI shows MSCI stock index. RBD shows regional bank development. LL shows liquid liabilities to GDP. MC shows stock market capitalization to GDP and is defined as the value of listed shares to GDP. MCPC shows stock market capitalization per capita; TCF shows total domestic credit provided by financial institution to private and public sectors relative to GDP. ST shows stocks traded to GDP and measures stock market liquidity that promotes more efficient resource allocation and reduces disincentive to investment (Ehigiamusoe et al., 2019). STPC shows stocks traded per capita. TR shows turnover ratio for stock market and measures the value of trades of domestic shares in the domestic market divided by market capitalization (Ehigiamusoe et al., 2019). DBA shows the sum of deposit and loan balances of financial institutions to GDP. LR shows lending rate. DR show deposit rate. RR shows real interest rate. CBL show commercial bank lending (CBL). IFIN shows financial product innovation degree (see Tian et al., 2017). GFI shows a green finance index including based on green credit, green securities, and green investment (see Wang et al., 2021). PDS shows outstanding domestic private debt securities to GDP. DTE shows financial sector leverage (debt to equity) (see Zioło et al., 2020). ATE shows banking leverage (assets-to-equity multiple) (see Zioło et al., 2020). GDP shows gross domestic product and is a proxy for economic growth. GDPPC shows economic growth (GDP) per capita. GDP2 shows GDP squared. FDI shows FDI inflows (Čihák et al., 2012). TI shows technological innovation. EC shows energy consumption. ECPC shows energy consumption per capita. REC shows energy consumption from renewable sources. REE shows renewable energy electricity to total electricity generation. FFC shows fossil fuel energy consumption to total energy consumption. EPC shows electric power consumption. TOP shows trade openness. TX shows trade expansion which is the sum of export and import to GDP. IS shows industrial structure. ISU shows industrial structure upgrading effect. IVA shows industry value added. IVAPC shows industry value added per capita TE shows products of high-technology export to total manufactured product export. RD shows research and development expenditure to GDP. RD2 shows RD squared. HC shows human capital. CO2 shows carbon emissions (CO_2). CO2PC shows CO_2 emissions per capita. CO2coal shows CO_2 emissions from coal. CO2oil shows CO_2 emissions from oil. CO2gas shows CO_2 emissions from natural gas. CO2Pi shows CO_2 emissions by the power industry. CO2B shows CO_2 emissions by buildings. CO2T shows CO_2 by transportation sector. CO2OCI shows CO_2 emission by other combustion industries. CO2OS shows CO_2 emissions by other sectors than power, buildings, transportation. CI shows carbon intensity measured by CO_2 emissions to GDP. GHG shows greenhouse gas emissions. SO2PC shows sulphur dioxide emissions per capita. FFUEL shows emissions from fossil fuel combustion. NOE shows nitrous oxide emissions. EFP shows ecological footprint. CFP shows carbon footprint. LFP shows land footprint. EMS shows a composite index of CO2, SO2, N2O, and CH4 emissions. Ω shows inverted u-shaped relationship. Y shows u-shaped relationship. ↑ shows increases, ↓ shows decreases, ↔ shows bidirectional causality, and → shows unidirectional causality. S/T shows short term. M/T shows medium term. L/T shows long term.

Appendix D. Correlation characteristics between environmental harm variables and explanatory variables (L/T)

Study #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FD													c		a					c			a	a			a	c							
N_FD															a																				
FI																																			
N_FI																																			
FID	a														a			c								Y,a				a	a	c		Ω	
N_FID																																			
FIA																																			
FIE																																			
FIS																																			
FM																																			
FMD			a												a		a													a					
N_FMD																	a																		
FMA																			a																
FME																																			
FMS																																			
FR																							a												
EG	Y	Ω								Ω		Y	a,d		b	Ω	a	Ω,d	Y,a	a,d		a,d	a	a,b,d		Ω		c,d		a		Ω,b,d			
FDI	a			b																				b,c,d						c		b,d			
TI/RD				b											a,b							a,d		a,b,d		Ω									
EC / EPC													a,d				a	a,b	a			a,d		b2				a,d		a					
N_EC																																			
REC													a										a												
TOP/TX													a																						
HC																				a,d			a					c.d							
IVA/ISU				b															a																
Inflows													X							X							X								
Outflows	X	X	X	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X

Note: The '**#**' shows the identification number of the studies conforming with the numbers in Appendix A and Appendix C. The colour implies identified correlation: **green** indicates a significantly negative association, **red** indicates a significantly positive association, **yellow**/**orange** indicates that the study has detected both significantly positive and negative associations, and **grey** indicates an insignificant association. Blank fields represent variables not studied. Blue fields indicate qualitative studies. The '**a**' indicates a causal relationship between financial system indicator or alternative mechanism indicator and indicator or environmental impact. The '**b**' indicates a unidirectional causal relationship running from financial system indicator(s) to indicator(s) of mechanisms through which the financial system may impact the environment to environmental indicator(s) or a bidirectional causal relationship between the two. The '**b2**' indicates a unidirectional causal relationship running from financial system indicator(s) to indicator(s) of mechanisms through which the financial system may impact the environment to environmental indicator(s) via another mechanism or a bidirectional causal relationship the other mechanism and the third mechanism. The '**c**' shows a unidirectional relationship running from environmental indicator(s) to financial system indicator(s) or indicator(s) of mechanisms through which the financial system may impact the environment. The '**d**' shows a unidirectional relationship running from indicator(s) of mechanisms through which the financial system may impact the environment to other such mechanism(s) or financial system indicator(s). **Ω** shows inverted u-shaped relationship between explanatory variable and environmental indicator. **Y** shows u-shaped relationship between explanatory variable and environmental indicator. **FD** shows overall financial development. **N_FD** shows negative shocks in overall financial development. **FI** shows financial institution development. **N_FI** shows negative shocks in financial institution development. **FID** shows development in financial institution depth. **N_FID** shows negative shock in the financial institution. **FIA** shows the development in financial institution access. **FIE** shows the development in financial institution efficiency. **FIS** shows the development in financial institution stability. **FM** shows the financial market development. **FMD** shows the development in financial market depth. **N_FMD** shows negative shocks in the development of financial market depth. **FMA** shows development in financial market access. **FME** shows development in financial market efficiency. **FMS** shows development in financial market stability. **FR** shows financial risk. **EG** shows economic growth. **FDI** shows foreign direct investment inflows. **TI** shows technological innovation. **EC** shows energy consumption. **N_EC** shows negative shocks in energy consumption. **EPC** shows electric power consumption. **REC** shows renewable energy consumption. **TOP** shows trade openness. **TX** shows trade expansion. **HC** shows human capital development. **IVA** shows industry value-added. **ISU** shows industry structure upgrading.

References

Anser, M. K., Yousaf, Z., Zaman, K., Nassani, A. A., Alotaibi, S. M., Jambari, H., Khan, A. & Kabbani, A. (2020). Determination of resource curse hypothesis in mediation of financial development and clean energy sources: Go-for-green resource policies. *Resources Policy*, 66: 101640. doi: 10.1016/j.resourpol.2020.101640.

Boufateh, T. & Saadaoui, Z. (2020). Do Asymmetric Financial Development Shocks Matter for CO2 Emissions in Africa? A Nonlinear Panel ARDL–PMG Approach. *Environmental Modeling & Assessment*, 25 (6): 809-830. doi: 10.1007/s10666-020-09722-w.

Chang, C.-L., Ilomäki, J., Laurila, H. & McAleer, M. (2020). Causality between CO2 Emissions and Stock Markets. *Energies*, 13 (11). doi: 10.3390/en13112893.

Chen, Y., Cheng, L., Lee, C.-C. & Wang, C.-s. (2021). The impact of regional banks on environmental pollution: Evidence from China's city commercial banks. *Energy Economics*, 102: 105492. doi: 10.1016/j.eneco.2021.105492.

Čihák, M., Demirgüç-Kunt, A., Feyen, E. & Levine, R. (2012). Benchmarking financial systems around the world. *World Bank policy research working paper* (6175).

Clapp, J. (2015). Distant agricultural landscapes. *Sustainability Science*, 10 (2): 305-316. doi: 10.1007/s11625-014-0278-0.

Crona, B., Folke, C. & Galaz, V. (2021). The Anthropocene reality of financial risk. *One Earth*, 4 (5): 618-628. doi: 10.1016/j.oneear.2021.04.016.

Ehigiamusoe, K. U., Guptan, V. & Lean, H. H. (2019). Impact of financial structure on environmental quality: evidence from panel and disaggregated data. *Energy Sources, Part B: Economics, Planning, and Policy*, 14 (10-12): 359-383. doi: 10.1080/15567249.2020.1727066.

Galaz, V., Gars, J., Moberg, F., Nykvist, B. & Repinski, C. (2015). Why Ecologists Should Care about Financial Markets. *Trends in Ecology & Evolution*, 30 (10): 571-580. doi: 10.1016/j.tree.2015.06.015.

Galaz, V., Crona, B., Dauriach, A., Scholtens, B. & Steffen, W. (2018). Finance and the Earth system – Exploring the links between financial actors and non-linear changes in the climate system. *Global Environmental Change*, 53: 296-302. doi: 10.1016/j.gloenvcha.2018.09.008.

Ganda, F. (2019). The environmental impacts of financial development in OECD countries: a panel GMM approach. *Environmental Science and Pollution Research*, 26 (7): 6758-6772. doi: 10.1007/s11356-019-04143-z.

Guo, M., Hu, Y. & Yu, J. (2019). The role of financial development in the process of climate change: Evidence from different panel models in China. *Atmospheric Pollution Research*, 10 (5): 1375-1382. doi: 10.1016/j.apr.2019.03.006.

Hove, S. & Tursoy, T. (2019). An investigation of the environmental Kuznets curve in emerging economies. *Journal of Cleaner Production*, 236: 117628. doi: 10.1016/j.jclepro.2019.117628.

Khalid, K., Usman, M. & Mehdi, M. A. (2021). The determinants of environmental quality in the SAARC region: a spatial heterogeneous panel data approach. *Environmental Science and Pollution Research*, 28 (6): 6422-6436. doi: 10.1007/s11356-020-10896-9.

Khan, H., Weili, L., Khan, I. & Oanh, L. t. K. (2021). Recent advances in energy usage and environmental degradation: Does quality institutions matter? A worldwide evidence. *Energy Reports*, 7: 1091-1103. doi: 10.1016/j.egyr.2021.01.085.

Li, X., Ozturk, I., Majeed, M. T., Hafeez, M. & Ullah, S. (2022). Considering the asymmetric effect of financial deepening on environmental quality in BRICS economies: Policy options for the green economy. *Journal of Cleaner Production*, 331: 129909. doi: 10.1016/j.jclepro.2021.129909.

Mahmood, H., Alrasheed, A. S. & Furqan, M. (2018). Financial Market Development and Pollution Nexus in Saudi Arabia: Asymmetrical Analysis. *Energies*, 11 (12). doi: 10.3390/en11123462.

Mhadhbi, M., Gallali, M. I., Goutte, S. & Guesmi, K. (2021). On the asymmetric relationship between stock market development, energy efficiency and environmental quality: A nonlinear analysis. *International Review of Financial Analysis*, 77: 101840. doi: 10.1016/j.irfa.2021.101840.

Mohammed Saud, M. A., Guo, P., Haq, I. u., Pan, G. & Khan, A. (2019). Do government expenditure and financial development impede environmental degradation in Venezuela? *PLOS ONE*, 14 (1): e0210255. doi: 10.1371/journal.pone.0210255.

Nasir, M. A., Canh, N. P. & Lan Le, T. N. (2021). Environmental degradation & role of financialisation, economic development, industrialisation and trade liberalisation. *Journal of Environmental Management*, 277: 111471. doi: 10.1016/j.jenvman.2020.111471.

Ngoc, B. H. & Awan, A. (2021). Does financial development reinforce ecological footprint in Singapore? Evidence from ARDL and Bayesian analysis. *Environmental Science and Pollution Research*. doi: 10.1007/s11356-021-17565-5.

Obiora, S. C., Bamisile, O., Opoku-Mensah, E. & Kofi Frimpong, A. N. (2020). Impact of Banking and Financial Systems on Environmental Sustainability: An Overarching Study of Developing, Emerging, and Developed Economies. *Sustainability*, 12 (19). doi: 10.3390/su12198074.

Qayyum, M., Ali, M., Nizamani, M. M., Li, S., Yu, Y. & Jahanger, A. (2021). Nexus between Financial Development, Renewable Energy Consumption, Technological Innovations and CO2 Emissions: The Case of India. *Energies*, 14 (15). doi: 10.3390/en14154505.

Qin, L., Hou, Y., Miao, X., Zhang, X., Rahim, S. & Kirikkaleli, D. (2021). Revisiting financial development and renewable energy electricity role in attaining China's carbon neutrality target. *Journal of Environmental Management*, 297: 113335. doi: 10.1016/j.jenvman.2021.113335.

Rafique, M. Z., Li, Y., Larik, A. R. & Monaheng, M. P. (2020). The effects of FDI, technological innovation, and financial development on CO2 emissions: evidence from the BRICS countries. *Environmental Science and Pollution Research*, 27 (19): 23899-23913. doi: 10.1007/s11356-020-08715-2.

Scholtens, B. (2017). Why Finance Should Care about Ecology. *Trends in Ecology & Evolution*, 32 (7): 500-505. doi: 10.1016/j.tree.2017.03.013.

Shahbaz, M., Nasir, M. A., Hille, E. & Mahalik, M. K. (2020). UK's net-zero carbon emissions target: Investigating the potential role of economic growth, financial development, and R&D expenditures based on historical data (1870–2017). *Technological Forecasting and Social Change*, 161: 120255. doi: 10.1016/j.techfore.2020.120255.

Sharma, R., Sinha, A. & Kautish, P. (2021). Does financial development reinforce environmental footprints? Evidence from emerging Asian countries. *Environmental Science and Pollution Research*, 28 (8): 9067-9083. doi: 10.1007/s11356-020-11295-w.

Sheraz, M., Deyi, X., Ahmed, J., Ullah, S. & Ullah, A. (2021). Moderating the effect of globalization on financial development, energy consumption, human capital, and carbon emissions: evidence from G20 countries. *Environmental Science and Pollution Research*, 28 (26): 35126-35144. doi: 10.1007/s11356-021-13116-0.

Taher, H. (2020). Financial Development and Economic Growth Impact on The Environmental Degradation in Lebanon. *International Journal of Energy Economics and Policy,* 10 (3): 311-316.

Thampanya, N., Wu, J. & Cowton, C. (2021). Carbon neutrality targets, optimal environmental management strategies & the role of financial development: New evidence incorporating non-linear effects and different income levels. *Journal of Environmental Management*, 297: 113352. doi: 10.1016/j.jenvman.2021.113352.

Tian, Y., Chen, W. & Zhu, S. (2017). Does financial macroenvironment impact on carbon intensity: evidence from ARDL-ECM model in China. *Natural Hazards*, 88 (2): 759-777. doi: 10.1007/s11069-017-2925-0.

Vo, X. V. & Zaman, K. (2020). Relationship between energy demand, financial development, and carbon emissions in a panel of 101 countries: “go the extra mile” for sustainable development. *Environmental Science and Pollution Research*, 27 (18): 23356-23363. doi: 10.1007/s11356-020-08933-8.

Wang, X., Huang, J., Xiang, Z. & Huang, J. (2021). Nexus Between Green Finance, Energy Efficiency, and Carbon Emission: Covid-19 Implications From BRICS Countries. *Frontiers in Energy Research*, 9. doi: 10.3389/fenrg.2021.786659.

Zeeshan, M., Han, J., Rehman, A., Ullah, I. & Alam Afridi, F. E. (2021). Exploring determinants of financial system and environmental quality in high-income developed countries of the world: the demonstration of robust penal data estimation techniques. *Environmental Science and Pollution Research,* 28 (43): 61665-61680. doi: 10.1007/s11356-021-15105-9.

Zioło, M., Kluza, K., Kozuba, J., Kelemen, M., Niedzielski, P. & Zinczak, P. (2020). Patterns of Interdependence between Financial Development, Fiscal Instruments, and Environmental Degradation in Developed and Converging EU Countries. *International Journal of Environmental Research and Public Health*, 17 (12). doi: 10.3390/ijerph17124425.