Dec 12th, 12:00 AM

Developing a Taxonomy for Sustainable Digital Finance

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Completed Research Paper

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Abstract

The financial system is currently being transformed by digitization and sustainability. However, existing research on the topic of sustainable digital finance, which bridges both areas, is still rare and a more comprehensive understanding of the domain is a missing component in existing research. Therefore, this paper develops a taxonomy based on a comprehensive literature analysis to structure this emerging field more precisely. The taxonomy includes a strategic, an organizational, a systems and a sustainability benefits perspective. The application of the taxonomy to 126 startups reveals that their solutions primarily focus on applications in the energy, financial services and government sector and their major focus is only on five of the seventeen SDGs, which shows a clear preference for climate, energy, infrastructure, cities, and partnerships as the primary goals. Surprisingly, the startups focus merely on operational efficiency optimization like improved processes rather than disruptive innovations in product or customer-related areas.

Keywords: Digital finance, fintech, insurtech, blockchain, sustainability, sustainable development goals

Introduction

This paper examines the emerging research area of "sustainable digital finance" which analyses how the two key driving forces of the financial industry, namely "sustainability" and "digitalization" interact with each other. Recently, the role of the financial system in achieving the United Nations' seventeen sustainability goals (SDGs) has been intensively discussed among both scholars and practitioners. In general, the financial system holds five key functions: (1) produce information ex-ante about possible investments and allocate capital, (2) monitor investments and exert corporate governance after providing finance, (3) facilitate the trading, diversification, and management of risk, (4) mobilize and pool savings, (5) ease the exchange of goods and services (Levine 2005). The first three functions are particularly relevant for achieving the SDGs. First, financial institutions define in their lending strategies which sectors and firms are eligible for lending or not. If the financial sector chooses to finance sustainable companies and startups, it can accelerate the transition to a more sustainable economy. This is especially relevant as according to the UN estimation, there is an investment gap of US $5-$7 trillion per year between 2015 and 2030 to fully fund the SDGs (Vorisek 2020). Second, investors can monitor the performance and business practices of the companies in which they invest, including their activities relevant to the SDGs. Third, finance prices risk of future cash flows for valuation purposes, which facilitate the appropriate management of risk related to sustainability issues such as climate change risks. While only some large financial incumbents have begun to align their existing profit-driven business models with the SDGs, an increasing number of SDG-focused startups have emerged that incorporate SDG objectives in their initial business models. They

consider an SDG approach as their competitive advantage that allows them to pursue both business, environmental and social benefits, which are very often enabled by innovative technologies, so-called "FinTech" or "InsurTech" (Nassiry and Wheeler 2011; Rohlfer et al. 2020).

While many literature discusses either the implication of "digitalization" or "sustainability" in the financial industry, only limited literature examines how these two topics interact with each other. Literature mostly focuses on isolated aspects, such as case studies that show single use cases of how FinTech solutions can be applied to achieve the SDGs (e.g., how a digital marketplace can improve agricultural sustainability by using FinTech (Anshari et al. 2019)) or it develops models for specific areas (e.g., currency innovation for sustainable financing of SMEs (Bendell 2017)). However, due to the early development of these approaches, none of these sources provides a comprehensive overview of this emerging research area. Therefore, this paper aims to develop a comprehensive framework of this new field of "sustainable digital finance" based on both literature and empirical data. More specifically, this research attempts to answer the research question of "how can dimensions and characteristics of FinTech-driven solutions for sustainability be classified in a comprehensive taxonomy?" To answer this question, this paper develops a taxonomy based on a comprehensive literature analysis and applies it to 126 startup companies. The remainder of this paper is structured in seven sections. Section two discusses the theoretical background in FinTech, InsurTech, and sustainability. Section three introduces the research methodology, literature analysis and data selection. Section four presents the results of the taxonomy development, which is applied to the data of 126 startup companies for the verification of the taxonomy constructed in section five. These results are then discussed in section six and section seven concludes the major findings and highlight the future research areas.

Theoretical Background

Sustainability is most commonly defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). The etymology of the term originates in the French verb "soutenir" which means "to hold up or support." The concept of sustainability is comprehensively defined in the United Nations' (SDGs (George et al. 2016) which include (1) No Poverty, (2) Zero Hunger, (3) Good health and well-being, (4) quality education, (5) gender equality, (6) clean water and sanitation, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry, innovation and infrastructure, (10) reduced inequalities, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, (14) life below water, (15) life on land, (16) peace, justice and strong institutions and (17) partnerships for the goals. The intersection of sustainability and finance ("sustainable finance") has experienced different stages of development over the past decades and has evolved as a broader notion of business sustainability (Dyllick and Muff 2015). In the past years, the focus has shifted from short-term profit (Friedman 1970) towards long-term value creation (Schoenmaker 2017; Tirole and Rendall 2017). Schoenmaker (2017), for example, distinguishes three phases. Sustainable Finance 1.0 aims at avoiding investing in companies adversely impacting sustainability, such as tobacco or weapons. Sustainable Finance 2.0 incorporates social and environmental considerations in the stakeholder model and firms that are compliant with it. Sustainable Finance 3.0 considers SDGs not only in investing and lending decisions, but include them as a core component in their business models which is often supported or enabled by technology. The idea that business activity can result in financial, social, and environmental benefits without any profit compromise is in line with recent developments in sustainability and related concepts such as the circular economy (Bocken et al. 2014; Geissdoerfer et al. 2017). However, one of the major challenges of sustainable finance is the availability of (financial) data, which can in most cases only be uncovered by the use of technology. These technology induced innovations most recently led to the so-called "FinTech revolution" (The Economist 2015), which is now becoming a major catalyst for sustainable finance.

The digitization of financial services is not a new phenomenon. For example, in 1950, Bank of America introduced the world's first computer used in banking called "ERMA" (Electronic Recording Method of Accounting) which went live in 1954. "FinTech" is generally defined as providing digital innovations and technology-enabled business model innovations in the financial sector (Philippon 2017; Gomber et al. 2018). It includes technologies, such as distributed ledger technology (blockchain), artificial intelligence, the internet of things, big data, cloud computing, and application programming interfaces (API) for open

banking. In this context FinTech is based on at least three developments: (1) the use of these technologies, (2) the convergence of different technologies, and (3) the enabling effect of them on new application areas and business models (Gomber et al. 2018). Therefore, in this paper, FinTech companies are ones whose applications and business models are based on such technologies. An example is "open banking" which allows customers to share their financial data with third parties by using APIs and leads to the provision of better customer experience (Gomber et al. 2018). Besides FinTech, this research considers InsurTech" as an additional term, which is generally referred to as an "insurance-specific branch of FinTech" (PricewaterhouseCo 2016). It considers insurance-specific applications of technology such as underwriting or risk data analytics.

The taxonomy developed in this paper has a connection to the field of "Green Information Systems" which examines the development and use of information systems in the context of sustainability. Most literature in this field either provides systematic reviews (Elliot 2007; Hasan et al. 2014; Kharchenko and Illiashenko 2017; Sabbaghi and Vaidyanathan 2012; Tushi et al. 2014; Zeng et al. 2020), while a few also develop taxonomies for specific areas, such as sustainability in supply chain management systems (Kumar et al. 2015; Eitiveni et al. 2017). These papers often see technology as a support function, rather than an enabler for innovation of business models in the startup field and do also not have a specific focus on the financial industry. However, the connection to this field is important, because this paper complements it with an innovation-focused and industry-specific perspective.

Research Method

Taxonomies are usually applied to classify novel approaches or topic areas, thereby helping to structure an emerging domain. They can be defined as "the theoretical study of classification, including its bases, principles, procedures and rules" (Simpson 1961, p. 11). Different types of taxonomy methods, such as numerical taxonomy, quantitative classification, or empirical classification can be distinguished (Bailey 1994). This paper uses the taxonomy development method from (Nickerson et al. 2013), because it is specifically tailored to the classification in information system studies that match with our FinTech-related datasets. In addition, it has a unique interactive character, which helps to increase the overall validation and reliability of the taxonomy.

The taxonomy consists of seven steps (Nickerson et al. 2013): the first step determines the meta-characteristics based on the purpose of the taxonomy. To obtain the relevant meta characteristics, a comprehensive literature analysis was conducted. The second step specifies the ending conditions for terminating the taxonomy development process. For this research, three ending conditions were defined: (1) at least one object has to be identified for each character in each dimension, (2) no additional dimension or characteristic was added in the last iteration, and (3) no characteristic or dimension was modified in the last iteration. For the steps 3 to 6, a deductive conceptual-to-empirical approach was first applied by analyzing literature comprehensively and deducing appropriate dimensions and characteristics. More specifically, step 4 conceptualized the characteristics and dimensions of the objects and step 5 examined the objects for these characteristics and dimensions. Based on that, step 6 created / revised the taxonomy by grouping characteristics into dimensions. The taxonomy development ends when the ending conditions described previously are met (step 7). To verify the taxonomy, an empirical-to-conceptual approach was in a second step applied (by applying the steps 3-6 again) using the data of 126 relevant startups in the domain of sustainable digital finance (see Appendix). The conceptual-to-empirical approach was first chosen, because characteristics and dimensions can typically be derived on the taxonomy developers' knowledge complemented by existing literature, in order to more precisely focus the research field if already some literature is available in this domain (Nickerson et al. 2013).

Literature Analysis

First, the appropriate literature search terms were delineated as the following Boolean search: abstract:("sustainability" OR "sustainable") AND abstract:("fintech" OR "insurtech" OR "blockchain" OR "distributed ledger technology" OR "artificial intelligence" OR "internet of things" OR "big data" OR "cloud computing" OR "application programming interfaces") AND abstract:("banking" OR "insurance" OR "finance"). These search terms were chosen according to the terminology that is most frequently used in the FinTech and InsurTech domain (Gomber et al. 2018). These terms were applied on the databases Business Source

Complete (relevant hits: 18), ScienceDirect (relevant hits: 21), and ProQuest (relevant hits: 16). Our selection of these databases is due to their broad coverage of the information systems literature. Only English-written journal articles have been selected, that were cited by other papers at least once to maintain the quality of the sample. The search was performed in the time frame from September 2 to September 5, and updated again from April 2 to April 5, 2021. In an additional step, a backward search was performed, which examined cited references, and a forward search, which identified articles that cite an original article after it had been published. The total sample included 53 papers. The literature included in the collection can be divided into four topical areas: (1) FinTech, InsurTech, and sustainability in supply chain management, (2) FinTech, InsurTech and environmental sustainability in energy-related fields, (3) FinTech, InsurTech and social sustainability objectives, and (4) FinTech, InsurTech and smart cities and the circular economy (see table 1).

Topic Groups	**Papers and Research Methods**
FinTech, InsurTech and sustainability in supply chain management	*Literature Review:* (Anshari et al. 2019; Choi and Luo 2019; ; Leng et al. 2020; Pizzi et al. 2021; Venkatesh et al. 2020; Bal and Pawlicka 2021; Kamble et al. 2020; Shoaib et al. 2020; Yu et al. 2020; Zhang 2019) *Case study:* (Bal and Pawlicka 2021; Fu et al. 2018; Hinson et al. 2019; Leng et al. 2020; Oerther 2016; Pizzi et al. 2021; Venkatesh et al. 2020; Zhang 2019) *Model development:* (Anshari et al. 2019; Choi and Luo 2019; Fu et al. 2018; Kamble et al. 2020; Leng et al. 2020; Pizzi et al. 2021; Yu et al. 2020; Cole et al. 2019) *Technical analysis:* (Choi and Luo 2019; Fu et al. 2018; Tseng et al. 2021)
FinTech, InsurTech and environmental sustainability in energy-related fields	*Literature Review:* (Anshari et al. 2019; Venkatesh et al. 2020; Zhu et al. 2020) *Case study:* (Ahl et al. 2020; Hartmann and Thomas 2020; Fu et al. 2018; Oerther 2016; Zhang et al. 2021; Zhu et al. 2020) *Model development:* (Sarkar 2020; Anshari et al. 2019; Fu et al. 2018; Kirpes and Becker 2018; Wu and Tran 2018; Mannaro et al. 2017; Mihaylov et al. 2014; Schmidt and Matthews 2018) *Technical analysis:* (Burer et al. 2019; Fu et al. 2018; Li et al. 2019; Wu and Tran 2018; Mihaylov et al. 2014)
FinTech, InsurTech and social sustainability objectives	*Literature Review:* (Anshari et al. 2019; Yu et al. 2020) *Case study:* (Oerther 2016; Ajibade and Mutula 2020; Blakstad and Amars 2020; Dal Mas et al. 2020; Frimpong Boamah and Murshid 2019; Kshetri 2017; Ning et al. 2019; Schulz et al. 2020) *Model development:* (Anshari et al. 2019; Brunnhuber and Jacobs 2020; Blakstad and Amars 2020; Castillo et al. 2016; Hagan et al. 2019; Kamath 2018; Kshetri 2017; Ning et al. 2019; Sarkar and Swami 2019; Schulz et al. 2020; Tavares et al. 2019; Thomason 2017) *Technical analysis:* (Ajibade and Mutula 2020)
FinTech, InsurTech and smart cities and the circular economy	*Literature Review:* (Yu et al. 2020; Guo et al. 2021; Shin and Choi 2019; Bendell 2017) *Case study:* (Kranz et al. 2019; Guo et al. 2021; Kranz et al. 2019; Vogel et al. 2019; Bendell 2017) *Model development:* (Yu et al. 2020; França et al. 2020; Chidepatil A 2020; Guo et al. 2021; Sharma et al. 2020; Shin and Choi 2019; Stanković et al. 2020; Taghizadeh-Hesary and Yoshino 2019; Vogel et al. 2019; Yu and Shen 2019) *Technical analysis*: (Guo et al. 2021)

Table 1. Summary of the Literature Review

Most research at the intersection of sustainability and digital finance has been undertaken in the area of social sustainability objectives. Other important areas are supply chain management and energy. A more limited volume of literature provides research on topics such as waste management and other smart city and circular economy related topics.

Startup Data

For the verification of the taxonomy, a collection of 126 startups was used. This analysis uses startups as an empirical base of analysis in contrast to incumbent financial institutions, because radical innovations more frequently emerge from new market entrants rather than from the incumbents (Weiblen and Chesbrough 2015). This is in line with the findings of most studies in the field of FinTech, which show that disruptive innovations mainly come from startups, rather than from financial institutions that merely partner or invest in those firms. The vast amount of potentially relevant startups was identified in relevant reports and databases (Braden 2019; Climate-KIC. 2018; Cornis van der Lugt 2018; Environment 2019; Forum 2018; OECD 2019; Secretary 2019; Voshmgir 2019) and Crunchbase. The startups which satisfy all three of the following criteria were selected: ((1) sustainable) the startup contributes to the area of sustainability and is supporting at least one of the 17 UN Sustainable Development Goals, ((2) finance) the startup is related to any process concerned with financial services (payments, investments, financing, insurance) and ((3) digital) the startup is using information technology (IT) as a major component of its business model. Most of the identified startups are from the U.S. (20%), followed by Switzerland (16%), the U.K. (14%), and Germany (10%), which represent 60% of all startups in this field together. The rest is split between the Netherlands (6%), Singapore (4%), Australia, Israel, Spain (3% each), Canada, Sweden, China, Finland, France, and Gibraltar (2% each) and other countries (9%). While countries with developed traditional finance, such as the United States, Switzerland, and the U.K., account for high proportions, while other tech startups hot spot countries, such as Singapore and Israel are also ranked highly. Summarized, the following industries and applications could be identified in the analysis:

Energy: The analysis revealed that 50% of the startups are focused on this sector. The energy industry is responsible for more than 70% of greenhouse gas emissions globally and therefore has a huge impact for environmental sustainability. Significant improvements can be achieved by decentralizing democratizing (peer-to-peer instead of business-to-consumer), and digitalizing energy management. Among the examples are the platform Share&Charge for electric vehicle charging or WePower, a marketplace that directly connects companies with of green energy producers, as well as Power Ledger, an energy trading platform that allows selling and buying renewable energy. A second field is emissions trading, for which blockchains hold promising potentials. Today, this market is mainly focused on big industrial emitters of carbon pollution due to high transaction costs. Blockchain could reduce these transaction costs and, by combining blockchain with IoT, automating the analysis of pollution levels. Since most companies globally belong to the SME segment, the expansion to smaller companies would increase the reach of carbon trading. Examples of startups in this area are CarbonX, Climatecoin, Veridium, and Earth Token.

Financial services: The analysis shows that 29% of the startups are focused on this industry. The financial services sector is closely linked with other economic activities and is an enabler for relationships among the various stakeholders in digital ecosystems. One application area is impact assessment, for which the ixo protocol is a good example. ixo assumes that proven impact data is an asset for all those interested in funding sustainability-oriented activities. Ideally, the impact of a given project is automatically measured by sensors or, if not possible, verified by some intermediaries. Another example for measuring the impact is your SRI.com or Covalence, which provides tools for evaluating companies about sustainability criteria. A second area is financing solutions for sustainability projects of all kinds, such as solar projects in developing countries. An example is a Ground-Up project that brings together startups and investors or Carbon To Clean, an investment community dedicated to renewable energy investing and sustainable energy solutions. Wild Finance is a sustainability fintech startup, which provides a card that rewards consumers with cashback and matches their reward with a donation to partner nonprofits. A third area is risk management solutions, such as the evaluation of sustainability risks. Carbon Delta, for example, identifies climate-related risks and measures the future impact on the business models of firms and their supply chains.

Government/NGO: A third sector is the one of governments and NGOs. The analysis revealed that 4% of the startups are focused on this sector. One important area is the impact on entrepreneurship and investing. In many countries, the achievement of sustainability goals is currently being connected to entrepreneurship. For example, the Swiss Entrepreneurship Program focuses on supporting innovation ecosystems in other countries, rather than providing money for self-development activities. However, still, sustainability projects often do not correlate with public funding schemes. Blockchain-based solutions can

leverage sustainability-oriented innovation by providing novel ways of financing and investing through digital assets on blockchains. Amongst the examples in this area are DAO IPCI, Planet N Group, and Envest, a global microfinance fund that offers impact investment opportunities for investors. A second field is common/public goods. FinTech enabled sustainability may contribute to this by incentivizing individuals or organizations for certain behavior. These may be areas such as energy reduction, preservation of biodiversity. Examples in this area are SolarCoin, Electric Chain, or Sun Exchange. A third area is financial inclusion. An important development in this area is digital IDs, which provide the entry point to financial services and other fields for many individuals such as land registries. Based on this, other services such as cash transfers to the underbanked can be provided more efficient, transparent, and secure, through digital vouchers and wallets that allow people to purchase their food, medicines. with their mobile phones, make lower-cost remittances, or can purchase insurance policies. A fourth area is corruption and fraud prevention. Digital IDs are an essential requirement for this. So-called "Know-Your-Customer" (KYC) solutions enhance them by allowing providers of digital services to onboard their clients electronically.

Results of the Taxonomy Development

Conceptual-to-Empirical Approach

According to (Nickerson et al. 2013) a taxonomy comprises of a set of dimensions. Each of these dimensions itself consists of two or more characteristics. The factor of each cluster is identified by specified attributes that are mutually exclusive and collectively exhaustive. The literature sources that were identified in the literature analysis are used to design the taxonomy. These include the following elements: strategy, organization, systems (perspectives), business model, product/service type (strategic dimension), network type, stakeholder interaction, and business process (organizational dimension), application type and application design (systems dimension) as well as economic (SDGs 1, 2, 3, 8, 9), social (SDGs 6, 7, 12, 13, 14, 15) and environmental (SDGs 4, 5, 10, 11, 16, 17) sustainability. The taxonomy also mentions whether the dimension is exclusive (E) or non-exclusive (N). The exclusiveness of a dimension indicates that exactly one characteristic can be identified within a certain dimension. In contrast, a non-exclusive dimension allows the identification of multiple characteristics for each identified dimension. As FinTech and InsurTech are enablers for networked ecosystems (Gomber et al. 2018), research on networked ecosystems typically distinguishes the three perspectives strategy, organization, and systems that are typical for these ecosystems (Abe 2005). Based on this, the following perspectives, dimensions, and characteristics could be derived from the literature analysis, which are summarized in table 2:

Strategy perspective: The strategic perspective concentrates on business models, firms, customers, and services that are exchanged between them. One way to describe the business models is using the value disciplines typology devised by (Wiersema 1995), which was also confirmed by other research (Palmer and Markus 2000; Weill 2004). Firms that follow these models can either focus on "operational excellence" which is centered around low cost, reliability, accuracy, and availability, on "customer intimacy", meaning service quality, or "product leadership", which emphasizes innovative products and services. Following the concept of core competencies, only one of these strategies shall be followed. Besides, the outcome of these value generation processes, which may involve different network configurations are products and/or services, where business and consumer services are typically distinguished.

Organizational perspective: The organizational perspective distinguishes network types, stakeholder interaction models and processes as major structural configuration options (Wigand et al. 2008). A prominent distinction between a firm's and a customer's network configuration is one of the intra- and inter-organizational networks as well as peer-to-peer networks (Ahuja 2000). For example, a company's outputs are impacted by its position in the network: firms with collaborative arrangements with other companies can increase knowledge transfer and innovation capabilities (Wigand et al. 2008). These collaborative arrangements are designed in different stakeholder interaction models (government-to-government, government-to-business, government-to-consumer, business-to-business, business-to-consumer, consumer-to-consumer) as well as different business processes (advice, payments, investments, financing, life insurance, non-life insurance, risk management, cross-process, and trading).
Systems perspective: The systems perspective distinguishes application types and designs as major configuration options. FinTech applications use technology in one of the business processes advice,

payments, investments, financing, cross-process, and trading. On the other hand, the InsurTech applications, focus on insurance-related processes, such as life insurance, non-life insurance, and insurance risk management. Besides, the design of an application can either be centralized or decentralized. Although centralized databases and systems are still the core of most organizations, the concept of DeFi has emerged as part of the discussion, especially around blockchain and its application for the financial system most recently. In a centralized system, financial institutions act as intermediaries for financial transactions where an institution uses its databases and systems. In a decentralized system, financial transactions can lead to reduced transaction costs while at the same time creating network effects from which all participants can benefit (Catalini and Gans 2016). While blockchain was very often mentioned in many literature sources separately, other technologies, such as AI, big data, cloud computing, etc. are summarized hereunder FinTech and InsurTech applications.

Perspective	Dimension	Characteristics									E/N
Strategy	**Business model**	**Customer intimacy** [Bendell 2017; Kranz et al. 2019; Ning et al. 2019]			**Product leadership** [Kranz et al. 2019; Oerther 2016; Tavares et al. 2019]			**Operational efficiency** [Kemble et al. 2020; Mannaro et al. 2017; Mihaylov et al. 2014]			E
	Product/ Service Type	**Business services** [Hartmann and Thomas 2020; Sarkar and Swami 2019; Vogel et al. 2019]			**Consumer service** [Kirpes and Becker 2018; Li et al. 2019; Mihaylov et al. 2014]			**Government** [Fu et al. 2018; Venkatesh et al. 2020; Wu and Tran 2018			N
Organization	**Network type**	**Consumer Peer-to-Peer networks** [Ahl et al. 2020; Burer et al. 2019; Zhu et al. 2020]			**Intra-organizational networks** [Cole et al. 2019; Hinson et al. 2019; Ning et al. 2019]			**Interorganizational networks** [Blakstad and Amars 2020; Fu et al. 2018; Schmidt and Matthews 2018]			E
	Stakeholder Interaction	**Government-to-government** [Ning et al. 2019]	**Government-to-business** [Choi and Luo 2019; Kamath 2018; Zhang 2019]		**Government-to-consumer** [Kranz et al. 2019; Tavares et al. 2019; Thomason 2017]	**Business-to-business** [Hartmann and Thomas 2020; Oerther 2016; Yu et al. 2020]		**Business-to-consumer** [Brunnhuber and Jacobs 2020; Frimpong Boamah and Murshid 2019; Sarkar and Swami 2019]	**Consumer-to-consumer** [Burer et al. 2019; Kirpes and Becker 2018; Yu and Shen 2019]		N
	Business Process	**Advice** [Hagan et al. 2019; Ning et al. 2019; Schmidt and Matthews 2018]	**Payments** [Kirpes and Becker 2018; Wu and Tran 2018; Zhang 2019]	**Investments** [Brunnhuber and Jacobs 2020; Fu et al. 2018; Ning et al. 2019]	**Financing** [Blakstad and Amars 2020; Burer et al. 2019; Zhu et al. 2020]	**Life Insurance** [Castillo et al. 2016; Kshetri 2017; Stanković et al. 2020]	**Non-Life Insurance** [Dal Mas et al. 2020; Kamble et al. 2020; Oerther 2016]	**Risk Management** [Cole et al. 2019; Hartman and Thomas 2020; Pizzi et al. 2021]	**Cross-process** [Bal and Pawlicka 2021; Schulz et al. 2020; Taghizadeh-Hesary and Yoshino 2019]	**Trading** [Mannaro et al. 2017; Mihaylov et al. 2014]	N
Systems	**Application type**	**FinTech application** [Ajibade and Mutula 2020; Castillo et al. 2016; Stanković et al. 2020]			**InsurTech application** [Dal Mas et al. 2020; Kamble et al. 2020; Kshetri 2017]			**Blockchain application** [Yu et al. 20202; Kamath 2018]			N
	Application design	**Centralized** [França et al. 2020; Schmidt and Matthews 2018; Shin and Choi 2019]				**Decentralized** [Dal Mas et al. 2020; Li et al. 2019; Mihaylov et al. 2014]					N
Sustainable Benefits	**Economics sustainability**	**SDG1** [Kshetri 2017; Ning et al. 2019; Sarkar 2020]	**SDG2** [Anshari et al. 2019; Hinson et al. 2019; Stanković et al. 2020]		**SDG3** [França et al. 2020; Kranz et al. 2019; Venkatesh et al. 2020]		**SDG8** [Dal Mas et al. 2020; Ning et al. 2019; Shoaib et al. 2020]	**SDG9** [Bal and Pawlicka 2021; Shoaib et al. 2020; Vogel et al. 2019]			N
	Social sustainability	**SDG6** [Brunnhuber and Jacobs 2020; Taghizadeh-Hesary and Yoshino 2019; Zhang et al. 2021]	**SDG7** [Burer et al. 2019; Guo et al. 2021; Kranz et al. 2019]		**SDG12** [Choi and Luo 2019; Cole et al. 2019; Kamble et al. 2020]	**SDG13** [Chidepatil A 2020; Fu et al. 2018; Mihaylov et al. 2014]		**SDG14** [Hartmann and Thomas 2020; Schmidt and Matthews 2018; Zhang et al. 2021]	**SDG15** [Leng et al. 2020; Tavares et al. 2019; Zhang et al. 2021]		N
	Environmental sustainability	**SDG4** [França et al. 2020; Kshetri 2017; Stanković et al. 2020]	**SDG5** [Brunnhuber and Jacobs 2020; Stanković et al. 2020; Thomason 2017]		**SDG10** [Ajibade and Mutula 2020; Castillo et al. 2016; Yu and Shen 2019]	**SDG11** [Fu et al. 2020; Hartmann and Thomas 2020; Tseng et al. 2021]		**SDG16** [Brunnhuber and Jacobs 2020; Kamath 2018; Schmidt and Matthews 2018]	**SDG17** [Kamath 2018; Kamble et al. 2020; Yu et al. 2020]		N
Cumulated relative frequencies can be different from 100% if a dimension is non-exclusive.											

Table 2. Taxonomy of Sustainable Digital Finance

Sustainability benefits perspective: The perspective of sustainability benefits distinguishes economic, social, and environmental sustainability as its core dimensions (George et al. 2016). Economic sustainability means the ability of an economy to consistently maintain a respectable level of increasing gross domestic productivity or maintenance of capital stock over a long period (Daly 1990). On the other hand, social sustainability refers to circumstances where formal and informal norms and processes are ensured and systems, structures, and relationships actively support the capacity of current and future generations to create healthy communities. Socially sustainable communities are equitable, diverse, connected & democratic, and provide a good quality of life (Emma 2005). And environmental sustainability refers to societies that utilize environmental resources in a way that it becomes possible for civilizations to support themselves indefinitely (Daly 1990). The achievement of these three fields of sustainability is typically measured by the three SDG categories (1) economic (SDGs 1, 2, 3, 8, 9), (2) social (SDGs 6, 7, 12, 13, 14, 15), and (3) environmental (SDGs 4, 5, 10, 11, 16, 17) sustainability.

The iterative taxonomy development process to conceptualize the dimensions and characteristics and examine the objects for these characteristics and dimensions (steps 3-6) was repeated four times until it satisfied the three defined ending conditions. The taxonomy has evolved over these four iterations and led to adaptions during this process. For example, initially, in the "systems" dimension the meta-characteristics only included FinTech and InsurTech applications. However, it turned out that companies applying blockchain technology have starkly distinctive business models (especially with a decentralized application design) compared to those with non-blockchain FinTech applications.

Empirical-to-Conceptual Approach

In order to validate the taxonomy, the startups are mapped with the perspectives, dimensions and characteristics. This demonstrates the applicability of the taxonomy and its usefulness (Nickerson et al., 2013). Table 3 summarizes the results of the startup mapping and reveals that within the strategic perspective, most of the firms have designed their business models in the field of operational efficiency, focusing on costs rather than on customer intimacy or product leadership. An example is the startup CelsiusPro, which has specialized in insurance solutions to mitigate the effects of severe weather, climate change, and natural disasters, and offers its services primarily to insurance firms for improving their business. The same applies to Carbon Delta, which provides data based on the value assessment method to measure the climate-related risks and opportunities in investment portfolios. Another important observation in this perspective is that business services outperform consumer services. This is in line with the focus on operational efficiency, as these services are usually provided in the b2b domain rather than in the b2c sector. The result also shows that intra- and inter-organizational networks have the highest relevance among the startups from an organizational perspective. This proves the fact that operational efficiency and business services are the focus of startups. Third, the systems perspective identifies blockchain applications as the main pattern, while FinTech and InsurTech play a minor role. The following paragraphs summarize the findings of the startup application in each perspective:

Strategy perspective: Compared with their business models, startups primarily focus on operational excellence (89%). This is in line with many FinTech models that specifically target operation efficiency as their main goal, while only limited startups aim at customer intimacy (7%) or product leadership (4%). The analysis clearly shows that the improvement of business processes (operational excellence) is one of the main goals, while new products and novel ways of customer interaction are still in an early phase of development. Besides, the first approaches concentrate on payment infrastructures while other forms of investments, financing, and insurance are still limited. The analysis also shows that literature and startups have the same focus. The product/service focus of the analyzed startups is rather mixed, containing startups that cover business services (58%), followed by consumer services (42%). However, there are also methods that combine both approaches. An example for combining both service types is energy blockchains, which integrate consumer services and business services from producers, providers, and distributors.

Organizational perspective: To get a more detailed view of the startups, the firms were categorized by the network focus (peer-to-peer, intra- organizational, inter-organizational), product/service focus (consumer services, business services, consumer, and business services). The results indicate a strong focus on p2p networks (48%), while a smaller number focuses on the intra- (33%) and the inter-organizational domain (19%). Another important dimension in the organizational domain is the stakeholder interaction, which

differentiates which stakeholders are involved in a certain network configuration. Usually, this includes government-to-government (g2g), government-to-business (g2b), government-to-consumer (g2c), business-to-business (b2b), business-to-consumer (b2c) and consumer-to-consumer (c2c). The results of the analysis show that b2b (83%) interactions, followed by b2c (52%) and c2c (6%) dominate. However, for the latter ones, only literature provides some research on this topic so far, while startups have not entered the field yet. A third and final relevant dimension from the organizational perspective is the business processes which are in the focus of a specific solution. From this perspective, advice, payments, investments, financing, insurance, risk management, cross-process, and trading can be differentiated. The results of the analysis show that the payments, financing, and trading characteristics are predominant in the startup sector.

Perspective	Dimension	Characteristics									E / N
Strategy	Business model	Customer intimacy (7%)			Product leadership (4%)			Operational efficiency (89%)			E
	Product/Service Type	Business services (82%)			Consumer services (60%)			Government (0%)			N
Organization	Network type	Consumer Peer-to-Peer networks (48%)			Intra-organizational networks (33%)			Interorganizational networks (19%)			E
	Stakeholder Interaction	Government-to-government (0%)	Government-to-business (0%)		Government-to-consumer (0%)	Business-to-business (83%)		Business-to-consumer (52%)	Consumer-to-consumer (6%)		N
	Business Process	Advice (23%)	Payments (7%)	Investments (26%)	Financing (37%)	Life Insurance (6%)	Non-Life Insurance (6%)	Risk Management (13%)	Cross-process (12%)	Trading (33%)	N
Systems	Application type	FinTech application (15%)			InsurTech application (6%)			Blockchain application (85%)			N
	Application design	Centralized (20%)				Decentralized (83%)					N
Sustainable Benefits	Economics sustainability	SDG1(9%)	SDG2 (4%)	SDG3 (2%)		SDG8 (3%)		SDG9 (83%)			N
	Social sustainability	SDG6 (2%)	SDG7 (65%)		SDG12 (31%)	SDG13 (56%)		SDG14 (5%)	SDG15 (8%)		N
	Environmental sustainability	SDG4 (1%)	SDG5 (2%)		SDG10 (10%)	SDG11 (81%)		SDG16 (4%)	SDG17 (33%)		N
Cumulated relative frequencies can be different from 100% if a dimension is non-exclusive.											

Table 3. Relative Frequencies of the Characteristics among the Startups

Systems perspective: FinTech (15%) and blockchain (85%) applications are at the core of the technology domain. In some cases, FinTech and blockchain applications are mixed. InsurTech is still in its infancy with 6%. The analysis shows that blockchain applications lead the systems perspective and are currently seen as the enabler for novel sustainable business models. One example is the energy sector where innovation might improve through blockchain technology in the future. For example, for investors, it is still almost impossible to support decentralized renewable energy generation in other countries. On the other side, access to capital provides a great barrier for renewable energy producers in many countries, particularly the developing ones, especially as power production today is mainly based on centralized power grids were often the vast majority of society is not being connected to such grids. In this case, FinTech and blockchain applications could solve this issue by energy tokens that are stored on blockchains, and which are directly linked to the production of renewable energy. This offers a huge opportunity for change as for the first time (p2p) payments of renewable energy as well as investments and financing in such solutions would be possible on a global scale. Combined with novel ways of decentralized organizations, this approach provides a powerful instrument. As blockchain applications provide the majority of all startup solutions, most startups in this field apply a decentralized application approach, which means that in contrast to centralized, traditional databases, technologies like blockchain uses distributed ledgers for the storage of data, transactions on the data as well as the validation of the data. However, centralized and decentralized systems can be combined. An example is a decentralized, blockchain-based supply chain trade finance solution that is used in combination with a centralized crowdfunding marketplace.

Sustainability benefits perspective: The fourth perspective relates to the benefits. In general, literature differentiates business and sustainability benefits which are in some cases interrelated. From the business perspective, the benefit categories revenues, costs, quality, and time can be distinguished. From the sustainability perspective, the seventeen sustainability goals from the United Nations are used here to map the identified benefits to sustainability considerations. The analysis shows that the main focus is on the SDGs 7 to 13 and 17. The clear leader in sustainability is SDG 9 which aims at developing a resilient infrastructure, the promotion of inclusive and sustainable industrialization and innovation such as for online forest credit platforms.

While the taxonomy table shows relative frequencies of the characteristics among the startups, the dependencies among all possible combinations of the three dimensions are another important field of research to identify patterns. For this, Pearson's chi-squared test provides an ideal instrument (Agresti 2007). When the test shows independence between two perspectives, no significant relationship between those two perspectives do exist. Table 4 shows the contingency tables and Pearson's chi-squares test of independence among the archetype of the strategy, organization systems and sustainability benefits with its specific dimensions (n=126 for each sub-table). The analysis revealed that the dimension of network type is related to business models, product/service type, interaction processes, and sustainability benefits. However, a correlation between network types and business processes could not be confirmed. Therefore, one could argue that these startups take similar business models and strategy, contributing to the specific sustainable benefits, while their application areas of fintech are versatile and depend on their more specific business strategy. Table 4 summarizes the findings in the contingency tables from the startup analysis.

Network Type **Business Model**	**Inter-organizational**	**Intra-organizational**	**Peer-to-peer network**	**Total**
Customer Intimacy	3	5	1	9
Operational Efficiency	18	35	59	112
Product Leadership	3	1	1	5
Total	24	41	61	126
Pearson's chi-squared test of independence X^2=11.493; p-value=0.0215	Result: confirmed			
Network Types **Product/Service Types**	**Inter-organizational**	**Intra-organizational**	**Peer-to-peer network**	**Total**
Business services	23	36	44	103
Consumer Services	7	9	59	75
Total	30	45	103	126
Pearson's chi-squared test of independence X^2= 23.085; p-value=9.710	Result: confirmed			
Network Types **Interaction Processes**	**Inter-organizational**	**Intra-organizational**	**Peer-to-peer network**	**Total**
B2B	17	32	4	53
B2C	1	5	9	15
B2C & B2B	6	4	41	51
C2C	0	0	7	7
Total	24	41	61	126
Pearson's chi-squared test of independence X^2=22.900; p-value= 0.000133	Result: confirmed			
Network Types **Business Processes**	**Inter-organizational**	**Intra-organizational**	**Peer-to-peer network**	**Total**
Advice	3	18	8	29
Risk Management	0	6	0	6

Cross-process	4	4	7	15
Financing	7	20	20	47
Investment	5	0	2	7
Insurance	0	1	2	3
Payment	2	1	6	9
Trading	6	1	35	42
Total	24	33	72	130
Pearson's chi-squared test of independence X^2= 65.882; p-value= 1.064	Result: not confirmed			
Network Types / Sustainable Benefits	**Inter-organizational**	**Intra-organizational**	**Peer-to-peer network**	**Total**
SDG1: No poverty	2	3	6	11
SDG2: Zero hunger	1	3	1	5
SDG3: Good health and well-being	0	2	1	3
SDG4: Quality education	0	0	1	1
SDG5: Gender equality	1	1	1	3
SDG6: Clean water and sanitation	1	0	1	2
SDG7: Affordable clean energy	14	28	40	82
SDG8: Decent work and economic growth	1	1	2	4
SDG9: Industry, innovation and infrastructure	18	36	51	105
SDG10: Reduced inequalities	2	9	1	12
SDG11: Sustainable cities and communities	30	35	47	102
SDG12: Responsible consumption and production	8	18	13	39
SDG13: Climate action	11	26	33	71
SDG14: Life below water	2	1	3	6
SDG15: Life on land	3	1	6	10
SDG16: Peace, justice and strong institutions	1	1	3	5
SDG17: Partnerships for the goals	8	11	23	42
Total	100	177	233	503
Pearson's chi-squared test of independence X^2= 30.452; p-value= 0.545	Result: not confirmed			

Table 4. Contingency Tables (Startups; N=126)

Discussion

The analysis of the literature and the startups indicates that the topic is currently emerging. Most of the literature is from the past two years which clearly shows that the maturity is still low. Although digital finance models emerged already in the 2010s, their use in the context of sustainability was rather low and has only recently increased significantly. The taxonomy developed in this paper shall shed light on the classification of these approaches. The main contribution is a theory based and empirically validated taxonomy which closes the research gap of a comprehensive model bridging the fields of sustainability and FinTech. The results of this research lead to at least four findings which have theoretical, practical and political implications.

First, from a theoretical lens, this research indicates a strong connection of the startups' strategies, organizational setup and systems with their contribution to the sustainability benefits. For these startups, sustainability is not just being compliant with environment, social and governance (ESG) frameworks, but it is part of the "DNA" of their business models, that is, sustainability-enabled FinTech as a competitive advantage. This approach complements previous research in Green Information Systems with a specific focus on the financial industry and leverages FinTech as an enabler for innovation, rather than viewing it as a support function for optimizing business processes to improve sustainability in certain areas such as supply chain management. The taxonomy also complements existing research, which often focuses either

on isolated environmental, social or economic factors. The taxonomy revealed that startups consider multidimensional sustainability, not only environmental aspects but also including social and economic sustainability. A typical example are FinTech platforms, which integrate various services such as mobile payment, peer-to-peer lending and blockchain-based supply chain management tracking solutions and connect them to digital ecosystems. This not only fosters financial inclusion for previously unbanked people engaging in agriculture in rural areas and thus contributes to social and economic sustainability, such as zero poverty (SDG 1) and zero hunger (SDG 2). But at the same time, it also positively impacts their agriculture practices with more effective and streamlined businesses with sufficient financing according to the harvest cycles, consumers and supply chains managers.

Second, from a managerial perspective, the taxonomy shows potential areas of novel configuration forms of future business models in this emerging field. For example, from the strategic perspective, there is a clear trend towards operational efficiency optimization rather than disruptive innovations in product or customer-related areas. One reason for this might be the fact that FinTech in the past primarily provided a tool for improving, formerly paper-based, business processes with digitized solutions. Regarding the network focus, there is a clear trend to peer-to-peer and intra-organizational networks. This reflects the majority of the examples from the energy (mostly peer-to-peer focus) and financial sector (mostly intra-organizational focus). However, the inter-organizational field is still rare. This might be due to the fact that many business models in this domain are currently evolving (trade finance, etc.) and many challenges have yet to be solved (data privacy, digital ID, etc.).

Third, from a political view, the taxonomy might help to improve existing digital infrastructures. For example, in the organizational domain, most startups are focused on B2B, B2C, or C2C approaches and government solutions (G2C, G2B) are not the dominant pattern today, although governments play a major role in developing policies and might also be involved in future solutions as digital notaries or providers of digital identities. However, there is a clear need to involve governments in such solutions, as they touch two domains of high relevance for policy development: sustainability and financial services. In addition, the major focus is currently only on five of the seventeen SDGs (7, 9, 11, 13, 17). This clear focus is on climate, energy, infrastructure, cities, and partnerships are in line with the current media attention of climate change as a major driver. The literature analysis also reflects this trend, and it can be expected that with higher maturity also other areas like the sustainable management of water, the sustainable management of forests, combat desertification, or biodiversity loss will earn increased relevance in the forthcoming years.
However, the analysis in this paper also has limitations as it only provides a picture of the status quo, because the literature and the startup landscape are highly dynamic and develop rapidly. Novel types of emerging patterns might be underrepresented by future developments. In addition, the incumbent institutions from the banking and insurance sector also started to offer products and services in this emerging field. The examples range from impact investing solutions from banks to climate-related risk management tools from insurance companies. The analysis could be extended to those solutions and might lead to different results and patterns. Finally, this analysis provides a market-oriented perspective, however, an analysis of customer behavior is another important part, as the wider use of these solutions is an important factor for their success.

Conclusion

This research develops and evaluates a taxonomy for the emerging field of sustainable digital finance, which connects the previously isolated domains of sustainability, finance, and digitalization in an overall framework. The result obtained from the analysis of relevant literature and startups show that this novel field is still premature. It answers this paper's research question of "how can dimensions and characteristics of FinTech-driven solutions for sustainability be classified in a comprehensive taxonomy?" The findings of this research reveal at least five areas for future research.
First, the taxonomy showed some patterns of startups in this emerging sector. However, the configuration of offerings of startups in this novel domain is an area of future research. The taxonomy might serve as a starting point to develop other novel approaches and models that have an impact on achieving the 17 SDGs more efficiently and effectively. For example, today, most startups concentrate on the SDGs 7, 9, 11, 12, 13, and 17 while others are mostly outside the scope. Innovative approaches might evolve also for other SDGs when entrepreneurs realize that there are big potentials and niches in such fields, which is currently the

case for the area of green FinTech. *Second,* while the topic is still in its infancy, real data is limited. Therefore, measuring the impact based on real data is another important area for further research. For example, if single startup models are applied more frequently in practice by more customers, the real impact of those models can be measured against the 17 SDGs. This could mean that if investments in robo-advisors become more sustainable, this should also have an impact on the firm structure in certain indices. (Sandberg 2018). *Third,* the perspective on startups is a starting point for the field of digital ecosystems and their configurations and business models as these firms are often integrated into networks with incumbents (b2b networks) or provide platforms for consumer networks. Today, the knowledge about such ecosystems is limited (Jacobides et al. 2018). Future research might concentrate on questions such as the impact of startups on sustainability in digital ecosystems. *Fourth,* the role of regulation has not yet been discussed in the context of sustainable digital finance and might become even more complex than today as the two main drivers of sustainability and digitalization put pressure on the financial system from two different directions. *Fifth,* the snapshot of this study is limited to the current time frame. Another important research domain might be longitudinal studies in this new field to re-evaluate the taxonomy and the developments in sustainable digital finance. This allows to monitor the impact over time and adjust the approaches and models if necessary. Sustainability is one of the major challenges of our time, and some SDGs require immediate action. This can only be achieved if capital is allocated in ways that innovation and entrepreneurship promote the achievement of these goals. Sustainable digital finance is one of the research areas that could improve this (re-)allocation more effectively and efficiently.

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Appendix: List of Startups

Nr.	Name	Nr.	Name	Nr.	Name
1	1bank4all	43	Foodgates	85	Plastic Footprint
2	Adaption Ledger	44	Fsight	86	Plenitude
3	aidhedge	45	GainForest	87	Poseidon
4	alandsbanken	46	Giveth	88	PowerLedger
5	Ant Forest 120 mobile application	47	Globalabce	89	Powerpeers
6	Apollo Agriculture	48	GPX Energy	90	PowerToShare
7	Arcade City	49	Green Asset Wallet	91	Procenance
8	Artis	50	Green Energy Wallet	92	Prosume
9	Avenews GT	51	Greeneum	93	PULA
10	bext360	52	Grid Sigfularity	94	Pylon Network
11	BItGive	53	Grid.vc	95	Regan Network
12	Bithope	54	Grid+	96	RepRisk
13	bitlumens	55	GridX	97	ReWatt Power
14	Blockchain Capital	56	Hive Power	98	Riddle&Code
15	Blockchain for Humanity	57	I-Warranty	99	RobecoSAM
16	Car eWallet	58	IBISA	100	SatoshiPay
17	Carbon Delta	59	ImpactPPA	101	Set Ventures
18	Carbonx	60	Innogy Innnvation Hub	102	SKUchain
19	CelsiusPro	61	Jouliette at de Veuvel	103	Social Coin
20	CleanCoin	62	Katapult Acceleatoror	104	Solar Bankers
21	Climate Coin	63	KIC InnoEnergy	105	SolarCoin
22	ClimateTrade	64	Kiwi New Energy	106	Solshare
23	CoEnergy.app	65	KWHCoin	107	Spectral
24	Cogo	66	L03 Energy	108	Spread Energy
25	covarence	67	La'Zooz	109	StromDAO
26	CyStellar	68	Laumenaza	110	SUNCHAIN
27	DAO IPCI	69	lemonade	111	Sustainability.Exchange
28	Datamaran	70	Lition Engergie	112	Swiss Sela-labs
29	dena	71	M-PAYG	113	Tennet
30	Earth token	72	Magnefico	114	Terra0
31	Ecosphere+	73	Mineral Track	115	KIT
32	Ekofolio	74	MotionWerk	116	The Sun Exchange
33	ELectraSeeD	75	My Drop in the Ocean	117	TokenMarket
34	Electrify_Asia	76	Neural Alpha	118	TRINE
35	Energimine	77	NRGcoin	119	Truvalue Labs
36	Energy Unlocked	78	OLZ AG	120	Volt markets
37	Energy Web Foundation (EWF)	79	Omega Grid	121	Wattcoin Labs
38	Enian	80	Opus One Solutions	122	WePower
39	Ethos	81	owl analytics	123	Wpo
40	Everledger	82	Oxyn	124	Xpansiv
41	FairChain	83	Pexapark	125	Yova
42	FlexiDao	84	PinkCoin	126	Zero Carbon Project