"Enabling circular business models in the fashion industry: the role of digital innovation"

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Abstract

Purpose – Digital innovation and circular business model innovation are two critical enablers of a circular economy. A wide variety of digital technologies such as blockchain, 3D printing, cyber-physical systems, or big data also diverges the applications of digital technologies in circular business models. Given heterogeneous attributes of circular business models and digital technologies, the selections of digital technologies and circular business models might be highly distinctive within and between sectorial contexts. This paper examines digital circular business models in the context of the fashion industry and its multiple actors. This industry as the world's second polluting industry requires an urgent circular economy (CE) transition with less resource consumption, lower waste emissions and a more stable economy.

Design/methodology/approach – An inductive, exploratory multiple-case study method is employed to investigate the ten cases of different sized fashion companies (i.e. large, small medium-sized firm (SME) and startup firms). The comparison across cases is conducted to understand fashion firms' distinct behaviours in adopting various digital circular economy strategies.

Findings – The paper presents three archetypes of digital-based circular business models in the fashion industry: the blockchain-based supply chain model, the service-based model and the pull demand-driven model. Besides incremental innovations, the radical business model and digital innovations as presented in the pull demand-driven model may be crucial to the fashion circular economy transition. The pull demand–driven model may shift the economy from scales to scopes, change the whole process of how the fashion items are forecasted, produced, and used, and reform consumer behaviours. The paths of adopting digital fashion circular business models are also different among large, SMEs and startup fashion firms.

Practical implications – The study provides business managers with empirical insights on how circular business models (CBMs) should be chosen according to intrinsic business capacities, technological competences and CE strategies. The emerging trends of new fashion markets (e.g. rental, subscription) and consumers' sustainable awareness should be not be neglected. Moreover, besides adopting recycling and reuse strategies, large fashion incumbents consider collaborating with other technology suppliers and startup companies to incubate more radical innovations.

Social implications – Appropriate policies and regulations should be enacted to enable the digital CE transition. Market patterns and consumer acceptances are considered highly challenging to these digital fashion models. A balanced policy on both the demand and supply sides are suggested. The one-side policy may fail CBMs that entail an upside-down collaboration of both producers and consumers. Moreover, it is perhaps time to rethink how to reduce unnecessary new demand rather than repeatedly producing and recycling.

Originality/value – The pace of CE research is lagging far behind the accelerating environmental contamination by the fashion industry. The study aims to narrow the gap between theory and practice to harmonise fashion firms' orchestration and accelerate the transition of the fashion industry towards the CE. This study examines diverse types of digital technologies in different circular business models in a homogeneous context of the fashion industry with heterogeneous firm types.

Keywords Fashion industry, Sustainability, Circular economy, Digital innovation, Circular business model

Paper type Research paper

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1. Introduction

Circular business model innovation (MacArthur, 2013; Brennan *et al.*, 2015; Pieroni *et al.*, 2019) and digital innovation (Reuter, 2016; Antikainen *et al.*, 2018; Hofmann, 2019) are two critical drivers for the transition towards circular economy (CE). CE aims to minimise resource inputs and waste emissions through circular activities of reducing, reusing, recycling, recovering and remanufacturing (Gharfalkar *et al.*, 2018; Geissdoerfer *et al.*, 2020). In the CE transition, the organisational structure, logistic and production methods of firms are reformed from the linear model of "take-make-dispose" to the circular model of "make-use-return". Digital innovations are believed to be both the critical enablers and triggers for circular business models (Ranta *et al.*, 2021). It means that digital technologies are adapted to circular business models and, at the same time, require business models to change to necessitate technological functions. In many industries, a digital transformation is co-occurring with the sustainability transition (Ranta *et al.*, 2021).

Types of circular business models can be classified by CE strategies such as recycling, extending, intensifying, dematerialising (Geissdoerfer *et al.*, 2020) or narrowing, slowing, and closing resource flows (Bocken *et al.*, 2016). Firms may adopt circular business models considering both internal factors (i.e. organisational structures and CE strategies) and external factors (i.e. underlying industrial and market issues). A wide variety of digital technologies such as blockchain, 3D printing, cyber-physical systems or big data also diverges the applications of digital technologies in circular business models. Given the heterogeneous attributes of circular business models and digital technologies, the selections of digital technologies and circular business models might be highly distinctive within and between sectorial contexts. The complexity of the CE transition goes beyond the scope of one generic CE framework. Needless to say, no circular business model (CBM) can fit all sectors and firm types. Different sectors require different business models, and different business models entail different digital innovations.

For example, the petroleum sector as a business-to-business sector is likely to introduce process innovations by cyber-physical systems and data analytics for the resource efficiency and recovery CBMs to reduce shutdown time and oil loss during the drilling process. By contrast, business-to-consumer sectors such as the fashion industry with multiple stakeholders may require radical innovations in both products and processes to shift from the existing production–consumption paradigm and solve the paradox of reducing new demand but maintaining profitability. Agostini *et al.* (2019) indicated that because of the "industrial and competitive dynamics", "between sector's heterogeneity" diverges the intricate patterns of digital innovation. Firm sizes and firm characteristics influence environmental sustainability (Balasubramanian *et al.*, 2020). Moreover, the dynamics of digital innovation and circular business model strategies may also be dissimilar between large incumbents, small and medium-sized firms (SME) and startup firms. Because of organisational inertias, large firms are more inclined to select marginal CE principles such as recycling and reuse for incremental innovations instead of changing the entire business models (Hockerts and Wüstenhagen, 2010; Schaltegger *et al.*, 2016). In contrast, small firms tend to introduce radical CE models and radical innovations (Hockerts and Wüstenhagen, 2010; Schaltegger *et al.*, 2016; Kennedy *et al.*, 2017).

Although some conceptual research attempted to bridge the knowledge gap of digital technologies and circular business models, the research field still lacks empirical evidence to examine how digital technologies enable different circular business models of different industrial settings (Lieder and Rashid, 2016; Pagoropoulos *et al.*, 2017; Ranta *et al.*, 2021). This paper adopts a holistic, interdisciplinary approach to the circular business model and digital innovation research in the context of the fashion industry and its multiple actors. The fashion industry requires an urgent sustainability transition with less resource consumption, less waste emissions and a more stable economy. This second most polluting industry consumed 98 million tons of oil and released 1.2 billion tons of CO_2 in 2015 (Ellen Macarthur Foundation,

2017). Every year, fashion firms release about half a million tons of plastic microfiber equivalent to more than 50 billion plastic bottles into the ocean after textile washing (Ellen Macarthur Foundation, 2017). Severe resource degradation and environmental pollution are caused by various factors such as clothing overproduction, underutilisation and low recycling quality. The global pandemic coronavirus disease 2019 (COVID-19) also causes growing concerns about the security of outsourcing supply and firm profitability.

The pace of CE research is lagging far behind the accelerating environmental contamination by the fashion industry. Most CE studies were centred on waste, metallurgy, agri-food and energy sectors (Merli *et al.*, 2018), whereas only a few papers examined the fashion and textile sector. Among some studies about fashion CE (Todeschini *et al.*, 2017; Niinimäki, 2018) and circular textile supply chain (Kazancoglu *et al.*, 2020), no prior research has investigated digital-enabled fashion CBMs and, thus, left several significantly important CBMs yet to be explored. The absence of empirical evidence and research efforts might significantly hinder the CE transition of fashion firms. The report in 2020 of the Circular Fashion Summit and PwC and Vogue Business claims that circular fashion cannot be fully exercised without digital technologies. Taking into account the significant emergence of digital technology in fashion businesses, this study aims to address the following research questions:

(1) What are digital-based circular business models used by the fashion industry?

(2) How do fashion companies of different sizes (i.e. large, SMEs and startups) differently adopt those digital-based circular business models?

The various digital technologies are investigated in a homogeneous context – the fashion industry (i.e. where firms in the same sector may face the same industrial barriers) – and in a heterogeneous context in terms of actor types (i.e. large, SMEs and startup firms). A comparison across cases is conducted to understand fashion firms' distinct behaviours in adopting various digital CE strategies. An inductive, exploratory multiple-case study method is employed for investigating innovation projects of large, SME and startup fashion companies. The study aims to narrow the gap between the fashion CE theory and practice to harmonise fashion firms' orchestration and accelerate their transition towards the CE. This study's empirical evidence may better inform business managers about how to apply digital technologies into circular business model innovations for their fashion businesses. Policymakers could also enact appropriate policies to reinforce fashion circularity in both the production and consumption sides.

2. Literature review

2.1 Circular business model and digital innovation in the circular economy

The CE transformation is central to many national policies and business plans in recent years. CE minimises resource depletion and environmental contamination caused by the linear process of "take-make-discard". Turner and Pearce (1990) introduced the concept of a circular economic system to replace the traditional linear production model. From an economic perspective, Andersen (2007) also argued that material and resource inputs into the economy should be kept minimal, and product values should be retained through activities of recycling and reuse. Korhonen *et al.* (2018, p. 547) define CE as "a sustainable development initiative to reduce the societal production-consumption systems' linear material and energy throughput flow by applying materials cycles, renewable, and cascade-type to the linear system." The cooperative role of consumers and producers and other societal actors in the sustainable transition of CE is emphasised (Hobson, 2016; Korhonen *et al.*, 2018). To a certain degree, CE can be linked to the concept of sustainability; for example, sustainability is one of the main goals of CE. However, sustainability is a relatively broad concept, while CE provides

more explicit, specific and actionable guidance at the micro-level (Geissdoerfer *et al.*, 2017). CE principles can be translated into CBMs that firms can explicitly adopt (Korhonen *et al.*, 2018).

The CBM and digital innovation are two significant elements behind CE. A CBM refers to "how an organisation creates, delivers, and captures value in a circular economic system" (Den Hollander and Bakker, 2016, p. 2), and "a business model in which the conceptual logic for value creation is based upon utilising economic value retained in products after used in the production of new offerings" (Linder and Williander, 2017, pp. 2, 3). CBMs reflect business model innovations in the CE, replacing the linear production–consumption system with circular models (Boons *et al.*, 2013; Mendoza *et al.*, 2017). Urbinati *et al.* (2017) classified CBMs in terms of downstream circular adoption, upstream circular adoption and full circular adoption. The downstream circular adoption alters the customer value proposition and interface through the "reuse" activities of products or usage-based models such as the pay-per-user but does not vary the internal activities or suppliers. The upstream circular adoption affects internal activities such as product design, development, production or supply logistics, but does not appear visible to final consumers. Full circular adoption involves both internal and external changes on value networks, customer value proposition and interface. The strategy of adopting CBMs is affected by a number of financial, technological, market, policy and organisational barriers (Kazancoglu *et al.*, 2021).

CBM innovation refers to the shift from a linear to a circular business model (Linder and Williander, 2017). Geissdoerfer *et al.* (2020) defined the four types of CBM innovation, including CBM transformation (i.e. modification of an existing business model), circular startups (i.e. the creation of new business models that entail CE strategies), circular business model diversification (i.e. the addition of the CBM into the existing business model) and CBM acquisition (i.e. the merger, acquisition and integration of the CBM into the organisation). Radical CBM innovation is considered a novel improvement to value creation and capture, while incremental CBM innovation is an improvement in addition to the existing business models (Foss and Saebi, 2017; Ranta *et al.*, 2021). Firm sizes and characteristics affect firms' innovation and environmental strategies differently (Balasubramanian *et al.*, 2020). Therefore, the discrepancy in CBM adoption and CBM innovation strategies of large, SME and startup fashion companies is anticipated. The long tradition of fast fashion requires business model innovations to transform business practices into circularity. Based on these frameworks, this study also explores how CBMs are adopted when it comes to differences in firm sizes of fashion firms.

Digital innovation is defined as "product or business process innovations that contain ICT, as well as innovations that rely to a significant degree on information and communication technologies (ICTs) for their development or implementation (OECD, 2019, p. 38)." Table 1 summarises various types of digital technologies. In the era of digitalisation, a wide range of CBMs are dependent on digital technologies to retain and restore value losses of goods and materials in the production and consumption systems to explore new markets and to satisfy new market demands (Pagoropoulos *et al.*, 2017; Nambisan *et al.*, 2019). Some CBMs are based on the sharing economy concept, such as Uber and Airbnb, that would not have been successful without digital technologies (e.g. real-time data, the internet of Things, digital platforms). Digital innovations enable CE (Rosa *et al.*, 2020) by optimising material flows and enabling reverse material flows (Pagoropoulos *et al.*, 2017), by integrating value chains through data collection and sharing (de Sousa Jabbour *et al.*, 2018), and by improving traceability and transparency through the product timeline (Antikainen *et al.*, 2018).

Also, digital technologies alter innovation inputs, processes and outcomes *per se* (Agostini *et al.*, 2019). For example, with real-time data and digital platforms, innovation inputs are shared in a more open, collaborative, transparent, faster way among the stakeholders in the digital innovation systems. The processes of creating and managing innovations driven by digital technologies also involve higher participation and feedback of partners and

Internet of Things (IoT)	The connectivity of physical objects such as electronic devices, smartphones and transportation modes is facilitated by the Internet, radio-frequency identification (RFID) technology tags, sensors and barcodes (de Sousa Jabbour *et al.*, 2018)
The cyber-physical system (CPS)	The integration of cyberspace, physical processes and objects enables the autonomous coordination of production lines in real-time to optimise decision-making, production orders and preventive maintenance in manufacturing (Ahmadov and Helo, 2018; de Sousa Jabbour *et al.*, 2018)
Big data	The capacity to store, manage and analyse a high variety, volume and velocity of data (Rajput and Singh, 2019)
Blockchain	The immutable tracking data of the product and process are provided through a supply chain or financial flow (Rajput and Singh, 2019; Kshetri, 2018)
3D printing	The printing of physical objects in layers directly from digital design models, which may shorten the lead time for production and which integrates designers, producers, and users (Beltagui *et al.*, 2020; de Sousa Jabbour *et al.*, 2018)
Online Platform	An interface or digital service that involves interactions between two or more users (whether individuals or firms) via the Internet (OECD, 2019)

Table 1.
The types of digital technology

consumers (Agostini *et al.*, 2019). Digital technologies can be flexibly embedded to generate a wide range of product and service innovations with less complexity and less uncertainty during product development phases (Agostini *et al.*, 2019). Also, digital advances make innovation outcomes less predefined, more easily enacted and modified in an iterative cycle after first launching to the market (Nambisan, 2017).

Given the emergent role of digital technologies in the CE, several papers, as shown in Table 2, examined this topic. However, the research streams are predominately theoretical or conceptual and focused on one particular company, one process of the CE or one or a few types of digital technology that makes it hard to generalise to an entire industry (Rosa *et al.*, 2019). The current research of digital technologies and CE, especially digital technologies for specific CBMs, lacks empirical research and considerations of sectoral contexts and comparisons across different firm sizes in a homogeneous sectoral context. Little is known on how different firm types in one industry have different digital innovation strategies to succeed with CE impacts. With the same opinion, Rosa *et al.* (2019) and Ranta *et al.* (2021) also stressed the essential needs for further holistic, integrated, empirical research to explain how CE and digital innovation are intertwined in heterogeneous conditions of different sectors.

Using case studies of four medium and large companies in several sectors (i.e. construction, machinery, waste management, oil refinery), Ranta *et al.* (2021) examined digital technologies (i.e. the Internet of Things, cloud, enterprise resource planning (ERP) system, artificial intelligence (AI), big data) grouped as data collection, data integration and data analysis on the dimensions of the incremental versus radical business models and incremental versus radical CE strategies. Bressanelli *et al.* (2018) examined a case study to explore the Internet of Things and big data applications, particularly on the product-service system (PSS)/servitised models. Most studies are focused on the Internet of Things, big data and Industry 4.0. However, only a few papers explore the role of 3D printing (i.e. additive manufacturing), which is considered as a game-changing, disruptive technology (Despeisse *et al.*, 2017) for the CE but has not been much explored in the CE literature. 3D printing may significantly change the ways things are produced and how the stakeholders are involved. If used with other emerging digital technologies (e.g. the Internet of Things, big data, Industry 4.0), 3D printing may radically change the industries (Despeisse *et al.*, 2017). This paper also adds to the knowledge of how a mass-production industry, such as the fashion industry, can utilise 3D printing technology and radical CBMs to become more sustainable in fashion production and consumption.

Authours	Studies	Digital technologies	Approach
Ranta *et al.* (2021)	Digital technologies catalyzing business model innovation for circular economy – Multiple case study	Data collection (by radio-frequency identification (RFID), IoT), data integration (by cloud computing, ERP system), and data analysis (big data, AI)	The empirical study examined variety of digital technologies on the circular business model innovation in consideration of the narrowing, slowing and closing resource flows and the novelty (radical versus incremental), using four cross-sectoral cases of the construction, machinery, waste management, and oil refinery companies
Jabbour *et al.* (2019)	Unblocking the circular economy through new business models based on large-scale data: An integrative framework and research agenda	Large-scale data on the CBMs based on the ReSOLVE framework	The conceptual study focused on one digital technology (large-scale data) to review and propose a framework and research themes of large-scale data on the ReSOLVE CBM model
Bag and Pretorius (2020)	Relationships between industry 4.0, sustainable manufacturing and circular economy: a proposal of a research framework	Industry 4.0	Literature review on the applications of Industry 4.0 in the context of supply chain management, focused on the interplay between institutional pressures, tangible resources, and human skills
Bressanelli *et al.* (2018)	Exploring How Usage-Focused Business Models Enable Circular Economy through Digital Technologies	IoT, big data	The empirical study examines the application of IoT and big data on a single firm case (i.e. household appliance sector) that uses the PSS business model
Nobre and Tavares (2017)	Scientific literature analysis on big data and internet of things applications on circular economy: a bibliometric study	IoT, big data	Systematic literature review on the IoT and big data in the CE in general, not focused on the CBMs
Despeisse *et al.* (2017)	Unblocking value for a circular economy through 3D printing: a research agenda	3D printing	The conceptual paper proposed research agenda of 3D printing for the CE
Antikainen *et al.* (2018)	Digitalisation as an enabler of circular economy	Digitalisation	The qualitative paper examined the role of digitalisation in the CE and its challenges. The sectoral contexts and distinct CBMs were not mentioned

Table 2.
Prior studies of digital innovation in the CE

(*continued*)

Authours	Studies	Digital technologies	Approach
Nascimento *et al.* (2019)	Exploring industry 4.0 technologies to enable circular economy practices in a manufacturing context. A business model proposal	Additive manufacturing	The empirical study examines additive manufacturing technology in waste collection, sorting, and treatment
Rosa *et al.* (2019)	Assessing relations between circular economy and industry 4.0: a systematic literature review	Industry 4.0	Systematic literature review of Industry 4.0 in the CE
Pagoropoulos *et al.* (2017)	The emergent role of digital technologies in the circular economy	Data collection (RFID, IoT), data integration (data management system, product lifecycle management system), and data analytics (machine learning, big data analysis)	The systematic literature review on data collection, data integration and data analytics in the circular economy

Table 2.

2.2 The fashion industry and circular economy

The fashion industry requires sustainable innovations for its imperative transition toward a CE. The production processes and unsold inventories of products and the throwaway culture of consumers generate an extreme amount of garment waste. Fifty years ago, consumers preferred tailor-made garments, whereas consumers nowadays tend to buy cheap and low-quality clothes, use them only a few times before discarding them. This throwaway culture leads to massive amounts of consumer waste for which many countries struggle to provide waste treatment solutions. According to Statistics Norway, each Norwegian throws about 23 kilos of textile per year, and in 2018 Norwegian fashion retailers sent approximately 277 tonnes of new unsold clothes out of Norway.

Producers, because of trying to meet market demands, also exacerbate the issues. Fashion production is an extremely resource-consuming and polluting process with tons of harmful chemicals and wastes emissions. During fabric production, in addition to high consumptions of water, resources, and energy, chemicals and pesticides are used and then discharged into the environment (Ellen MacArthur Foundation, 2017). The long-existing linear production process relies upon nine-month market forecasts. In that long timespan, market trends and consumer preferences are liable to change quickly and unpredictably, leading to vast amounts of inventories being unsold and having to be donated, burned or buried.

The recycling of garments retains the value of used fabrics, but fabrics have diverse forms of material, design and colours, so garments ought to be well sorted by types before recycled. The garment recycling process consumes a large amount of chemical for fabric decolourisation and deodorisation before the fabric is re-made for new garments. The lack of collecting, sorting and recycling is reported in the study of Kazancoglu *et al.* (2020) as one of the most important barriers to the fashion industry's CE.

The global "fast fashion" economic prospects are not optimistic; many fast-fashion companies struggle to stay profitable and resilient. The global COVID-19 pandemic and economic downturns aggravate firms' financial issues. Consequently, many large fashion incumbents such as H&M and Zara consider CBMs and technologies to transit to the CE. The circular fashion economy aims to reduce resource use and waste during production, prolong garment uses, enhance recyclability and reduce unnecessary new demand. Firms consider their resource capacities and organisational structures to adopt appropriate CE strategies for their business models to increase firms' productivity and sustainability performances (D'Agostini *et al.*, 2017).

The CE solution for the fashion industry has become a topic of interest. Some circular fashion business models in the form of service-based models, such as the sharing/subscription-based/collaborative consumption model (Todeschini *et al.*, 2017; Niinimäki, 2018), the second-hand retailing model (Todeschini *et al.*, 2017) and the take-back model (Kant Hvass and Pedersen, 2019), have been mentioned in some empirical studies. However, some business model innovations that potentially disrupt and shift the fashion production–consumption paradigm have not yet been studied. Kazancoglu *et al.* (2020) revealed a varied set of fashion CE barriers, such as lack of communication and collaboration, lack of tracking and tracing, design challenges, lack of market acceptance or lack of economic benefits. The fashion industry's supply chain is long and complicated, with many manufacturing and distribution processes (Kazancoglu *et al.*, 2020).

Among the few articles mentioned above that deal with digital technology and the CBM, to the best of our knowledge, no prior study has investigated digital innovation for CBMs in the fashion industry context to the best of our knowledge. The papers of Todeschini *et al.* (2017) and Niinimäki (2018) mentioned the role of technological innovation for fashion CBMs in general but did not explicitly investigate digital innovation. Therefore, two essential points remain missing in the academic debates regarding this topic of the fashion CE: the comprehensive view of radical fashion CBMs and how different types of digital innovations facilitate different fashion CBMs.

3. Methodology

3.1 Research design

This study employs the explanatory, multiple-case study approach to examine the firm-level innovation projects as the analysis unit. The case-study approach is selected for this study as it is suitable for either exploratory, descriptive or explanatory research to examine questions such as "how" and "why", the behaviour of the research subjects cannot be controlled, and the focus of the research is in a contemporary phenomenon (Baxter and Jack, 2008; Yin, 2011). The case study method's main interest is to "illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result" (Schramm, 1971, p. 6; Yin, 2011). The multiple case study method allows the comparison across cases to find similarities and dissimilarities in the sample (Stake, 2013).

The multiple case study approach of this study seeks to understand fashion firms' decisions of adopting the specific types of CBM innovations and digital innovations, and how the innovations are implemented and for which potential results. Multiple case studies provide empirical evidence for literal replication (i.e. cases with the same results) and for theoretical replication (i.e. cases with contrasting results) to develop theoretical insights (Yin, 2011). Moreover, both CE and digital transformation research are relatively nascent topics; large-scale quantitative data of the CE may not be available at this point. For that reason, exploratory and inductive qualitative research is desirable to seek empirical evidence and theoretical understanding, and explore the "how" and "why" of the phenomenon before further hypothesis testing in the subsequent stage.

3.2 Case selection

The cases are selected from the fashion industry in Norway. Compared to other European countries such as Spain, Turkey and Italy, the Norwegian fashion industry is relatively small (i.e. turnover NOK 67 billion and 42,000 workers) but had growing exports of almost 8% in 2016 (according to the Norwegian Fashion Hub). Besides several large fashion incumbents, a majority of Norwegian fashion firms are small and medium-sized. Norwegian textile, which were started in the 18th century, are well-known for wool, pattern knitting and outdoor

sportswear. In recent years, more Norwegian small and medium-sized fashion companies promote "made in Norway" products. Despite its relatively smaller scale compared to other larger textile exporters, the Norwegian fashion industry is relevant and important to be examined for several following reasons:

(1) Norway is a developed economy with advanced research, innovation and technology. Norwegian authorities strongly emphasise the CE and digitalisation transformation strategies and provide support for fashion firms that participate in these sustainability transitions. In Norway, the fashion industry is driven by the digital technology and sustainability-oriented mindset of both producers and consumers, appearing as a useful case context to examine digital advances for the fashion CE and for other developed countries to consider their fashion CE strategies.

(2) A number of research and training projects in Norway and with other European countries are initiated by the Norwegian fashion industry, showing some political supports for this sector in Norway. Some Norwegian fashion companies place sustainability as one of their core business values and aim to re-shore parts of their production processes to be less dependent on outsourcing supply, more sustainable and better prepared for global shocks like COVID-19.

(3) The ten selected cases belong to various sub-sectors (e.g. casual fashions, high-end fashion, sportswear), representing different firm sizes (i.e. large incumbents, SMEs, startups), and actor roles in the value chain (e.g. manufacturers, technology suppliers, service providers). Some locate factories abroad (e.g. Varner Group, Bergans of Norway, Høyer), and some manufacture in Norway (e.g. Oleana, Lillunn). This strategy of selecting multiple cases in the same context (fashion industry) but with different characteristics provides an integrative, holistic view of the industry and allows a comparison across cases to distinguish various CE digital strategies. Table A1 provides company profiles.

3.3 Data collection

Both primary data (i.e. interviews) and secondary data (i.e. project descriptions, project applications, website and newspaper articles) are collected. Compared to surveys that provide simple information in numeric and short-text form but limited in in-depth details, the interview method is appropriate for capturing more complex and in-depth information to obtain a more comprehensive and deep understanding of processes and motivation (Creswell and Poth, 2016). Thus, our primary data is gathered through semi-structured interviews. However, to reduce the interviewees' personal biases and achieve data triangulation, secondary data such as company website information and news articles were also employed. In total, eleven semi-structured interviews with the project managers, chief executive officers (CEOs), CTOs and sustainability officers, together with six project descriptions and forty-three archival documents, are collected (see Table 3). The forty-three news articles from Norwegian media were downloaded and coded into a framework that classifies the details of publications, contents, companies and innovation projects.

The first interview was conducted with the Norwegian Fashion Hub's head director to gain a comprehensive insight into the industry. Norwegian Fashion Hub is a cluster organisation consisting of forty established Norwegian fashion companies and a wide network of suppliers, universities, innovation labs and institutes for research, education and innovation. The snowball sampling technique was then used to get further contacts with other company representatives in the network. The interviews were conducted by in-person meetings, video calls and phone calls from October 2019 to June 2020. All the interviews were recorded and transcribed by the author and a research assistant. The interviews were based

No	Project	Firm size	Project description	Interview	Website and news articles
1	Lillunn	Medium	Yes	Yes, with project leader	Yes
2	Varner Group	Large	Yes	Yes, one with system manager and one with project partner	Yes
3	The Hapticians	Startup	No	Yes, with chief executive officer (CEO)	Yes
4	Oleana	Small	No	Yes, with CEO	Yes
5	Høyer	Medium	Yes	Yes, with project leader	Yes
6	Bergans of Norway	Large	No	Yes, with sustainability manager and with Chief of Information	Yes
7	Go Good	Startup	Yes	Yes, with project partner	Yes
8	Fjong	Startup	No	No	Yes
9	Norwegian Rain	Startup	Yes	Yes, with project partner	Yes
10	Livid Jeans	Startup	Yes	Yes, with project partner	Yes

Table 3.
The summary of data collection

on the narrative approach (Polkinghorne, 1988; Czarniawska, 1997) that allows the interviewees to openly share their opinions and stories closer to actual events, with minimal interruptions and personal biases of researchers. Follow-up questions (e.g. "why did you consider to do that?", "how do you do that?") were used to clarify the interview answers. In addition to the interviews, project descriptions in the form of funding applications of innovation projects serve as useful data. The project descriptions are written documents of 10–30 pages, explaining the objectives and processes of how the digitalisation and CE should be achieved together. Most of the projects have been successfully granted funding and are being implemented. Some of the projects are in the early stages, while others are further developed (see Table 4).

3.4 Data analysis

The analysis protocol suggested by Wolcott (1994) was employed in this study. The four-ordered steps proceeded as follows: First, the entire transcripts and documents are thoroughly read to obtain overall ideas. Next, relevant sentences, phrases, sections in the transcript or those related to theoretical concepts from our literature reviews (e.g. the types of

No	Project	Status	Type	Circular business model
1	Lillunn	Being implemented	SME	Pull demand-driven model
2	Varner Group	Being implemented	Large	Pull demand-driven model
3	The Hapticians	Being implemented	Startups	Pull demand-driven model
4	Oleana	Being implemented	SME	3D knitwear model/pull demand-driven model in consideration
5	Høyer	On plan	SME	Pull demand-driven model
6	Bergans of Norway	Being implemented	Large	Service-based model (Rental, subscription, repair)
7	GoGood	Being prepared to launch	Startups	Service-based model (Second-hand sale)
8	Fjong	Being implemented	Startups	Service-based model (Rental, subscription)
9	Norwegian Rain	Being implemented – pilot phase	SME	Blockchain-based supply chain model
10	Livid Jeans	Being implemented – pilot phase	SME	Blockchain-based supply chain model

Table 4.
The companies and their digital-based circular business models

digital technologies, CE strategies and CBM actions) were highlighted, whereas irrelevant information was discarded to avoid distractions during the coding stage.

Next, the related and repeated patterns in the codes were found and grouped together before being assigned into themes and categories. Creswell and Poth (2016) suggested having not more than thirty categories and five to six themes, regardless of the database size, to keep the analysis less complicated and more interpretable. The process of coding and categorising is central to qualitative research as it lays the foundation for elaborating and reasoning theoretical interpretations.

In the last step, the categories are labelled to define similar and contrasting patterns between the categories. For interpretation of data observations, the analytical technique suggested by Orton (1997) was used to link the existing theoretical perspectives to an empirical context for finding understanding based on found patterns in and between categories. NVIVO-12 software program supported the processes of coding and analysis.

4. Findings

Three main patterns of CBMs based on digital technologies are found by the examination of the ten large, SMEs and startup fashion companies as manufacturers, technology suppliers and service providers. The three CBMs include the blockchain-based supply chain model (two companies), the service-based model (three companies) and the pull demand–driven model (four companies). The service-based model entails two subtypes: the clothing renting/subscription-based model and the repair/second-hand sale model. The pull demand–driven model accounts for the majority of firms in this data sample. Large, SMEs and startup firms adopt this CBM innovation but at different extents. Table 4 provides the profiles of the firms with their CBMs. Table 5 presents a summary of the three digital-based CBMs. Some barriers are also considered to understand how digital technologies help address those issues.

4.1 The blockchain-based circular supply chain model

This model's core strategy is to improve the fashion value chain's traceability performance and automated sorting performance for recycling. The blockchain-based circular supply chain model is focused on upstream business to mitigate the barriers of the "lack of collecting, sorting and recycling" and "problems of tracking and tracing" emphasised in the systematic investigation of Kazancoglu *et al.* (2020). Garment products contain complex materials that make the process of sorting and recycling difficult, so technological innovations are required (Hawley, 2014). In practice, only 1% of clothing materials can be recycled (according to the Circular Fashion Summit Report, 2020)

Blockchain is a central technology in this model, together with real-time data and the Internet of Things to enable a transparent, verifiable and immutable information flow throughout the entire product lifecycle from "cradle to grave" (i.e. from the raw material production to retail sales) in the supply chain network. This technology may help provide information to increase sorting automation and recycling efficiency.

> We think that blockchain is super enabling technology, and it can change the circular model (Projects of Norwegian Rain and Livid Jeans).

Blockchain technology registers each transaction of garments throughout the value chain process without spatial boundness. The value chain actors in any location can decentralise the access, exchange information, and do not need third party operators. Concurrently with blockchain, the Internet of Things gives data access through interaction with personal electronic devices connected with the Internet. Information data at each point of the garment life are immutable to enhance the transparency of tracking and tracing performances. Blockchain data can be used for all internal and external stakeholders and should be verified

Model	Functions	Digital innovation
Blockchain-based supply chain model	Provide information to track and trace transaction activities of garment products Provide consumers with sustainability metrics of the products (e.g. garment components, carbon emissions, production process, logistics) Increase capabilities of reusing, repairing and recycling activities for a circular economy	Blockchain: register transaction activities during the value chain process The Internet of Things: connect the objects and enable the blockchain activities QR code: scanned to provide transaction data
Service-based model	Prolong the lifecycle of garments, increase garment uses Offer consumers with clothing renting, repairing, second-hand selling with more cost-saving, sustainable solutions	Digital platform: host the operational activities and services The Internet of Things: connect the objects and enable service activities Blockchain: enhance the clothing sorting process
Pull demand-driven model	Shift from mass production based on six-nine months market forecast to real-time demand-driven production to reduce overproduction Dematerialise physical designs by 3D virtual designs to reduce false samples and reduce lead time of product developments Provide tailor-made solutions for consumers to customise clothing designs with higher quality and better fitness to reduce overdemand Allow integrated communication between designers with end-users and with supplier partners Automate productions to reduce labour costs and increase higher preciseness in making clothes	3D design: virtualise designs and prototypes that can be modified on the online system Avatar-based 3D model: measure and modify designs according to consumers' avatars Digital platform: communicate and interact between end-users and designers and business partners 3D printing: produce clothing directly based on 3D virtual designs AI and automation: automated production without human involvement

Table 5.
The three main digital-based circular fashion business models

by a third party to ensure data creditability. A wide range of sustainability metrics (e.g. material components, garment types, production time, logistics and delivery, using history and carbon emissions) can be recorded and showcased to fashion consumers and brands by simple QR-code scans.

This model contributes to a circular supply chain of the industrial system at various levels (Korhonen *et al.*, 2018). The model provides mutual CE benefits for both brands and consumers in a broad sense. Given more credible, transparent information, consumers are more incentivised to choose sustainable products and fashion brands. For example, by scanning QR codes, consumers can obtain information on product sustainability indicators (e.g. chemical use, water use, carbon emission, waste emission). Firms can centrally monitor and control the production and supply chain processes to boost efficiency and sustainability performances. Firms can also integrate this model with other CBMs such as recycling, repairing and renting models to improve efficient automation in garment sorting. Furthermore, the collaboration process in the supply chain is less geographically limited. The actors' vertical and horizontal integrations and collaborations are consequently

enhanced through real-time data on each production stage to optimise resource consumption and production conditions.

To fully optimise this model, several operational barriers should be taken into account, for example, the extent to which data should be shared, accessed, verified and trusted among the network of supplier partners and consumers. One fashion company may have multiple suppliers in diverse locations, and, ideally, all suppliers in the blockchain network should be able to register their single activities into the chain. In this study, this model is adopted by the two small medium-sized companies that perhaps have more flexible organisational structures to adopt this new system compared to larger firms with more complicated corporate structures.

> You might know your first level and the second level of providers in terms of materials and origins where you sell your clothes and so on. But the deeper you go into the value chain, the harder it gets to build the blockchain because you need that physical and digital touchpoint (Projects of Norwegian Rain and Livid Jeans).

Thus, firms need to figure out how to collaborate and engage their supply partners in this new supply chain model. To a certain degree, third parties' verification may be required to maintain trust in the blockchain. Also, it is to consider which indicators and comparison benchmarks should be included in the chain to ensure the chain's information traceable and trustful; consequently, it may involve data management.

4.2 The service-based model (rental/subscription-based, repair, reuse/second-hand sales, e-commerce model)

The service-based models, including two subtypes (i.e. the rental/subscription model in section 4.2.1 and the repair/second-hand sale model in section 4.2.2), mainly focus on the user side, downstream business. Service-based models have received substantial interest in the recent CE literature. Similar to music, film and accommodation being subscribed and rented (e.g. Spotify, Netflix and Airbnb), fashion items can also be lent, rented and subscribed. These models help servitise, dematerialise and virtualise fashion to increase garment reuse, ownership sharing and keep garments in more extended use to slow the loop. They provide consumers with more conveniences, varieties and lower costs to expand their clothing wardrobes without causing wastes and environmental pollution.

4.2.1 The clothing renting/subscription-based model. The clothing renting/subscription-based model is built upon the sharing economy concept. Fjong, a Norwegian fashion startup, offers a digital platform for peer-to-peer rentals of garments and accessories. Users can sign up as lenders and get updated about how their garments are rented out to generate incomes of renting. Simultaneously, others can rent garments that suit their styles, fitness and affordable prices. The company facilitates transactions between lenders and renters and guarantee service quality. Extra services such as free cleaning and free delivery are offered along with clothing rentals. This model directly reduces new purchases and improves the garment utility as plenty of garments are bought but underused. 3D technology may also increases clothing personalisation, so consumers can try fitting products online. The company's ambition is to expand its businesses to the larger-scale subscription-based model in which consumers can rent clothing for the long term and daily basis. With its digital platform, the company can also offer an extra service for its peer companies and designers to test market opinions about new designs before sending the designs to mass-production.

The startup firm, Fjong, pioneers in these new market segments, whilst the large fashion incumbents such as Bergans of Norway also identified market promises and gradually participated in the market with some new added-in services (e.g. renting camping gears and children clothes with less frequent use and quickly changed) along with traditional businesses. Bergans of Norway implements the new renting/subscription services on a small

scale to test the market. The company offers only the services in geographical proximity and collaboration with local organisations such as tourism organisations in the early stage. Believing that the trends of second-hand sale, rental and subscription businesses will continue to proliferate in the near future, the company prepares itself to react to consumption changes. Digital platforms and systems are planned to improve the qualities of customer services and supply chain operations.

4.2.2 The repair/second-hand sale model. GoGood is an entrepreneurial venture providing second-hand sale businesses based on digital platforms. Their model aims to the "reuse" strategy of CE. An opinion survey conducted by GoGood indicated that one out of three Norwegians would choose second-hand products in the next years. Low prices and environmental friendliness are among the advantages of this model; however, some disadvantages also exist, such as decreased quality after use and the lack of effective delivery service and distribution. Understanding customer preferences to redesign according to their fitness and styles is a critical factor for this model's success. This company offers a systematic solution to collect and classify garments by types, evaluate reusable values, wash, redesign and repair. With this model, old clothes are brought a new life and are kept longer in a closed-loop instead of being sent early for fabric recycling.

New consumption patterns and digital advances have substantially contributed to the emergence of both the renting/subscription-based and repair/secondhand-sale models.

> In the fashion industry, the development of new consumption patterns has contributed greatly to service-based business models with rental and subscription services through digital platforms. . .The digital maturity increases the willingness to use new digital services and gives the service economy opportunities. The transition from traditional products to digital services of sharing, renting, and subscribing will escalate (Project GoGood).

The service-based models are mainly dependent on the digital platform and the Internet of Things technologies. Most business activities and services (e.g. renting, sharing, buying and selling) are organised and operated on virtual interfaces such as mobile apps, websites or e-commerce channels.

> Our costs in the next few years will largely depend on the development of technology in the digital platform. But what we are going to spend money on is also what will generate money in the future (Project Fjong).

Besides digital platforms, the Internet of Things is often used to facilitate individual actions and interactions among users. For example, when a consumer wants to rent a new garment for a special occasion, he or she will use personal devices to log onto the mobile app to make an order, scan the QR codes to check-in and return the product. Blockchain technology in the supply chain model could be integrated with the service-based models because blockchain technology helps provide data to enhance the quality and efficiency of classifying garments for rental and second-hand sales.

However, some consumers may perceive that their social values could be lowered if they dress in used garments. This factor may hinder these models' successes. The companies pointed out the importance of understanding consumer mindsets, enhancing consumer awareness about new sustainable ways of clothing consumption and normalising used garment consumption. Reshaping consumer patterns can take time and include several stages, such as reducing social prejudices to encouraging more clothing renting and second-hand buying before fully expanding to larger-scale businesses.

> I think a lot is about finding the balance between listening to what the customer wants and educating them in the service we provide. We can offer the same value proposition, but at the same time, be a sustainable alternative! (Project Fjong).

4.3 The pull demand-driven model

The pull demand-driven model facilitates a radical shifting in the whole production–consumption paradigm of both the supply and demand sides and upstream and downstream businesses. It shifts from the push model in which deadlocked volume-based production based on six-to nine-month forecasts to the pull demand-driven model built on real-time driven output to solve two underlying problems of the fashion industry: overproduction and underuse. Since the designs and prototypes can be digitalised in the product development and production phases, all chain stakeholders can get involved quickly from the beginning stage.

The pull demand–driven model reforms the linear process of fashion production to a more circular, collaborative and integrative process to adapt designs, demands and production on an ongoing basis. Therefore, the "lack of communication and collaboration problems" between multiple stakeholders in the supply chain (Kazancoglu *et al.*, 2020) may be improved. Data inputs for production processes are updated following actual preferences of end-consumers. Garment production can be fully customised, tailored-made directly from virtual designs to minimise prototype wastes and optimise production.

> With the pull business model, we are able to increase the speed from design to delivery, do more collaboration, produce more personalised items, and be more flexible for small-scale production (Project Oleana).

Moreover, virtual 3D designs and digital platforms also enable remote monitor and control to help address travel restrictions because of the pandemic. Thus, manufacturers and outsourcing partners can collaborate without having to travel physically.

> And then we got the Coronavirus, and everything stopped, I'm sure that, since it's not possible to travel in the same way as before, we need to see other ways of working because of the COVID-19 and the economical way of doing things (Project Varner).

The model is shifted from the economy of scale to the economy of scope. In other words, producers do not have to produce a large-scale quantity in advance. It could also be the solution for the "diseconomies of scale" barrier of the fashion industry mentioned in the study of Kazancoglu *et al.* (2020). The situation where fashion stores were forced to close in the COVID-19 led to high volumes of unsold clothing. With the pull demand–driven model, the risk of unsold inventory is reduced when the production does not depend on the mass production of long-period forecasts but instead based on real-time demands. The cash flow will be more fluid and flexible without too large fixed cost investment required.

Moreover, the simplified production process of the model reduces the costs of intermediary and material logistics. The model is not only more sustainable for society but may also be potentially profitable for the firms. Once the financial performance is improved, firms may become more resilient against external adversities. Given fewer investment costs required, the model provides more entrepreneurial opportunities for small, new firms with small-scale production and limited financial capacity.

> Digital tools are competitiveness for the factories to start producing smaller volumes because it enables us to lower the product development costs a lot,. . .and can produce locally instead in a factory in India (Project The Hapticians).

Digital production of this model also brings competitive advantages for high-cost countries such as Norway to compete with lower-wage cost countries.

> You can save the labour cost because you don't have that many people in processes. And it would be more sustainable because you will eliminate a lot of the wastes. The whole production can be controlled more easily when you don't have that many human factors involved (Project Oleana).

3D printing (i.e. additive manufacturing), avatar-based 3D design and AI technologies are the key technologies to unblock the model's full customisation and integration. 3D designs and digital platform provide multiple parties (e.g. designers to developers, suppliers and buyers) access to the same system to reduce lead time of product developments and testing errors. The "real-time" flexibility in communication and collaboration between value chain partners from the beginning phases of design and testing until the later production stages help reduce physical prototypes and false samples.

> The lead time for this model will go down dramatically, which means we will be more fashionable and more right in time with our garment (Project Varner).

> Digitalising the process will potentially cut down 50% of samples and optimise the use of material to minimise waste. Virtual products can also test demand in advance of production to reduce inventory, optimise conversion rates, and limit the volume that may harm the environment (Project Lillunn).

Noticeably, the model not only may improve production efficiency (by enhancing productivity and collaboration between value chain actors) but also may significantly disrupt the whole production–consumption paradigm. Consumers are incentivised to change their consumption behaviours from low-quality fast fashion to more sustainably-made, better quality, better-fitted and more personalised clothing. In the pull demand-driven model, consumer data and market data are collected for production based on individual preferences. Through avatar-based 3D technology, consumers can measure their body sizes, interact on virtual interfaces to create their own 3D designs and then send them to production.

> Another benefit is that fitting and styles will be more accurate to the customer. And also, in the future, maybe it's possible to make tailored-made garments because it's possible to make the individual type of garment (Project Varner).

Direct communication with end-users is also helpful not only for tailor-made producers but also for large-scale producers such as the Varner Group. Before mass production, the producer can load 3D designs on digital platforms to survey consumer opinions about the new models to avoid overproduction because of unmatched market patterns.

> If you are a designer and want to be more sure if the consumers will like your designs, you can make your design 3D and put it on the webshop, then just get the feedback from the consumers if they like this type of colour, pattern before you produce (Project Varner).

The degree to which firms will adopt the entire CBM innovation or only some parts of the model differ among firms. Some large and medium-sized firms (e.g. Varner Group and Oleana) with well-established organisational structures and business models tend to adopt this model incrementally and gradually. They aim to first adopt this digital innovation into some production parts before implementing the whole model and fully participating in the new market. They await higher certainty in market opportunities and technologies.

> A lot of different companies have been starting up, but it's in the starting step. The model just [emerged] a couple of years ago but has been growing (Project Varner).

By contrast, fashion startups such as The Hapticians adopt the entire digital tailor-made model for their entrepreneurial ventures to possibly create potential sustainable impacts, diffuse digital advances for new consumer patterns.

In addition to technical and financial capabilities, a major challenge the companies in this study perceive is consumer acceptance. While the model may change consumer patterns of buying ready-made garments in stores to tailor-made garments from online designs, several challenges need to be addressed. For example, if and to which extent consumers will be

capable of using new digital technologies, whether they will accept this business model innovation and will be willing to pay more for sustainable tailor-made products. The tailor-made clothes are believed to be more emotionally bonded with the consumers and, therefore, may be kept longer.

> You may have more personal relationships with the tailor-made clothes. So that's kind of the strategy as well in terms of sustainability, and the garments fit the consumers better

5. Discussion

5.1 Theoretical contribution

The paper addresses the first research question by presenting three archetypes of digital-based fashion circular business models: the blockchain-based supply chain model, the service-based model and the pull demand-driven model. The mechanism of how digital technologies enable those circular models as well as their impacts on firms' CE performances is also explained. This study adds to the current stream of CE and digital technology research an alternative holistic approach to understand how an industry with various actors (i.e. producers, suppliers, consumers) and different firm types (i.e. large, SMEs, startups) can take advantages of digital technologies and become more circular, sustainable and profitable simultaneously. A product lifecycle of fashion items entails several main stages: demand forecast, design, production, retailer selling, consumer use and recycling (Kazancoglu *et al.*, 2020). Figure 1 demonstrates the parts of the fashion production and consumption process that the three models affect.

The rapid emergence of service-based models contributes to recurrent, longer uses of ready-made fashion items through the activities of reuse, shared-ownership, and rental. This model may involve fashion service mediums in between producers and consumers to operate and facilitate retailing services of second-life fashion products. The blockchain-based circular model affects the value chain's long process from the fashion items are made until recycled. The pull demand–driven model changes the whole process of how the fashion items are forecasted, produced and used. The pull demand–driven model is radical because it helps predict market demands more accurately to narrow overproduction and shift to the "real-demand" production based on consumer preferences at the real point. Moreover, it may also necessitate changes in consumer behaviours in buying and using clothes. Thus, for firms to adopt this model, new value creation and value capture in the business system may be required. The paths of adopting this model can be relatively distinguishable among large, SMEs, and startup fashion firms.

Despeisse *et al.* (2017)'s study places the focus of 3D printing application primarily on repairing, remanufacturing and recycling benefits. This empirical study complements the conceptual research of Despeisse *et al.* (2017) by adding knowledge on how 3D printing may also contribute to the "reduce" benefits for the fashion CE. 3D printing technology may result in disruptive effects on the whole process of designing, production, and consumption to shift market preferences, value proposition, economic models (from scale to scope), and minimise

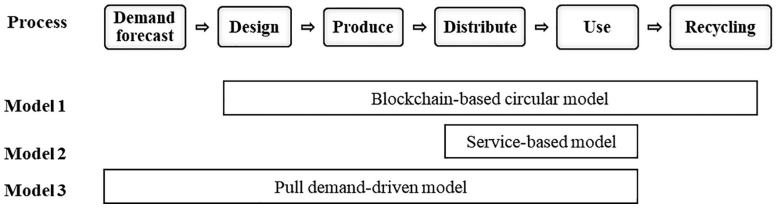


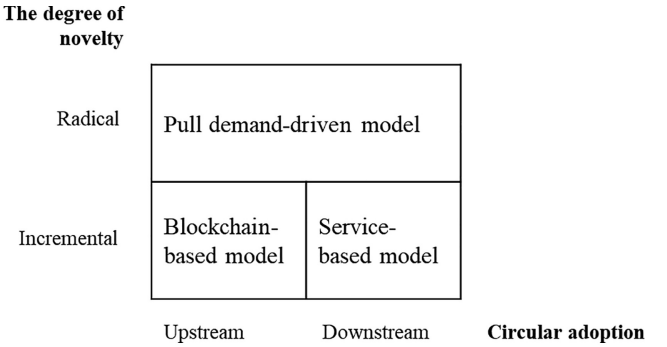
Figure 1.
Digital-based CBMs on the process of the fashion product lifecycle

overproduction. In that way, 3D printing would lead to higher resource efficiency and reduction in consumption.

Figure 2 reflects the three fashion CBMs on the combined framework of the downstream versus upstream circular adoption (Urbinati *et al.*, 2017) and the radical versus incremental innovation Ranta *et al.* (2021). On the one hand, the blockchain-based circular supply chain model, as incremental innovation, focuses more on upstream adoption and can be added to the existing business models. The service-based models predominately focus on downstream adoption and can also be included as extra services alongside the company's existing business system. The pull demand–driven model may affect the whole structure of the production–consumption paradigm and may necessitate radical innovations.

Even though this study and the study of Kazancoglu *et al.* (2020) examined the fashion industry in different economic contexts (i.e. of developed economy and of an emerging economy), the barriers found in this study are relatively consistent with the barriers highlighted in Kazancoglu *et al.* (2020)'s study. Norwegian fashion companies also encountered some main challenges such as "lack of communication and interaction", "lack of collecting, sorting and recycling", "problem of tracking and tracing", and "diseconomies of scale" (Kazancoglu *et al.*, 2020), in addition to some other specific barriers of the digital CBMs. The fashion CBMs using digital technologies may help mitigate those barriers.

Firstly, digital technologies (e.g. the digital platform) improve the predictability of the innovation process and market patterns with the right targeted customers and actual preferences and increase the dynamics of commercialisation activities on the virtual interface. The technologies (e.g. 3D printing, AI and 3D design) enable full customisation, automation and close dialogues between value chain stakeholders and consumers for quicker innovation modifications during the product development and production processes. Digital technologies enhance innovation process dynamics with a higher level of consumer and designer engagements than the early phases. This point of view also aligns with Andrews (2015)'s argument that designers should not passively wait for the development of reuse and recycling infrastructures but should be involved in the early stage and prepare for the CE processes. In that sense, digital innovations may significantly contribute to balance the equilibrium of market supply and demand to reduce excess stock wastes and consumer wastes. Also, the economy of fashion may shift from scale to scope by real-time–based, tailor-made production. Together with the pull demand-driven model, fashion as services such as rental, subscription, secondhand-sale models and dematerialise tangible prototypes would help slow down the fashion loop. Secondly, digital technologies



Source(s): Based on the framework of Urbinati *et al.* (2017) and Ranta *et al.* (2021)

Figure 2.
Three digital fashion CBMs on the degree of novelty and upstream versus downstream business

(e.g. blockchain, the Internet of Things) increase traceability and transparency of garment products to enhance consumer consciousness and recyclability. This digital attribute also changes the way how the supply chain stakeholders interact and coordinate in the innovation ecosystem.

The communication flow of CE may also be changed by digital technology. Figure 3 illustrates the conventional, linear communication flow versus the collaborative, integrative digital communication flow. The conventional, linear communication flow (illustrated by the black lines) is passive and single-way, with a long and fragment value chain process (e.g. from product development, production, to distribution and recycling). For instance, designers and producers hardly have direct communication with consumers but mostly based on a long mass-market forecast period.

On the contrary, the digital communication flow (illustrated by the dashed blue lines) become more multi-actors, multi-dimensional and integrative. Consumers are placed central in the digital communication flow, and fashion production is based on real-time. Consumers can communicate with designers for tailor-made production, and, in another way, producers can also communicate with consumers to test the designs before mass production. Material and technology suppliers receive more direct, accurate, real-time info to react to production plan more quickly and flexibly. Consumers may interact directly with the e-commerce and service provider retailers (e.g. renting, second-hand buying, repairing). Consumers may also get informed about recyclable products by recyclers. Recyclers can receive information on recyclable garments by blockchain and communicate with producers for sustainable designs. In the digital communication flow, the role of designers is also involved from the early stage of the value chain.

About the second research question, this study explores how different large, SME and startup fashion firms adopt digital CBM innovations. Based on the framework of Geissdoerfer *et al.* (2020) regarding types of CBM innovation (i.e. circular business model transformation, circular startups, circular business model diversification, circular business model acquisition), a comparison across different firm sizes in this study reveals that most of the large and medium-sized firms tend to adopt circular business model diversification strategy that added new business functions (e.g. clothes renting, subscription, blockchain-based model) to existing models. Large fashion firms are more likely to adopt the marginal changes in their system to assess the appropriateness of digital business model innovation and market acceptances before fully adopting an entirely new model. The pull demand–

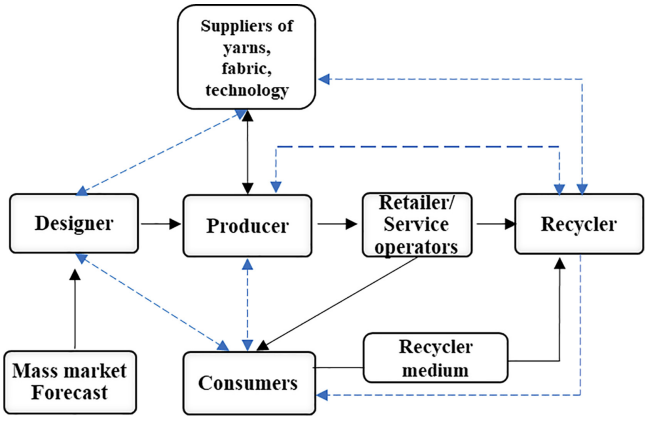


Figure 3.
The traditional, linear versus digital, integrative communication flow

driven model entailing significant shifting in the value creation and value capture system is more likely to derive from circular startups. This study is in line with Balasubramanian *et al.* (2020)'s research that small startup fashion firms tend to be at the forefront of digital technologies and radical business model innovation.

5.2 Managerial implications

The study provides business managers with empirical insights on how CBMs should be chosen according to intrinsic business capacities, technological competences and CE strategies. In addition to innovation in design and material science, business managers may also take into account digital advances to fully unblock the benefits of fashion circularity. This study informs business managers on how they can shift to digital circular fashion businesses. Digital transformation and CE transition are simultaneously accelerating among many well-known fashion brands around the world. For example, H&M and Adidas already offered consumer campaigns such as closing the loop. Fashion experts forecast that the sustainable technological shift in the industry from global to local businesses will continue growing drastically in the upcoming years, with an estimated CE value of 5 trillion US dollars (according to the Circular Fashion Summit Report, 2020). So, business managers should prepare for this drastic green technology shift, especially because consumers become increasingly conscious of sustainable corporate and their individual responsibilities. Businesses that fail to adjust themselves to sociotechnical systems' paradigm shifts could be eliminated from the markets. For instance, even the giants such as Kodak and Nokia lost their markets because they failed to innovate and keep up with rapid technological changes.

Given distinctive intrinsic advantages and disadvantages, each type of company holds its different role in industrial symbiosis. Large firms tend to adopt incremental digital and CBM innovations in a gradual manner to wait for the maturity of markets and technologies. In contrast, new firms are more likely to implement the entire CBM innovations and more willing to try disruptive technologies. Therefore, besides adopting recycling and reuse strategies, large fashion incumbents should consider collaborating with other technology suppliers and startup companies to incubate more radical innovations. Open innovation could also improve the digital ecosystem of the fashion industry. Fashion business managers should not neglect emergent startup and fashion markets, for example, fashion as services (e.g. rental, subscription), 3D instant customised fashion (e.g. pull demand-driven model). The arrival of digital startups (e.g. Airbnb, Uber, Spotify and Netflix) may significantly disrupt traditional markets, create new markets and undermine the competitiveness of many large incumbents.

5.3 Policy implications

Lack of governmental awareness and supportive policies is one of the most influencing factors for the CE transition (Kazancoglu *et al.*, 2021). The authorities should also be highly aware of the digital CE transition to enact appropriate policies and regulations. When interviewed, companies in this study emphasised that market patterns and consumer acceptances are highly challenging to their digital fashion models. Whether consumers accept business model innovations (i.e. pull demand model, rental and subscription model) may also significantly determine circular fashion's success. Sustainability and technology adoption of consumers might take place gradually in a sequence of stages. Together with both hard and soft incentive schemes, consumer education programs are crucial to enhancing technological knowledge, increasing market certainty and incentivising sustainable fashion consumption. This study highlights that the fashion circular economy is driven by both demand pull and supply push. Therefore, a balanced policy on both the demand and supply

sides are suggested. The one-side policy may fail CBMs that entail an upside-down collaboration of both producers and consumers.

Lack of collecting, sorting and recycling is a considerable challenge to the fashion industry (Kazancoglu *et al.*, 2020). Even if the blockchain supply chain model tries to partly improve traceability, automatic sorting and collecting, recycling may still be a substantial challenge to the industry because of excessive resource intake and toxic emissions in fabric and yarn recycling processes. It is perhaps time to rethink how to reduce unnecessary new demand rather than repeatedly producing and recycling. The pull demand-driven model shifting from the economy of scales to the economy of scope could be a possible solution for the paradox of reducing production but maintaining profitability, regardless of reduced unnecessary new demand. Thus, policymakers should also consider policy strategies to incentivise and facilitate this radical shifting of the CE effectively.

6. Conclusion

The shifting of the fashion industry to digital circular fashion is occurring all around the world, but surprisingly little known in academia. With the attempt to bridge the gap between theory and practice, this paper presents pieces of empirical evidence on how fashion firms may embrace digital innovations and business model innovations to improve their sustainable performances – using less, wasting less, and gaining more. Digital technologies offer some considerable potentials to enable the sustainable CE transition both incrementally and radically, provided that the technology must be used with a proper consideration of consumer privacy, data management and security. Digital technologies are not a perfect solution *per se*, as they also have negative sides. However, suppose the power of digital technology is harnessed in the right way. In that case, the digital CBM innovations of upstream circular adoption (i.e. the blockchain-based circular business model), downstream circular adoption (i.e. the service-based model), or full circular adoption (i.e. the demand pull model) may substantially contribute to a fashion industry of circularity and sustainability. The fashion industry issue is caused by a double-effect of overproduction (i.e. mass production forecast) plus underutilisation (i.e. the fast-fashion throwaway culture). Thus, double-effect issues require two-way producer–consumer solutions. Consumers' role should also be placed centrally in the fashion CE because the new digital fashion is likely to be determined by new consumer behaviours.

In acknowledging limited data scope, this paper does not try to generalise new theories but provide holistic, integrative empirical insights that broaden, to some extent, understanding about digital circular economy and strengthen conceptual findings. Since this study is conducted in the fashion industry context of a developed economy (Norway) with specific social and economic characteristics, the extent to which this study's findings may hold on other settings, such as less developed countries and emerging economies, should also be considered carefully.

CE is a relatively nascent concept, and the CE transition is still ongoing. Hence, it may take academics some time to collect large scale quantitative data and fully document CE transition results. This paper may lay a basis for further research to build upon at some later stages. Several research directions may be possible to explore, for example, (1) the development, adjustment, and modification of digital technologies for fashion circular business models over time and vice versa; (2) the barriers to the adoption of digital fashion CBMs; (3) the effect of digital fashion business models on a macro level, for example, how the global fashion value chain may change and reallocate resources from one country to another; and (4) the economic and sustainable performance measurements of digital fashion CBMs compared to traditional fashion CBMs.

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Appendix

Table A1.
The company profiles

No	Firm lead	Firm type	Firm profile
1	Lillunn	Medium	Lillunn is a Norwegian iconic outerwear brand made by 100% pure lambswool. It was founded in 1953 by Norwegian designer Unn Søiland Dale who leads Lillunn to collaborate with French fashion houses such as Dior and Givenchy in the 80s, as well as designing iconic knits such as Eskimo and Marius. Lillunn has a great part of the seam production in Oslo, Norway, continuing the traditions with a modern take. They have more than 80 stores located in Norway, Netherlands, America and Japan
2	Varner Group	Large	Varner Group is one of the largest fashion retailers in Scandinavia, with nearly 11,000 employees and 1,400 stores across eight countries. The first store was opened in Oslo in 1962. Bik Bok, Cubus, Dressmann are among the concepts of Varner Group. To make the business becomes more sustainable and improve the environmental footprint of the fashion retailing industry, Varner Group has defined three focuses: to be fair and responsible to all people, to be climate-conscious and think circular, and to involve and engage the consumer in sustainable developments. Besides, Varner Group's goal is to become the leading data and tech-driven fashion company in Scandinavia by combining the best of online and offline worlds to create a truly seamless experience for the consumer
3	The Hapticians	Startups	The Hapticians was established since 2018, specialising in tailor-made fashion with innovative digital solutions of design, production, and display to change how clothes are made more sustainably. The Hapticians is funded by Innovation Norge to promote sustainable growths in fashion
4	Oleana	Small	Oleana was founded in 1992 and currently has 52 employees. Wool and alpaca with superior quality made at the intersection between craft and industry are the focus of the company. Products of Oleana are made in Norway
5	Høyer	Medium	Høyer has become a Mecca for quality-conscious and fashion-interested Norwegians, since 2004. Today, with a total of 24 stores, Høyer offers high-end and luxury clothes in high quality
6	Bergans of Norway	Large	Bergans of Norway is a pioneer in hiking equipment and technical clothing since 1908. Bergans is now setting a goal of using more sustainable materials to extend the product lifecycles to secure responsible handling of natural resources, animal welfare and innovation in the design processes. Moreover, since 2009, Bergans has become a member of the Ethical Trading Initiative (IEH) to promote acceptable working and environmental conditions throughout the supply chain. With the purpose of long-living products, Bergans has played a major role in the Norwegian outdoor life for more than a century
7	Go Good	Startups	GoGood is a Norwegian startup company with experiences in office and home furnishing. The modern reuse solutions in areas such as fashion, children's equipment, sports and electronics are also considered to be the main purpose of this company. The company developed a system which drives innovation in the reuse model of clothing and furniture to provide CE solution for saving the climate and environmental footprint
8	Fjong	Startups	Fjong was established in 2016 with a digital platform for renting outfits as "clothes' Airbnb". 20 employees of Fjong (2019) work hard to figure out innovative ways for more environmentally friendly fashion businesses
9	Norwegian Rain	Small	Norwegian Rain was founded in 2009 in Bergen specialising in tailored rainwear by recycled materials and high technology against bad weather conditions. Products of the brand are not only functional but also elegant, which are inspired by Japanese functionality, classic men's fashion and Scandinavian purity. The brand has been very successful with the first store outside of Norway in London and now is sold in many stores all over the world
10	Livid Jeans	Small	Livid Jeans was founded since 2010 as a Norwegian textile company from Trondheim, focussing on making jeans inspired by Japanese finesse within fabric construction while maintaining the classic silhouettes of contemporary Scandinavian design. The brand's ambition not only hold core values but also create unique and authentic products against poor products being made unsustainably