Circular economy and digital capabilities of SMEs for providing value to customers

Combined resource-based view and ambidexterity perspective

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Abstract:

Some small and medium-sized enterprises (SMEs) are involved in recycling plastic waste to produce innovative products. These SMEs have adopted digital technologies, such as 3D printing and blockchain, to gain competitive advantage from their circular economy (CE)-based business models. However, the specific capabilities needed to create value for customers and to generate a competitive advantage for such SMEs are not known. In this study, we conducted in-depth interviews with four SMEs engaged in the CE to identify the specific resources and capabilities needed to provide value to customers. Our findings reveal that SMEs focusing on circular economy initiatives demonstrate exploitation and adaptive capabilities in utilising their CE resources followed by exploration and adaptive capabilities while implementing digital technologies. Our study extends the resource-based view by combining it with ambidexterity to explain the role of specific circular and digital resources and capabilities that SMEs need to provide value to their customers.

Keywords: Circular economy, SMEs, 3D Printing, blockchain, RBV, ambidexterity, value to customers, business model

1. Introduction

Plastic waste is one of the primary sources of pollution and biodiversity loss. Cleaning rivers, oceans, and cities of plastic waste has been attempted by many countries with varying degrees of success. The plastic waste, if sorted and graded, can be used to produce value-added products; this process has created opportunities for SMEs to develop innovative business models. Developing a circular economy (CE) around plastic is the key challenge for firms around the world (WEF, 2016).

Digitalisation is opening up new opportunities for SMEs to innovate and flourish (OECD, 2019, p.7). Therefore, SMEs are adopting different emerging technologies, including 3D printing and blockchain, to support their engagement in CE-related initiatives. The natural environmental orientation of firms leads to higher profitability in the long term (Menguc and Ozanne, 2005). Indeed, digital and environmental orientation has a positive direct effect on product innovation performance. However, pursuing a dual strategy towards digitalisation and environmental sustainability was not found to be significant for product innovation performance (Ardito et al., 2021). Ranta et al. (2018) studied the business models of CE-driven business ventures in terms of their value proposition, value creation and delivery, and value capture; they do not explicitly consider the value such models provide to customers, and nor do they consider the role of digital technologies in enhancing the value of CE initiatives. Therefore, it is unclear how SMEs can generate value for customers from a CE-oriented business model by utilising digital technologies and what kind of capabilities they need to develop to generate such a competitive advantage.

Recent studies have shown the positive influence of digital technologies in the circular economy sector. Nandi et al. (2020) proposed a resource-based framework for blockchain implementation in supply chains. Kristoffersen et al. (2020) developed a digital-enabled circular strategies framework for manufacturing companies and considered the Internet of Things (IoT), big data, and data analytics, while Bag et al. (2021b) analysed the role of big-data analytics-powered artificial intelligence for sustainable manufacturing and CE adoption in manufacturing companies. Indeed, there is a small but growing number of entrepreneurs who are working within the 3D printing (3DP) ecosystem to create a CE (Despeisse et al., 2017) and using blockchain to facilitate its implementation (Kouhizadeh et al., 2020). However, the resources and capabilities needed to adopt 3DP and blockchain for the circular economy is not known. Kouhizadeh et al. (2020) also concluded that a more critical examination of blockchain's potential in a CE context is needed.

In this research, therefore, we explore the capabilities needed by SMEs to implement 3DP and blockchain to generate competitive advantage from their CE-based business models. The specific research questions we consider are as follows:

a) Which capabilities are needed by SMEs implementing a circular economy to adopt digital technologies such as blockchain and 3D printing?
b) How do the circular economy and digital technology-based resources and capabilities of SMEs provide value to their customers?

We conducted in-depth interviews with SMEs involved in recycling plastic waste and utilising 3DP and blockchain, and we drew insights from those cases using qualitative analysis and so develop testable propositions. The results show that, combined with digital resources and explorative capabilities, CE resources and exploitative capabilities help SMEs to create value. Furthermore, we extend RBV by using organisational ambidexterity to explain how CE and digital technology adoption by SMEs can provide value to customers.

2. Literature Review

To develop an understanding of the relevant body of knowledge and theoretical support, we first review the literature associated with a CE-oriented business model innovation followed by technology as an enabler for the CE, and how the CE and digitalisation can create value for customers. We then identify the gaps from the literature and conclude the section by providing theoretical support for our research.

2.1 Circular economy-oriented business model innovation

Business model innovation consists of creating, diversifying, acquiring, or transforming a business model as a response to internal and external incentives (Foss and Saebi, 2017; Geissdoerfer et al., 2018b). The dynamic process of business model innovation can occur in different intensities, which are related to the degree of novelty introduced (i.e., ‘new to the firm’ or ‘new to the industry’) or the scope of changes (i.e., individual components or systemic/architectural structure) (Foss and Saebi, 2017).

To respond to increasing pressure on our natural resources, a CE aims to create multiple types of value with the ultimate goal of achieving a more resource-effective and efficient economic system (EMF, 2015). CE-oriented business model innovation incorporates principles or practices from CE as guidelines for a business model design (Pieroni et al., 2019). It aims at boosting resource efficiency and effectiveness (by narrowing or slowing energy and resource loops) and ultimately closing energy and resource flows by changing the way economic value and the interpretation of products are approached (DenHollander and Bakker, 2016). There are three available modes of integrating CE principles in business models: downstream circular (altering value capture and delivery through new revenue streams and customer interface), upstream circular (changing value creation systems), and fully circular (combining upstream and downstream principles) (Urbinati et al., 2017). CE-based business model innovation needs a multi-disciplinary approach (Antikainen & Valkokari, 2017; Sakao and Brambila-Macias, 2018), requiring interfaces with product design, value chain, and digital technologies (Geissdoerfer et al., 2018a). Environmental and CE orientation is relatively easier to communicate within SMEs, which creates a strong organisational identity (De Roeck & Delobbe, 2012).

2.2 Technology as an enabler for a circular economy

Digitalisation can boost CE business models by helping to close the loop, slowing the material loop, and narrowing the loop with increased resource efficiency (Antikainen et al., 2018).

Among the recently emerging technologies, 3DP has a strong potential to act as an enabler of the CE; it has the potential to alter the economics of the existing manufacturing value chain and can enable the local economically viable small-scale production needed to collect and process waste plastics to turn them into 3DP feedstock (Garmulewicz et al., 2018). However, significant barriers exist due to the quality of the 3D printed product, whether made from virgin or waste material, and because of the unfavourable value proposition of 3D printed products turning waste plastic being economically viable (Garmulewicz et al., 2018). Unruh et al. (2018) analysed the biosphere rules of materials parsimony, value cycle, power autonomy, sustainable product platforms, and function over forms to analyse how CE can be built on a 3DP infrastructure. Kristoffersen et al. (2020) developed a detailed digital-enabled circular strategies framework for manufacturing companies; however, their framework did not consider 3DP or blockchain, and nor was it developed specifically for SMEs. Using case studies of large companies, Kouhizadeh et al. (2020) showed that blockchain can benefit CE practices across industries, but it is not a one-size-fits-all solution. Industrial implications for the blockchain-CE linkages will tend to vary due to product, process, and supply chain characteristics.

2.3 Circular economy, digitalisation and value to customers

The overarching goal of CE-based business models is to help companies create value through using resources in multiple cycles and reducing waste and consumption. To achieve this, the input side, the transformation processes, and the output side of business models must be considered (Lewandowski, 2016). Production inputs can be composed of used, recycled, or recaptured materials and usually require the involvement of partners and experts who know about the benefits and limitations of such materials (Lüdeke-Freund et al., 2019). The design of processes by which production inputs are transformed into customer value propositions is driven by continuous cycling of materials and waste reduction and elimination (Linder and Williander, 2017). Dey et al. (2020) identified the resources and competencies, such as material selection, eco-design, recycling, repair, reuse, reverse logistics, etc., across the different CE fields of action, such as sourcing, making, distributing, using, and recovering, that SMEs will need to improve their sustainability performance.

Adoption of digital technology can also lead to enhanced competitiveness, productivity, and performance (Dibrell et al., 2008; Kleis et al., 2012). Pursuing a digital orientation helps in the development and acquisition of new skills, competencies, and knowledge, which can contribute to the launch of new products and/or processes (Nambisan et al., 2020). Digitalisation can help in developing sustainable circular products, and customers' involvement will be necessary for developing such innovative sustainable circular products using digitalisation (Agrawal et al., 2021).

However, the motivation for digitalisation and CE address dissimilar organisational and societal goals that may be in conflict and may compete for (scarce) organisational resources (Ardito et al., 2021). Therefore, unless digital transformation is specifically considered as part of an environmental orientation strategy (de Sousa Jabbour et al., 2018), the effect of digitalisation on CE-based business models may be unknown. Nonetheless, focusing on digital orientation or environmental orientations will enable an SME owner to enhance and allocate resources in such a way as to extend, create, or modify existing products and processes, thereby increasing the likelihood of product and process innovations. Therefore, the mere adoption of digital or environmental solutions will not create value for SMEs and their customers unless digital and environmental aspects are integrated within the organisation through a clear strategic orientation (Ardito et al., 2021).

2.4 Gaps from literature

The literature review shows that there is limited research on the role of digital technologies such as 3D printing and blockchain in providing value to customers for SMEs engaged in CE initiatives and the resources and capabilities that SMEs will need. Dey et al. (2020) identified the resources and competencies needed by SMEs to improve sustainability performance, while Ranta et al. (2018) studied the business models of CE-driven businesses. Neither of these studies specifically analysed the value provided to the customers, and nor did they consider the role of digital technologies in enhancing the value from its CE initiatives. Studies such as Kristoffersen et al. (2020), which developed a framework for digital-enabled circular strategies, did not explicitly consider the role of SMEs.

2.5. Theoretical support

Resource-based view (RBV) explains how resources help a company to gain and sustain a competitive advantage. When resources are accumulated by a firm in a specific way, they are harder to imitate or substitute and are more closely tied to competitive advantage (Barney, 1991).

Resources are firm-specific assets that are difficult to imitate (Teece et al., 1997). Such resources can be tangible, such as infrastructure, or intangible, such as “know-how”. Tangible and intangible resources help firms establish relational competitive capabilities. The RBV identifies the characteristics that the resources must possess to generate a competitive advantage. These characteristics are value, rarity, non-imitability, non-substitutability, and non-transferability (Barney, 1991). Resources are valuable when they enable a firm to implement strategies to improve efficiency and effectiveness. and rare when they are not possessed by a large number of competing or potentially competing firms. A firm may be able to imitate another firm’s resources or acquire different resources that can be strategic substitutes; if a resource is substitutable, it cannot help a firm generate and sustain a competitive advantage.

Capabilities are created when the resources have been integrated, and they are usually acquired through the development, learning, and exchange of knowledge of the staff (Prieto-Sendoval et al., 2019). Knowledge allows dynamic organisational learning in organisations for the natural environment while relational capability can augment the resources of alliance partners to create, extend, or modify their resource bases (Teece, 2000).

Circular economy business models require the acquisition of waste as resources (Centobelli et al., 2020), and access to reusable and recyclable products and materials to design circular processes and products (Prieto-Sandoval et al., 2019). Design and creativity are also critical for developing competitive circular products or services (Prieto-Sandoval et al., 2019). Other CE capabilities identified by Prieto-Sandoval et al. (2019) include developing green and circular products or services, understanding a competitor's strategy, the ability to attract talent with environmental values, managing traceability, creating synergies with compatible organisations, performing logistics operations and sharing logistics operations with other organisations, developing effective green marketing to open new markets, etc.

The conceptual research framework is shown in Figure 1.

Insert Figure 1 here

3. Methodology

We use qualitative case studies to identify the resources and capabilities needed to generate a competitive advantage for SMEs who have CE-based business models and who are implementing digital technologies. The study follows Eisenhardt and Graebner's (2007) approach to develop propositions from the case-based empirical evidence.

3.1 Case selection, data collection and data analysis

News articles were searched using the Nexis database with the search string "circular economy" AND "small and medium enterprises OR "SMEs" AND "3D printing" OR "Additive manufacturing" OR "Blockchain". This process resulted in five cases. We documented information such as the name of the company, the partners involved, the action taken by the companies, and the products developed. From this raw database, we shortlisted three cases based on the following criteria:

a. the focal company developing the product or service must be an SME
b. either 3D printing or blockchain must have been used to deliver the product or service.

We also used a fourth case that only uses recycled materials to develop the product. Its product could be used for 3DP, but the case company was not itself involved in 3DP activities. Such a case was selected to contrast with the other three cases.

We collected the companies' contact information from their websites and LinkedIn, and emailed a brief note about our project and an invitation to participate to the appropriate person(s) identified. Once the person(s) accepted the invitation to connect on LinkedIn, we sent them requests for interviews. The interviewees validated the transcripts sent to them. If needed, they answered further clarifying questions over email or through an additional interview.

The first step in our data analysis involved an in-depth analysis of the case document consisting of the interview transcripts and the collected additional material. Two of the authors independently coded the case documents to identify the CE and digital resources and capabilities, and the analysis of the resources and capabilities in terms of value, rarity, non-substitutability, non-imitability, and non-transferability. Inter-rater reliability was 0.85. The authors collectively discussed any differences observed in the coding, and conclusions were reached. The findings of the study, the propositions developed, and the frameworks were also validated with the interviewees. The details of the interviews conducted are provided in Table 1.

Use of triangulated data, highly knowledgeable key informants, use of an interview protocol, and review and validation of the findings by the key informants ensured construct validity (Yin, 2017). Choice of cases covering the use of different digital technologies for enabling a CE, the use of knowledgeable respondents, and pattern matching among cases ensured internal validity (Yin, 2017). Following a multiple case study approach and consideration of the case contexts ensured external validity (Eisenhardt, 1989). The use of the case study protocol and systematic analysis of the case documents ensured reliability (Yin, 2017).

3.2 Profile of case companies

Plastic Bank, based in Vancouver, Canada, builds recycling eco-systems in coastal communities and reprocesses the recycled plastic materials to be used to manufacture products for its customers. The collected material, which is processed as Social Plastic®, is reintegrated into products and packaging. This creates a closed-loop supply chain while helping those who collect it. Plastic Bank's customers, who are consumer goods companies, want to have the traceability that the recycled plastic they are buying is indeed 100% recycled. They also want to ensure that the people collecting the plastic are adequately paid. Therefore, Plastic Bank has developed a private blockchain with a customised token system in which it writes all the consensus rules. It also uses a tokeniser reward system to reward plastic collectors by paying them above the market rate. It is a medium-sized company with 175 employees and revenues of US$50 million in 2020-21.

Benthos Buttons is based in Cornwall, UK, and produces buttons. Most buttons use a couple of grams of typically Nylon PA6 and, with around 25 billion buttons produced each year, this implies the use of nearly 50,000 tonnes of plastics annually. About 60% of the buttons used globally are made in Qiaotau, China, which means that transportation emissions add up. As most buttons are also made from Nylon 6, the production of the material alone could produce nearly half a million tonnes of CO_2 each year (https://benthosbuttons.com/what-we-do-1). To address the above problem, Benthos Buttons uses ethically sourced, reclaimed Marine Nylon® plastic to produce sustainable garment buttons using 3D printing. Fishy Filaments are the manufacturers of the Marine Nylon® material used for the production of these buttons. Currently, Benthos Buttons is a one-person company.

Waste2Wear supplies innovative textiles made from post-consumer plastics that are fully certified and traceable using blockchain technology. It has 48 full-time and 24 part-time employees. Its turnover in 2020-21 was US$21 million, and this is expected to double in the coming year.

Waste2Wear's founder, being a textile engineer, was disturbed by the fact that over 50% of all fibres used for textiles are made from non-renewable fossil fuels. Coupled with the problem of plastic waste and the availability of technology to process recycled plastic, this motivated her to explore using recycled plastic for textile products. The Waste2Wear® blockchain system provides indisputable evidence that Waste2Wear® fabrics are made from plastic waste.

UK-based **Filamentive** has created a new brand of filament from recycled industrial plastic, which simultaneously addresses the environmental impact and the need for high quality materials to meet the needs of the 3D printing market. Filamentive's founder realised that the high-quality 3D printing filament available in the market was not sustainable, and the recycled filaments did not meet quality requirements. With support from his alma mater, the University of Leeds, as well as external funding through awards and grants, Filamentive's founder was able to research, explore, and develop his idea into action (https://www.filamentive.com/about-filamentive-recycled-filament/)'. Currently, Filamentive has three employees.

Details of the interview and the role of respondents, together with the number and duration of interviews, are shown in Table 1.

Insert Table 1 here

3.3 Theory elaboration

The context of digital technology adoption by SMEs engaging in the CE is not mature enough to deduce testable hypotheses using a general theory (Ketokivi and Choi, 2014). Theory elaboration is the process of conceptualising and executing empirical research using a preliminary model as a basis for developing new theoretical insights (cf. Fisher and Aguinis, 2017). Therefore, theory elaboration is suitable when the researcher can apply an existing general theory but the context is not known well enough to obtain sufficiently detailed premises to deduce testable hypotheses (Ketokivi and Choi, 2014). There is a need to improve the explanatory adequacy of RBV for the context of digital technology adoption by SMEs engaging in the CE (Fisher and Aguinis, 2017). Therefore, theory elaboration was considered to be the most suitable approach for this research. Theories can be elaborated by introducing new concepts, conducting an in-depth investigation of the relationships among concepts, or examining boundary conditions (Whetten, 1989). We investigated the RBV theory and the context simultaneously. Therefore, we did not formulate *a priori* propositions but remained open to unanticipated findings (Ketokivi and Choi, 2014).

4. Within-Case Analysis

4.1 Plastic Bank

4.1.1 Circular economy-related resources

The regular supply of recycled plastic through waste collection centres and pickers: A regular supply of recycled plastic is a critical resource for Plastic Bank's operations. It runs collection and sorting operations at its locations and sends the material to the recycling facilities. It recruits a local person to run and operate the facilities.

> "*Where the existing recycling ecosystem exists, we offer the ability to include them instead of competing with them, certify them to be Plastic Bank locations, follow our rules, code of conduct, use our digital system, register members, and continuously pass our audits and checks and become eligible for the bonus system.*" (CTO -Plastic Bank)

Motivated manpower with the entrepreneurial mindset: Having the right people on the ground is also very important for Plastic Bank, as it focuses on the scale of operations:

> "*We focus on team members with the capacity to pioneer. Our people have no self-limiting belief and like to do things differently. Thus, we look for people with an entrepreneurial mindset and not an NGO mindset. The person should embrace continuous improvement and learn their way to become the person they want to be.*" (CTO-Plastic Bank)

4.1.2 Digital technology capabilities

Having the most suitable technology is not sufficient, as there can be many implementation challenges due to people's lack of training or skills or the lack of network connectivity. Therefore, the solutions need to be adapted to the local conditions.

Developing blockchain enabled tokenised digital savings and wallet: Blockchain was needed to ensure tracking and tracing of the recycled plastic and ensure payment for the plastic collectors without investing in a separate security system.

Adapting to local conditions: Adapting to local conditions is a critical capability needed to adapt the solution to local conditions. It may require much more preparation and the creation of the appropriate conducive environment before the technological solution can be implemented:

> "*We had learned the broken ecosystem; for example, in a community where plastic processors are not used to using any system, collectors do not use phones. We needed a way to work in reality. We had to use solar power for phone charging, which now allows the phone to work in the community. We even followed it up with phone usage training.*" (CTO -Plastic Bank)

Table 2 analyses the resources and capabilities of the Plastic Bank case based on interviews and verification of other archival data. It needs a regular supply of recycled plastic waste that is critical for running the business and cannot be substituted, but it is not rare, and other competitors can also try to access such resources. Motivated manpower is a high-value resource for them, but its rarity, non-substitutability, and non-transferability are medium, and non-imitability is low, as other organisations can also recruit and motivate their employees towards achieving their vision. The ability to set up plastic collection locations with processes for collection and payment is of high value, with medium rarity and non-substitutability, but it can be imitated by other competitors. Adapting to local conditions while setting up operations and implementing the blockchain-based solution is of high value with a high degree of non-substitutability, as such capabilities enable Plastic Bank to implement its solution effectively, thereby guaranteeing customers of the quality of the recycled material. Moreover, such capability cannot be substituted by something else to make the solution work.

Insert Table 2 here

4.1.3 Value provided by Plastic Bank

Plastic Bank provides end-to-end auditability of the entire supply chain and guaranteed capacity. Many consumer goods companies have promised to use 100% recycled plastic by 2025. To achieve those objectives, the capacity needed is 10 times more than the current market of recycled plastic. With Plastic Bank, therefore, its customers are assured of capacity. Consumers also want to be part of something meaningful. For Plastic Bank’s customers, using Plastic Bank material to produce their products is a trusted way to make an impact with no backlash.

4.2 Waste2Wear

4.2.1 Circular economy-related resources

A regular supply of recycled plastic: Waste2Wear ensures that urban plastic waste, as well as plastic waste from beaches and oceans, is collected and sorted daily and brought to its partners’ recycling facilities.

Recycling partners’ capacities: Recycling partners’ facilities in China, India, Belgium, and Spain are critical to process the collected plastic waste, which can then be used to produce the finished products.

Collaboration with universities: Collaboration with universities in China has helped in developing the processes for using recycled plastic, and the company has a patent pending.

4.2.2 Circular economy-related capabilities

Waste2Wear also has years of experience in deciding which feedstock to use for what purpose and has in-depth knowledge about handling and processing.

Knowing which feedstock to use and how to process it for which end product:

> "*We can use multiple types of feedstock, for example, non-woven recycled polypropylene, which is the feedstock of appliances and food containers to PET, ABS, recycled nylon, etc.* - *knowledge of which feedstock to use for which application is critical. For example, for underflooring - you don't need highly selective plastic, but it should not be a mixture of PET or PVC. We have developed this knowledge and how to process different materials to obtain the desired quality*." (Waste2Wear Founder)

Handling different types of feedstock:-

> "*[It] needs a special way of handling, for example, treatment with chemicals, dyes etc. We know what needs to be done to maintain stable, usable feedstock by an environmentally friendly process.*" (Waste2Wear Founder)

Training of people across the value chain from different cultural backgrounds on different aspects of the process and the reasons for doing it: Training people at the recycling facilities about the processes and the importance of following best practices and reporting procedures was also necessary:

> "*We need to first explain and get the concept clear. Language and cultural differences can create a lot of problems; we have to explain it in a very simple way. Every country has a different system of reporting; we need to explain to the right people and have to get buy-in from the right people.*" (Waste2Wear Founder)

The proprietary process to test the content of recycled plastic: Waste2Wear has also developed the Waste2Wear®RA-3 test; this is a proprietary process (patent pending) to test and measure the content of recycled plastic bottles in a product. It can be applied to fibres, yarn, fabric, and final product.

4.2.3 Digital technology implementation capabilities

Developing customised blockchain solution

> *"We created the solution ourselves and put all the certifications online. We introduced it in September 2019, and it took more than 1 year to build it."*

Implementation of the blockchain-enabled system is a very challenging process, as the users have to be convinced about its benefits, and they also need to be trained.

Training of people within the company and other users

> *"Implementation is very time consuming – you may have the tool but if you do not implement it properly, tell the story well, it will not work. It has to be simple, it also has to be in their interests. If it gets too complicated, people will not implement it. You have to convince the person on the floor to register the data. We make sure that someone from our company is there.*" (Founder of Waste2Wear)

4.2.4 Value provided by Waste2Wear

Reducing the carbon footprint across the supply chain: Using R-PET (Recycled Polyethylene Terephthalate) instead of regular polyester, Waste2Wear consumes 70% less energy and 86% less water and emits 75% less CO_2. For example, if five pounds of RPET yarn is used to make Waste2Wear® fabric, it can save one full gallon of gasoline, save enough water to provide drinking water for one person for five days, and save the amount of greenhouse gas emitted while driving a hybrid car for almost 15 miles.

Demonstrating the authenticity of the recycled material: If customers are using recycled plastic, they want to be sure that the raw material is indeed 100% recyclable. Any customer complaint or even litigation can be very damaging to the brand. Waste2Wear's biggest value is demonstrating this authenticity:

> "*Biggest challenge in recycled plastics is to prove whether the feedstock is recycled. Now, the only way it can be done is through blockchain. The moment customers said we were expensive, we made our process and costs transparent and thus could prove that ours is fully recyclable but it is not for others. Our proprietary process to check the content of recycled plastic coupled with the blockchain solution creates a unique competitive advantage for us.*" (Waste2Wear Founder)

Therefore, all Waste2Wear® textiles and products are fully traceable, Global Recycle Standard (GRS) certified, and verified by blockchain technology. GRS is a third-party certification standard that verifies that products do have the recycled content they claim to have. Waste2Wear® blockchain technology is the first blockchain system to trace post-consumer recycled materials to their source. It secures complete transparency of the value chain for its partners, and the final consumer can use a QR code that shows the collecting spot of the plastic waste:

> "*Blockchain provides an additional advantage, as customers can see that it is indeed recycled plastic. It distinguishes us from everybody else. We can have the supply chain completely transparent. We created the solution ourselves in Germany. We also put all the certifications online. If you say that you use recycled material and you find out later it is not, brands will suffer a lot. Customers do not want that. They look for security.*" (Waste2Wear Founder)

Table 3 summarises the analysis of the resources and capabilities of Waste2Wear.

Insert Table 3 here

Collaboration with universities, knowledge of handling different materials, training of people across the value chain, and developing proprietary processes to check the content of recycled plastic are all of high value, while the last one also is rare and not easily imitable and transferable, as it is a proprietary technology developed by Waste2Wear. Its blockchain solution, designed for the specific application and training of users to adopt blockchain, is also of high value and non-substitutable.

4.3 Benthos Buttons

4.3.1 Circular economy-related resources

Locally sourced recycled material: Recycled fishing net filament is the key raw material for the buttons. It is sourced locally and sustainably. Fishy Filaments produce high-quality 3D print filament and injection moulding plastic made from 100% recycled Marine Nylon®. Fishy Filaments is based in the trust port harbour of Newlyn, Penzance, where the end-of-life fishing nets used by the Cornish hake fishery are dropped off. Fishy Filaments produce pellets from the nets; these are then processed into a 3D printable filament or injection moulding pellets.

4.3.2 Circular economy-related capabilities

Design skills to use recycled materials: The founder of Benthos Buttons designed the buttons considering aesthetics, ergonomics, and multi-functionality:

> "*I started my research by laser cutting as many interesting button shapes as I could imagine. Some were based on ergonomics, others based on edges and points, with the idea that they will be more engaging with users that have cold/low dexterity hands. I put six different plywood buttons on a shirt and asked 15 people to put on/take off the shirt. Most people were impressed by how much easier fastening/unfastening the shirt was with the tab button and how it looked on the garment*." (Benthos buttons founder)

4.3.3. Digital technology-related resources

Local 3D printing manufacturers: Local manufacturers who have invested in processing Fishy Filaments Nylon are critical for Benthos buttons. They produce the buttons and ensure that those are of high quality.

Guidance and mentorship: The founder of Fishy Filaments trained the Benthos Buttons founder on how to 3D print using the recycled material. He also put him in contact with another company that not only helped in his student project but also paved the way to start his business.

> "*I can never thank Fishy Filaments enough, how the founder helped a student like me, gave me advice and confidence. He also got me in touch with Addifab so that the sample buttons could be produced.*" (Benthos Buttons founder)

4.3.4 Digital technology implementation capabilities

Optimising process for 3DP of buttons: It is difficult to 3D print nylon, as nylon naturally absorbs moisture.

> "*To print with the Fishy Filaments nylon, it had to be baked at 55 degrees for 12 hours before printing. Whilst these trials were going ahead, I tested printing the different components' sizes and forms using PLA plastic. This helped me understand how the printer will handle each file*." (Benthos Buttons founder)

The 3D printed buttons have a rugged look and feel and can appeal to some customers. However, if details like branding have to be printed, Benthos Buttons realised that 3DP alone will not be the best solution. Therefore, they worked out that it would be better to 3D print the moulds and produce the buttons using injection moulding. Addifab from Denmark, which pioneered free-form injection moulding (FIM) technology, worked with Benthos Buttons and Fishy Filaments with this method. Using 3D printed moulds, Addifab injected the Fishy Filament injection moulding pellets and could produce these buttons at low volume. Currently, Benthos Buttons uses local 3DP manufacturers to print the buttons, but, if needed, they can also use FIM.

4.3.5 Value provided by Benthos buttons

100% recycled and sustainable buttons:

> "*Ours is the only marine nylon button in the world. Also, the fact that we can make 46 of these buttons which is equivalent to making 1 button –only based on production cost. If we also add transportation cost associated with importing the buttons, then we can produce many more buttons locally using our technology*." (Benthos Buttons founder)

One of the customers of Benthos Buttons is a local garment designer. She said:

> "*The garments are handmade by me, and I believe this knowledge is appealing to the wearer. The connection to Cornwall, famously a creative hub, works well as a memorable and distinctive quality. The buttons sourced from Benthos are incredibly unique, and I'm so excited to be using them. They have caught the eye of consumers, who love that they are locally sourced and are genuinely sustainable*."

Customisation enabled by 3DP:

> "*No button is the same, which gives personality to the product. The recycled material dictates the colour. I offer complete customisation - size, thickness, chamfer, fillet. The customers like the rough version and the fact that these are not perfect. I believe my products sell because of 3DP. When 3D printed, it still gives the fishing net and nylon feel. These shirts become so unique that people are going to hold onto them and [they will] get passed on*." (Benthos Buttons founder)

Table 4 summarises the analysis of the resources and capabilities of Benthos Buttons based on the authors' independent evaluation of interview coding. The locally sourced unique material and the design skills to use the filaments produced using that material have high value for Benthos Buttons, but the rarity, non-imitability, and non-transferability of that resource and the associated capability is of medium value. The guidance and the mentorship provided by Fishy Filaments to Benthos Buttons are of high value, rare, and not substitutable. Moreover, having local 3DP manufacturers who can process the recycled fishing net is also quite rare. Optimising processes for the 3D printing of buttons is of high value, rare, and non-substitutable.

Insert Table 4 here

4.4 Filamentive

4.4.1 Circular economy-related resources

A reliable source of recycled plastic: Filamentive primarily uses post-industrial, single source, and homogenised plastic as feedstock, which is meticulously checked to ensure homogeneity.

Effective distribution channels: Filamentive developed a wide network of distributors selling engineering goods, tools, and office supplies to sell its products. It also had a good business relationship with a leading 3D printer distributor and gained a lot of customers through that relationship.

4.4.2 Circular economy-related capabilities

Technical expertise: Filamentive and its primary source, the recycler, have strong capabilities in polymers, recycling, pelletisation, analysing printability, and mechanical properties of materials.

Marketing and building relationships: Filamentive focuses on communicating value through high visibility marketing and communications, search engine optimisation, and social media engagement, and has pushed the agenda of recycled materials and sent free samples.

4.4.3 Value provided by Filamentive

Filamentive provides value to its multiple segments of customers mainly because of the quality of its sustainable and recycled material. In the words of its founder, the value provided by Filamentive for different categories of customers is stated below:

> ***Hobbyists***: "*We are not a low-cost product. We are appealing to the green consciousness and sustainability aspects. Thus, there is an environmental motivation to the purchase and self-esteem of buying green for our hobbyist customers*."

> ***Businesses- service bureau****x:* "*The service bureaus are promoting their use of recycled material as their unique selling proposition, which is essentially helping them to gain customers, They also see the quality benefits*."

> ***Large corporates****: "Use of recycled material for 3DP applications fits [the] corporate agenda for sustainability [and] CSR programmes and is thus good for the company."*

Universities*: Universities also have sustainable procurement guidelines and prefer to use recycled material.*

Table 5 shows the analysis of resources and capabilities of Filamentive.

Insert Table 5 here

For Filamentive, its marketing and building business relationships are valuable capabilities; this is critical for its business and are not substitutable.

4.5. Circular economy and digital technology resources and capabilities

Regular and reliable sources for recycling plastic and recycling capacities are the CE resources found across all the cases. High-value CE resources observed in Waste2Wear include university collaboration, while that observed in Plastic Bank included a team of people with an entrepreneurial mindset who could work in a resource-constrained environment. Locally sourced recyclable material, i.e., fishing nets, is also of high value to Benthos Buttons. Entrepreneurial orientation captures proactiveness, innovativeness, and a risk-taking attitude (Miller, 1983; Covin and Slevin, 1988), and such behaviour by employees will be needed to implement digital technologies. Proactiveness means acting in anticipation of future problems, needs, and changes and therefore refers to efforts to take the initiative by anticipating and enacting new opportunities (Entrialgo et al., 2000). Risk-taking means the ability to take appropriate actions while facing uncertainty (Ricketts, 2006).

Similarly, the blockchain solution developed for the specific application and local 3D printing capacities is the digital resource utilised by the cases depending on whether they used blockchain or 3D printing. Technical skills in terms of design capabilities to use recycled materials were needed for the cases using 3D printing, while acquiring knowledge of which feedstock to use and developing a proprietary process to check the content of recycled plastic was valuable for Waste2Wear in adopting blockchain. Optimising processes for 3D printing and training people to adopt the blockchain solution and adapt to the local conditions were the valuable digital technology-related capabilities for the cases adopting 3D printing and blockchain, respectively. The guidance and mentorship provided to the Benthos Buttons founder in using 3D printed filaments for producing the buttons was also an invaluable resource for him. Although some CE resources were valuable, training provided to partners to adopt blockchain and adapting the blockchain solutions to local conditions are the capabilities associated with digital technology implementation. These are not only valuable but are also rare, and have high degrees of non-substitutability and non-imitability.

Therefore, the CE resources identified in this research, and that were also discussed in the literature, include a regular supply of recyclable plastic (Prieto-Sendoval et al., 2019) and collaboration with other organisations (Bag et al., 2021a), while such CE capabilities in congruence with the literature include green design (Bag et al., 2021a), design and marketing, and relationship building (Prieto-Sendoval et al., 2019). The unique CE capabilities identified in this research, and that have not been discussed in the literature previously, are developing knowledge of which feedstock to use, developing knowledge of handling different materials, developing a proprietary process to check the content of recycled plastic, and the ability to set up plastic collection locations with processes for collection and payment. Similarly, the unique digital capabilities identified include developing a customised blockchain solution, adapting the blockchain solution to the local needs, and training users to adopt the blockchain solution and optimising processes for 3DP.

5. Discussion

5.1 Linkage of circular economy and digital resources and capabilities with the value provided to customers

Figure 2 shows the relationships between CE-related resources and capabilities with digital technology implementation-related resources and capabilities, together with value offered to customers. For example, the capabilities of design skills to use the recycled materials and knowledge of which feedstock to use are needed to use the resources of a regular and reliable source of recycled plastic material and recycled partners' capacities. Therefore, recyclers in developing countries can contribute to a CE by collaborating with an SME with the required know-how, as observed in the Waste2Wear case.

Collaboration acts as an enabler to make the supply chain more resource-efficient and facilitates the use of cleaner technology. For this, shared understanding among different members of the supply chain is imperative (Mishra et al., 2019). Similarly, collaboration with universities also helps further develop the above capabilities. A team of people with an entrepreneurial mindset helps in training people across the value chain. Training is a particularly critical capability, as partners across the value chain may not be aware of the best practices and the protocols that need to be followed while collecting and processing the recycled plastic. Indeed, training suppliers could address the complexities and challenges in the logistics of recycled materials (Mishra et al., 2019).

The use of recycled material and following appropriate processes ensures that the end product meets the customers' requirements in terms of attaining their sustainability goals and enhancing the brand value of their products. However, this also requires marketing, continuous engagement, and communicating the value to the customers. Promotion (i.e., how much content around the CE is promoted through marketing campaigns) has been suggested as a measure for the degree to which a company makes its compliance with CE principles visible to the customers (Urbinati et al., 2017; Ünal et al., 2019).

For the digital resources, applying the unique blockchain solutions developed for the application also requires training, as it can be intimidating for the users in the recycled plastic processing facilities to perform additional work and log the data onto the blockchain platform. Queiroz et al. (2020) also confirmed the need for investment in training for blockchain adoption. It also requires adaptive capabilities in terms of adapting the solutions to the local conditions because of connectivity issues, etc. Therefore, the recycled material provided by blockchain, together with security and trust, ensured the authenticity of the recycled material and end-to-end auditability of the supply chain. This is a key requirement for customers, as they would not like to face a situation where the product is stated to be manufactured using recycled material and this was found to be untrue. This would have a much more detrimental effect on the brand value and the customers' reputations.

To adopt 3DP, local manufacturers were needed who had the 3DP capacity and knowledge to process the recycled material. For Benthos Buttons, mentorship and guidance from the recycled filament supplier, who had deep expertise in using the material as well as contacts in the industry, were needed. The 3D printed end product from recycled plastic also helped in customisation and appealed to customers as a locally sourced sustainable product.

Insert Figure 2 here

5.2 Elaboration of RBV with ambidexterity

Value can be generated and competitive advantage attained if the firm is capable of exploiting its resources (Newbert, 2008). Exploitation focuses on current internal knowledge and resources, while exploration focuses on learning new knowledge, discovering new capabilities, and investigating new ways of doing business (Levinthal & March, 1993; Cenamor et al., 2019). An organisation's ability to pursue two separate activities (i.e., exploration and exploitation) at the same time is termed organisational ambidexterity (Adler et al., 1999). Contextual ambidexterity assumes that exploration and exploitation can be reconciled within a subsystem, firm, or business unit (Gibson & Birkinshaw, 2004), and is more suited for smaller firms or firms that face larger resource constraints (Chang & Hughes, 2012). Indeed, Cao et al. (2009) found that balance between exploitation and exploration is more beneficial to resource-constrained firms in improving firm performance. For SMEs that face resource constraints, such balance may be needed. However, these orientations require different structures and resources (Gonzalez & de Melo, 2018), and many firms that pursue ambidexterity fail in the process (Solis-Molina et al., 2018).

Our findings show that CE resources are exploited using exploitative and adaptive capabilities, while digital resources are developed and utilised using explorative and adaptive capabilities, as shown by three of the case firms, to generate value from customers. Therefore, a combination of RBV and contextual ambidexterity helps to explain how the SMEs were able to generate value from customers.

For example, Plastic Bank demonstrated the exploitation capability of setting up plastic collection locations with well-defined processes for collection, sorting, and payment to the collectors. Combined with the blockchain-enabled system, it has developed to ensure traceability of the recycled plastic and transparent payment to the collectors; it has also developed explorative capabilities of adapting the solution to the local conditions that helped it to create value for its customers. Waste2Wear demonstrated exploitation capabilities in maximising the utilisation of recycled facilities and pursuing high volume production to achieve economies of scale and utilisation of its proprietary processes to process the recycled plastic. Customers' questions regarding why recycled products developed by Waste2Wear were costlier than other recycled products led Waste2Wear to explore alternative ways to demonstrate the purity of their products in terms of using 100% recycled materials compared to others who may not use 100% recycled plastic. They then started exploring solutions that would enable them to demonstrate that quality for every order. Searching for such solutions led them to develop their blockchain solutions that could make the entire process visible and transparent to the customers. Therefore, this is an exploration capability demonstrated by Waste2Wear. However, implementation of the blockchain solution needed additional capabilities.

Consequently, to generate value for customers, Waste2Wear needed to implement blockchain, as the customers demanded evidence that its material is indeed 100% recycled. However, implementing blockchain posed a significant challenge due to the lack of awareness amongst its partners and the difficulty in convincing them to adopt it. Waste2Wear had to be adaptive to develop an understanding of the ground realities and to train its employees, as well as its partners, to ensure that the developed blockchain solution could be implemented. Waste management companies and garment factories understood the importance of demonstrating the benefits of using 100% recycled plastic only from approved sources, but the workers on the floor also had to be convinced to make sure that the solution worked in practice. It was still difficult to convince the fabric mills and the yarn producing units; they agreed to adopt only for high volumes.

> "*You are working on a high-level technology with not-so educated people. Implementation is very time consuming – you may have the tool, but if you do not implement it properly, tell the story well, it will not work. We had to take risks to implement blockchain, as it was crucial for our business. When customers commented [that] our prices were higher, we had to demonstrate that ours is 100% recycled while others are not. We could do that because of blockchain and the way we implemented it..*" (Waste2Wear founder)

> "*One person in every shift had to be trained. Language and cultural differences can create a lot of problems. Hence, we had to explain in a very simple way. You had to convince the person on the floor about registering the data that this was not too much additional work and the company will benefit if they can show that the material used was only from approved sources.*" (Waste2Wear founder)

The above quotations implied that the users of the technology, i.e., the workers in the waste management companies, garment factories, and transportation companies in the case of Waste2Wear, were uneducated people or people with only limited education. However, their involvement was important for the accurate logging of data and to demonstrate that the plastic used by Waste2Wear was indeed 100% recycled. Therefore, Waste2Wear had to develop capabilities for understanding the ground realities and the problems that were faced in implementation. Accordingly, training programmes were developed for its employees as well as the partners, such as the plastic waste collectors and the personnel in the plastic recycling factories.

Therefore, Waste2Wear demonstrated exploitation capabilities about choosing the appropriate feedstock to use, handling different materials, and developing a proprietary process for checking the content of recycled plastic, together with the digital resource of their own blockchain solution, which was developed using exploration capabilities to implement the solution through extensive training. Such a combination of exploitation and exploration capabilities helped Waste2Wear to create value for its customers, and so it has succeeded in steadily increasing demand for its products.

Similarly, the filaments produced from the recycled fishing nets had to be utilised, and 3D printing was therefore found to be the suitable manufacturing technology for Benthos Buttons to produce the buttons. In this way, Benthos Buttons demonstrated exploitation capabilities in utilising design skills to design the buttons that could be produced using the filaments from recycled fishing nets as raw material. Despite efforts to learn the technology, producing the buttons using that technology proved to be futile for Benthos Buttons due to a lack of detail and the finish quality. Such a roadblock could have led to the project being abandoned. However, buoyed by support from Fishy Filaments and Addifab, moulds could be produced using 3D printing while the buttons were produced by injection moulding. This demonstrated that high-quality buttons could indeed be produced using the filament. However, Benthos Buttons continued to experiment with the 3D printing process and later realised that, for low volumes, the rugged authentic feel of the button could itself be a differentiator; this was eventually proven when the founder got the first orders from a local clothing designer. Therefore, while CE-related resources were exploited, the implementation of digital technologies required exploration capabilities in experimenting and optimising the manufacturing process for 3D printing.

On the other hand, Filamentive relied on recycled material and produced materials for 3D printing. It does not own the process know-how and is reliant on its key supplier; instead, it focuses on customer relationships and brand building. Therefore, it only utilises recycled resources, but it has involved the implementation of digital technologies, primarily demonstrating exploitation capabilities.

Exploration is characterised by search, variation, risk-taking, experimentation, flexibility, discovery, and the pursuit of new knowledge external to the organisation, while exploitation involves efficiency, production, implementation, execution, and the pursuit of the development of things already known by the organisation (March, 1991). Therefore, utilising the knowledge of the plastic recycling process and optimal utilisation of recycling capacities or 3D printing capacities are exploitation capabilities, while developing an individual blockchain solution and implementing it by taking into account the ground realities (as observed in Plastic Bank and Waste2Wear) requires adaptability as a form of contextual ambidexterity. Similarly, exploring alternative manufacturing processes and continuous experimentation are exploration capabilities, as observed in Benthos Buttons. It is important to note that both exploration and exploitation capabilities were needed by three of the studied SMEs. The other case, Filamentive, followed a CE-based business model but did not adopt any digital technology, for example, 3DP or blockchain, although the filament it now sells is used as a raw material for 3DP. We therefore suggest the following propositions:

> **P1:** SMEs focusing on circular economy initiatives demonstrate exploitation and adaptive capabilities in utilising their circular economy resources prior to digital technology implementation followed by exploration and adaptive capabilities while implementing digital technologies to generate value for their customers.

> **P2:** Simultaneous use of exploitation and exploration capabilities help the SMEs focussing on circular economy initiatives to provide value to their customers by implementing digital technologies.

5.3 Theoretical contribution

Our analysis shows that the SMEs that engaged with CE initiatives that adopted digital technologies, such as 3DP and blockchain, demonstrated both exploitations (e.g., maximising utilisation of recycled facilities, setting up plastic collection locations with well-defined processes for collection, choosing the appropriate feedstock to use, developing proprietary processes for checking the content of recycled plastic), and exploration capabilities (e.g., developing their own blockchain solution and implementing it by providing extensive training, adapting the solution to the local conditions, experimenting and optimising the manufacturing process for 3DP) as well as adaptive capabilities to adapt the digital solutions suited to the local conditions. However, the SME that had a CE-based business model but had not adopted any digital technology demonstrated only exploitation and adaptive capabilities. Our findings demonstrate that the CE resources and exploitative capabilities were not enough to provide value to customers unless those were combined with explorative capabilities. Therefore, we demonstrate how ambidextrous capabilities allow SMEs with CE-based business models to create value for customers by adopting digital technologies. This is in line with Cao et al. (2009), who found that balance between exploitation and exploration can be beneficial to resource-constrained firms such as SMEs in improving firm performance.

We also outline the characteristics of such resources and capabilities in terms of value, rarity, non-substitutability, and non-imitability, and how they help in providing value to customers. Implementing how CE generates economic value and improves sustainability performance for firms has already been studied (Ranta et al., 2018; Dey et al., 2020); however, there is limited research in terms of how CE and digital technologies provide value for customers. Therefore, we contribute to the literature on the adoption of digital technologies to enhance value from the CE by identifying the resources and capabilities needed. By doing so, we address the call for research by Kristoffersen et al. (2020) that the organisational resources and capabilities required to effectively leverage circular strategies need to be studied.

Additionally, we contribute to the literature by elaborating resource-based views by understanding the relationships between the resources and capabilities and by understanding the role of exploitative and explorative capabilities. Therefore, we contextualise RBV by considering organisational ambidexterity in the context of CE and digital technology adoption by SMEs to provide value to customers.

5.4 Managerial implications

The findings of this study will help SMEs with a CE-based business model to identify the capabilities they need to utilise the CE and digital resources to build a competitive advantage. The resources will not be enough unless explorative capabilities are developed. The technologies will be difficult to implement unless adequate attention is paid to adapt them to local conditions, by training the users and demonstrating blockchain's value to them, and by optimising the manufacturing process for 3D printing. For SMEs that have a CE-based business model but are not implementing digital technologies (e.g., Filamentive), only exploitation capabilities will be needed.

6. Conclusions

In this paper, we identified the CE and digital resources. We also identified the capabilities demonstrated by SMEs that have engaged in CE initiatives and that have adopted digital technologies such as 3DP and blockchain. Our analysis shows that the firms need to have exploitative, explorative, and adaptability capabilities to generate a competitive advantage. Future studies can validate our framework and propositions using large-scale empirical surveys.

The study has certain limitations as it is based on four case companies. At the same time, we must acknowledge that there may not be many SMEs with CE-based business models that have adopted 3DP or blockchain to generate a competitive advantage. Therefore, we believe our sample is very representative. Similarly, in this study, we have considered only 3DP and blockchain as the digital technologies adopted by SMEs. In future, there will be an opportunity to explore the capabilities SMEs will need in order to adopt other digital technologies, such as artificial intelligence or machine learning, or augmented and virtual realities to generate a competitive advantage from CE-based resources. The cases considered in this study are primarily engaged in recycling materials to provide value-added products and services, and therefore, they correspond to 'recycle' in the 3R Framework or 'looping' in the ReSOLVE framework (EMF, 2015). As more SMEs focus on adopting both CE-based business models and digital technologies, it will be worthwhile validating our proposition using a larger sample of cases covering the spectrum of Reduce, Reuse and Recycle. Similarly, longitudinal studies of the cases from inception to growth and maturity will help us analyse the relative role, balance, or simultaneous use of exploitation and exploration capabilities to generate value for customers, as it may be difficult for SMEs to achieve the above balance (Junni et al., 2013; Solis-Molina et al., 2018). It will also help to understand how SMEs that have a CE-based business model but have not adopted digital technologies develop different forms of exploitation and exploration capabilities in the long run. It is also important to note that the SMEs covered in our research developed a CE-based business model based on the existing resources and capabilities of the founding members that could be exploited. However, some other SMEs, which do not have a CE as the core foundation of their business, may have to develop explorative capabilities to adopt a CE. Therefore, future research should consider different types of SMEs and the sequence in which they adopt a CE and digital technologies.

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Appendix: Interview questions

1. What was your motivation to start your company? What did you do for needs assessment? How did you come up with the idea? When did you decide to start the company and why?
2. Who are your collaborators in the project and what are their roles? Were they involved in idea generation?
3. How are you practising circular economy at your company? Is it only related to sourcing? What about production, recycling of products and logistics?
4. Can you explain the process from collection and processing of raw materials to the finished product?
5. How did you ensure that the manufacturing process met the desired quality?
6. Can you tell us about the business model of your company and the value it provides to its customers? Who are your customers? What kind of response are you getting from your customers?
7. Does your company have any competitive advantage in the market? What is the source of that competitive advantage?
8. Why did you decide to use 3D printing/blockchain? What is the role of the technology in creating value? What is the role of the technology in creating competitive advantage?
9. What challenges did you face and how did you overcome those?

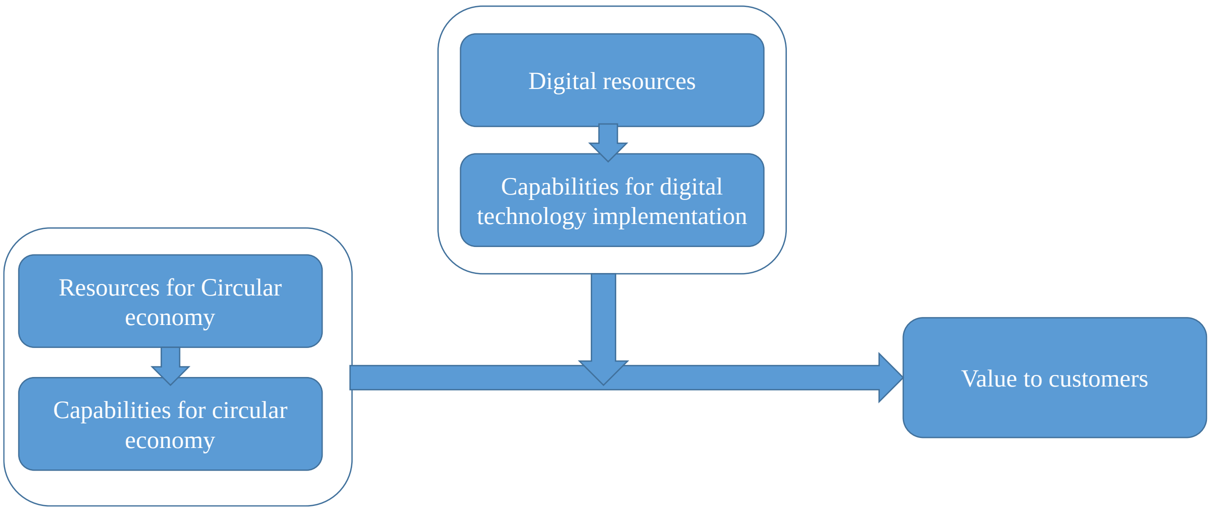

Figure 1: Conceptual research framework

Source: The authors

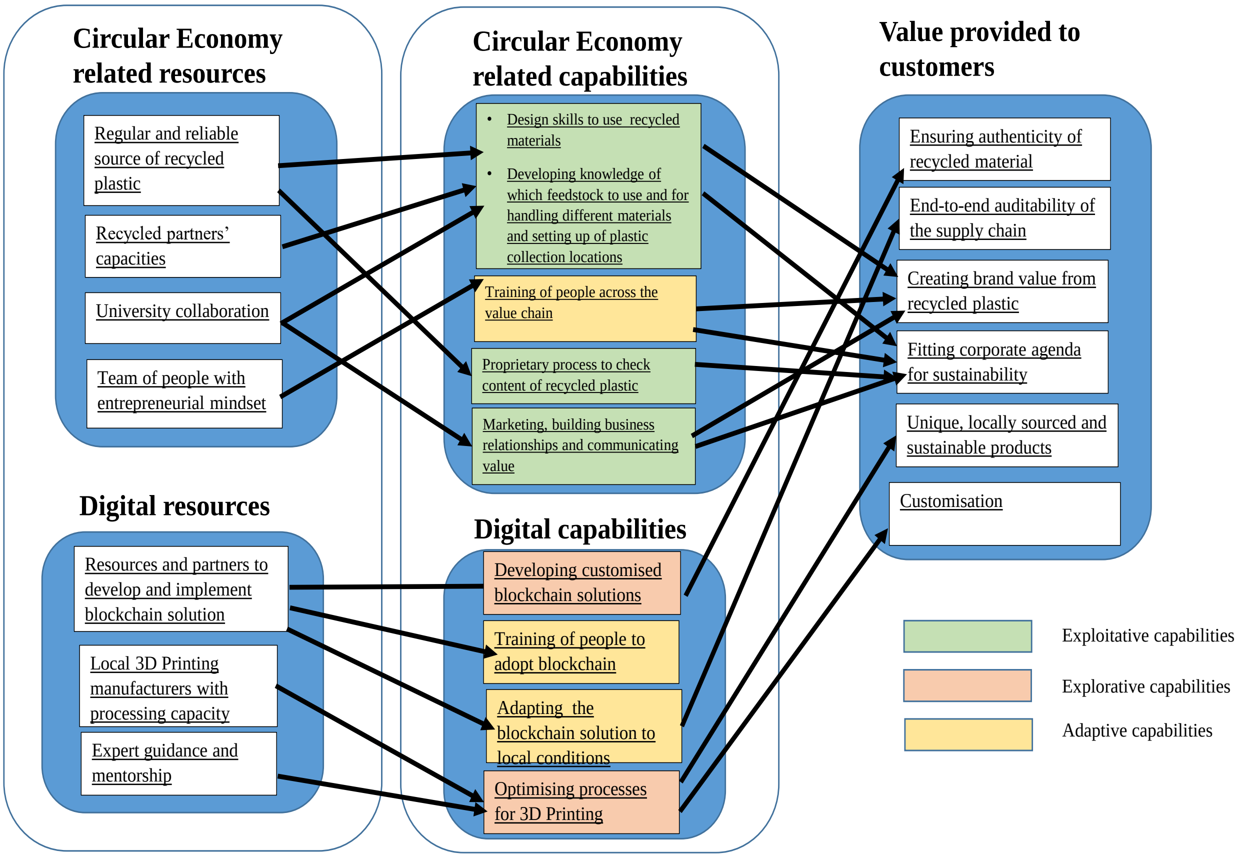

Figure 2: Relationship between resources, capabilities and value provided to customers

Source: the authors

Table 1: Details of the interviews conducted and data collected

Case	**Designation of the person(s) interviewed**	**Number of interviews (time taken in minutes)**	**Other data sources used**
Plastic Bank	Co-Founder and CTO	2(47, 29)	Company website, news articles, LinkedIn posts
Benthos Buttons	Founder, recycled materials supplier, customer	1(64), 1(45), 1(28)	Company website, a report shared by the company
Waste2Wear	Founder and CEO	2 (60,25)	Company website, videos from the company website, news articles, LinkedIn posts

Filamentive	Founder	2 (38,22)	Company website, videos about the company and its offerings

Source: The authors

Table 2: Analysis of resources and capabilities of Plastic Bank

Circular economy and digital resources and capabilities				
	Value	Rarity	Non-substitutability	Non-imitability
CE Resources- Regular supply of recycled plastic through waste collection centres and pickers	Low-Medium	Low	Low	Low
CE Resources- Team of people with an entrepreneurial mindset	High	Medium	Medium	Low
CE capabilities- Ability to set up plastic collection locations with processes for collection and payment	High	Medium	Medium	Low
Digital resources- Resources and partners to develop private blockchain and tokeniser reward system	High	Medium	High	Low
Digital capabilities- Developing customised blockchain enabled tokenised digital savings and wallet	High	Medium	High	Medium
Digital capabilities- Adapting the blockchain-enabled solution to local conditions	High	Medium	High	Medium

Source: The authors

Table 3: Analysis of resources and capabilities of Waste2Wear

Circular economy and digital resources and capabilities				
	Value	Rarity	Non-substitutability	Non-imitability
CE resource- Supply of recycled plastic	Low	Low	Low	Low
CE resource- Recycling partners' capacities	Medium	Low to Medium	Medium	Medium
CE resource- Collaboration with universities	High	Medium	Medium	Medium
CE capabilities- Developing knowledge of which feedstock to use	Medium	Medium	Medium	Medium
CE capabilities- Developing knowledge of handling different types of materials	High	Medium	Medium	Medium
CE capabilities- Developing a proprietary process to check the content of recycled plastic	High	High	Medium	High
Digital resource- Resources and partners to develop and implement blockchain solution	High	Medium	High	Low
Digital capabilities- Developing customised blockchain solution	High	Medium	High	Low
Digital capabilities- Training of users to adopt blockchain	High	High	High	Medium

Source: the authors

Table 4: Analysis of resources and capabilities of Benthos Buttons

Circular economy and digital resources and capabilities				
	Value	Rarity	Non-substitutability	Non-imitability
CE resource- Locally sourced recyclable (fishing net) material	High	Medium	Medium	Medium
CE capabilities- Design to use recycled materials	High	Medium	High	Medium
Digital resource- Local 3D printing manufacturers processing recycled fishing net	Medium	High	Medium	Medium
Resource- Guidance and mentorship to adopt technology	High	Medium	High	Medium
Digital capabilities- Optimising process for 3D Printing of buttons	High	High	High	Medium

Source: The authors

Table 5: Analysis of resources and capabilities of Filamentive

Circular economy resources and capabilities				
	Value	Rarity	Non-substitutability	Non-imitability
CE resource- Reliable source of recyclable plastic	Medium	Low	Medium	Low
CE resource- Effective distribution channels	Medium	Medium	Medium	Low
CE resource- Technical expertise and capacity of the service provider to convert the recycled material	Medium	Low	Medium	Low
CE capabilities- Marketing and building business relationships to promote the product made out of recycled material	High	Medium	High	Low

Source: The authors