Prospektiven

Neues zur zirkulären Wertschöpfung

Circular Economy News

2025 | 02_EN

Transformation towards Circular Economy in incumbent German firms

Evaluating the role of dynamic capabilities

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Reihe

Prospektiven – Neues zur zirkulären Wertschöpfung / Circular Economy News
Uwe Handmann, Wolfgang Irrek, (Hrsg.)
ISSN (Print) 2750-4840
ISSN (Online) 2750-4859
1. Auflage, 17.03.2025

Titelbild

www.pixabay.com, Photo by ELG21

Please cite as:
Mast, Julian and Wolfgang Irrek (2025): Transformation towards Circular Economy in incumbent firms. Evaluating the role of dynamic capabilities. Prospektiven – Circular Economy News 2025/02. Bottrop, Germany: Prosperkolleg e.V.

Impressum / Kontakt

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Projekt:

www.circular-performer.de

Gefördert durch:

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Abstract

Circular Economy (CE) can be seen as one of the key strategies for economies to become sustainable. By innovating business models and product design, CE shall result in the longevity of material flows and eventually improve economic resilience by reducing supply and price risks. However innovating products, processes and business models (PPBM) towards CE is still not well-established, especially in incumbent firms. The general orientation of firms towards innovation and, in particular, their dynamic capabilities might affect the degree of CE innovations they implement.

Therefore, the paper analyses the interconnectedness between firms' dynamic capabilities (DC) and their already implemented approaches of circular innovations regarding PPBM based on a survey with data of 391 raw materials processing firms in North Rhine-Westphalia/Germany. The data was collected in October 2022 by using standardised interviews with responsible firm members (e. g. head of production, innovation managers, environmental stewards). As the research topic is rather unexplored, the data were to be analysed by applying structural equation modelling, a method suitable for gaining exploratory insights from quantitative data.

In the analysis of the collected cases, the measurement constructs turned out not to be statistically reliable and valid. Therefore, the results represent noticeable trends that are not guaranteed to be statistically significant. The trends that are revealed by the study are that DC might have a positive effect on the implementation of circular innovations and that reconfiguring capabilities play a particularly important role for incumbent firms. Therefore, it seems to be particularly relevant for firms to address a transformation towards more CE by recombining internal resources and developing new ones to exploit these emerging opportunities. Another interesting research area for the future could therefore be how these reconfiguring capabilities could be built and expanded in firms with respect to CE implementation along the whole value chain.

1. Introduction

From an economic perspective, the negative effects of the currently prevailing economic system, the linear value creation, are increasingly noticeable, both socially-economically and privately as the resource availability and the ease of dispose of waste are no longer given. From a private sector perspective, firms are permanently dependent on raw material imports due to linear business models, which exposes them to constant supply risks or bottlenecks, as well as the risk of price volatility in the procurement of raw materials (Reike et al., 2018; European Environment Agency, 2016). From an ecological perspective, the planetary boundaries already described by the Club of Rome in the 1970s are being reached, environmental catastrophes such as the destruction of habitat or climate change are becoming increasingly visible (e. g. in the form of severe weather catastrophes or droughts) and are posing greater challenges to peoples and countries (Meadows et al., 1972). The volume of waste, especially in industrialized and developing countries, has been on a significantly high level (European Environment Agency, 2023). One of the main reasons for this is the currently prevailing way of doing business linearly. A characteristic feature of linear value creation is that it always starts with extracting primary resources from which the customer's desired product is manufactured. After the end of the benefit generation by the product, it is disposed as waste and the materials of the product leave the technosphere and thus the economic system (Ellen MacArthur Foundation, 2015; Heinrich, 2009). The constant material extraction and waste disposal efforts are directly related to environmental impacts.

Circular value creation is seen as a key strategy to prevent the creation of waste and negative environmental impacts from product extractions by making products last longer and keeping the materials needed for them in the cycle, i.e., by reusing them (Geissdoerfer et al., 2017; Kirchherr et al., 2017). Increased material residence time in the economic system and the recycling of materials at the end of product life cycles reduce primary material requirements and waste creation. Therefore, the development of circular products, processes and business models should be seen as an imperative to achieve a sustainable society and economic system (Bocken et al., 2021; Reike et al., 2018). Nevertheless, linear products and business models currently dominate economic systems for the most part, and only a few firms have been able to establish circular products or business models (Horbach and Rammer, 2020). In addition, most of the improvement measures undertaken are results of efficiency-enhancing measures and thus not circular-transformative in the true sense (Horbach and Rammer, 2020; Liu et al., 2021). A more detailed description of different types of circular innovations is provided during the next chapter. A comprehensive transformation of the economic system towards circular value creation is therefore as inevitable as it is challenging for private-sector firms due to the problems of linear value creation (European Commission, 2020; Geissdoerfer et al., 2018).

The increasing drive for circularity is one of the emerging trends of the recent past, which firms perceive in their direct or wider (political) environment (e. g. European Commission, 2020). This is noticeable on the one hand, for example, through a more important role of product sustainability among customers and suppliers, and on the other hand, through political regulations and action plans such as the Green Deal or the Circular Economy Action Plan of the EU (European Commission, 2019; European Commission, 2020). An important task for firms in the future will be to identify trends in their environment and to measure their potential impact on their operations. Due to the increasing importance of the topic of circular value creation in the corporate environment, the products, processes and business models of firms often must be changed or adapted (Bocken et al., 2016; Kirchherr et al., 2017). The development and implementation of circular products or business models is linked to the innovativeness of firms. Products must be developed based on a new logic (e. g., from recycled materials or in such a way that the materials can be recycled in the future). And therefore, the implementation of circular products or circular business models is an important transformational task within the recent future (Prieto-Sandoval et al., 2018; Geissdoerfer et al., 2017; Bocken et al., 2016). In terms of complexity, sustainable and especially circular business models extend conventional, linear models. First, the goal of sustainable and circular business models is to create positive long-term value for both, customers and the whole society by creating economical, ecological and societal benefits (Boldrini and Antheaume, 2021; Bocken et al., 2014). Second, to achieve sustainability by creating circular business models, firms need to take all stages of life cycle of products into account, such as distribution, use phase or end of life, and associated stakeholders such as retailers, recyclers and similar. In addition, it is urgent to consider that new business models must be supported by the customer. The introduction of innovative concepts such as sharing therefore strongly depends on customer acceptance (Lieder and Rashid, 2016; Lewandowski, 2016). As shown above, circular business models expand the components of business models compared to linear ones. Since the new components often lie outside the firm's own sphere of influence and competence, establishing circular business models requires close exchange and communication with external partners. Research shows that coordinated and collaborative processes across multiple organizations might be supportive to successfully develop and implement new innovations in uncertain and complex business environments, as these organizations possess the different resources and competences needed to develop and operate innovative business models (Antikainen and Valkokari, 2016; Santa-Maria et al., 2021; Köhler et al., 2021).

Hence, it is crucial for transforming firms to be able to internalize external knowledge from related entities as customers, suppliers or research institutes and translate this into new types of products, processes and business models (Aarika-Steenroos et al., 2021). Within this paper, we consider the dynamic capabilities according to Teece et al. (1997) as capabilities having a positive impact on the transformation to a circular economy and being important to implement it in firms with rapidly changing environments, as these skills enable the identification and utilization of new trends by leveraging external knowledge and resources (Teece et al., 1997; Teece, 2007; Borland et al., 2016). However, the transformation of incumbent firms to circular value creation is a rather unexplored and new area that has only received increasing attention in recent years (e. g. Kuhlmann et al., 2021; Santa-Maria et al., 2021). Khan et al. (2021) found evidence of the link between circular economy implementation and dynamic capabilities, but there is little further evidence in the existing literature, as transformation recently has started to become increasingly important from the political side.

The objective of this paper is to provide empirical evidence on the relationship between the existence of dynamic capabilities and the implementation of circular innovations. Two aspects will be highlighted. First, it will be shown that firms with dynamic capabilities have a higher implementation rate of circular innovations than firms that do not have these capabilities. Regarding the dynamic capabilities, it will also be shown that new PPBM, which are more than just efficiency-enhancing, can only be implemented if the implementing firm possesses certain dynamic capabilities. The remainder of this paper is therefore structured as follows: In chapter two, the underlying concepts of circular economy (CE) and dynamic capabilities (DC) and their previously studied interrelationship are presented. Based on the literature examined here, chapter two also elaborates the hypotheses for this paper. Chapter three discusses the methodological approach of the research approach and the research framework of the study. Chapter four addresses the results of the survey, and chapter five discusses the key messages and findings from chapter four. Finally, chapter six discusses the significance and limitations of the paper, as well as a recommendation for further research activity that should be considered desirable in this area.

2. Theoretical Background

As it is a promising concept to achieve the sustainability goals, CE must be established holistically in the economic system. Recently, more and more political initiatives have been launched for this purpose, but the implementation of CE in the firms' business activities is still rather low (Horbach and Rammer, 2020). The following chapter addresses the fundamentals of circular business model transformation and managerial measures which might support this transformation.

The concept of CE is not a brand-new concept but has been developed from antecedent concepts as the Industrial Ecology (e. g. Frosch and Gallopoulos, 1989) by political and societal trailblazer organizations as the Ellen MacArthur Foundation. As the political attention and the practical relevance rose recently, researching CE scientifically also experienced a rise. However, researchers define their concepts of CE differently. There are review articles that characterize similarities and differences of CE research. According to those, it is common understanding that CE stands in contrast to the linear approach and shall enable sustainability within the economic system (Korhonen et al., 2018; Kirchherr et al., 2017; Geissdoerfer et al., 2017). In terms of contributing to the triple bottom line of sustainability, CE reduces the demand for primary resources and therefore decreases the environmental impact of material extraction and product creation in terms of ecological contribution. From an economic view, future competitiveness is safeguarded as material values are preserved and resource dependence decreases (Bocken et al., 2021). Finally, considering social impacts of circular actions, keeping materials and products in the economic system might lead to an increase in recycling and remanufacturing businesses (Korhonen et al., 2018).

Within this paper, we follow the definition of Geissdoerfer et al. (2017) who state that firms and other organizations achieve circularity by slowing down, narrowing or completely closing their resource cycles and using the materials several times in order to operate their businesses. As CE is an alternative approach to the currently dominant model of linear economy, becoming circular requires the transformation of the current business operations by innovating them or developing new innovations (Reike et al., 2018; Zhu et al., 2010). Currently, the circular innovations have not been sufficiently introduced into businesses in the economic system (Ghiselli et al., 2016; Bocken and Geradts, 2020; Bocken et al., 2021). Therefore, there is an urgent need of capabilities for the firms which might lead to a higher development and implementation rate. Due to CE's novel character for incumbent firms within a complex and dynamic firm environment, identifying external circularity trends and developing new business models by utilizing external knowledge and resources might lead to more circular innovations (Borland et al., 2016; Köhler et al., 2022; Khan, 2020). Hence, the concept of DC might foster circular innovations (Bocken et al., 2021; Lewandowski, 2016). Especially, in dynamic and complex business environments (e. g. but not exclusively CE-transformation), there is huge potential of benefitting from knowledge and capabilities of external entities as suppliers, customers or other organizations (Bocken et al., 2021; Lee and Yoo, 2019; Snihur et al., 2018).

Benefitting from external knowledge, however, still requires maintaining internal capabilities, knowledge and expertise, as the external resources are complementary resources and need to be utilized by firm-own expertise and need to be integrated into the firm-own business models (Bogers et al., 2019). In order to be able to internalize external knowledge and resources within the firm, a firm needs to adapt its strategy and processes, which requires a suitable management and certain skills that enable the integration of external resources (Leih et al., 2015).

Theoretically, the DC represent the capabilities needed for a transformation towards CE (Teece et al., 1997). The DC were developed by Teece et al. (1997), who describe them as skills that are required to recognize and quickly adapt to changing conditions and to therefore to secure competitive advantage in complex and changing business environments. According to the author, the DC are constantly updating capabilities depending on the changing business environment that enable 'adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences to match the requirements of a changing environment' (Teece et al., 1997: 515). DC therefore are processes and activities through which a firm can adapt the own business strategy, resources or operations. DC consist of the 'capacity (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise's intangible and tangible assets' (Teece, 2007: 1319).

(1) Sensing capabilities shall secure to identify changes in the business environment regarding new opportunities or threats arising. Therefore, they can be described as scanning, learning an interpreting the environment.

(2) Seizing capabilities shall enable the implementation of the identified opportunities by mobilizing and combining complementary resources from internal and external sources.

(3) Reconfiguring capabilities shall iteratively adapt firms' structure, strategy, resources and processes to the changes in the business environment.

In terms of circular or sustainable transformation, the DC as enabler capabilities recently became a popular research object (Khan et al., 2020; Mousavi et al., 2018; Prieto-Sandoval et al., 2019). The DC view represents a theoretical ground of researching capabilities of firms to apply the identification, development and implementation of new and sustainable business models (Santa-Maria et al., 2021) and can therefore be seen as core competences of creating circular innovation (Khan et al., 2020). This leads to the first hypothesis, which will be tested in the following paper: (H1) Firms that possess DC have advantages in identifying CE-related trends and successfully implementing them into their business operations. Accordingly, possessing DCs has a positive effect on the implementation of circular innovations. In the further course, we investigate the impact of sensing capabilities (H1a), seizing capabilities (H1b) and reconfiguring capabilities (H1c) on implementing circular innovations.

In terms of developing circular innovations, researchers discuss on different strategies which contribute to one of the three certain types of circularity (slowing, closing, narrowing) according to Geissdoerfer et al. (2017). The exact specifications and quantities of the strategies, the so-called R-strategies, differ from study to study (Reike et al., 2018). Potting et al. (2017) shape one of the most popular approaches, the 9R framework. According to their rule of thumb, the degree of CE implementation is considered higher for strategies referring to closing and slowing down loops rather than narrowing. However, this is not a universally applicable rule and does not allow any conclusions to be drawn about the economic, ecological or social effects of the measure (cv. Blum, 2020). An increasing degree of circularity also seems to correlate with certain types of innovation (Bocken et al., 2021; Potting et al., 2017; Brix, 2019a). To this date, there is no consensus on what types of circular innovations are necessary to achieve CE. As circularity can be achieved by closing, slowing and narrowing resource flows, these strategies will affect the business models by modifying or adapting existing ones and holistically innovating new business models (Saebi, 2015). In our understanding, incremental innovations differ from disruptive innovations in the sense that they do not expand or significantly change the architecture of business models. Instead, individual components of it are modified or adapted slightly, as is the case with efficiency measures. In our understanding, radical innovations require a significant change in the business model architecture or a completely new innovations of business models. This also includes components such as the addition of reverse logistics mechanisms, new value captures through sharing models, and many more.

Some authors (e. g. Gusmerotti et al., 2019) see incremental innovations (e. g. efficiency improvements in products and processes) as one of the valid strategies for achieving more circularity. Incremental innovations might be gathered by exploiting the existing business architectures and products (Brix, 2020; Brix, 2019b). Exploiting existing architectures has the advantage of a rather low risk in implementation (Alexy et al., 2013). As there are antecedent products available, it is likely that the improved product will also be accepted on the market. In their study, Horbach and Rammer (2020) show that firms have predominantly implemented incremental circular innovations. However, some researchers assume incremental innovations as efficiency efforts might not be sufficient to achieve long-term sustainable competitiveness holistically in a dynamic world (Liu et al., 2021). Therefore, many authors (e. g. Bocken et al, 2016; Lüdeke-Freund et al., 2018; Brown et al., 2021) call for radical circular innovations which require to change the architecture of the current business operations and business models of a firm. Hence, there is need of reconfiguring organizational structure, strategy, operations, firm culture and even firm boundaries (Leih et al., 2015; Teece, 2010). Radical innovations are often associated with the introduction of a new logic of value creation by developing a completely new or very strong adaptation of the architecture of the business model, which needs to be explored and developed systemically in networks with external partners in most of the times, as firms do not possess all necessary competences and resources to develop radical circular innovations on their own (Brown et al., 2021). Along with the development and implementation of new business models, the acceptance risk on the market increases (Alexey et al., 2013) and hence firms often hesitate in starting research and development activities towards radical and circular innovations. For many researchers, radical innovations represent the core of the measures to achieve CE, while modifying or adapting existing business model architectures is only considered to be able to make a less substantial contribution to CE transformation and therefore not sufficient.

In our understanding, however, considering both, incremental and radical innovations as appropriate to achieve CE is not a contradiction per se and could be linked. Rather, the certain types of innovation contribute to different aspects of circularity. Incremental innovations mostly represent a progressive modification or adaptation of existing products or processes, for example in the form of an efficiency strategy. This contributes to the narrowing of material cycles according to Geissdoerfer et al. (2017) because, ceteris paribus, it reduces material consumption. To contribute to Geissdoerfer et al. 's (2017) other strategies, closing and slowing, it may be necessary to significantly change the structure of previous business models. This may involve e. g. the introduction of reverse-logistics, new strategic partners or adaption of product design on the one hand, and the method of value capture on the other (Bocken et al, 2014; Bocken et al., 2016, Lewandowski, 2016). One example might be a pay-per-service model instead of the usual sale of processes. In this case, novel business models or products need to be explored. These developments often belong to the consistency strategy. In the further procedure, we assign the introduction of new business models and significant redesigns of products or processes to the radical innovation type, while we assign smaller product or process improvements to the incremental innovation type.

(H2) This leads to the second hypothesis of the paper, which is divided into two parts and focuses on the type of implementation of circular innovations. First, the study aims to provide empirical evidence that radical circular innovations can only be implemented in those firms that possess DC. Second, firms that have introduced circular innovations but do not possess DC tend to implement circular innovations which were created by modifying or adapting existing business models.

In summary, we define incremental innovations as exploitations by adapting or modifying existing business or process architectures. However, this does not change the way in which value is created. Radical innovations represent the exploration of new business models or products. Accordingly, completely new business models are developed or existing business models are significantly changed. In terms of circular innovations, most often this affects the introduction of return logistics or new strategic partnerships through which a firm can continue to generate value after having given the products to the customers (e. g. through leasing models, maintenance or retrofitting). Accordingly, radical innovations are associated with new ways of creating and capturing value. In our view both, radical and incremental innovations are necessary for achieving a Circular Economy. DCs represent a bundle of capabilities to identify trends from the business environment and generate new business models by leveraging non-corporate resources and knowledge. These are particularly relevant for the CE transformation. For this reason, we propose the DC as having a positive influence on the CE transformation, which we will empirically investigate in the following.

3. Methodology

The empirical investigation of the relationship between the two concepts requires quantitative data collection and statistical analysis of the current situation in real companies. To achieve this goal, in co-operation with the market research organisation Kantar, standardised interviews with 391 firms were carried out using a multiple stratified random sample of the address provider Heins & Partner GmbH. Quantitative research methods were then applied to analyse the data collected (Rasch et al., 2008). The research was part of the Prosperkolleg project, which mainly includes an action research approach to the transformation of small and medium enterprises (SME) towards circular value creation in the state of North Rhine-Westphalia in Germany. Although structural change has already diminished the share of manufacturing firms in North Rhine-Westphalia, heterogeneous manufacturing firms, particularly supply industries delivering to OEM, still play an important role. Regarding the European Green Deal and expected regulations and market developments, these firms are going to be forced to transform their business base towards CE in the future. Since the Circular Economy primarily aims to narrow, slow down and close the resource flow of the economic system (Geissdoerfer et al., 2017) and the study focuses the transformation of incumbent firms, only those firms were considered relevant for the study that were already established on the market and (re)process or reuse materials or raw materials in some way, as those are considered particularly relevant for the implementation of CE. This corresponds to incumbent firms within the following sectors: manufacturing industry, energy supply, water supply and disposal of environmental pollution, construction industry, trade, car trade and repair, as well as traffic and warehousing (sections C to H according to the German statistical classification of economic activities WZ 2008 or NACE, Rev. 2). Micro firms with a very low number on employees were excluded from the survey. The reason for this is that small establishments in terms of employees are not expected to possess enough capacity to develop DC or to actively take care of DC or CE aspects. Therefore, the surveyed firms in the study were expected to have a minimum size of ten employees. In order to measure the recent progress of the firms in the area of CE transformation and the current influence of DC on this transformation, the questions were designed for the progress that could be achieved within the past three years. The attributes and characteristics of the survey framework are summarized in Tab 1.

Tab. 1: Scope of the study

Decision criteria	Characteristics
Type of firm	Related to processing of raw materials
firm size	At least ten employees
Research subject	Circular innovations within the last three years
firm boundaries	State of North Rhine-Westphalia

By using standardized questionnaires, the interlinkages between DC and CE can be quantified and statistically analyzed. However, conducting quantitative statistical research requires the use of existing and tested scales that represent the concepts under study (Rasch, 2008). Accordingly, it is necessary to identify scales that make the CE and DC representable as quantified variables. The research of measuring CE with well-fitting indicators receives increasing attention. Due to the high complexity of CE, there are many different indicators covering CE issues partly. However, there is no generally usable indicator for the impacts of CE yet. Life Cycle Assessment (LCA) is well-fitting in terms of the impacts, however it cannot cover all aspects of circularity (e. g. Elia et al., 2017; Sassanelli et al., 2019). With regards to the quantitative character of our study in this paper, we consider LCA as a not suitable method as its indicators do not seem to make different firms comparable in terms of CE implementation (for the sake of comparability of different LCA and the impact indicators, see DIN ISO EN 14040ff). Therefore, we consider existing quantitative studies as the sources of already existing and tested scales that map the implementation of CE. As this research topic has been quite recently started, there are just a few studies available yet. To the best of our knowledge, these are the following: Horbach and Rammer (2020), Schmidt et al. (2021) and Khan et al. (2021) who themselves build on Zhu et al. (2010). The studies measure CE issues differently.

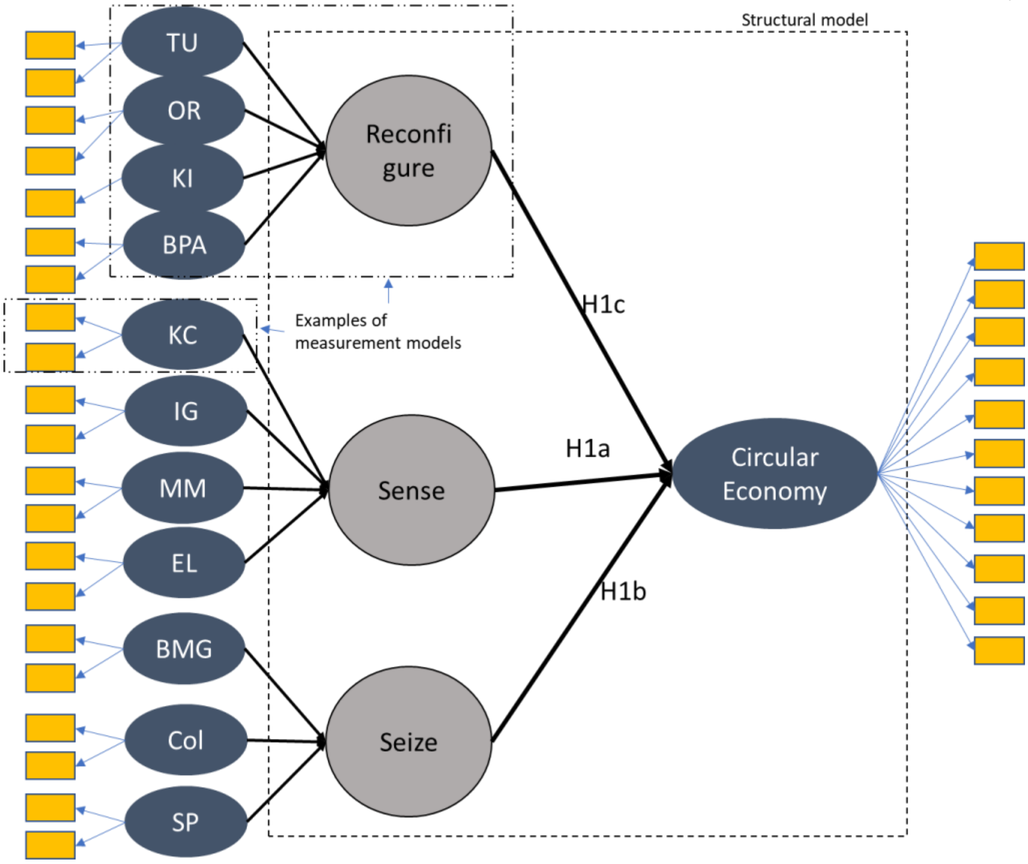

Fig. 1 Relationship of Dynamic Capabilities and Circular Economy

Horbach and Rammer (2020) use data measuring the CE-related progress of firms' products and processes (e. g. in terms of material savings). They gather their data from CIS datasets originated from German industries. Within their study, Schmidt et al. (2021) measure the implementation of CE within the operational practice of firms by assessing their environmental management, their corporate asset management and the eco-design of their products. Lastly, Khan et al. (2021) used slightly modified measures that were introduced by Zhu et al. (2010). The items are closely linked to the R-strategies introduced in the previous chapter and do represent different strategies to implement CE within the own firm. By assessing the different strategies pursued, the items enable an assessment of the degree of circularity according to Potting et al.'s rule of thumb (2017). Considering the goals of the study, the latter concept of measuring CE seems to be the most promising measurement approach in terms of differentiating between different strategies of pursuing circularity. Therefore, we use this approach to characterize different degrees of implemented circularity within our study to measure CE aspects. The first-order construct for CE and its ten subitems can be seen in Tab. 3.

The second concept represents DC according to Teece (1997). There are few studies that apply different indicator sets to measure DC. These are, e. g., Lee and Yoo (2019), Santa-Maria et al. (2021) and again Khan et al. (2021). Due to the qualitative character of Santa-Maria et al. (2021), we are not going to take their indicator sets into further consideration to be used within this quantitative study. Both other mentioned studies apply their developed indicator sets quantitatively. By comparing them closer, we find material similarities of both indicator sets, as both sets indicate the three types of DC, which are sensing ability, seizing ability and reconfiguring ability (Lee and Yoo, 2019; Khan et al., 2021). Due to their similarity and fitness to the nature of our study, we conclude them both as applicable and decided to use the indicator set of Khan et al. (2021) in our study to ensure a better degree of comparability. The second-order constructs for sensing abilities and reconfiguring abilities consist of four first-order constructs each, the one for seizing abilities consists of three first-order constructs. The certain first-order constructs consist of several sub-items themselves. Tab. 2 provides the exact content of the indicators/items that were used to measure the constructs in the survey.

In order to explore interrelationships between different constructs, literature (as e. g. Sarstedt et al., 2017; Hair et al., 2012) recommends using structural equation modelling which can be divided into partial least squares structural equation modelling (PLS-SEM) and covariance-based structural equation modelling. In terms of exploratory studies, the first mentioned alternative is considered to be more appropriate (Hair et al., 2011). Therefore, we apply PLS-SEM as our statistical method for the further findings. Fig. 1 shows the structural equation model examined. It illustrates the first-order and second-order constructs that represent CE and DC. It also shows the structural model and examples of measurement models, as well as the hypotheses 1a-c.

Tab. 2: Constructs of the Dynamic Capabilities

2nd-order Construct	1st-order Construct	Abbr.	Non-Resp.	Indicator
Sensing	Market Monitoring and Technology Scanning	MM1	2%	Identification of customer needs
		MM2	2%	Tracking new market trends
		MM3	1%	Analyzing competitors' actions
		MM4	1%	Observing technological developments
	Idea Generation	IG1	0%	Organizing internal brainstorming sessions
		IG2	1%	Involving suppliers and customers in the product development process
	Knowledge Creation	KC1	4%	Undertaking R&D activities to discover essential knowledge for developing new products
		KC2	1%	Undertaking R&D activities to increase the stock of knowledge /trying out new strategies)
	Experiential Learning	EL1	1%	Using LCA to assess potential environmental impacts of products
		EL2	1%	Networking with public organizations, industrial associations or universities, considered with each organization on their own
Seizing	Strategic Planning	SP1	0%	Formulation of a strategy
		SP2	1%	Finding strategic partners
		SP3	0%	Planning investments

		SP4	0%	Capital budgeting
		SP5	0%	Planning requisite human resources
	Business Model and Governance	BMG1	2%	Redesigning / transforming business models
		BMG2	2%	Restructuring of governance structure
	Collaboration	Col1	2%	Collaboration to acquire requisite knowledge / skills – considered with different partners
		Col2	1-3%	Collaboration to acquire requisite raw materials / resources considered with different partners
		Col3	2%	Interdepartmental cooperation
Reconfiguring	Organizational Restructuring	OR1	3%	Merger with or acquisition of another organization
		OR2	1%	Changed organizational structure
	Technological Upgradation	TU1	5%	Made slight modifications in existing technology / machinery
		TU2	12%	Introduced new or significantly improved technology
		TU3	1%	Acquisition of a new manufacturing plant
	Knowledge Integration	KI1	1%	Organized training to employees
		KI2	1%	Acquisition of existing know-how
	Best Practice Adaptation	BPA1	2%	Adopted new business practices for organizing procedures
		BPA2	2%	Adopted new methods of organizing external relations
		BPA3	4%	Adopted new or significantly improved logistics

Tab. 3: Construct of Circular Economy Implementation

Original description	Abbr.	CE Type	Survey item descriptions	*Non-Response 1	**Non-Response 2
/	CE1	high	Product sharing	20%	10%
Providing repairing / refurbishing services to customers	CE2	high	Service and maintenance	12%	4%
	CE3	high	Service and maintenance via external partners	13%	4%
	CE15	high	Availability of repair and retrofitting options	46%	24%
Recycling own production waste	CE4	high	Use of materials after product life	26%	5%
Utilizing biodegradable / recyclable packaging	CE5	high	degradable ingredients	37%	18%
	CE6	low	Alternative packaging	41%	23%

Using closed-loops in the production	CE7	low	Reprocessing own scrap	19%	2%
	CE17	low	Percentage of reprocessing	73%	65%
Reusing bi-products from other organizations	CE8	low	Reprocessing external scrap	18%	3%
Transferring / selling bi products to other firms	CE9	low	Selling of scrap	18%	4%
Increasing material and energy efficiency	CE10	low	Reduction of the use of materials	12%	11%
	CE11	low	Reduction of the use of energy	31%	11%
/	CE12	high	Extending life cycles of products	35%	12%
Designing products to be easily repaired and refurbished	CE13	high	Dismantlability of products	58%	40%
/	CE14	high	Retrofitting of products	52%	32%
Collecting end-of life products	CE16	high	Establishment of a recirculation concept	25%	6%
/	CE17	high	Share of reused materials	70%	67%

*Non-response 1: sample of 391; **Non-response 2: sample of 250

4. Findings

The first step of the analysis is the review and descriptive analysis of the survey results. The indicators for both, exogenous and endogenous variables were gathered by the same survey, which was drawn anonymously. The items surveyed to determine the constructs were based on those of the previous studies, but slightly adapted in consultation with interview experts. Due to the expected difficulties of accurate assessment, parts of the items that were originally ordinally scaled as Likert scales were changed into binary items. Since these depict whether a characteristic is fulfilled or not, they can nevertheless be described as ordinally scaled, since their distinction can be attributed more than just a nominal character. In the further course of the evaluation, the different scales of the items within individual constructs lead to the necessity to Z-transform the items in order to be compatible for the calculation of the structural equation model. Additionally, the quantity of indicators rose to increase the level of detail. For example, this concerns the items on Seize_col and Sens_EL, in which collaboration with individual stakeholders is surveyed, and the items on CE, which detail, for example, the extent to which resource and energy savings have been made, or whether internal or external resource circles have been closed.

The processing of the data sets and the calculation and evaluation of the PLS-SEM was realized using the softwares SPSS, Excel and Smart PLS 4. In this context, the higher-order constructs were modelled by applying the disjoint two-step approach. As an alternative to the disjoint approach, another approach is the embedded two-stage approach. Nevertheless, current research indicates that the choice of the modelling approach has no (significant) influence on the results of the calculations (Sarstedt et al., 2019). The first-order constructs were calculated and subsequently, their factor loadings were presented as item values that formatively built the second-order constructs. In case of data gaps, the calculations were performed with mean replacement and the generation of the results was based on 5000 subsamples by bootstrapping algorithm.

In the course of the data analysis, it is noticeable that the data sets are basically complete. However, within the survey, options were also frequently selected by firms that refused to make a statement or selected the question as not applicable. This affects the respective concepts of DC and CE very differently. The items relating to DC have a response rate of at least 95% of all surveys (exception: Reconf_TU2: 88%). These therefore correspond very well to the objectives of a quantitative evaluation. Considering the CE items, however, the situation is very different. Here, the rate of non-applicable answers was generally significantly higher than for the DC items. In addition, the response rate of the items differed very significantly among themselves. The rate of non-applicability ranged from 12% (optimal case) to 73% (worst case). The rate of non-applicability in the manufacturing industry is the lowest one. In a pretest with 20 firms, there were no noticeable problems regarding the high non-response rate for the CE indicators.

Tab. 4: Industry sector of the firms before and after excluding cases (from 391 cases to 250 cases)

Industry sector	Quantity original sample	Percentage original sample		Quantity adapted sample	Percentage adapted sample	Percentage excluded
manufacturing industry	117	29,9%		102	40,8%	12,8%
energy supply	12	3,1%		9	3,6%	25%
water supply disposal of environmental pollution	38	9,7%		14	5,6%	63,1%
construction industry	62	15,9%		46	18,4%	25,8%
trade, car trade and repair	72	18,4%		43	17,2%	40,2%
Traffic and warehousing	67	17,1%		26	10,4%	61,2%
others	23	5,9%		10	4,0%	56,5%

Additionally, some firms decided to consider their business operations to not be applicable to any of the CE-items. This ultimately led to the fact that we excluded cases from our sample which showed too low applicability regarding the CE items. We excluded all cases that indicated that the items were not applicable in more than one third of all CE cases. This reduced the sample by 141 cases to 250 cases. The questionnaire also contained a control question asking whether the concept of CE was known to the firm or the respective representative. Combined with the consideration of cases based on the response to the CE items, this results in an interesting constellation. Tab. 5 shows that a remarkably large number of firms that are familiar with CE can answer the questions, while firms that are unfamiliar with the concept have greater problems answering the questions. The two industries most likely to answer the CE items, manufacturing and energy and water supply, show only a slight increase familiarity with CE compared to other industries. However, this is by no means as significant as the response rates for the CE items have been. From this, we conclude that these industries have CE-relevant decisions in their business activities, even without explicit awareness of them.

Tab. 5: Awareness of CE and applicability of CE-items

		Are you familiar with the concept of CE?		
		yes	no	total
Reply on CE-items	sufficient	111	139	250
	insufficient	48	92	140

	total	159	231	390*

*one response was missing in the survey

Validating the measurement model

Conducting a PLS-SEM requires multiple stages of investigation when complex measurement and representation constructs have to be used in the course of modelling. As described earlier, DC cannot be represented by stand-alone items but require the creation of second-order and first-order constructs that represent the three core abilities (Sense, Seize, Reconfigure) and their subdimensions needed for measurement. Similarly, the representation of CE requires a first-order construct with multiple items. Accordingly, a statistical evaluation of the measurement constructs with respect to validity and reliability is required before the structural relationships to each other are examined and evaluated with respect to the established research hypotheses.

Firstly, we examine the measurement model for validity and reliability of the first-order constructs (reflective type) and the second-order constructs (formative type). In this context, a distinction must be made between the test criteria of reflective and formative constructs. Due to the reflective-formative nature of the measurement construct of DC, both test procedures are relevant. However, the order-level of the construct does not influence the testing criteria. For example, validating a first-order reflective concept is to be examined equally to validating a second-order reflective concept. In our case, all reflective constructs are first-order constructs, the second-order constructs are formative. Tab. 6 and Tab. 7 represent the decision criteria for both, reflective measurement models and formative measurement models to assess the quality of each model.

Validating first-order constructs (reflective constructs): Dynamic Capabilities

Hair et al. (2019) summarize the four test criteria for reflective measurement constructs: These are (1) indicator reliability, (2) internal consistency, (3) convergent validity and (4) discriminant validity. Tab. 6 shows the decision criteria and the characteristics necessary for the measurement model to be suitable for representing the subject under investigation. Accordingly, to consider the reliability of indicators, their loadings need to be 0,7 or higher for each item (Hair et al., 2011). In case the factor loading value ranges between 0,4 and 0,7 it still is considered acceptable if the AVE exceeds 0,5 at the same time (Hair et al., 2012).

Tab. 6: Validating reflective measurement constructs according to Hair et al. (2019)

Decision criteria	measurement	Least acceptable measurement value	According to
indicator reliability	Indicator loadings	>0,7 or	Hair et al., 2011
		0,4<x<0,7 & AVE >0,5	Hair et al., 2012
internal consistency	Cronbach's alpha	>0,708	Hair et al., 2011
	Composite reliability	>0,7	Hair et al., 2019
convergent validity	Average variance extracted (AVE)	>0,5	Hair et al., 2011
discriminant validity	Fornell-Larcker criterion	$\sqrt{AVE} > Correlation\ with\ other\ constructs$	Fornell-Larcker et al., 1981
	Heterotrait-Monotrait Ratio of Correlations	<0,9	Henseler et al., 2015

Considering the items of the DC constructs, Tab. 8 shows that three item values fall below the lower threshold (value less than 0,4). These are Seize_Col2b, Seize_SP2 and Seize_SP4. It is also noticeable that many other item values are within the critical range between 0,4 and 0,7 and require special critical observation. For the constructs Sense_MM, Seize_Col, and Reconf_BPA, corresponding items with a value of less than 0,7 would therefore have to be removed. This would affect the following items: BPA2, BPA3 (Reconf_BPA), Col1b-Col3 (Seize_Col) and MM1, MM2, MM4 (Sense_MM). However, there is a conflict with construct theory on this - Hair et al. (2012) describe that constructs are formed when the phenomenon under study cannot be represented by individual measurements and recommend that constructs should be formed from at least three to four items ideally. However, removing the items meant that the constructs would be represented by single items. To avoid this and since the values are mostly close to the lower threshold of 0,7, we decided to remove only the indicators already mentioned whose value is below 0,4 and to keep all other indicators and consider them as reliable for construct representation.

In terms of internal consistency of the construct, there are three different measures that slightly differ from each other. These are Cronbach's α, and the composite reliability factors ρa and ρc. The acceptable values to demonstrate internal consistency of the construct are >0.708 in the case of Cronbach's α and >0.7 for composite reliability (Hair et al., 2011). For Hair et al. (2019), composite reliability seems to be the most appropriate to assess internal consistency.

The results in Tab. 8 show that the internal consistencies of the constructs are only partially given and differ significantly depending on the chosen measurement methods. Regarding the second-order construct Reconfigure, the first-order constructs BPA and OR show insufficient values for all three measurement methods. The first-order constructs KI and TU show sufficiently good values for ρc, while the ρa and Cronbach's α values are also insufficient. The Seizing construct is slightly different in this respect. The subconstructs all show sufficiently consistent values according to ρa and ρc. Only the value of Cronbach's α is insufficient for BMG and Col. The α value for SP is sufficiently high according after removing the non-reliable indicators. In terms of the Sensing construct, all subconstructs show an adequate ρc value. While the first-order construct EL also shows acceptable α and ρa values, these are insufficient for the first-order constructs IG, KC, and MM.

To sufficiently satisfy convergent validity, the first-order constructs must exceed a value of AVE =0,5 according to Hair et al. (2011). After removing the unreliable indicators, the values of the first-order constructs Reconf_BPA, Seize_Col, and Sense_MM remain insufficient. All other constructs' values meet the minimum requirements and surpass the minimum threshold.The evaluation of discriminant validity can be tested by two methods. First, this can be determined by the Fornell-Larcker criterion, and second, by the Heterotrait-Monotrait Ratio of Correlations. The second method has recently been considered as more appropriate (Henseler et al., 2015). Acceptable values should be below 0,9. Tab. 9 shows that especially the construct Reconf_BPA is unsuitable to fulfill the criteria for discriminant validity, because e.g., the relational values of Reconf_BPA to Reconf_OR, Reconf_TU, Seize_BMG, Seize_Col and Sense_IG range above 1.

Validating second-order constructs (formative constructs)

The second-order constructs Sense, Seize and Reconfigure result from the previously formed first-order constructs and are illustrated in Tab. 8. Before examining the relationship between DC and CE, it is necessary to check whether the first-order constructs are suitable to represent the second-order constructs in a formative way. The quality criteria of the modelling are shown in Tab. 7. The evaluation of the criteria is shown in Tab. 11. Since the evaluated construct is a formative second-order construct, a redundancy analysis is not necessary. This is due to the multidimensional character of the construct and the fact that the construct is built content-wise from theory.

Tab. 7: Validating reflective measurement constructs according to Hair et al. (2019)

criteria	measurement	Least acceptable measurement value	According to
Convergent validity	Redundancy analysis	Correlation of a formatively measured construct with a single item >0,7	Chin (1998)

Indicator collinearity	Variance inflation factor (VIF)	VIF<3,0	Becker et al. (2015)
Statistical significance	p-value	p<0,05	Hair (2019)
Relevance of indicator weights	Loading factor	Larger significant weights are more relevant Loadings >0,5 and significant p-value	Hair (2019)

Tab. 8:Evaluating the first-order constructs of the Dynamic Capabilities

Constructs		Internal Consistency			Conv.Validity	Indicator Reliability	
2nd-Order	1st-Order	α	ρ_a	ρ_c	AVE	Item	Loading
Reconfigure	BPA	0,381	0,377	0,699	0,438	BPA1	**0,741**
						BPA2	**0,590**
						BPA3	**0,645**
	KI	0,514	0,520	0,804	0,672	KI1	0,846
						KI2	0,793
	OR	0,259	0,410	0,692	0,555	OR1	0,470
						OR2	0,943
	TU	0,503	0,537	0,749	0,504	TU1	0,808
						TU2	0,562
						TU3	0,736
Seize	BMG	0,381	0,799	0,711	0,579	BMG1	0,470
						BMG2	0,968
	Col	0,660 → 0,697*	0,715 → 0,715*	0,762 → 0,796*	0,343 → 0,399*	Col1a	0,717
						Col1b	0,603
						Col1c	0,671
						Col2a	0,445
						Col2b**	0,076
						Col2c	0,663
						Col3	0,654
	SP	0,616 → 0,860*	0,839 → 0,874*	0,761 → 0,916*	0,483 → 0,784*	SP1	0,921
						SP2**	0,353
						SP3	0,901
						SP4**	-0,087
						SP5	0,795
Sense	EL	0,753	0,761	0,835	0,504	EL1	0,630
						EL2a	0,783
						EL2b	0,687

						EL2c	0,708
						EL2d	0,734
	IG	0,425	0,520	0,762	0,622	IG1	0,908
						IG2	0,648
	KC	0,699	0,700	0,869	0,769	KC1	0,873
						KC2	0,880
	MM	0,644	0,667	0,787	0,482	MM1	0,596
						MM2	0,694
						MM3	0,791
						MM4	0,683

*values after item removal; ** removed Items

Considering the second-order construct of Reconfigure, the constructs BPA and TU show high loading values and significances, while KI and OR show low loading values and insignificances. For the second-order construct of Seizing, Col and SP seem to be of significant character and show high loading values while BMG seems to be less significant and has a lower loading value. In terms of Sensing, EL and MM show high loading values and are significant. IG and KC seem to be less significant and have lower loading factors compared to the previously mentioned constructs.

Validating first-order constructs (reflective constructs): Circular Economy

The first-order construct CE is tested for its quality in the same way as the first-order constructs of the DC. The results are shown in Tab. 10. In the context of the measurement of indicator reliability, it is noticeable that a large number of indicators fall below the critical threshold value of 0,4. These are CE_1, CE_2, CE_3, CE_9, CE_13, CE_14, CE_15 and CE_17. All other values are in the range between 0,4 and 0,7. Since the AVE is also below 0,5, in theory no indicator is statistically suitable for reliably representing CE. At the same time, this low AVE value means that convergent validity is not ensured for the first-order construct of CE.

Tab. 9: Evaluating discriminant validity according to the HTMT criterion

			Reconfigure				Seize			Sense			
		CE	BPA	KI	OR	TU	BMG	Col	SP	EL	IG	KC	MM
	CE												
Recon-figure	BPA	1,03											
	KI	0,40	0,83										
	OR	0,69	1,26	0,84									
	TU	0,83	1,26	0,65	0,95								
Seize	BMG	0,50	1,09	0,49	0,85	0,47							
	Col	0,68	1,05	0,66	0,78	0,88	0,57						
	SP	0,58	0,67	0,43	0,47	0,55	0,30	0,49					

Sense	EL	0,65	0,84	0,72	0,86	0,76	0,47	0,92	0,52				
	IG	0,61	1,01	0,67	0,94	1,08	0,41	0,92	0,45	0,70			
	KC	0,59	0,83	0,35	0,49	0,76	0,22	0,75	0,34	0,52	1,32		
	MM	0,67	0,84	0,71	0,74	0,70	0,47	0,82	0,40	0,82	0,80	0,71	

With regard to internal consistency, the ρc value turns out to be sufficient while Cronbach's α and ρa are insufficiently high, after removing the indicators whose factor loadings appeared to be under the minimum threshold. Due to the relation between CE and Reconf_BPA which exceeds the critical value of 0,9, considering the concept as discriminant valid is not possible.

Tab. 10: Evaluating the construct of CE

Construct	Internal Consistency			Convergent Validity		Indicator Reliability
1st-Order-Construct	α	ρ_a	ρ_c	AVE	Item	Factor Loading
Circular Economy	0,613 → 0,629*	0,635 → 0,645*	0,680 → 0,742*	0,141 → 0,233*	CE_1	0,037**
					CE_2	0,110**
					CE_3	0,137**
					CE_4	0,506
					CE_5	0,406
					CE_6	0,434
					CE_7	0,536
					CE_8	0,375
					CE_9	0,169**
					CE_10	0,590
					CE_11	0,648
					CE_12	0,498
					CE_13	**0,249****
					CE_14	0,213**
					CE_15	0,148**
					CE_16	**0,459**
					CE_17	**0,111****

*values after item removal; ** removed Items

Tab. 11: Outer Weights, T-values and p-values of the formative second-order models

SOC	FOC	Outer Weight	T-Statistics (OW)	p-value (OW)	Outer Loading		VIF
Re	BPA	0,625	6,396	0,000	0,906		1,484

	KI	-0,087	0,83	0,377	0,308		1,209
	OR	0,159	1,572	0,116	0,520		1,210
	TU	0,465	4,266	0,000	0,814		1,548
Seize	BMG	0,186	1,586	0,113	0,451		1,110
	Col	0,524	5,133	0,000	0,769		1,185
	SP	0,628	7,129	0,000	0,817		1,107
Sense	EL	0,436	3,651	0,000	0,786		1,341
	IG	0,148	1,171	0,242	0,569		1,383
	KC	0,189	1,413	0,158	0,597		1,426
	MM	0,527	4,427	0,000	0,873		1,523

Evaluating results according to the structural model

Due to the lack of validity and reliability of the measurement models, the results should be seen as trends and are not sufficient to generate statistically valid statements. The results and the discussion based on them must be conducted accordingly, considering uncertainties. The structural model assessed the impact of possessing DC on the implementation rate of CE. As the DC in our model consist of three subdimensions, H1 was threefold. Therefore, Tab. 12 presents the effect of Sensing, Seizing and Reconfiguring on CE implementation. The effect of Reconfiguring on CE was positive and significant (factor value=0,379, p=0.000, t=5,570). Seizing impact on CE was slightly smaller but still positive and significant (factor value=0,200, p=0.005, t=2,805) and Sensing impact on CE was positive and significant with a confidence interval of 95%, too (factor value=0,147, p=0.042, t=2,037). Hence, all the three parts of hypothesis 1 can be supported according to the structural model.

Tab. 12: Conclusions on H1

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Hypothesis
Reconfigure -> CE	0,379	0,385	0,068	5,570	0,000	supported
Seize -> CE	0,200	0,201	0,071	2,805	0,005	supported
Sense -> CE	0,147	0,164	0,072	2,037	0,042	supported

In terms of testing H2, we divided all cases into two subsamples, which in turn were used as the basis of the bootstrapping. The decision criterion for dividing the sample was whether a certain firm implemented incremental or radical innovations within the last years according to the differentiation of incremental and radical as explained in the theoretical background. As Tab. 13 shows, the created subsamples for incremental and radical innovations are of similar size as most of the cases combine incremental and radical innovations. The table shows that the implementation rate of radical innovations in the firms in the sample was less high than that of incremental innovations. In addition, large firms in particular (250 employees or more) seem to be able to show higher implementation rates of innovations. The differences between the various categorizations of SMEs are only marginal.

Tab. 13: Types of CE innovation implemented according to the firm size (number of employees)

			Firm size				
			1-9	10-49	50-249	>249	missing
radical	new business model	yes	6 (26%)	19 (21%)	17 (19%)	14 (33%)	4

		no	17 (74%)	71 (79%)	74 (81%)	28 (67%)	
	new products or substantial improvement	yes	11 (50%)	44 (49%)	66(72%)	29(67%)	4
		no	11 (50%)	45 (51%)	26(28%)	14 (33%)	
incremental	product improvement	yes	11 (50%)	37 (41%)	52 (56%)	38(88%)	2
		no	11 (50%)	53 (59%)	41 (44%)	5 (12%)	
	process improvement	yes	12 (57%)	44 (51%)	70 (78%)	39(91%)	9
		no	9 (43%)	43(49%)	20 (22%)	4 (9%)	

Tab. 14 represents the results of the subsampled and bootstrapped model, which was also used for testing H1. The effect of Reconfiguring on CE was positive and significant for both radical and incremental innovations (factor $value_{incr}$=0,264, p=0,003, t=2,984 & factor $value_{rad}$=0,357, p=0,000, t=4,498). However, the greater influence of Reconfiguring capabilities on radical innovations appears to be considerably larger because the difference of the loading factor is +0,093. Considering Sensing and Seizing capabilities, H2 does not prove true. The effect of Seizing on CE was positive and significant for both radical and incremental innovations (factor $value_{incr}$=0,242, p=0,006, t=2,730 & factor $value_{rad}$=0,186, p=0,036, t=2,101). Therefore, the influence of Seizing capabilities on radical innovations appears to be even smaller than on incremental innovations because the difference of the loading factor is -0,056. The same is to be considered with Sensing capabilities. The effect of Sensing on CE was positive and significant for both radical and incremental innovations (factor $value_{incr}$=0,226, p=0,007, t=2,695 & factor $value_{rad}$=0,197, p=0,024, t=2,252). Therefore, the influence of Sensing capabilities on radical innovations appears to be even smaller than on incremental innovations because the difference of the loading factor is -0,029.

Tab. 14: Conclusions on H2 by subsampling radical and incremental innovations

incremental	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P value s	Difference Rad. – incr.
Reconfigure -> CE	0,264	0,279	0,089	2,984	0,003	
Seize -> CE	0,242	0,242	0,089	2,73	0,006	
Sense -> CE	0,226	0,246	0,084	2,695	0,007	
radical						
Reconfigure -> CE	0,357	0,37	0,079	4,498	0,000	+0,093
Seize -> CE	0,186	0,19	0,089	2,101	0,036	-0,056
Sense -> CE	0,197	0,221	0,087	2,252	0,024	-0,029

5. Discussion

Originally, the study was conducted with the goal of providing empirical support for existing studies and demonstrating the benefit that the existence of DC brings to the implementation of CE. In addition, we also planned to scientifically contribute by distinguishing between the impact of DC on the implementation of incremental and radical innovations. However, it became apparent that the measurement models and constructs used did not have the statistical quality to make statistically sound statements. Therefore, the central focus of the discussion is on the reasons why the measurement models did not meet the requirements in terms of validity and reliability. For this purpose, the scope of the study, the meaningfulness of the modelling and the goodness of fit of the construct as a function of firm size need to be discussed.

Firstly, we evaluate the results regarding the scope set in this study. In retrospect, further specification of the scope of the study would have been beneficial. The sample shows that large parts of the firms are not very suitable to participate in an assessment of CE (high rate of "does not apply" in the questionnaire for the CE items). This results in the sometimes very low implementation of the sample participants for certain CE items (e. g. product sharing: 13% implement, 10% not applicable, 77% not applicable), which makes a statistical evaluation difficult. It is noteworthy that especially the manufacturing sector was able to give answers regarding the CE indicators sufficiently often. Hence, they were probably confronted with this issue more often in reality. Another difference to existing studies was that we basically surveyed SME to provide a representative overview of the economic region of NRW. From a statistical point of view, it might be advantageous to restrict the survey to larger firms. From a scientific point of view, we will return to this point in the discussion of the CE construct. Furthermore, CE-interested firms were better able to respond to the CE-related questions than those that have not yet dealt with the topic in detail. We therefore consider setting a very restrictive scope of the study as an essential task to generate statistically meaningful data in terms of valid and reliable constructs.

Next, we assume that there might have been a significant influence of our operationalisation of the survey on the results of the study. In contrast to previously conducted studies, we collected our data by telephone interview instead of (online) survey questionnaires. The advantage of this method is the provision of a minimum number of cases. However, this method also required changes in the questionnaire to make it understandable for telephone respondents. This may not have been conducive to statistical analysis but was done on the initiative and with the advice of experienced experts in the field of telephone interviewing and was pretested. Within the pretest, there were no negative anomalies found (ca. 5% of the total sample size). However, in the final study, some items which were very significant in a previous study even do not play a significant role at all in our survey (e. g. Sense_SP4). The main changes made were as follows: First, some questions were split into several questions for easier comprehension; this led to an increase in indicators. This mainly affected the set of CE items, but also, for example, the items of Seize_Col. Another important aspect was the establishment of many binary response options instead of Likert scales, since the underlying idea was that this would be easier for respondents to answer ad hoc. Changing the response alternatives however might have an influence of the statistical significance of the construct according to MacCallum et al. (2002). In our view, increasing the number of items, as well as decreasing the variance of the responses, might have had an impact on the results of the study. In addition, the formulation of some questions in the interview questionnaire needs to be investigated for further similar studies.

In addition, the meaningfulness and the goodness of fit of the application of the CE construct has to be discussed, as well as the statistical quality of considering it a reflective latent variable. This means that the variable explains the values of the items and that these should therefore show a relatively high correlation. In the studies already conducted, validity and reliability of the reflective construct were always given (e. g. Khan et al., 2021; Schmidt et al., 2021). However, the previous studies were collected in samples with larger firms. In our view, the different CE items are very heterogeneous as they explain different ways of achieving CE. Therefore, we attribute the already proven goodness of the construct to the firm size. We assume that especially large firms with an interest in CE implementation often do not only implement one strategy only but can implement several of the strategies within their large product portfolio and business activities. In contrast, smaller firms are more likely to (be able to) implement only individual strategies. In our view, the high correlation of the various items is therefore more of a pseudo-correlation that can be attributed to firm size. This impression is reinforced by taking a closer look at tab. 13, which shows that large firms, have a higher implementation of both radical and incremental innovations. Moreover, the implementation rates are at such a scale that the simultaneous implementations of different strategies are substantiated.

The R-strategies according to Potting et al. (2017) can be divided, for example, according to the three metastrategies of Geissdoerfer et al. (2017), which have completely different levels of impact within the product life cycle (cf. Heinrich, 2009). For example, the metastrategy "close" is most likely to deal with the strategies to maintain materials at the end of their life cycle, while "narrow" deals with the strategies in the context of product production and "slow" essentially has an impact on products while their use phase. In our view, this again underlines the heterogeneity and versatility of the items for CE. Due to the great heterogeneity and multidimensionality, it is at least worth considering whether the CE construct is not rather a formative type instead of being of reflective nature.

Another important issue in the discussion about the CE indicator is the question of whether it makes sense to rate different implementation strategies as “high” or “low”. In the literature, the different strategies are understood as heuristics of CE implementation (Potting et al., 2017; Kirchherr et al., 2017, Reike et al., 2018) according to which higher-grade CE strategies have a more positive effect on sustainability implementation as a rule of thumb. In contrast, Blum (2020) emphasizes that the success of strategies must be assessed in a case-by-case evaluation. The scenario could also arise that a firm with the implementation of one individual “low” strategy (according to the rule of thumb of Potting et al., 2017) makes a more significant contribution to environmental impact than firms that implement multiple “high” strategies and would therefore achieve a higher construct value. This also speaks for no perfect suitability of the construct in terms of achieving the goals of CE. Underlying this is the logic that CE is not implemented for its own sake, but to achieve the goals stated in the introduction (e. g., more sustainable products, reduction of supply risk, independence from resource prices, etc.). We therefore tend to recommend using other indicators that are closer to the impacts of CE implementation. However, in the case of quantitative studies, these must also be able to be mapped. For example, the use of LCAs as such seems difficult (cv. Elia et al, 2017), but maybe some rough indicators could be found to be suitable. This will certainly require further research. Moreover, higher-grade CE strategies do not necessarily require a higher effort regarding the degree of innovation needed. A key feature of DC according to Teece (2007) is the leveraging of external knowledge and resources to develop new business models. Thus, the external business environment is both, a major influence on the acceptance of newly developed or enhanced PPBM and a major source of knowledge and resources that a company can and should leverage to reduce its own development effort and increase potential user acceptance.

A final point to be discussed is the consideration of innovations implemented in the last three years. This excluded ideas that are currently being developed and strategies that have been established for a longer period of time and that make a significant contribution to achieving the goals of the CE or have the potential to do so.

From the point of view of managers, therefore, firms should not try to implement the highest-quality circular strategies possible according to the circularity rule of thumb for their own sake. Instead, in our view and adopting the argumentation of Saebi (2015), the decision of transformation should be weighed on a case-by-case basis which strategy is best suited for the firm to implement its sustainability goals. This decision should also take into account parameters such as the existing business model, the corporate environment, the firm's capabilities and the expected effects with regard to sustainability aspects.

6. Conclusion and Outlook

This study presented was planned to provide quantitative empirical support for the relationship between DC and CE. However, during assessing the study, it became apparent that the measurement constructs used, especially the one used to represent CE, may only be suitable for very specific survey frames to provide valid and reliable results on the implementation of circular strategies. Therefore, our recommendation would be to conduct such a survey, if required, with a modified scope and modified indicators or constructs to represent CE in order to obtain statistically robust results. In terms of adapting the scope of the study, we suggest to consider exclusively manufacturing firms with at least 50 employees that have an underlying interest on CE as these firms seem to be affected most by the urge of implementing CE and possessing DC. In terms of the measurement model, the CE construct we used in this study turned out not to be entirely useful. Therefore, there is the need for a resilient construct measuring CE. Additionally, we suggest querying a second and additional, independent construct which represents the impacts of implementing CE within a firm. This might affect resource availability, economic improvements and similar performance indicators.

Nevertheless, the study also indicates a trend. Although not completely supported statistically, it seems that all three types of DC are beneficial for implementing CE. Reconfiguring capabilities stand out. Therefore, it seems to be particularly relevant for firms to address a transformation towards more CE by recombining internal resources and developing new ones to exploit these emerging opportunities. Another interesting research area for the future could therefore be how these reconfiguring capabilities could be built and expanded in firms with respect to CE implementation along the whole value chain.

7. Acknowledgements

The research results were presented at the 30th IPDM conference in Lecco, Italy in 2023. This paper has been produced as part of the Prosperkolleg project, for which financial support by the Ministry of Economy, Industry, Climate Protection and Energy of the State of North Rhine-Westphalia, Germany, has been gratefully received. Moreover, the authors would like to warmly thank Miriam Gensicke and Nikolai Tschersich and their team of Kantar for their suggestions to improve the survey and particularly for having drawn the random sample from addresses provided by Heins & Partner GmbH and having carried out the data collection in the firms.

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