Aalto University
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THE ORDER OF CIRCULAR BUSINESS MODELS

An Empirical Taxonomy Using Cluster Analysis

Master's Thesis
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Abstract of master's thesis

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Abstract

In the wake of increasing demands for raw materials and the changing climate, the circular economy concept has recently gained traction in academia, business and policy making. A central constituent in order realize it, i.e. to shift to a system in which environmental impact is decoupled from economic growth by circulating products, components and materials at their highest economic and resource value at all times, is the design and implementation of circular business models. Hence, over the last years, academics and practitioners alike have created tools and frameworks that support firms in coming up with new or more effective models. Further, emulating the evolution of general business model literature, researchers have started to propose circular business model definitions and classifications in order to consolidate the existing work and establish common ground. However, a clear understanding of what a circular business model really constitutes is still missing and a careful review of the existing literature reveals that the proposed classifications are either lacking methodological transparency or being purely conceptually derived. Consequently, from a positivistic stance, there is no basis for wider generalization and mid-range theory development.

To address this gap, the thesis at hand constructs a conceptually grounded and empirically derived circular business model taxonomy. Following existing approaches to taxonomy development and building upon an extensive literature review as well as empirical data, it first creates an integrative framework on which basis circular business models can be described. In the process of its development, also a binary-coded matrix expressing the defining business model characteristics of 100 randomly selected firms is generated. This data is subsequently analyzed using hierarchical and non-hierarchical cluster analysis techniques. The final cluster solution reveals a set of seven major circular business model types which are further characterized on the basis of descriptive statistics and representative case examples. Split-sampling and the application of different cluster algorithms indicate that the solution is stable and a silhouette coefficient of 0.53 strengthens its internal validity. Finally, a comparison with existing classifications demonstrates the taxonomy's usefulness.

While not generating a definitive answer, the proposed circular business model taxonomy provides a novel perspective to the question of what types of circular business models exist and how they can be characterized. It offers a stepping stone for mid-range theory development and in combination with the review of 116 circular business model publications gives a comprehensive overview of the phenomena's current manifestations. From a practical viewpoint, the thesis' findings provide useful insights into the structure of circular business models thereby serving as a source of inspiration for the development of new models or as a tool for the strategic positioning of existing ones.

Keywords circular business models, circular economy, review, taxonomy, classification

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1. Introduction

In the following opening sections, the thesis at hand introduces the issue under study and specifies the identified research gap. Further, it lays out the research objectives and provides an overview of how the research question will be addressed. To explain some of the thesis' underlying motivations, the chapter starts off by describing the context it is embedded in.

1.1 Background

According to the Global Footprint Network (2018), 1.7 Earths are currently required to sustain humanity's lifestyle. Following a business-as-usual trajectory, WWF International's director general Jim Leape assumes that this situation will further worsen resulting in the exceedance of the environment's regenerative and assimilative capacity by the factor of three in 2050 (United Press International, 2012). In the long-term, a state less conducive to human development with profound and probably irreversible implications for everyday life could be the consequence (Steffen et al., 2004). However, that Earth does not provide unlimited resource reservoirs humankind can mine indefinitely at accelerating speed is itself not a new realization (e.g. Boulding, 1966) and over the last decades various ideas and research fields such as *Performance Economy* (Stahel, 2010) and *Industrial Ecology* (Frosch & Gallopoulos, 1989) have been formed to counteract the outlined development. Aiming at decoupling economic prosperity from environmental pressure, a concept that has lately gained increasing attention is *Circular Economy.* Influenced by a range of related schools of thought, ideas and research fields—including the two mentioned ones—it is studied and promoted by organizations such as the Ellen MacArthur Foundation, policy makers (see Law Info China, 2008; European Commission, 2015), practitioners (e.g. Lacy & Rutqvist, 2015; Kiørboe et al., 2015) and academia (e.g. Reike et al., 2018; Blomsma & Brennan, 2017). While definitions still vary, Geissdoerfer et al. (2017, 762) attempt to crystalize the terminology by defining the Circular Economy as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling."

As indicated above, the concept's central idea is that the circulation of materials aligns environmental benefits with a strong business case, or how Lacy & Rutqvist (2015, xxi) put it: "What company wouldn't want to reduce its dependence on increasingly scarce and costly natural resources while generating revenue from wasted opportunities?" From this perspective, it is not surprising that a recent Ellen MacArthur Foundation (2017) report regards the Circular Economy as a 320 billion Euro investment opportunity, up to 2025 and within Europe alone. Still, seizing the opportunity appears to be less straightforward. In a review, Ghisellini et al. (2016) conclude that in spite of economic potential highlighting consultancy reports as well as rising numbers of academic publications, the concept's worldwide practical implementation is still limited. Indeed, its key ideas were rarely mentioned in S&P 500 corporations' official communications between 2005 and 2014 (Bocken et al., 2017a) and also in forerunner countries recycling strategies dominate over potentially more effective ones such as reuse and remanufacturing (Reike et al., 2018).

Against this backdrop, it is argued that a central constituent in order to realize a stronger shift to a more circular economy, is the design and implementation of circular business models (e.g. Bocken et al., 2016; De Angelis, 2018; Antikainen & Valkokari, 2016; Linder & Williander, 2017; Lacy & Rutqvist, 2015; Ellen MacArthur Foundation, 2013). Put differently, "a CE [Circular Economy] understanding lacking business models is one with no driver at the steering wheel" (Kirchherr et al., 2017, 228). While early literature on circular business models has been mainly provided through practitioner-oriented contributions (Lüdeke-Freund et al., 2018a), scientific databases show that academic research on circular business models is growing rapidly. For instance, as of December 2018, Scopus listed 80 unique contributions on the terms "circular business model" and "circular economy business model" with 19 of them having been published in 2017 and 54 stemming from 2018. Emulating the evolution of business model literature in general (see Osterwalder et al., 2005), some of these publications concern the development of circular business model definitions and classifications. While Lambert (2015) points out that classifications are an essential part of business model research that help to organize a phenomena's existing manifestations and hence provide a foundation for the accumulation of knowledge, Whalen (2017, 418) observes that "the methodological approaches utilized to create such circular business model categorizations are not transparent within existing literature."

1.2 Research Gap

Whalen's (2017) observation is shared by Lüdeke-Freund et al. (2018a) and Urbinati et al. (2017). In order to address the need for more transparent categorizations that consolidate the existing work on circular business models and enhance the understanding of the research area, the authors develop new and more rigorous classifications. However, following

Lambert (2015), classifications are not all the same and can roughly be divided into typologies and taxonomies. While the former is understood to be derived deductively and to provide a foundation for limited generalization, taxonomies are derived empirically and can serve as a basis for wider generalization (Lambert, 2015). Furthermore, the author emphasizes the frequent misuse of the term *taxonomy* since carrying out taxonomic activity also refers to the construction of classifications in general. An illustrative example provides the study by Urbinati et al. (2017). Their "taxonomy" of circular business models is rather a theoretical typology as an empirical sample of organizations is only used in order to validate conceptually derived categories (see Rich, 1992; Warriner, 1984). While the classification provided by Lüdeke-Freund et al. (2018a) can also be viewed as a theoretical typology, other existing classifications often rather take the form of traditional typologies—according to Warriner (1984) these are classifications that do not use explicit criteria to derive the categories. A careful literature review shows that this is particularly the case for practitioner-based classifications which despite being partly based on empirical samples often fail to disclose their respective methodological approaches (e.g. Kiørboe et al., 2015; Lacy & Rutqvist, 2015). Against this backdrop and given the earlier outlined observation by Whalen (2017) as well as Groth & Nielsen's (2015, 17) notion that business model taxonomies, in general, are "still relatively new ground", the thesis at hand confidently assumes that a taxonomy of circular business models, along the lines of Lambert (2015), has not been developed yet.

However, for several reasons, the construction of such a taxonomy would provide value to Circular Economy research in general and circular business model literature more specifically. First, Baden-Fuller & Morgan (2010) argue that different approaches to classifying business models have the power to reveal new aspects about how different business models work, and in doing so enhance the understanding of the research area. Secondly, as already pointed out above, taxonomy studies are relevant because their more general form of classification provides a foundation for mid-range theory building (Lambert, 2015). For example, such mid-range theories could then answer why some types of business models are performing better than others. Thirdly, taxonomies can be used by companies to position themselves and, especially in connection with mid-range theories, to develop new and better-performing business models (Baden-Fuller & Morgan, 2010).

Finally, it is not only that constructing an empirically derived taxonomy of circular business models addresses a research gap that is worth filling, but it also appears that it is a suitable point in time to develop such a taxonomy. On the one hand, recent studies by Hartmann et al. (2016) as well as Täuscher & Laudien (2018) have shown that business model taxonomies that are derived through the application of inductive methods and statistical tools are useful for enhancing the understanding of specific business model categories, thereby providing proven methodological approaches and techniques. On the other hand, the highlighted typology studies (Lüdeke-Freund et al., 2018a; Urbinati et al., 2017) as well as publications related to circular business model representations (e.g. Lewandowski, 2016; Nußholz, 2017a; Hofmann et al., 2017) build a theoretical foundation that according to Groth & Nielsen (2015) is necessary in order to derive the variables used in taxonomy studies. Consequently, a taxonomy could complement the presented typology studies in addressing the need for consolidating existing work on circular business models.

1.3 Research Objectives and Research Question

Seen in a broader context, the thesis at hand is embedded into Circular Economy literature, particularly addressing calls for a stronger emphasis on circular business model research (e.g. Lieder & Rashid, 2016; Bocken et al., 2017b, Kirchherr et al., 2017). More specifically, it complements existing circular business model typology studies by developing a conceptually grounded and empirically derived circular business model taxonomy. While not generating a definitive answer, this taxonomy presents a novel approach to identifying circular business model types, their defining characteristics and distinctive configurations, and seeks to contribute to a more unified and better understanding of the research area. From an academic point of view, the thesis provides a stepping stone for other researchers to build upon and to develop mid-range theory. From a practical perspective, the thesis provides useful insights into the structure of circular business models and supports companies in positioning existing ones. Additionally, it can serve as an inspiration for the creation of new or more circular business models which appears to be of particular relevance as the practical implementation of the Circular Economy is still limited (Ghisellini et al., 2016; Reike et al., 2018; Bocken et al., 2017a).

Based on the above, the thesis' research question can be summarized as follows: *What types of circular business models exist and how can they be characterized?*

To address this question, the thesis broadly follows Lambert's (2015) approach to business model taxonomy development and adopts core elements from other business model taxonomy studies (Hartmann et al., 2016; Remane et al., 2016; Täuscher & Laudien, 2018) for its research design—these include principles of morphological analysis as well as different cluster analysis techniques. Thereby, circular business models are interpreted as *attributes of real firms* and the firm itself is employed as the main unit of analysis (see Massa et al., 2017). As a lack of methodological transparency and rigorousness in many of the existing circular business model classifications has been outlined before (see Whalen, 2017), the thesis puts special emphasis on the documentation of the research process. Part of this process is an extensive review of existing circular business model literature with regards to circular business model definitions and frameworks. Being based on 116 unique publications identified via Scopus, Web of Science, ProQuest as well as Google Scholar and grounded in general business model and Circular Economy literature, this review in itself provides further theoretical contributions to the research area as it gives a comprehensive overview of the phenomena's current manifestations. All in all, along the lines of Kirchherr et al. (2017), the thesis at hand attempts to draw a comprehensive picture of the driver that recent research has been put in the driver's seat of the Circular Economy.

1.4 Thesis Structure

As shown in figure 1, the thesis consists of five chapters. First, following this introduction, a literature review is conducted. This review is divided into two main parts and aims at positioning the thesis in the existing body of knowledge as well as building the theoretical backbone that is later used in combination with empirical data to identify variables on which basis circular business models can be described. Due to the topic's relative novelty the literature review thereby considers not only peer-reviewed journal articles but also relevant and reliable contributions from book chapters, conference and working papers as well as research reports (see Kirchherr et al., 2017; Geissdoerfer et al., 2017). In the first part of the literature review, the Circular Economy concept is introduced commencing with a sketch of its evolution and contemporary understanding. Next, considering different viewpoints on Circular Economy principles and definitions, the thesis clarifies its own interpretation and provides a synthesized definition of the concept. In the second part of the literature review, the thesis at hand takes a closer look at circular business models by drawing on 116 unique publications identified via Scopus, Web of Science, ProQuest as well as Google Scholar. Based on the finding that circular business models are predominantly seen as a sub-category of business models (e.g. Antikainen & Valkokari, 2016; Mentink, 2014; Linder & Williander, 2017), the chapter first discusses traditional business model literature with a focus on different interpretations and definitions. Subsequently, this review is used to analyze existing circular business model perspectives. Building on this analysis as well as the thesis' Circular Economy understanding, a synthesized circular business model definition is presented and positioned within literature. Lastly, to conclude the second part, different circular business model frameworks and classifications are reviewed.

The third chapter introduces the research design which is guided by the six decision steps Lambert (2015) proposes to support the development of business model classification schemes. Embedded into these steps is the selection of a specific procedure that generates the taxonomy. Following existing business model taxonomy studies (Hartmann et al., 2016; Remane et al., 2016; Täuscher & Laudien, 2018), this procedure is divided into two sequential phases: the creation of a morphological box-like framework on which basis circular business models can be described—hereinafter referred to as *variable space*—and the analysis of circular business model observations with different clustering techniques. In a first step, the former thereby draws on the constructed theoretical backbone consisting of the thesis' circular business model definition and existing circular business model frameworks. In a second step, a random sample of 100 circular business models is then iteratively evaluated against the developing variable space resulting in a refined, more comprehensive set of variables—this set is discussed in the fourth chapter—as well as a binary-coded matrix that describes the sample of circular businesses models. Subsequently, in the second phase of the introduced procedure, this data is analyzed using hierarchical and non-hierarchical clustering techniques. Like the variable space, the final cluster solution is described and discussed in the fourth chapter by, among others, interpreting its technical centroids as well as comparing it to the circular business model classifications identified in the literature review. In turn, the methodological choices that led to this final outcome are documented extensively in the third chapter including limiting factors as well as measures used to assess the taxonomy's overall validity.

Finally, the fifth chapter summarizes the main research findings providing answers to the research question. Additionally, the chapter elaborates on the thesis' theoretical contributions and managerial implications. Reflecting on its limitations, the thesis concludes by presenting suggestions for further research.

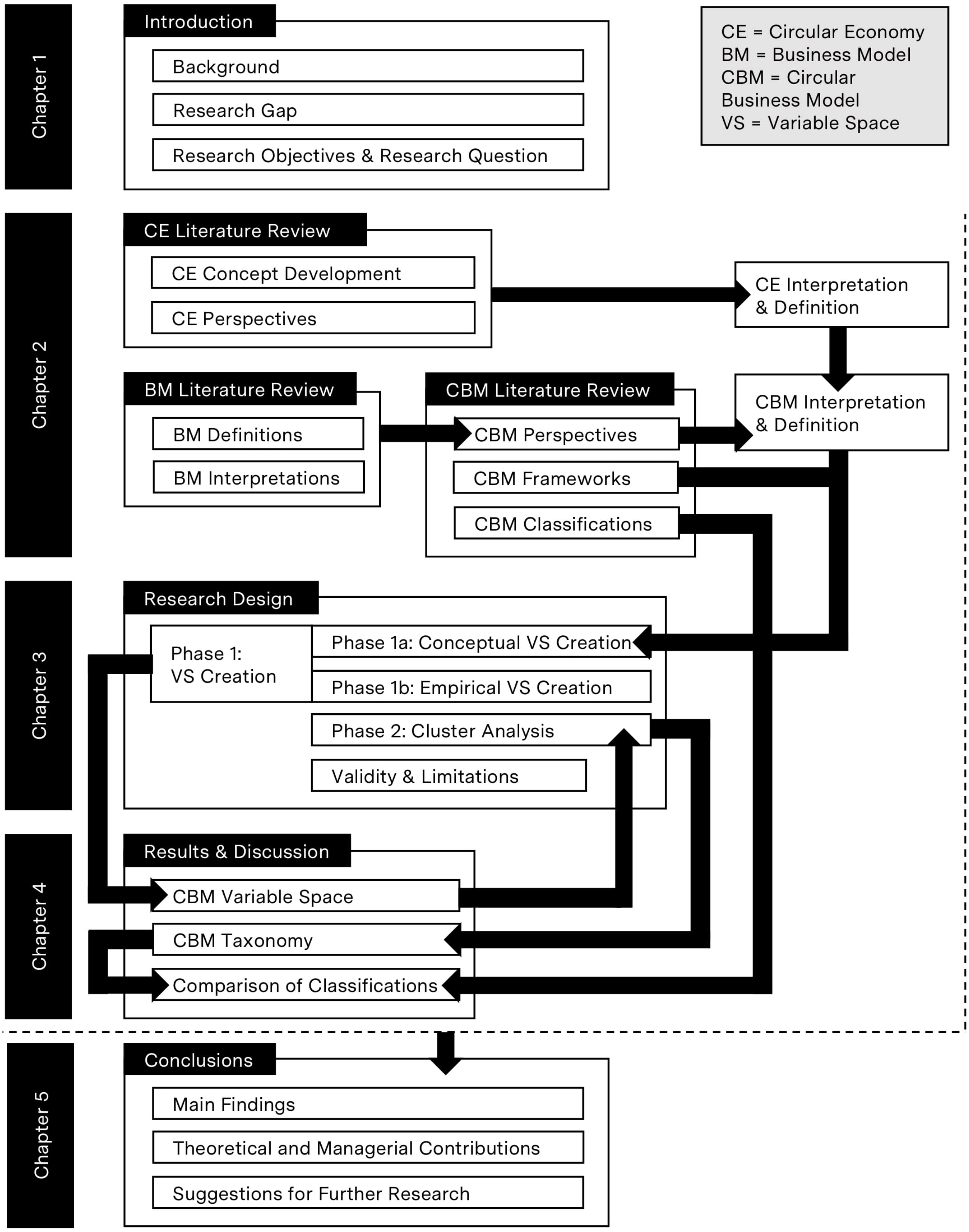


Figure 1. Thesis Structure.

2. Literature Review

As stated in the introduction, the following literature review is divided into two parts. Based on review articles and central practitioner publications—a more extensive review would be out of the thesis' scope—the first part presents a broad overview of the circular economy concept, related principles and definitions. Within this context, the second part then focuses on circular business models. Screening 116 circular business model related publications and building upon traditional business model research, existing circular business model definitions, frameworks and classifications are identified and analyzed. Throughout the literature review, the thesis thereby clarifies its own understanding and interpretation of key concepts and creates the theoretical backbone for taxonomy development.

2.1 Review of Circular Economy Literature

Recent reviews (e.g. Ghisselini et al., 2016; Lieder & Rashid, 2016; Blomsma & Brennan, 2017) and special issues in the Journal of Industrial Ecology (2017) and Journal of Cleaner Production (2018) describe Circular Economy as an emerging topic that has grown remarkably over the last years. In fact, a Web of Science search by Geissdoerfer et al. (2017) finds that the number of publications on Circular Economy increased by the factor of ten between 2006 and 2016 reaching more than 100 annual publications. This growth has most likely been supported by the introduction of China's *Circular Economy Promotion Law* (Law Info China, 2008) as well as the European Commission's (2015) *Circular Economy Package*. Furthermore, the topic has also drawn attention from the business world illustrated by a range of publications from leading consulting firms (Kirchherr et al., 2017). However, despite the relatively recent popularity of the Circular Economy, it itself is not new. On the contrary, fundamental ideas can even be traced back to time before the Industrial Revolution and the research community acknowledges the concept's deep roots in other concepts, schools of thought and research fields (e.g. Geissdoerfer et al., 2017; Ghisellini et al., 2016; Lieder & Rashid, 2016; Reike et al. 2018). Hence, in the first part of this chapter, a high-level overview of the concept's main development phases will be given, and its contemporary understanding and related academic discussions sketched. Subsequently, by referring to existing Circular Economy definitions and principles the variety of current viewpoints is described, concluding with the illustration of this thesis' perspective.

2.1.1 Development of the Circular Economy Concept

In their review, Lieder & Rashid (2016) argue that the closing of material loops has been common practice throughout long stretches of humankind's history. Referring to Strasser (2000), the authors outline that before the Industrial Revolution, waste was essentially unknown as craftsmen and consumers were aware of used objects' material value and naturally repaired, repurposed and recycled them. Also, larger scale circular business models—with Rolls Royce's 1962s *Power-by-the-hour* being one of the most commonly known (Ellen MacArthur Foundation, 2016)—existed before the actual term was coined by Pearce & Turner (1990) in their seminal textbook *Economics of Natural Resources and the Environment* (Ghisellini et al., 2016; Lieder & Rashid, 2016; Su et al., 2013, Blomsma & Brennan, 2017).

In the textbook's second chapter, Pearce & Turner (1990) give a high-level overview of the interactions between the economy and the environment and their implications. Building on Boulding (1966), the authors argue that both are inevitably intertwined given the First and Second Law of Thermodynamics. A major part of the resources required to produce consumer goods—whose consumption generates utility or welfare—stems from the natural environment. However, through the different stages of the product lifecycle waste arises from these goods. As according to the First Law of Thermodynamics neither energy nor matter can be destroyed or created, this waste has to be equal to the resource input and eventually ends up in the environment, again. Due to its regenerative and assimilative capacity, the natural environment can take in and convert part of the waste back into useful resources over time, closing the loop. However, the environment's regenerative and assimilative capacity is limited and can be impaired by extracting and harvesting resources too quickly. If this happens, not only the environment's third economic function—aesthetic enjoyment—is negatively impacted but also the flow of renewable resource inputs back into the economy. To reduce the amount of waste the environment has to take up in a given time and support the economy's circularity, Pearce & Turner (1990) introduce recycling as a way to convert waste back into valuable input resources.

While the focus on recycling as the main approach to create additional material loops is characteristic for what Reike et al. (2018) describe as the first phase of Circular Economy development—according to the authors, this phase dates from 1970 until the 1990s—Pearce & Turner's (1990) systems view is seen as a key element of the second one which spans the years from the early 1990s until 2010. In addition, according to Reike et al. (2018), this second phase is dominated by the view that environmental challenges provide economic opportunities and a focus on the prevention of waste through efficiency gains during the design phase instead of waste management. Consequently, eco-effectiveness through an absolute reduction of resource inputs and waste outputs only plays a minor role during this period. Finally, the third phase starts around 2010 with a focus on value retention maximization. While, as in the second phase, "the idea of resource input reduction and creating loops for reuse stands central" (Reike et al., 2018, 249), the concept is developed further. New is the connection to closed-loop supply chain and reverse logistics literature, highlighting the feasibility of closing loops over wider geographical distances. Additionally, the focus shifts from a mere analysis of resource flows to a more holistic view including business models, products' and materials' intrinsic value and organizational aspects. However, the authors conclude that conceptual clarity is still lacking. In their view, scholars are especially divided concerning the need for *absolute resource input reduction, modification to the economic order* and *a balance among sustainability dimensions*.

Similar to Reike et al. (2018), Blomsma & Brennan (2017) also distinguish between three main phases and acknowledge developments prior to the term's formal introduction. In fact, the authors introduce the view of the Circular Economy as an umbrella concept that provides a framing for ideas and concepts related to resource life-extending strategies. Apart from Pearce & Turner's (1990) influencing work, the concepts, schools of thought and research fields referred to and also cited consistently in other reviews (e.g. Geissdoerfer et al., 2017; Ghisellini et al., 2016; Lieder & Rashid, 2016; Reike et al. 2018) include Industrial Ecology, Cradle-to-Cradle, Performance Economy, Biomimicry and Blue Economy, among others. According to Blomsma & Brennan (2017), the development goes back to 1960 which marks the beginning of the *preamble* phase that spans until 1985. After having gone through an *excitement* (1985-2013) phase, the concept is now in the *validity challenge period*. This period is characterized by critical engagement on a range of existing interpretations without the existence of "theoretical or paradigmatic clarity" (Blomsma & Brennan, 2017, 610). In a similar vein as Reike et al. (2018), according to the authors, illustrative issues are the concept's relationship to sustainability as well as the lack of standardized language, metrics and tools in a range of areas including circular business model innovation.

The view of Circular Economy as a concept or framework is common in contemporary literature (Bocken et al., 2017b) and reflects the fact at least for now Circular Economy does not qualify as an own research field given the criteria outlined by Ehrenfeld (2004). According to the author, there are at least four criteria to fulfil in order to constitute an own research field. To ensure the fields' conceptual coherence, one of them is the existence of an authoritative structure, such as a specific and recognized journal and editorial board which does not exist for Circular Economy (Murray et al., 2017). Hence, it is not surprising that when looking further into the Circular Economy one still notices a strong influence by grey literature and practitioner reports.

2.1.2 Circular Economy Interpretations

In an analysis of 114 Circular Economy definitions, Kirchherr et al. (2017) find that 95 of them have been used only once, corroborating the above-stated claims by Blomsma & Brennan (2017) and Reike et al. (2018) that the concept still lacks a common understanding. Hence, in the following, the thesis attempts to provide a brief overview of some of the more prevailing interpretations by discussing different Circular Economy definitions and principles. As the concept has been strongly practitioner-driven in recent years (Merli et al., 2018), the first perspective to be introduced is the one by the Ellen MacArthur Foundation. According to Kirchherr et al.'s (2017) analysis, the foundation's conceptualization is currently the most employed one and, among others, adopted in Lieder & Rashid's (2016) influential Circular Economy review.

The Ellen MacArthur Foundation's Point of View

Since its establishment in 2009, the Ellen MacArthur Foundation has become a key player in shaping and promoting the Circular Economy and originally conceptualized it as "an industrial economy that is restorative or regenerative by intention and design" (Ellen MacArthur Foundation, 2013, 7). Thereby, its *restorative* quality refers to the elimination of the traditional end-of-life concept and the feedback of used products or their technical components back into the economy through activities such as reuse, repair, and recycle. *Regenerative* refers to the biological cycles and the regeneration of renewable materials in the biosphere. Later, the Ellen MacArthur Foundation (2015, 5) specified its initial formulation integrating a value-based approach to resource management by characterizing the Circular Economy as an "economy that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles." This conceptualization also blends into the concept's underlying purpose of "decoupl[ing] global economic development from finite resource consumption" (Ellen MacArthur Foundation, 2015, 5).

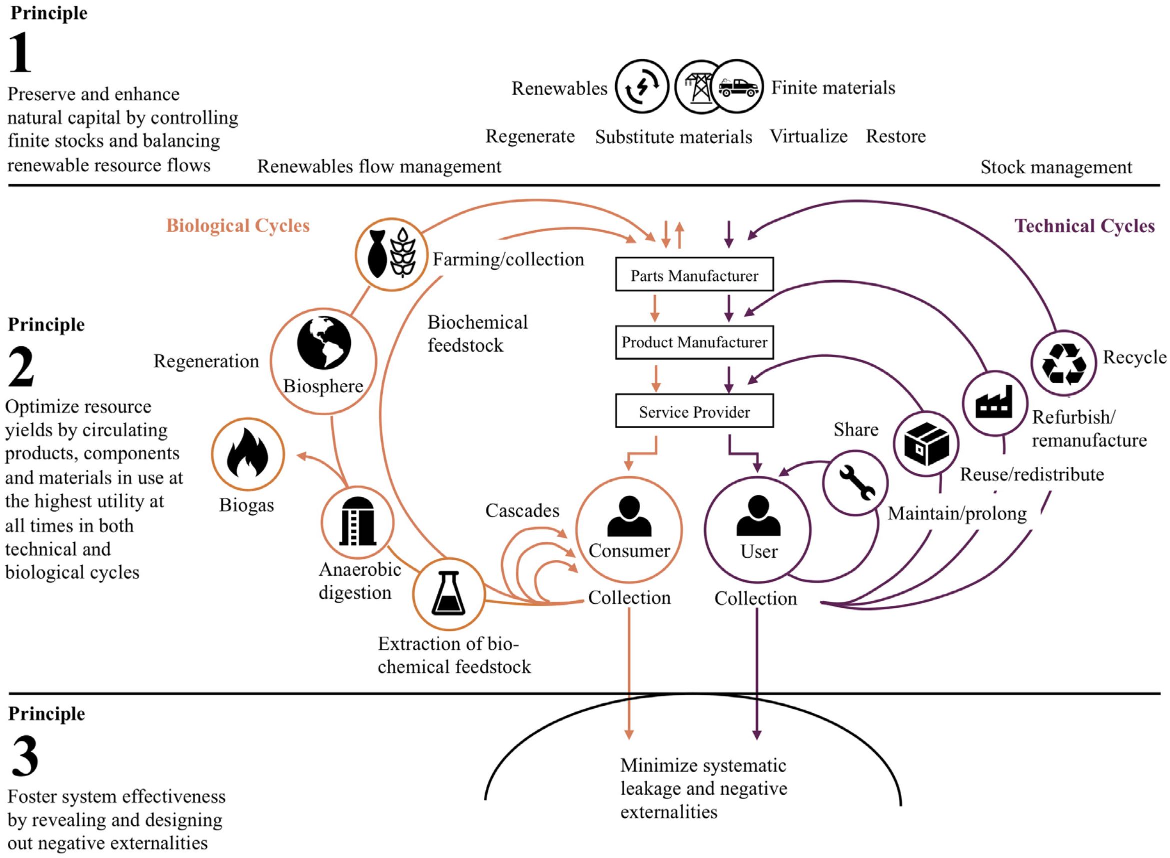


Figure 2. Circular Economy System Diagram. Adapted from Ellen MacArthur Foundation (2015).

In the view of the Ellen MacArthur Foundation (2015), the concept can be described by five fundamental characteristics which initially have been called *principles* (cf. Ellen MacArthur Foundation, 2013). First, it strives to *design out waste*, i.e. biological materials are safely returned to the soil providing renewable sources for the economy, and technical materials are designed to keep circulating so that—at least on a theoretical level—material loops are perfectly closed, and waste is fully eliminated. Secondly, the foundation's envisioned Circular Economy values *diversity as a means of building strength.* Biodiversity fosters the environment's resilience and a blend of large, efficient companies with agile, small and medium-sized enterprises supports the absorption of external shocks. Thirdly, as not only the production of products itself but also the activities to keep them in the loop at the highest value require energy, the Circular Economy *is powered by energy from renewable sources*. Furthermore, as a non-linear, feedback-rich system it demands to *think in systems.* In order to prevent unintended consequences, it is vital to understand the linkages between system components—such as the interaction between businesses and the environment—as well as the whole system's relationship to its parts. Lastly, *feedback mechanisms, including prices, should reflect real costs*, meaning that negative externalities are to be revealed and priced in. In contrast to the earlier version from 2013, this last characteristic replaces the formerly fifth one—*waste is food*—which is stronger incorporated in what the Ellen MacArthur Foundation (2015) now calls the three *principles for action*. However, as can be seen in figure 2, in which these principles are depicted, they appear to overlap especially with the first, fourth and fifth of the outlined characteristics.

Perspectives from Academia and Policy

The described characteristics and principles are not emphasized by all interpretations to the same extent, though. For instance, China's Circular Economy Promotion Law (Law Info China, 2008) refers to the 3R (reduce, reuse, recycle) principle when defining the Circular Economy as "a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption." In this way, it resembles a commonly used version of the waste hierarchy (see Sakai et al., 2011). This assumption is validated in the fourth article of the law which explicates the preference order that constitutes a waste hierarchy (see van Ewijk & Stegemann, 2016). The 3R principle is also taken up by Ghisellini et al. (2016). In their review, the authors outline six Circular Economy principles. In addition to *reduction*, *reuse* and *recycle*, these are *appropriate design, a reclassification of materials into technical and nutrients* and *renewability.* According to Ghisellini et al. (2016), the three latter are informed by the Ellen MacArthur Foundation's five Circular Economy characteristics, while the 3R principle is not explicitly mentioned in the foundation's publications. On the one hand, this proves true considering the circumstance that the Ellen MacArthur Foundation (2015) does not employ a strict waste hierarchy. However, on the other hand, the 3R principle is not completely neglected by the foundation either. As indicated by figure 2, recycling and reuse are viewed as crucial activities to design out waste and the reduction principle is additionally discussed concerning the control of finite input stocks and the minimization of negative externalities (see Ellen MacArthur Foundation, 2015). Still, the circumstance that the 3R principle is not explicitly mentioned by the foundation aligns well with Kirchherr et al.'s (2017) hypothesis that systems thinking may have replaced it as the core principle among the three outlined by them: 3R/4R framework, waste hierarchy (indication of an order of the different Rs), systems perspective.

The varying accentuations of the stated principles are also reflected in the Circular Economy definitions scholars have brought forward over time. In contrast to China's Circular Economy Promotion Law (Law Info China, 2008), Geng & Doberstein (2008, 232) highlight a system view by arguing that in China the Circular Economy "is understood to mean the realisation of a closed loop of materials flow in the whole economic system." Further, the definition emphasizes the concept's central idea of closed material loops. Similarly, this is also the key element of Sauvé et al.'s (2016, 49) definition in which the concept is described as the "production and consumption of goods through closed loop material flows that internalize environmental externalities linked to virgin resource extraction and the generation of waste (including pollution)." On the contrary, Geissdoerfer et al. (2017, 762) provide a broader perspective as they take up the renewability principle and integrate energy loops into their definition: "A regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling." Moreover, by building on Bocken et al.'s (2016) work and adding the slowing of resource loops as a strategy, this definition also places a greater emphasis on the reduction principle discussed above.

While these definitions focus particularly on economic development and environmental impact, other definitions additionally integrate a social component. Murray et al. (2017, 377) suggest defining the Circular Economy as "an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being" and from Franco's (2017, 834) viewpoint "the circular economy is a purposefully designed, interconnected system where materials flow in a closed-loop manner in order to advance sustainability." The introduction of this perspective reflects the academic division regarding the relationship between the concepts of sustainability and Circular Economy and raises additional questions. As it will be of relevance when defining circular business models, later on, the thesis provides a brief overview of this discussion in the following.

Circular Economy and Sustainability

According to Johnston et al. (2007), there exist more than 300 definitions for the terms *sustainability* and *sustainable development.* However, in a review of sustainability terms and their definitions Glavic & Lukman (2007) argue that in the end *sustainable development* is most of the time defined in the sense of the Brundtland Commission's (1987, 16) conceptualization, i.e. as a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs". According to Colocousis et al. (2017), this conceptualization was later broadened by the introduction of Elkington's (1997) triple bottom line approach and in this updated version served as the working basis for the creation of United Nations' current Sustainable Development Goals. Colocousis et al. (2017, 276) further claim that Elkington's (1997) three-pillared model—which consists of environmental, economic, and social dimensions—also "undergirds the dominant conceptions of sustainability". Among others, this is reflected in the classification of sustainability-oriented terms by Glavic & Lukman (2007) as well as Geissdoerfer et al.'s (2017, 759) recent definition of sustainability: *"the balanced and systemic integration of intra and intergenerational economic, social, and environmental performance".*

While the balancing of economic, environmental and social values constructs the core of sustainability, some authors such as Sauvé et al. (2016) explicitly note a complete lack of the social aspect in the contemporary Circular Economy understanding. This view is shared by Murray et al. (2017) resulting in the integration of a social component into their above-cited definition. However, according to Reike et al. (2018) this interpretation—in which sustainable development becomes the aim of the Circular Economy—is less common. More widespread is the viewpoint that the concept focuses on economic and environmental benefits. For instance, despite initially stating that the Circular Economy aims "to achieve a better balance and harmony between economy, environment and society", Ghisellini et al. (2016, 11) acknowledge that "the ultimate goal of promoting CE [Circular Economy] is the decoupling of environmental pressure from economic growth". Social value is mainly created indirectly by an increase in jobs and a reduction of hazardous waste. Further, Reike et al.'s (2018) view is substantiated by Kirchherr et al.'s (2017) study on Circular Economy definitions. According to their results, environmental quality (in 37-38% of all definitions) and economic prosperity (46%) related terms are substantially more often mentioned than social equity related ones (18-20%). Looking at the concept's roots, the minor role of the social dimension is not surprising as the Circular Economy is mainly built on environment-oriented concepts and frameworks. The above-mentioned work by Pearce & Turner (1990) which takes an environmental economics perspective is thereby as illustrative as the Industrial Ecology field which—in the tradition of ecologic economics—has "the goal […] to improve and maintain environmental quality" (Lifset & Graedel, 2002, 10).

Finally, additional support for the outlined predominant viewpoint is given by Geissdoerfer et al.'s (2017) investigation of relationship types between sustainability and Circular Economy. In there, the general role of circularity appears to be a contributing one—being either conditional or beneficial but never all-encompassing. Moreover, the authors highlight another difference that is of relevance. While sustainability can never be fully reached due to the open-ended nature of its goals, circularity theoretically can. This is the case when all waste or resource leakage is eliminated and there is no need to feed new finite resources into the system. Therefore, the Circular Economy provides the benefit of being able to give clearer directions on the way to full implementation may making it more attractive for businesses by overcoming the vagueness associated with sustainability.

2.1.3 A Synthesized Definition of Circular Economy

Given the different interpretations of the Circular Economy, Kirchherr et al. (2017) highlight the importance of clarifying one's own position when studying the topic. Such clarification is provided in the following by introducing a synthesized definition of the concept. Once the definition is stated, it is further supported through an elaboration on its key parts as well as a visual illustration.

Based on the discussion above, the thesis at hand takes the perspective that the Circular Economy first and foremost aims at decoupling economic prosperity from environmental pressure. Thus, the emphasis is clearly put on the economic and environmental dimensions of sustainability and Geissdoerfer et al.'s (2017) view in which the concept's relationship towards sustainability is more of a contributing one is adopted. Furthermore, the thesis follows the outlined principle of separating materials into biological and technical and employs a systems perspective. Another central element of the thesis' Circular Economy interpretation is a value-based approach to resource management similar to the one introduced in the Ellen MacArthur Foundation's conceptualization (2015) and viewed as characteristic for the concept's contemporary understanding by Reike et al. (2018).

Accordingly, this thesis defines the Circular Economy as *a system in which products, components and materials are kept circulating in the economy in order to minimize environmental pressure while driving economic prosperity. The system's effectiveness is influenced by its ability to keep products, components and materials at their highest value explicitly including the efficiency, frequency and speed at which they are circulated.*

Absolute decoupling and effectiveness. Core to the outlined definition is the introduction of *effectiveness* which, in general, expresses "the ability to be successful and produce the intended results" (Cambridge Dictionary, 2018). As stated, the intended result of the Circular Economy is to decouple economic prosperity from environmental pressure. What is paramount to differentiate is whether the intended decoupling is *absolute* or *relative*. Following Giljum et al. (2005, 33), "when relative decoupling occurs, economic growth is accompanied with lower growth in environmental pressures. […] Therefore, only in the case of absolute decoupling, environmental pressures are absolutely decreasing also in a growing economy." In other words, given economic growth, only an absolute decoupling can ensure that the natural environment's capacity to provide ecosystem services is permanently maintained. Hence, it can be argued that the Circular Economy has to achieve absolute decoupling in order to be deemed effective. Conversely, circular flows that only contribute to a relative or no decoupling threaten the environment's regenerative and assimilative capacity over time and, thus, have to be regarded as ineffective. Against this background, it would be reasonable to distinguish not only between a linear and circular economy but to have a more nuanced differentiation including a distinction between an effective and ineffective system. However, as this perspective would imply the introduction of another term, it might only add to the already existing confusion around the concept. Further considering that the thesis at hand does not attempt to develop a completely new conceptualization, the more conventional distinction between linear and circular economy is kept, while the system's effectiveness is introduced as a continuum. In this way, the definition still reacts to the concern brought forward by Kirchherr et al. (2017, 227) that the Circular Economy may get diluted if companies only "take the path of least resistance to adopt CE [Circular Economy]" without becoming overly complex.

Environmental pressure and resource value retention. While economic growth is traditionally measured as the percentage change in real gross domestic product, it is less clear how environmental pressure or impact is conceptualized in the light of the concept. A potential answer has recently been offered by Iacovidou et al. (2017) who postulate that the Circular Economy in its contemporary understanding takes a more multidimensional view than many other sustainability-related approaches. In specific, by focusing on maximizing the retention of resource value, the Circular Economy relates to both the quality and quantity component of environmental impact. How this approach differs from simply measuring material throughput—a common quantity-oriented proxy for environmental impact that relates to raw material inputs and waste outputs over time (van Ewijk & Stegemann, 2016)—is extensively illustrated by Gößling-Reisemann (2008). The example the author provides concerns the usage of the same amount of water in three different scenarios. If measured by material throughput, it would be concluded that independent from whether the water runs through a hydro power station, a cooling tower or a cleaning process, the resource use is the same. However, this neglects the quality of the transformation process. As Gößling-Reisemann (2008, 12) elaborates, "the water flowing from the hydro power station can still be used in many different processes, as it is chemically and physically indistinguishable from fresh water (except for its potential energy). This is not the case for the water output from the cooling plant and the cleaning process. Their potential utility has decreased", or in other words, less resource value is retained.

Against this backdrop, it would principally be sufficient to state that the system's effectiveness is largely influenced by its ability to keep products, components and materials at their highest resource and economic value. However, the thesis at hand attempts to additionally highlight how the concept's reduction principle contributes to the retention of resource value. To reduce waste and the input of virgin materials, finite resources should be circulated as long as possible by, first, slowing the loops and, secondly, increasing the total number of cycles. Thirdly, the demand for raw material inputs can be additionally reduced by using fewer resources per product in the first place—to what the *efficiency* parameter of the effectiveness function refers to. This emphasis is motivated by Kirchherr et al.'s (2017) observation that the reduction principle of the Circular Economy is often missing in practitioners' interpretations and the circumstance that the principle is an important building block in order to achieve an absolute decoupling (Kjaer et al., 2019).

Visual illustration. As outlined above, the thesis' definition shifts the focus from a discussion on adopting the Circular Economy to one on its effectiveness. On a general level, effectiveness is thereby defined in relation to the decoupling of economic prosperity from environmental pressure. More specifically, it is influenced by the system's ability to keep products, components and materials at their highest resource and economic value. Figure 3 illustrates this interpretation visually. As the term *linear economy* suggests—and the thesis adopts the common notion in which "a linear economy is one defined as converting natural resources into waste, via production" (Murray et al., 2017, 371)—economic growth and environmental pressure or impact are, first and foremost, coupled which is represented by the area between the two dotted lines in figure 3. However, due to the shift in perspective, the distinction between linear and circular economy becomes less important so that the divide between the two concepts is slightly blurred. In addition to the case in which economic growth and environmental pressure are coupled, a linear economy further encompasses states in which negative decoupling occurs. In contrast, from the thesis' point of view, the Circular Economy is characterized by the decoupling between economic growth and environmental pressure. As stated, an absolute decoupling (quadrant IV) thereby reflects an effective circular economy.

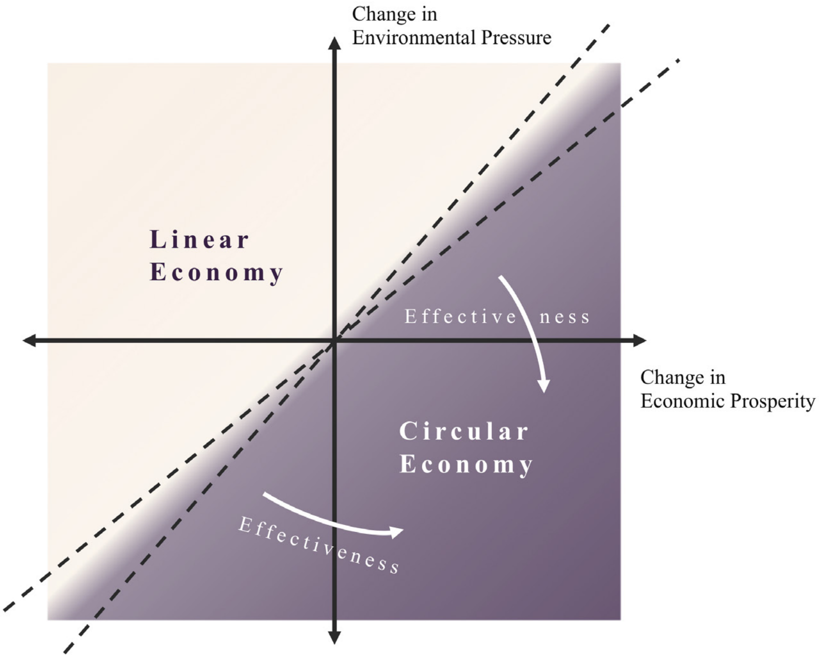


Figure 3. Linear versus Circular Economy.

2.2 Review of Circular Business Model Literature

In a similar vein as sustainable business models, circular business models are predominantly seen as a sub-category of business models (e.g. Antikainen & Valkokari, 2016; Mentink, 2014; Linder & Williander, 2017). While the notion of business models itself is also still relatively new with business model research only having started to grow significantly at the turn of the millennium, reaching 600 annual publications in 2015 (Massa et al., 2017), it is by far more established than its subcategories—for instance, circular business model publications registered by Scopus only amounted to a total of 54 in 2018—and hence provides a comparatively strong foundation when studying circular business models. Thus, this section starts off by giving a broad overview of business model definitions and interpretations. Subsequently, existing circular business model literature is mapped to these interpretations and additionally contrasted to sustainable business model research. On the basis of this analysis and the earlier outlined Circular Economy perspective, an own circular business model definition is suggested. Clarifying the thesis' viewpoint on (circular) business models is important as, according to Massa et al. (2017, 88), the presence of different interpretations of the meaning and function of business models "represents a major source of confusion." By acknowledging the different viewpoints and explaining one's own position, this confusion can be mitigated, and construct validity enhanced (Massa et al., 2017). Finally, in light of the thesis' objectives, the section concludes with a review of existing circular business model frameworks and classifications.

2.2.1 Business Model Interpretations

There are many approaches to find when it comes to interpreting and defining business models, as can be seen in Spieth et al. (2014). In their *R&D Management* editorial for a special issue on business model innovation, the authors themselves apply a role-based approach to categorize existing perspectives on business models. Acknowledging potential overlaps, they come up with three categories: *explaining the business, running the business* and *developing the business.* In the first category, business models are ascribed the role of explaining how the firm generates or is going to generate profits to external and internal stakeholders. Terms associated with this role include *abstraction, description, outline, reflection, representation, statement* and *story.* An exemplary definition is the one by Shafer et al. (2005, 202) who define business models as "a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network." Thereby, the notion of value networks also highlights the overlaps between the suggested categories as in the second one—*running the business*—business models give not only guidance to employees and managers on how the business operates but also to external partners. Terms associated with the role of *running the business* thus contain *activity system, architecture, framework/standard, structural template/blueprint* and *method*. For instance, Zott & Amit (2010, 216) define business models as "a system of interdependent activities that transcends the focal firm and spans its boundaries." Lastly, business models have the role of supporting managers in *developing the business* and creating a competitive advantage. Consequently, they are associated with the terms *approach, design, logic, conceptual tool* as well as *set of choices and consequences* and as an example Casadesus-Masanell and Ricart's (2010, 196) definition, in which business models are viewed as "the logic of the firm, the way it operates and how it creates value for its stakeholders", is cited.

Another approach to organizing the different business model perspectives is suggested by Wirtz et al. (2016) who distinguish between *organization theory-oriented, strategy-oriented* and *technology-oriented* interpretations. In contrast to previous studies which argue that business model research has to a large extent remained in its silos (e.g. Zott et al., 2011), Wirtz et al. (2016) thereby claim that the boundaries have become blurrier and the different perspectives are converging towards a rather strategic view on an operation-strategy spectrum with business models being mainly analyzed at a firm level. However, this perspective is still not shared unequivocally as one of the most recent review articles on business model research restates that literature is "branch[ing] into different camps" (Massa et al., 2017, 73). Starting from the observation that at the lowest common denominator business models intuitively appear to be seen as "*a description of an organization and how that organization functions in achieving its goals (e.g., profitability, growth, social impact, ...)"*, Massa et al. (2017, 73) distinguish between three different interpretations of business models. In the first category business models are interpreted as *an attribute of real firms,* in the second as *cognitive or linguistic schemas* and in the third as *formal conceptual representations of how a business functions.*

The overall idea behind the first interpretation is that by empirically testing hypotheses related to business model variables specific attributes can be derived, frequently resulting in the construction of business model archetypes and patterns (e.g. Gassmann et al., 2017). The obtained attributes can often be articulated and understood by describing the activities a business performs in order to create or capture value. According to Massa et al. (2017), in this interpretation, the word *model* is understood as an organization's *core logic* of how the firm's objectives are achieved. Thereby, the organization itself and/or its value network represent the appropriate unit of analysis. For instance, this view is reflected by Hienerth et al.'s (2011, 346) definition in which "a business model describes the logic of how a business creates and delivers value to users and converts payments received into profits" as well as the above-cited one by Shafer et al. (2005).

While scholars in this first category look at how firms do business, scholars in the second category are rather concerned with the question of how managers interpret the way their firm conducts business. They argue that managers hold images of real systems in their head, not the real systems themselves. Subsequently, since these images are framed by the managers' cognition, business models rather have to be viewed as implicit mental schemas instead of fixed attributes of a company. Following this argumentation, narratives play a major role in shaping the business model as is highlighted by Magretta (2002, 87) who defines business models as "stories that explain how enterprises work." In conclusion, the word *model* is not understood to represent an organization's *core logic* but rather the *dominant logic* that manifests itself through the managers' shared beliefs of how their business works.

Research clustered into Massa et al.'s (2017) third category sees business models as a *formal conceptual representation of how a business functions.* While also modeling the way how a business works, in contrast to the second interpretation here business models do not hold implicitly as mental images but are explicated by depicting the model symbolically, mathematically or graphically. Thus, here the units of analysis are the business model itself and the subject of modeling and not individual or collective minds. Further, the word *model* is interpreted similarly to how a map is interpreted as a model of the territory it depicts: as a simplified and abstract visual representation of reality. As maps, these representations can come with different levels of abstraction and Massa et al. (2017) outline two of such levels in specific. First, on a less abstract firm level business models can be described as a system of interdependent choices and their consequences (Casadesus-Masanell & Ricart, 2010). Secondly, on a more abstract level, the authors refer to business model meta-models which are concerned with depicting a more general architecture and its components. An illustrative example of such a meta-model is the Business Model Canvas by Osterwalder & Pigneur (2010). Finally, as an exemplary definition in this third category the one by Baden-Fuller & Haefliger (2013, 419) is cited: "We define the business model as a system that solves the problem of identifying who is (or are) the customer(s), engaging with their needs, delivering satisfaction, and monetizing the value. The framework depicts the business model system as a model containing cause and effect relationships, and it provides a basis for classification."

Before moving on and comparing circular business model literature with the outlined interpretations and definitions in the next section, a last approach to categorize business model conceptualizations is introduced. In an article published in *Long Range Planning*, Demil & Lecocq (2010)—whose business model definition is grouped into the third category of business model interpretations by Massa et al. (2017)—argue that business model perspectives can be roughly clustered into static and transformational approaches. According to the authors, in the static approach business models can be interpreted as *blueprints* in which business model components and their arrangement are clearly described. This rigid structure facilitates the construction of business model classifications as well as the close study of an organization's activities and their impact on business performance. It helps to communicate the business model and to draw comparisons between firms (Demil & Lecocq, 2010). In contrast to the static perspective business model scholars traditionally take (Lindner et al., 2010), the transformational approach rather describes the process of business model evolution (Demil & Lecocq, 2010). Business models are seen as a *tool* for managers to adapt the organization to changing environments and refine the model itself in order to create internal consistency and outperform the competition. In this way transformational viewpoints are rather concerned with the question of how to change the business model and, in contrast to the static approach, often do not define business model components or features beforehand. An advantage of this approach is that it allows for more flexible representations of business models such as causal loop diagrams (see Casadesus-Masanell & Ricart, 2010).

However, as this strictly transformational view lacks the strengths of the static one and vice versa, Demil & Lecocq (2010) set out to reconcile these two approaches. Their resulting framework "adopt[s] a deductive approach to identify first the BM's [business model's] component parts—corresponding to the static approach—and then to deduce how these components change at the organizational level" (Demil & Lecocq, 2010, 228). Ending with the authors corresponding interpretation of business models as a concept that "refers to the description of the articulation between different business model components or 'building blocks' to produce a proposition that can generate value for consumers and thus for the organization" (Demil & Lecocq, 2010, 227), the thesis will now turn to circular business model literature and link it to the discussed interpretations and definitions.

2.2.2 Circular Business Model Perspectives

Generally, definitions of what a circular business model constitutes are scarce (De Angelis, 2018; Nußholz, 2017a). While some authors do not define circular business models explicitly and simply refer to business models that are congruent with Circular Economy principles or support the transition to a more circular economy (e.g. Mendoza et al., 2017; Lieder et al., 2017; Lüdeke-Freund et al., 2018a; Urbinati et al., 2017; Manninen et al., 2018), others slightly adapt (e.g. Bocken et al., 2018; Oghazi & Mostaghel, 2018) or fully adopt one of the two most prevailing definitions (e.g. Antikainen & Valkokari, 2016; Bressanelli et al., 2017; Stål & Corvellec, 2018) which stem from Linder & Williander (2017) and Mentink (2014). However, with the increasing interest in circular business model research, some alternative definitions are outlined. Screening 116 circular business model related publications, this thesis identifies four additional definitions (Nußholz, 2017a; Lathi et al., 2018; Hofmann et al., 2017; Geissdoerfer et al., 2018) and a comprehensive circular business model conceptualization (De Angelis, 2018)—the latter can be viewed as a statement that provides an indirect definition (see Massa et al., 2017). In the following, all seven definitions are analyzed and first mapped to the four presented business model interpretations—an overview of the definitions and their mapping is provided in table 1. Afterwards, by positioning the definitions in the business model and sustainable business model realm the thesis attempts to derive the construct's differentiating characteristics. These will be of relevance when presenting a synthesized circular business model perspective in the subsequent section.

Circular Business Models and Business Model Interpretations

Analyzing the different circular business model definitions and the work they are embedded into reveals that it is often not possible to clearly link them to the presented business model interpretations. An example provides the peer-reviewed work of Geissdoerfer et al. (2018) in which circular business models can be interpreted as both *attributes of real firms*—for instance, signified by stating that "CBMs [circular business models] *achieve* [emphasis added] the best sustainability performance" (Geissdoerfer et al.; 2018, 715)—as well as *formal conceptual representations*—since circular business models are seen as specific business models and these are, in turn, explicitly defined as "simplified representations" by Geissdoerfer et al. (2018, 713). While it has to be acknowledged that the presented interpretations are not necessarily without overlap, this issue is also highlighted by Massa et al. (2017). In the appendix of their review, Massa et al. (2017, Appendix, 7) remark that "many nested cases exist in which an analysis of the function of the business model provides evidence of two or even three interpretations simultaneously." According to them, this "suggests that the sources of confusion on the term business model are not immediately apparent and that, in many cases, they have not been recognized" (Massa et al., 2017, Appendix, 8). With circular business models being mainly seen as a subset of business models (e.g. Antikainen & Valkokari, 2016; Mentink, 2014; Lieder & Williander, 2017; De Angelis, 2018), it is not surprising that the same appears to hold true for the term *circular business model* and that its research faces a similar construct validity problem. Hence, the mapping in table 1 should be viewed with particular caution—in especially ambiguous cases, thus, two interpretations are marked.

Circular business model definitions/conceptualizations \ Business model interpretations	Wirtz et al. (2016): Organization theory-oriented	Wirtz et al. (2016): Strategy-oriented	Wirtz et al. (2016): Technology-oriented	Spieth et al. (2014): Explaining the business	Spieth et al. (2014): Running the business	Spieth et al. (2014): Developing the business	Massa et al. (2017): Attribute of real firms	Massa et al. (2017): Cognitive or linguistic schema	Massa et al. (2017): Formal conceptual representation	Demil & Lecocq (2010): Static	Demil & Lecocq (2010): Transformational	Demil & Lecocq (2010): Static/Transformational-Hybrid
”We define a circular business model as a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings.” (Linder & Williander, 2017, 183)	x	x				x			x		x	
“A circular business model is the rationale of how an organization creates, delivers and captures value with and within closed material loops.” (Mentink, 2014, 24)	x	x				x	x		x			x
“A Circular business model describes the rationale of how an organization creates, offers, and delivers value through the structured linkage of various elements while minimizing ecological and social costs in order to achieve the goals of strong sustainability. Only the integration in a circular business network enables organizations to contribute to closing material and product loops.” (Hofmann et al., 2017, 174)	x			x			x			x		
“We propose a circular business model definition to explain how an established firm uses innovations to create, deliver, and capture value through the implementation of circular economy principles, whereby the business rational are realigned between the network of actors/stakeholders to meet environmental, social, and economic benefits.” (Lathi et al., 2018, 3)	x		x	x			x			x		
“A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops.” (Nußholz, 2017a, 12)	x				x				x			x
“CBMs can be defined as SBMs - which are business models that aim at solutions for sustainable development by creating additional monetary and non-monetary value by the pro-active management of a multiple stakeholders and incorporate a long-term perspective - that are specifically aiming at solutions for the Circular Economy through a circular value chain and stakeholder incentive alignment.” (Geissdoerfer et al., 2018, 713-714)		x		x		x	x			x		
“Circular business models are business models wherein enhanced customers’ value is produced as a result of more comprehensive ‘circular offerings’ (e.g. products as services; greater convenience; dematerialised products; superior product durability and ecological performances; product upgradability; take-back schemes) and ‘circular relationships’ (access over owner- ship, e.g. leasing, renting, sharing). In circular business models diffused forms of value are created, local/regional supply chains are implemented, maximisation of resources value across the activity system is pursued, boundaries spanning relational competences for the adaptation or development of ‘circular’ resources and capabilities are developed, and idiosyncratic value capture mechanisms are observed (De Angelis, 2018, 65)	x				x		x		x	x		

Table 1. Circular Business Model Definitions and Business Model Interpretations.

Circular business models and strategy. As stated, in their review, Wirtz et al. (2016) postulate that the perspectives on business models are converging to a point at which strategic aspects becoming more and more influential. In general, this notion aligns well with circular business model interpretations. Although not all of the reviewed definitions can be referred to as *strategy-oriented*—for instance, De Angelis' (2018) conceptualization is more operational and in Lathi et al.'s (2018) definition circular business models are rather viewed as theoretical constructs than strategic tools—the highlighted role of value and stakeholder networks emphasizes a strategic characteristic (see Wirtz et al., 2016). In contrast to more conventional business models, the focus is thereby not necessarily on gaining a competitive advantage but rather on positioning one's business in such a way that from a system's perspective material and product loops can be closed—this is particularly highlighted by Hofmann et al. (2017) as well as Mentink (2014). Another facet of the discussion on the relationship between circular business models and strategy is the role of circular strategies or principles such as *slowing* or *narrowing material loops*. On the one hand, following De Angelis (2018) and Lathi et al. (2018), these strategies determine the configuration of the business model's individual components. On the other hand, from Nußholz' (2017a) perspective, circular strategies are embedded in the model's value creation logic. However, as the author further outlines that circular business models *operate* and *support* circular strategies and are rather to be seen as a concept than a strategic tool, also her interpretation is categorized as *organization theory-oriented*. A third viewpoint is provided by Geissdoerfer et al. (2018, 713) who explicitly consider circular business models as a "class of or generic strategy for sustainable business models." Finally, as can be seen in table 1, a strategy-oriented view in the sense of Wirtz et al. (2016) can be generally linked to the perspective that a circular business model's role is to *develop the business* in Spieth et al.'s (2014) categorization. However, it has to be noted that the categories are not necessarily directly connected and, thus, an analysis should, first, always look at each categorization approach individually before making cross comparisons.

Circular business models in the light of other interpretations. In order to determine whether circular business models in the reviewed literature are rather interpreted as *attributes of real firms*, *cognitive schemas* or *formal conceptual representations*, the thesis follows the approach by Massa et al. (2017) who analyze not only a study's definition but also additional statements that express what a business model *does.* While it becomes relatively clear that none of the reviewed definitions interprets circular business models as *cognitive or linguistic schemata*, a differentiation between the other categories is more difficult. As has been already illustrated briefly when discussing the construct validity problem, this is because there often exists evidence for both viewpoints. A particularly interesting case in the light of this thesis' work thereby presents Hofmann et al.'s (2017) study. Given that the core of the authors' definition—according to which a circular business model "describes the rationale of how an organization creates, offers, and delivers value" (Hofmann et al., 2017, 174)—closely resembles the business model definition of Osterwalder & Pigneur (2010) and that over the course of the study a graphical circular business model representation is developed, it would stand to reason that the authors interpret circular business models as *formal conceptual representations.* However, Hofmann et al. (2017, 174) also regard their *C3 Business Model Canvas* as a *reference model* which "can be used to visualize, analyze, design, and communicate the business model of an enterprise". This points to the view that a circular business model itself is not a representation but rather an *attribute of a real firm* that can be visualized by specific tools, such as the *C3 Business Model Canvas*.

Lastly, the seven circular business model definitions are mapped to the business model interpretations provided by Demil & Lecoq (2010). In line with the distribution of general business model research, the mapping thereby shows that the *transformational* perspective is only taken on by Linder & Williander (2017) who are particularly interested in the continuous change of circular business models through iterative refinements by management. Other authors interpret circular business models from a rather static viewpoint which facilitates the study of an organization's activities and their impact on business performance and helps to communicate the circular business model—hence this viewpoint also seems closely connected to the interpretations in which circular business models are seen as *attributes* and their role is described as *explaining the business.* Despite not exactly following the approach suggested by Demil & Lecocq (2010), Mentink's (2014) as well as Nußholz' (2017a) definitions can be seen as hybrids between the two anchor points. Both studies present circular business model representations with pre-defined components but regard their arrangement and features as rather flexible with Nußholz (2017a, 10), for instance, emphasizing that "the value proposition element may be regarded as more fluid and dynamic" since products in the Circular Economy live through several use cycles.

Key Characteristics of Circular Business Models

It has been already outlined before that circular business models are largely seen as a subset of business models. A few of the reviewed definitions make this point now explicit by defining circular business models as business models with particular configurations. According to Linder & Williander (2017), one of these adaptation concerns the model's value creation component which in the case of circular business models integrates closed loop supply chains. In contrast, De Angelis (2018) postulates that further also value delivery and capture components differ in content from conventional business models and that an overemphasis on closed loop supply chains rather blurs the conceptualization of circular business models. While Nußholz (2017a) and Geissdoerfer et al. (2018) also put emphasis on the supply chain side as being the differentiating dimension, they largely follow De Angelis (2018), Lathi et al. (2018), Mentink (2014) and Hofmann et al. (2017) in pointing out the changes in the configurations of other components. However, apart from these changes and the earlier outlined accentuation of value and stakeholder networks, what mainly distinguishes circular business models from business models is the different notion of value itself. While more conventional business model interpretations are mainly concerned with the creation of economic value, circular business models generally widen that view by explicitly integrating environmental and in some cases social value. This is often expressed by formulating why value should be created, delivered and captured: "in order to achieve the goals of strong sustainability" (Hofmann et al., 2017, 174); "to meet environmental, social, and economic benefits" (Lathi et al., 2018, 3); "to improve resource efficiency" (Nußholz, 2017a, 12). In the remaining paragraphs of this section, this particular notion of value will be further dismantled.

Circular business models in contrast to sustainable business models. When introducing the Circular Economy in the first part of this literature review, the work of Blomsma & Brennan (2017) as well as Reike et al. (2018) is cited, stating that the concept's relationship to sustainability is still a widely discussed issue. This is also reflected in the reviewed circular business model definitions with the studies by Linder & Williander (2017) and Hofmann et al. (2017) representing the two anchor points. While the former mainly links circular business models to the notion of retained economic value in products and hence focus on economic and—to a lesser degree—on environmental sustainability, according to the latter the proclaimed goal is *strong sustainability*. The view in which circular business model's notion of value considers economic, environmental and social benefits is also promoted by Geissdoerfer et al. (2018) and particularly Lathi et al. (2018). However, defining circular business models in this way raises the question how they actually differ from sustainable business models as the term *sustainable business model* is similarly connected to an augmented stakeholder view and Elkington's (1997) triple bottom line approach. Both society and the environment are thereby seen as key stakeholders (Stubbs & Cocklin, 2008; Bocken et al., 2014) and equal weight is placed on creating economic, environmental and social value (Boons & Lüdeke-Freund, 2013; Schaltegger, 2016). Exemplary definitions can be found in Breuer & Lüdeke-Freund (2014, 3) who define sustainable business models as a reflection of how a company "creates, delivers, and captures value for all its stakeholders without depleting the natural, economic, and social capital it relies on" and Bocken et al. (2014, 42) for whom "sustainable business models (SBM) incorporate a triple bottom line approach and consider a wide range of stakeholder interests, including environment and society." Against this backdrop, what distinguishes circular business models from sustainable business models are merely the specifications on how the aim of sustainable development is pursued, namely by the integration of closed-loop supply chains and the implementation of Circular Economy principles. This view is aptly reflected by Geissdoerfer et al.'s (2018, 713) study in which circular business models are seen as a "class of or generic strategy for sustainable business models."

More in line with how the Circular Economy is regarded in relation to sustainability in this thesis (see section 2.2.3), are the circular business model definitions by Mentink (2014), Linder & Williander (2017), Nußholz (2017a) and De Angelis (2018) which focus, first and foremost, on the notion of economic and environmental value, discarding sustainable business models' balanced triple bottom line approach. This being said, there also exist subtle differences among this stream of circular business model interpretations. For instance, Nußholz (2017a) links environmental impact mainly to an improvement in resource efficiency which is rather contradicting to the contemporary idea of the Circular Economy (cf. Blomsma & Brennan, 2017; Reike et al., 2018). Closer to the current interpretation is De Angelis' (2018) understanding, postulating the pursuit of resource value maximization.

Degrees of circularity. Comparing circular business models to more conventional as well as sustainable business models, it becomes apparent that boundaries among the terms are not necessarily clear cut. Hence, in his thesis, Mentink (2014) introduces a *scale of circularity* that ranges from 100% linear business models to 100% circular business models and outlines exemplary key performance indicators with which a specific degree can be determined. In contrast, Linder & Williander (2017, 184) propose that the circularity of business models is determined "by the fraction of new products that come from used products." While not as explicit such a degree perspective can also be found in most of the other reviewed circular business model interpretations. For instance, Geissdoerfer et al. (2018) rank circular business models according to their sustainability performance and Nußholz (2017a) outlines that circular business models should be assessed using life-cycle-assessments. Still others, like Lathi et al. (2018), refer to the Circular Economy principles and highlight preferential choices such as the implementation of reuse and remanufacturing over recycling. A last approach to this degree perspective stems from Urbinati et al.'s (2017) circular business model typology. As will be further elaborated when reviewing existing circular business model classifications in section 2.2.5, the authors create a 2x2 matrix with the business model's circularity regarding price and promotion being represented on the x-axis and its circularity in terms of design practices being displayed on the y-axis. Crossing these axes results in four business model categories consisting of the increments *linear*, *downstream circular*, *upstream circular* and *full circular*. Next, against the background of this review, the thesis at hand attempts to provide a synthesized circular business model definition and to clarify its own viewpoint.

2.2.3 A Synthesized Definition of Circular Business Models

In general, definitions of key concepts "are an important starting point for research as they clarify a concept's objectives and prevent concepts being used arbitrarily" (Nußholz, 2017a, 7). Having highlighted the diversity of existing circular business model definitions and found that in a similar vein to business model research the construct validity problem also seems to be apparent in circular business model research, it is hence of particular importance to explicitly express how the thesis at hand defines and interprets circular business models. Based on the provided Circular Economy, circular business model and business model definitions and interpretations as well as the thesis' objectives, circular business models are defined as follows:

A circular business model describes how an organization creates, delivers and captures value while retaining resource value within the firm and the firm's transcending system. Its degree of circularity is influenced by the set of interdependent activities the organization performs and how those contribute to the overall's system effectiveness.

Adopting the idea that "business models […] involve performing value-adding activities to create and/or capture value" (Massa et al., 2017, 80), the thesis at hand interprets circular business models as *attributes of real firms*. Viewed as such, circular business models can serve as a descriptor of kinds in a taxonomy—a role that is further underlined by the notion of the term "describes". This is because the term is associated with the most general and intuitive level of defining business models (see Massa et al., 2017) which, in turn, is referred to as being "intimately linked with notions of taxonomies and 'kinds'" (Baden-Fuller & Morgan, 2010, 157). Moreover, the usage of the term also connects this thesis' definition to the *explaining the business* category presented in Spieth et al. (2014). This interpretation fits well as circular business models in this thesis are seen as related to but conceptually distinct from strategy. Thus, also the *organizational theory-oriented* perspective in the sense of Wirtz et al. (2016) is taken. Lastly, in line with the taxonomy study by Hartmann et al. (2016), the thesis' interpretation can be grouped to the static view in Demil and Lecocq (2010) since not the development of model configurations are examined but snapshots of organizations' circular business models.

Unpacking the definition further, it can be noticed that the thesis at hand employs a broader notion of value than more traditional business model definitions. In specific, the outlined definition integrates the idea of resource value retention which in section 2.1.3 has been introduced as a proxy for determining environmental impact. However, at the same time, the notion of value is narrower than the one in sustainable as well as some of the reviewed circular business model definitions as there is no specific focus on social value. Thus, while Geissdoerfer et al. (2018) rank circular business models according to their performance on all three sustainability dimensions, this thesis' interpretation—in line with its general Circular Economy understanding—only takes into account sustainability's economic and environmental dimensions. At this point, the idea of resource value retention is still a rather abstract one ideally requiring case-by-case evaluations as the value retained most likely depends on the particular product category (Iacovidou et al., 2017). To make it more applicable, Reike et al. (2018) develop a framework that presents different resource value retaining activities and ranks them according to their potential environmental impact. This hierarchy of resource value retention options is outlined in table 2 and complemented by generic examples.

Environmental impact

	Retention Activity	Description	Example
Down-cycling	Re-mine	Retrieval of materials after the landfilling phase	"Mine" valuable resources such as metals stored in old landfills and other waste plants
	Recover (Energy)	Energy production as by-product of waste treatment	Incineration
	Recycle	Processing of mixed streams of post-consumer products or post-producer waste streams to capture (nearly) pure materials	Used paper is sorted into grades, broken down into fibers, remaining contaminants are removed and the fibers are bonded together again into clean paper sheets
	Repurpose	Reusing of discarded goods or components in a new product with a different function	Transforming defective microchips into jewelry
Product Upgrade	Remanufacture	Product is disassembled, functional modules and components are taken out and together with new parts reassembled into a new product with the same function	Engine is pulled out of abandoned car, all its components are checked against original equipment standards and replaced by new parts if necessary. Engine is resembled and put to work in another car
	Refurbish	Product is returned into a good working condition replacing key modules or components while overall structure remains intact	Restoring a phone into a good working condition by replacing its battery, cleaning and function testing
	Repair	Making the product work again by repairing or replacing deteriorated parts	Fixing or replacing a bike tube that has a puncture
Client/User Choices/ Production	Re-sell/ Reuse	Product is reused in its original form by someone else for the same purpose	2nd hand clothing
	Reduce	Product is used less or longer by user or the use of product is shared; Product is produced with less resource input per unit	Tractor which can be given more horsepower through a software update so that it can be longer kept in use by the user
	Refuse	Potential user refrains from buying; Designers refrain from using virgin materials	Potential user refrains from buying a house telephone and music player using her smartphone instead

Table 2. Resource Value Retention Activities. Based on Reike et al. (2018).

Similar to existing circular business model research, the thesis thereby acknowledges the existence of interdependencies beyond organization boundaries and argues that product, component and material loops not necessarily have to be closed by a circular business model alone but can be part of a network of circular business models that through their interaction contribute to the Circular Economy (see Mentink, 2014). Thus, a circular business model's own degree of circularity is also influenced by how the set of activities the firm performs—consisting of value creation, value delivery, value capture as well as resource value retaining activities—contributes to the overall's system effectiveness. In other words, to assess how circular a business model is, it is not enough to only analyze the performed activities from a company perspective but, in addition, requires a system-level view.

Apart from the broadened but not all-encompassing notion of value, the multi-stakeholder perspective and the viewpoint that circular business models can be ranked—which similarly to the thesis' Circular Economy definition shifts the focus from a binary "circular/non-circular" discussion to one revolving around "how circular or effective"—there are two more aspects that need to be noted in order to clarify the thesis' circular business model understanding. First, in line with most of the reviewed circular business model definitions, it is assumed that the configurations of all existing circular business model components may differ from more traditional business models. This also implies that a transition from linear to circular business models can be both radical—changing the content of several or even all components at the same time—as well as incremental. Secondly, while the performance of circular business models is measured against economic and environmental indicators, in contrast to Hofmann et al. (2017), Geissdoerfer et al. (2018), De Angelis (2018), Nußholz (2017a) and Lathi et al. (2018), the thesis does not postulate that the pursuit of a specific aim such as *minimizing ecological costs or maximizing resource value* is inherent to a circular business model. Rather, the viewpoint is supported that circular business models can arise intentionally as well as unintentionally. Among others, this argumentation is backed by Urbinati et al.'s (2017) study that identifies cases in which companies with circular business models are not making their circular efforts visible as well as the circumstance that circular business models such as Rolls Royce's 1962s *Power-by-the-hour* had existed long before the terms Circular Economy and circular business model were coined.

2.2.4 Circular Business Model Frameworks

Besides business model definitions, Groth & Nielsen (2015) highlight the usefulness of business model frameworks as a starting point for the identification of variables in business model taxonomy studies. Thus, in the following, the thesis provides a brief review of existing circular business model frameworks. As most of these frameworks are thereby based on or readily adopt the general business model frameworks developed by Osterwalder & Pigneur (2010) and Richardson (2008), the overview depicted in table 3 is structured accordingly.

Scanning the 116 identified circular business model publications resulted in the identification of 28 papers that include some form of circular business model framework. Apart from studies dedicated to the construction of formal representations (e.g. Hofmann et al., 2017; Lewandowski, 2016), these also include publications which only use circular business model dimensions to explain circular strategies, outline illustrative circular business model cases or focus on tools to foster circular business model innovation (e.g. Bocken et al., 2016; D'Amato et al., 2018; Antikainen & Valkokaari, 2016). Given this relatively wide scope as well as the already outlined circumstance that circular business models are often seen as a subset of business models or closely related to sustainable business models, it is not surprising that several authors thereby make direct use of existing business model frameworks (e.g. Heyes et al., 2018; Goyal et al., 2018; Bocken et al. 2016; Muerza & Urciuoli, 2018). An argument that is regularly brought forward in these cases is that the circular characteristics of the business model are only reflected in the content of its components but not in the naming of dimensions and components itself. For example, Levänen et al. (2018) integrates circular activities into all traditional components and De Angelis (2018, 59) states that "merging the 'value' dimension of the business model concept, as represented in the business model components (i.e. value proposition, value creation and delivery and value capture), with the implications for these components deriving from the application of Circular Economy principles, would lead to the identification of the qualifying features of the value proposition, value creation and delivery and value capture and thereby to the conceptualisation of the CBM [circular business model]."

However, as highlighted in grey in table 3, there are also a number of frameworks which follow Massa et al. (2017) who emphasize the usefulness and common practice of adjusting or adding elements, such as *social and environmental impact* in the case of sustainable business model studies. The frameworks that differ most from more traditional business model frameworks are the ones by Hofmann et al. (2017) and Antikainen & Valkokari (2016). In line with the observations made when reviewing circular business model definitions above, both frameworks reflect the importance of a multi-stakeholder systems perspective and a firm's interrelationship with the environment. Generally, these aspects are incorporated into a range of existing circular business model frameworks, although often subtler and in different ways. For instance, Mentink (2014) highlights that environmental and social costs and benefits should be regarded alongside financial ones in the value capture component. This is also emphasized by Bocken et al. (2018) who additionally divide the value proposition component into *people*, *planet* and *profit*. To incorporate sustainability characteristics that cannot be integrated into the classic business model dimensions, De Padua Pieroni et al. (2018) add a *value transformation* dimension into their framework. In contrast to Bocken et al. (2018) and De Padua Pieroni et al. (2018) who make explicit that circular business models can be represented through sustainable business model frameworks, Manninen et al. (2018) put special emphasis on sustainability's environmental aspect by introducing an environmental value proposition. With regards to the multi-stakeholder network view, D'Amato et al. (2018) divide the value capture dimension into capturing value *for the company* and *for others*, while Urbinati et al. (2017) reframe the traditional value creation dimension as *value network* and Ranta et al. (2018) introduce *position in the value network* as a new component or sub-dimension. Lastly, Lüdeke-Freund et al. (2018a) add the term *stakeholder* to the partner component, while Bocken et al. (2018) reframe the whole component to *key stakeholders*.

	Value proposition (VP)		Value capture			Value creation (VC)				Value delivery				Other dimensions
	Value proposition	Other elements	Revenue streams	Cost structure	Other elements	Key partners	Key activities	Key resources	Other elements	Channels	Customer segments	Customer eelationships	Other elements	Other elements
Component-based frameworks														
Ranta et al. (2018)		Offering	Revenue sources		Economics of the business			Resources & capabilities	Organization, position in the value network		Target customer (under VP)			
Nußholz (2017b; 2018)	Value proposition	Offer	Revenue flows	Costs		Key partners	Key activities	Key Resources/ capabilities		Channels	Customer segments (under VP)	Customer/partner relationships (under VP)		
Bocken et al. (2018)		Profit, people, planet	Revenues (financial, social, environmental)	Costs (financial, social, environmental)		Key stakeholders	Key activities	Key Resources/ capabilities		Channels	Customer segments	Customer relationships		
D'Amato et al. (2018)	Value proposition				For company, for others	Partners		Resources	Technology					
Nußholz (2017a)	Product/service offer and VP (containing circular strategies)		Revenue streams	Cost structure		Key partners	Key activities	Key resources		Channels	Customer segments	Customer relationships		
Lewandowski (2016)	Value proposition		Revenue streams	Cost structure		Partners	Activities	Key resources		Channels	Customer segments	Customer relations		Adoption factors, take-back system
Levänen et al. (2018)		Offer (+circular activities)			Financial model (+circular activities)				Supply chain (+circular activities)				Customer interface (+circular activities) (under VC)	
Goyal et al. (2018); Heyes et al. (2017); Horvath et al. (2018)	Value proposition		Revenue streams	Cost structure		Key partners	Key activities	Key resources		Channels	Customer segments	Customer relationships		
Lüdeke-Freund et al. (2018a)		Products, services	Revenues	Costs		Partners and stakeholders			Value creation processes		Target customers		Value delivery processes	
Hofmann et al. (2017)	Value proposition		Revenue streams	Cost structure			Key activities	Key resources						**Stakeholder, biosphere, c**ircular business network (CBN), CBN channels, CBN relationships
Antikainen & Valkokari (2016); Uusitalo & Antikainen (2018)	Value proposition		Revenue streams	Cost structure		Key partners	Key activities	Key resources		Channels and logistics	Customer and stakeholder identification and understanding	Customer relationships and collaboration		**Business ecosystem level** (trends and drivers, stakeholder involvement), **Sustainability impact** (requirements, benefits)
Beulque & Aggeri (2016)	Value proposal		Revenues volume and structure	Costs volume and structure				Resources & competences	Internal and external organization					
Wastling et al. (2018)	Value proposition				Financial incentives					Channels		Customer relationships		Take-back system, rules
Sousa-Zomer et al. (2018)		Product/service, value for customer, environment and society	Cost structure and revenue streams		Value captured for key actors, growth strategy	Partners and suppliers	Activities	Resources	Technology & product features	Distribution channels	Customer segment and relationship (under VP)			
Mentink (2014)	Value proposition		Revenues (financial, social, environmental)	Costs (financial, social, environmental)		Key partners	Key activities	Key resources		Channels (indirect)	Customer segments	Customer relationships (indirect)		
Dimension-based frameworks														
De Padua Pieroni et al. (2018)	Value proposition				Value capture (triple bottom line)				Value creation				Value delivery	**Value transformation**
Ünal et al. (2018); Urbinati et al. (2017)	Customer value proposition and interface				Financial aspects				Value network				Customer value proposition and interface	
Manninen et al. (2018)	Value proposition	Environmental value proposition			Financial model				Supply chain				Customer interface	
Whalen et al. (2018)		Offer			Finance				Supply chain		Customers			
Oghazi & Mostaghel (2018)	Value proposition				Value capture				Value creation					
Bocken et al. (2016); De Angelis (2018); Muerza & Urciuoli (2018)	Value proposition				Value capture	Value creation and delivery								

Table 3. Overview of Existing Circular Business Model Frameworks.

2.2.5 Circular Business Model Classifications

With the interest in the Circular Economy and circular business models growing, scholars and practitioners have also started to examine what kinds of circular business models exist. Thereby, they have come up with a range of classifications including “patterns” (Lüdeke-Freund et al., 2018a), “archetypes” (Moreno et al., 2016), “taxonomies” (Urbinati et al., 2017; Lewandowski, 2016), “strategies” (Bocken et al., 2016), “categories” (Kiørboe et al., 2015) or not otherwise specified constructs (Lacy & Rutqvist, 2015). However, as the following review shows, the range of classifications is not as diverse as the different terminologies let assume. Further, similar to sustainable business models (see Lüdeke-Freund et al., 2018b) and as highlighted by Whalen (2017), detailed information on how the classifications are constructed is not always provided leading some classifications to be less suitable for further theory building.

The two earliest classifications found in the established database of circular business model publications stem from practitioners. In collaboration with *Nordic co-operation*, Kiørboe et al. (2015), who are members of the Copenhagen Resource Institute, establish six categories to map the circular business models of 18 Nordic businesses (table 4). While the categories themselves—apart from being illustrated by the case examples—are not further defined in the report, they are referred to by and integrated into Lewandowski’s (2016) as well as Lüdeke-Freund et al.’s (2018a) classifications. Similar to Kiørboe et al. (2015), also the second classification constructed by practitioners is based on case studies whereby the authors, Lacy & Rutqvist (2015), study a total of 120 cases across the world. Apart from the overall approach, both publications further have in common that detailed information on how exactly the clusters have been identified are lacking. However, despite this lack of information, a third joint characteristic is that also Lacy & Rutqvist’s (2015) classification has found its way into circular business model literature. Apart from Lewandowski’s (2016) and Lüdeke-Freund et al.’s (2018a) studies, it is referred to by Moreno et al. (2016) who blend Lacy & Rutqvist’s (2015) five circular business model categories with the six strategies developed by Bocken et al. (2016) to derive a set of five circular business model archetypes. In turn, Bocken et al.’s (2016) classification is conceptually derived from Bakker et al.’s (2014) framework—which Lüdeke-Freund et al. (2018a) regard as a practitioner contribution—as well as Bocken et al.’s (2014) sustainable business model archetypes.

Author/Classification Type/Approach	Circular Business Model Categories	Category Descriptions (Def = based on provided category definitions; Ex = based on provided examples, if specific definition is not available)
Lewandowski (2016) **Type**: Traditional typology **Approach:** Categorization using Ellen MacArthur Foundation's (2015) ReSOLVE framework which has been developed based on case studies and expert interviews	1.1 Regenerate	Ex: Includes models that recover energy from biomass, use renewable energy and lease chemicals; linked to 2.1
	1.2 Share	Ex: Concerns the sharing of assets, their reuse and life-extension and different product-service systems; linked to 2.3, 2.4, 2.5
	1.3 Optimize	Ex: Related to more efficient products and production technqiues, including production on demand and outsourcing
	1.4 Loop	Ex: Includes remanufacturing, recycling and upcycling models and models using circular supplies; linked to 2.1, 2.2, 2.3
	1.5 Virtualize	Def: Shifting physical products, services or processes to virtual
	1.6 Exchange	Def: New technologies of production such as 3D printing
Lacy & Rutqvist (2015) **Type:** Traditional typology **Approach:** "Structured analytical process" based on 120 case studies of companies that are generating resource productivity improvements in innovative ways	2.1 Circular Supply Chain	Def: Provide renewable energy, bio based-or fully recyclable input material to replace single-lifecycle inputs
	2.2 Recovery & Recycling	Def: Recover useful resources/energy out of disposed products or by-products
	2.3 Product Life Extension	Def: Extend working lifecycle of products and components by repairing, upgrading and reselling
	2.4 Sharing Platform	Def: Enable increased utilization rate of products by making possible shared use/access/ownership
	2.5 Product as a Service	Def: Offer product access and retain ownership to internalise benefits of circular resource productivity in any part of the value chain
Bocken et al. (2016) **Type:** Theoretical typology **Approach:** Derived from the business model frameworks of Bocken et al. (2014)—developed based on literature and practice—and Bakker et al. (2014)— not accessible, but practitioner-oriented according to Lüdeke-Freund et al. (2018)	3.1 Access and Performance	Def: Providing the capability or services to satisfy user needs without needing to own physical products
	3.2 Extending Product Value	Def: Exploiting residual value of products—from manufacture, to consumers, and then back to manufacturing—or collection of products between distinct business entities
	3.3 Classic Long Life	Def: Business models focused on delivering long-product life, supported by design for durability and repair for instance
	3.4 Encourage Sufficiency	Def: Actively seek to reduce end-user consumption through principles such as durability, […], warrantees and reparability and a non-consumerist approach to marketing and sales
	3.5 Extending Resource Value	Def: Exploiting the residual value of resources: collection and sourcing of otherwise "wasted" materials or resources to turn these into new forms of value
	3.6 Industrial Symbiosis	Def: A process-orientated solution, concerned with using residual outputs from one process as feedstock for another process, which benefits from geographical proximity of businesses
Kiørboe et al. (2015) **Type**: Traditional typology **Approach**: Categorization based on 18 case studies whereby no further information is available	4.1 Repair	Ex: Includes repair and maintenance service models as well as models in which old equipment is retrieved from one company, refurbished and resold to another company
	4.2 Reuse	Ex: Concerns services that enable users to exchange information about needs and functional surplus as well as systems that incentivize the reuse of goods
	4.3 Product Design	Ex: Inlcudes products that are cradle-to-cradle certified as well as products that are, for instance, specifically designed for reuse or recycling
	4.4 Recycling and Waste Management	Ex: Related to providers of waste management and recycling services as well as manufcaturers of new and more efficient recycling technologies
	4.5 Service-and Function Based Models	Ex: Concerns product-service systems in which the seller remains the owner of the product and revenues are generated, for example, through monthly access fees
	4.6 Collaborative Consumption	Ex: Includes C2C platforms that enable users to sell and buy user products
Moreno et al. (2016) **Type**: Traditional typology **Approach**: Summary of the classifications provided by Bocken et al. (2016) and Lacy & Rutqvist (2015)	5.1 Circular Supplies	Def: A business model based on industrial symbiosis in which the residual outputs from one process can be used as feedstock for another process; linked to 2.1, 3.6
	5.2 Resource Value	Def: A business model based on recovering the resource value of materials and resources to be used in new forms of value; linked to 2.2, 3.5
	5.3 Product Life Extension	Def: Those business models that are based on extending the working life of a product; linked to 2.3, 3.2
	5.4 Extending Product Value	Def: Those business models based on offering product access and retaining ownership to internalise benefits of circular resource productivity; linked to 2.5; 3.1
	5.5 Sharing Platforms	Def: Those business models that enable increased utilisation rates of products by making possible shared use/access/ownership; linked to 2.4, 3.1
Lüdeke-Freund et al. (2018) **Type:** Theoretical typology **Approach**: Morphological analysis of circular business models found in academic and practice publication. Final categories are conceptually derived using results of morphological analysis and literature review	6.1 Repair and Maintenance	Ex: Includes repair and maintenance services by OEMs or independent service operators; linked to 2.3, 3.3, 4.1
	6.2 Reuse and Redistribution	Ex: Concerns the offering of used products through C2C marketplaces as well as commercial resellers; linked to 2.3, 4.2
	6.3 Refurbishment and Remanufacturing	Ex: OEMs or third party service providers sell refurbished or remanufcatured products whereby products are collected through take back-programs or donations linked to 2.3
	6.4 Recycling	Ex: Includes models that extract ingerdient materials as well as models that create new products out of discarded products, components and materials; linked to 4.4
	6.5 Cascading and Repurposing	Ex: Includes service business models that create and manage reverse cycles for third-party companies as well as industrial symbiosis networks
	6.6 Organic Feedstock	Ex: Concerns the processing of organic residuals via biomass conversion, composting or anaerobic digestion
Urbinati et al. (2017) **Type:** Theoretical Typology **Approach:** Based on literature review and subsequent validation through mapping of case companies by an expert panel	7.1 Downstream Circular	Def: Concerns firms that adopt a price scheme or a marketing campaign that is based on the "use" and "re-use" of products, but where internal practices and design procedures for products do not seem to reflect the characteristics of a circular "adopter"
	7.2 Upstream Circular	Def: Concerns firms that adopt circular principles in their product design activities and eventually establish effective relationship with new suppliers, but that do not make visible to their final customers, neither on the price or in the marketing campaigns their adoption of Circular Economy
	7.3 Full Circular	Def: Concerns firms that are circular both internally (upstream circular) and externally (downstream circular)

Table 4. Overview of Circular Business Model Classifications.

While these linkages cause most of the classifications to be very similar, the ones by Lewandowski (2016) and Urbinati et al. (2017) differ significantly. In specific, Lewandowski (2016) utilizes Ellen MacArthur Foundation's (2015) ReSOLVE framework in order to systemize individual circular business models, circular business models described in other classifications as well as constructs conceptually related to circular business models such as Tukker's (2004) eight types of product-service systems. As the ReSOLVE framework represents six actions companies can take in order to transition to the Circular Economy, the classification by Lewandowski (2016) hence encompasses six categories. Of these categories particularly the two latter—virtualize and exchange—differ from other classifications presented in table 4 in that they emphasize models that dematerialize physical goods such as CDs or apply new production technologies such as 3D printing. While Lewandowski's (2016) classification is still largely informed by a framework originally developed based on case studies and expert interviews (see Ellen MacArthur Foundation, 2015), Urbinati et al.'s (2017) categorization of circular business models builds on prior theory from a range of Circular Economy related fields including *Product Lifecycle and Supply Chain Management* as well as *Design for Sustainability*. The framework the authors create along the business model dimensions *value network* and *value proposition & interface* comprises features related to the degree of circularity with regards to pricing—from a pay-per-own to a pay-per-use approach—promotion—from the communication of circular efforts on the company's website to the communication of circularity across all channels—as well as design—from a focus on energy efficiency to a focus on materials and the implementation of *design for X* practices such as the design for disassembly. Thereby, price and promotion define the business model's external circularity while design represents the model's internal circularity. Plotted against each other, they create the categories *linear, downstream circular, upstream circular* and *full circular*. To confirm the categories' validity, Urbinati et al. (2017) subsequently form a panel of several experts and task them with mapping the business models of 86 companies to the outlined categories.

Finally, another approach to classifying circular business models is presented by Lüdeke-Freund et al. (2018a). First, by reviewing six practitioner-based contributions and six research papers, the authors identify a total of 36 circular business models that they subsequently aggregate to 26. Secondly, Lüdeke-Freund et al. (2018a) conduct a morphological analysis—a modeling technique to structure different problem complexes (Im & Cho, 2013)—on these 26 circular business models. The result is a framework of 64 circular business model design options structured along traditional business model dimensions. In a third step, this framework is then used to conceptually derive a typology of six major circular business model patterns. As the authors highlight, the first four patterns (table 4) thereby closely resemble and directly build on categories also found in Kiørboe et al. (2015), Lacy & Rutqvist's (2015) and Bocken et al. (2016). However, since largely related to the concept of industrial symbiosis, it could be argued that also the fifth pattern is at least partly reflected by Bocken et al.'s (2016) classification. In a similar vein, the sixth pattern, which concerns the processing of organic residuals and overlaps to some extent with the fifth pattern (Lüdeke-Freund et al., 2018a), aligns at least in some parts with the *regenerate* category in Lewandowski's (2016) classifications.

In conclusion, this thesis' review on circular business model classifications generally confirms the finding by De Angelis (2018) that there are different circular business model constructs available in literature. However, while researchers have started to develop more robust theoretical circular business model typologies, empirically derived classifications are predominantly practitioner-based and lack methodological rigor. Hence, the latter are more aligned with what Warriner (1984) originally refers to as *traditional typologies* which are classifications established without explicit criteria and, thus, less useful as a basis for making wider generalizations (Lambert, 2015). Against this background, what is lacking is the third type of classification which is referred to as *taxonomy* and uses observations and computerized statistical software to derive categories (Lambert, 2015). It will be discussed in more detail in the following chapter on the thesis' research design.

3. Research Design

In her article on the importance of classification in business model research, Lambert (2015, 55) proposes six decision steps that support "the application of theoretical rigor to the design of classification schemes in business model research and communicating their underlying structure to potential users" and, hence, seem suited to set the frame for the thesis' research design. In the following, the thesis will present these steps while integrating central elements from several taxonomy studies.

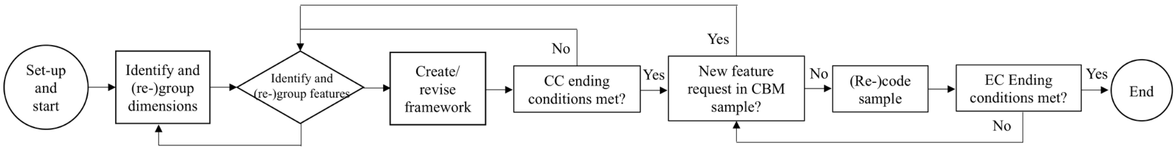
In a first step, Lambert (2015) asks the researcher to specify the classification's intended purpose. Having reviewed existing Circular Economy, business model and circular business model literature, the thesis at hand aims at constructing a holistic perspective on the defining characteristics and distinctive configurations of circular business models thereby seeking to contribute to a more unified and better understanding of the research area and providing a stepping stone for other researchers to build upon. Thus, it poses the rather broad question: *what types of circular business models exist and how can they be characterized?* Secondly, given this objective, the resulting classification should be more general in nature and provide a basis for wider generalization. Consequently, a rather large number of variables has to be considered and while existing research can be utilized in order to ensure that key variables are included the resulting categories themselves have to be empirically derived. Following Lambert (2015), such functions and characteristics relate to an empiricist philosophy of classification that generates a taxonomy—in contrast to an essentialist philosophy that underlies typologies. This viewpoint, in turn, also aligns well with the interpretation of (circular) business models as attributes of real firms since Massa et al. (2017) explicitly ascribe the interpretation to a positivistic stance in which knowledge is gained through empirical research. With step three, the selection of a classification philosophy, completed, Lambert's (2015) guideline then suggests deriving classification principles in the fourth step. Following her paper, the classification principles relevant to empiricism are the formation of polythetic instead of monothetic groups as well as the already addressed collection of data based on many variables and the derivation of categories through observation. Steps five and six concern the selection of a procedure that is consistent with the outlined classification principles as well as the establishment of rules to operationalize this procedure. A procedure that aligns well with the notions of Lambert (2015) can be found in the existing business model taxonomy studies of Täuscher & Laudien (2018), Remane et al. (2016) as well as Hartmann et al. (2016). In a nutshell, the studies first review relevant literature and manually parse documents related to the business models of a random sample of companies in order to discover variables, then codify the observations made during content analysis based on the defined variable set and, finally, perform cluster analysis using non-hierarchical and hierarchical clustering techniques. Building on top of the authors' approaches, in the following, the thesis at hand will outline in more detail the procedures and rules it adopts in order to construct a taxonomy of circular business models. This also includes the introduction of several validation criteria. In contrast, limitations to the approach are discussed separately in section 3.2.

3.1 Research Methodology

Following Täuscher & Laudien (2018), Remane et al. (2016), as well as Hartmann et al. (2016), the thesis' research approach can be divided into two distinct phases. Building on the literature review and hand-collected data, the first phase aims at creating a morphological box-like framework on which basis circular business models can be described. This framework will be referred to as variable space. In the process of its development, a sample of 100 circular business models is iteratively evaluated against it resulting in a binary-coded matrix that describes the observations. Taking this matrix as an input, in the second phase, cluster analysis techniques are then used to generate the circular business model taxonomy.

3.1.1 Phase 1: Variable Space Creation and Coding

The first phase is mainly informed by the design principles of morphological analysis. According to Im & Cho (2013, 4464), morphological analysis "is a non-quantified modeling method for structuring and analyzing technological, organizational, and social problem complexes" and as such also seems well suited to study (circular) business models (see Lüdeke-Freund, 2018a; Hartmann et al., 2016; Täuscher & Laudien, 2018). Morphological analysis usually consists of three basic steps (Alvarez & Ritchey, 2015). In a first step, the problem complex' relevant dimensions are distilled. This step is followed by the identification of the dimensions' potential conditions or features. The result is a morphology matrix or variable space with mutually exclusive features for each dimension. In traditional morphological analysis, a possible solution to the stated problem is then displayed by selecting one feature of each dimension (Alvarez & Ritchey, 2015). However, in spaces with many dimensions and features, the number of potential configurations quickly becomes too large in order to be managed with non-quantified modeling methods such as morphological analysis—for instance, a matrix being comprised of seven dimensions with four features assigned to each of them results in more than 16,000 different combinations. Thus, as the third step of traditional morphological analysis, a cross-consistency assessment is conducted eliminating all configurations which contain mutually contradictory conditions (Alvarez & Ritchey, 2015). However, as this thesis uses quantitative methods to analyze the variable space created during the first two steps, cross-consistency assessment is expected to be of minor value. Hence, only the first and second step of morphological analysis will be adopted (see Hartmann et al., 2016; Täuscher & Laudien, 2018). In line with the method, these steps are conducted iteratively (Alvarez & Ritchey, 2015) whereby the exact process further draws on Nickerson et al. (2013), Remane et al. (2016) and Groth & Nielsen (2015). The process is depicted in figure 4 and its application described in the following.



1. Set-up (conceptual cycles (CC)):
- Construction of circular business model (CBM) literature database (116 publications)
- Sources: Scopus, Web of Science, ProQuest, Google Scholar
- Definition of circular business models based on review of selected publications, Circular Economy as well as general business model literature
- Ending conditions: all publications from the circular business model literature database are reviewed and and all features have been grouped to a specific dimension

2. Set-up (empirical cycles (EC)):
- Creation of database containing a sample of 100 companies with circular business models and 318 documents for analysis
- Sources: Circular Economy Club database, annual reports, sustainability reports, websites, media articles, blog posts
- Ending conditions adopted from Nickerson et al. (2013)

Figure 4. Overview of Phase 1: Variable Space Creation and Coding.

Conceptual Cycles

In their article on constructing business model taxonomies Groth & Nielsen (2015, 12) outline that "the backbone of the variables [used to perform cluster analysis] should be found in the general definitions of business models". However, this does not mean that definitions alone are sufficient. Rather, in interplay with existing (circular) business model frameworks, the definitions guide the development of a framework—in this case called variable space—that is relevant for the issue under study (Groth & Nielsen, 2015). Thereby, it is important to point out that while acknowledging circular business model frameworks as a basis for classification, in contrast to Baden-Fuller & Haefliger (2013), the thesis at hand does not interpret them as circular business models themselves but, along the lines Hofmann et al. (2017), as reference models that can be used to describe and analyze a circular business model as an attribute of a real firm. This being said, the first step in the displayed approach is to build the foundational elements on which the iterative process can subsequently run. The thesis at hand started the development process by constructing a database of circular business model literature. To find relevant publications, the popular academic databases Scopus, Web of Science and ProQuest were searched using the search parameters listed in table 5. The results were stored in an excel sheet and subsequently screened for duplicates. A second filtering process involved reading the publications' abstracts to further remove articles that contained the desired keywords but did not address the topic itself. Secondly, to ensure that no publication of relevance had been overlooked, the potential of performing backward and forward search on key articles was evaluated. However, due to the circumstance that many articles still heavily build on studies from Circular Economy and circular business model adjacent literature—such as closed-loop supply chain literature (see Lüdeke-Freund et al., 2018a)—as well as thesis related resource constraints, the former was discarded. Forward search, i.e. the scan of publications that cite already identified key articles, was performed on Google Scholar but did not yield any additional findings. In contrast, another search on Google Scholar—with the aim to compensate for not performing a backward search—resulted in three additional findings. In specific, the scan of papers that matched the previous search terms while additionally having been cited at least 50 times, led to a master's thesis (Mentink, 2014), an article in the Open Journal of Business Model Innovation (Planning, 2015) as well as a paper in Environmental Innovation and Societal Transitions (Schulte, 2013). With these additions integrated, the database amounts to 119 unique publications whereby three of them were not fully accessible.

	1. Scopus	2. Web of Science	3. ProQuest	4. Google Scholar
Search terms	"circular business model"; "circular economy business model"			
Search scope	Article title, abstract, keywords	Topic, title	Abstract, document text, document title	No specifications
Date range	All years			
Documents types	Article, conference paper, article in press, review, book, conference review	Article, proceedings paper, review	Scholarly journals, conference papers & proceedings, working papers, books	No specifications
Further restrictions	None	None	None	Publications not identified in searches 1-3 with at least 50 citations
Search date	18th December 2018			
Search results (search term 1; search term 2)	60; 25	30; 9	43; 14	3; 0
Unique and topic-related publications	119 (of which 3 publications were not fully accessible)			

Table 5. Search Parameters for Circular Business Model Literature Review.

Defining circular business models. To develop the framework's *backbone* in the sense of Groth & Nielsen (2015), a subset of the 116 accessible publications was created by screening them for existing definitions and conceptualizations. The screening was supported using the search terms "defin", "conceptu", "CBM", "circular business model", "CEBM" and "circular economy business model". Subsequently, the papers in the subset were carefully read in order to understand their definitions in context. In total, seven unique circular business model definitions were found reflecting the circumstance that circular business model research is still in its infancy but rapidly growing—a review by De Angelis (2018) conducted in August 2017 only found one definition in academic literature—and further highlighting the importance of clarifying this thesis' circular business model understanding. As outlined in section 2.2 the identified definitions and their contexts were then analyzed using existing business model interpretation categories, before reflecting on previous reviewed Circular Economy and business model literature—note that due to the thesis' scope both literature streams were mainly discussed based on existing reviews and other relevant academic and practitioner publications—and providing a synthesized definition.

Iterating through conceptual cycles. Similar to Remane et al. (2016), the thesis further used the identified circular business model literature to kick-off the creation of the variable space. In specific, the 116 accessible publications in the database were first screened for existing circular business model frameworks including not only studies that develop new ones but also studies in which existing frameworks are just used to describe circular business models. Next, the 28 identified constructs were reviewed and compared to each other resulting in table 3. Based on this comparison as well as the previously developed circular business model definition, the thesis initially identified four main dimensions containing ten additional sub-dimensions. Further scrutinizing the selected 28 publications, potential conditions or features of these dimensions were derived. Within different excel sheets—one per each sub-dimension—the features were first stored, and subsequently grouped in order to create more generic options. To visually highlight this procedure in the process, the *identify and group features* component in figure 4 takes the shape of a diamond symbolizing the divergent and convergent characteristics of this step. The completion of the feature identification step resulted in a first version of the framework to be constructed and closed the first conceptual cycle. In succeeding conceptual cycles, the remaining 88 accessible publications from the circular business model literature database were then screened one-by-one for additional features. Once a new feature was found it was either added to an already generalized group of features or otherwise stored in a separate sheet with other so-called candidate features. As the highlighted diamond shape suggests, in this way the existing framework was not updated every time a new potential feature emerged but rather once it became evident that a relevant and generic-enough feature could be formed, thereby enhancing the framework's robustness. The process depicted in figure 4 further accounts for the possibility that candidate features that are transitioning to real features cannot be grouped to an existing dimension so that the dimensions need to be regrouped. However, while iterating through the conceptual cycles this has not been the case. Overall, the remaining 88 publications mostly strengthened the constructed framework and once the ending conditions were met—this was the case once all publications from the circular business model literature database had been reviewed and no candidate features were left in the excel file—only one feature, *informational value*, had been added.

Empirical Cycles

As depicted in figure 4, when the ending conditions for the conceptual cycles are met, the framework is further developed through empirical cycles. Again, this is similar to Remane et al.'s (2016, 6) approach in which the dimensions identified during the literature review are iterated on by cycles that are "empirical-to-conceptual, which means that a subset of the objects to be classified must be evaluated for common characteristics and dimensions". However, in contrast to the authors who build on Nickerson et al.'s (2013) taxonomy development approach, the thesis at hand did not create subsets of sampled companies based on previously developed typologies and other taxonomies. Rather, the companies from the sample were evaluated one by one reducing a potential bias that is introduced through the creation of subsets and their joint evaluation before the actual clustering. In the following, more details on this process will be outlined starting with the sample creation.

Sample creation. As the basis for the sample creation served a database of Circular Economy initiatives provided by the Circular Economy Club, an "international network of over 3,100 circular economy professionals and organizations from over 100 countries" (Circular Economy Club, 2019). The database, which is publicly available on the network's website, has mainly been created over multi-day mapping sessions in February 2018 (Circular Economy Club, 2018). These group sessions were hosted by local chapters of the network and involved around 2,000 participants in 67 cities of 45 countries. They resulted in the mapping of 3,017 initiatives which had to be engaged in at least one of the value circles of the Ellen MacArthur Foundation's Circular Economy System Diagram (see figure 2) in order to be integrated into the database (Circular Economy Club, 2018). The list of initiatives is stored in a comment-only Google sheet containing the initiatives' names, a short as well as long description of their activities, their website address, primary circular strategies ("design", "resources", "business models", "product-life extension", "waste as a resource" and "other"), their organization's type ("private sector" ("multinational corporate", "small and mid-sized enterprise", "national corporate", "startup", "private sector (undefined)", "education", "non-profit", "government", "support", "other"), the sector ("cities", "consumer products and electronics", "fashion", "food and beverages", "manufacturing", "other"), region, country and city they are operating in as well as by which chapter they have been submitted. The database was downloaded and stored in an editable excel file on 16th February 2019. Subsequently, the obtained data was pre-processed providing a more robust basis for the sampling procedure. The following paragraphs elaborate on the particular measures taken, and figure 5 summarizes the process visually.

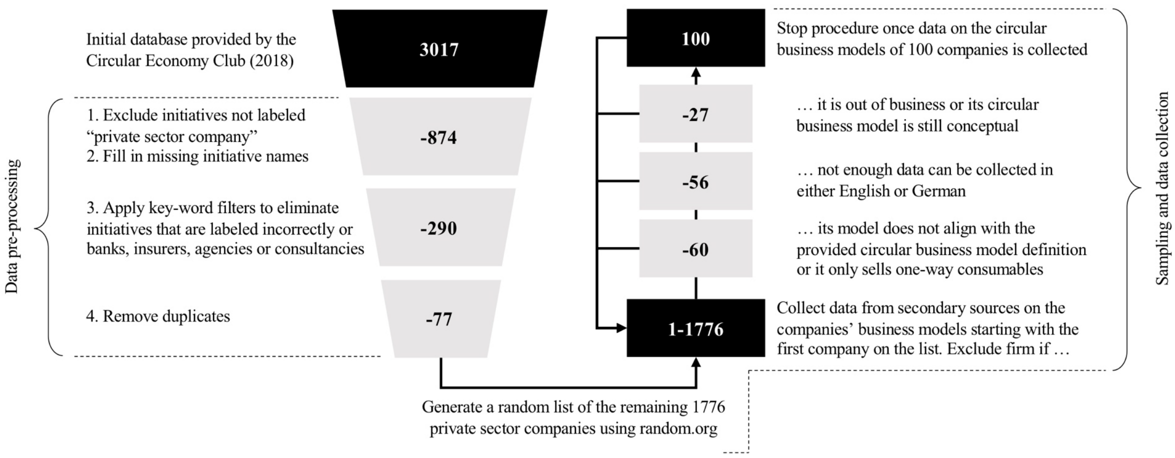


Figure 5. Data Pre-processing and Sample Creation.

The procedure to pre-process the data involved four steps. Due to the thesis' focus on companies with circular business models, in a first step, all initiatives that were not assigned the type "private sector company" were excluded. The 2,143 companies left in the database—760 small and mid-sized enterprises, 140 multinational corporations, 139 national corporations, 343 startups and 761 undefined private sector companies which together accounted for 71% of the initial database—were then screened for any missing information. In the column containing the organizations' names, 159 blank cells were identified. These were filled using the information available in the respective initiative's description or the website it was linked to. With the data complete, the dataset was screened again for companies that did not align with the thesis' focus on circular business models but had still been classified as a private sector company by the database creators. To eliminate initiatives that rather matched the types previously eliminated, i.e. initiatives of type "education", "non-profit", "government", "support" or "other", the dataset was searched for consultancies, banks, insurance providers, media agencies, city initiatives, public institutions, community projects and generic cases by applying keyword filters in the columns containing the organizations' names and descriptions. With the dataset cut down by 290 additional initiatives to a total of 1,853 remaining ones, in a fourth step, the data were checked for duplicates. This procedure completed the pre-processing resulting in the elimination of 77 additional elements reducing the overall dataset to 1,776 companies.

According to Sarstedt & Mooi (2011, 243) "there is no generally accepted rule of thumb regarding minimum sample sizes or the relationship between the objects and the number of clustering variables used." Still, the relationship between the sample size and the number of variables should not be underestimated, as "from a statistical perspective, every additional variable requires an over-proportional increase in observations to ensure valid results" (Sarstedt & Mooi, 2011, 242-243). While the selection of variables will be elaborated on in the second phase of the research approach, the taxonomy studies by Hartmann et al. (2016) and Täuscher & Laudien (2018) provide a benchmark for choosing the sample size. The authors demonstrate that clusters of business models can be successfully generated using a sample of 100 companies and up to nine variables from the created variable space (Hartmann et al., 2016; Täuscher & Laudien, 2018). Against this backdrop and given the general resource constraints related to the nature of a master's thesis, the sample size aimed at by this thesis was also 100. Following the studies by Hartmann et al. (2016) and Täuscher & Laudien (2018) further, the sample was picked by using random.org. In specific, the service's list randomizer, which creates randomness via atmospheric noise, was applied. The result was a randomized list of all 1,776 companies that had remained in the database during data pre-processing with the positions on the list becoming the companies' identifiers. Next, starting with the first company on the list, data regarding the companies' business models were collected from secondary sources—which seemed to be sufficient given that "the gross elements of business models are often quite transparent and (in principal) easy to imitate" (Teece, 2010, 179). The collection process was conducted from late February to early March 2019. Apart from the firms' websites, sources included annual and sustainability reports, online articles of newspapers and journals, blog posts, crowdfunding campaigns, interviews as well as slide decks and marketing brochures. In each case, the most up-to-date business model was used, disregarding previous ones and those that had not been implemented.

Moreover, given the thesis' understanding of (circular) business models as attributes of real firms, the firm was chosen as the main unit of analysis (see Massa et al., 2017). In larger corporations with a broad range of offerings such as Hewlett-Packard, the description from the database was used to identify a part of the business that could then be regarded as an independent firm with a circular business model—in the case of Hewlett-Packard, the thesis selected the firm's B2C printing business. All information was stored locally and transferred into a word-document for additional content analysis and coding. During the data collection, it was evaluated whether the selected companies were indeed private sector companies with business models that met the applied definition of circular business models. Thereby, companies from the food sector provided a special case as food is a one-way consumable that basically fulfills the criteria of biological cycles by nature (Mentink, 2014). Hence, for the sake of clarity, only food-related businesses with specific circular activities such as selling leftover food or establishing a closed-loop production system were allowed to be included. Moreover, it was checked whether enough information on a firm's business model was available and whether this information was available in English or German. If one of these criteria had not been fulfilled, the company was excluded from the sample and the next company on the list selected. In total, around 59% of the companies had to be excluded from the list. Of the excluded ones around 42% did not operate a circular business model—such as consultancies, non-profits, charities and agencies—or were only selling one-way consumables, 19% were still in a conceptual phase or already out of business and for 39% not enough data could be collected in English or German. This being said, the general procedure outlined and applied has been proven valid by previous studies (Hartmann et al., 2016; Täuscher & Laudien, 2018) and also the number of companies that needed to be replaced in the sample appears to be reasonable given the circumstance that the initial database creation took place in 45 countries—including many non-English speaking ones—as well as comparable data from Täuscher & Laudien's (2018) taxonomy study. Next, it will be discussed how the 318 collected documents were analyzed and used in the coding process.

Content analysis and coding. With the sample established, the thesis can now further discuss the transition from conceptual to empirical cycles and the development of the variable space. Drivers of the empirical cycles were thereby the manual examination of the collected documents and the subsequent coding of the samples on the established framework. In specific, once the conceptual cycles had been completed, the documents related to the first company in the sample were analyzed with regard to the framework's features. If relevant statements were identified in the documents, they would be transferred to the excel file in which the samples were stored. The extracted text snippets were then used for the coding process. Following Hartmann et al. (2016) and Täuscher & Laudien (2018), the features were represented with a binary value, meaning that a "1" indicates that a specific feature is present in the circular business model and a "0" that it is absent. At this point, it is important to highlight that in contrast to traditional morphological analysis a dimension's features were not demanded to be mutually exclusive. For instance, a business could conduct various resource value retention activities at the same time. Apart from conceptual reasons this approach is further backed by two of the taxonomy studies the thesis followed (Hartmann et al., 2016; Täuscher & Laudien, 2018). Moreover, if not enough information were found in the stored documents, additional information would be collected and added to the database. Besides, if it was particularly difficult to obtain enough relevant information to code a specific feature, the coding would be marked with an asterisk so that, later, it was easier to identify features less suitable for the cluster analysis. Lastly, if the content analysis and coding process revealed that there was a feature missing to accurately express a certain circular business model, the feature would be added to the "diamond-shaped pool" of features displayed in figure 4. From there a candidate feature followed the same process as described above when introducing the meaning behind the element's shape. In total, the iterations on the variable space through empirical cycles led to the addition of nine features as well as the restructuring and reframing of one sub-dimension. Each change in the structure of the framework also required the revision of some of the previous codifications. Due to the text snippets attached to each coding and the linkage to the documents they originated from—this was done via the earlier introduced identifier system—this revision could be performed relatively efficiently. As stated, the circular business models of the sample companies were coded one by one and after each coding is was evaluated whether the ending conditions had been met. These ending conditions were adopted from Nickerson et al.'s (2013) method for taxonomy development and are briefly elaborated on in the following. Apart from identifying when to terminate the iterative process, they further add rigor to the process and help to ensure the quality of the resulting framework and its codification.

Ending Conditions. In contrast to this thesis which defines taxonomies in the sense of numerical taxonomies (see Lambert, 2015, Sneath & Sokal, 1973), Nickerson et al. (2013) use the term rather loosely. According to the authors, a taxonomy is first and foremost a set of dimensions with mutually exclusive as well as collectively exhaustive characteristics (Nickerson et al., 2013). However, since this interpretation closely resembles the design principles of morphological analysis outlined above and underlies the taxonomy development approach Remane et al. (2016) build upon in their study, it is not surprising that it can also be descriptive of the variable space created in this phase. In fact, Nickerson et al. (2013, 338) state that they "could use any of the terms discussed here – classification, framework, typology, or taxonomy – for the object of study in [their] paper". Consequently, despite the differences in interpretation, it seems reasonable to utilize the ending conditions the authors integrate into their taxonomy development method, also for this approach and at this stage. In specific, the ending conditions Nickerson et al. (2013) introduce consist of nine objective and five subjective ones (table 6). Besides the circumstance that the features within the dimensions are not mutually exclusive—as has already been discussed in the previous paragraph—these ending conditions are met by the final version of the constructed variable space which is described in section 4.1 and displayed in figure 10.

Objective ending conditions	All objects have been examined
	No object was merged with a similar object or split into multiple objects in the last iteration
	At least one object is classified under every feature of every dimension
	No new dimensions or features were added in the last iteration
	No dimensions or features were merged or split in the last iteration
	Every dimension is unique and not repeated
	Every feature is unique within its dimension
	Each cell (combination of features) is unique and is not repeated
	Dimensions contain mutually exclusive and collectively exhaustive features (this condition is not met by the framework at hand)
Subjective ending conditions	Conciseness: with 4 dimensions and 9 sub-dimensions the framework appears to be meaningful without being overwhelming
	Robustness: the framework contains enough dimensions and features to clearly differentiate the objects of interest
	Comprehensiveness: the framework can classify all objects included in the random sample
	Extendibility: new dimensions or a new feature of an existing dimension can be easily added when new types of objects appear
	Explanatory power: the framework contains dimensions and features that do not describe every possible detail of the objects but provide useful explanations of the nature of the objects under study

Table 6. Objective and Subjective Ending Conditions. Based on Nickerson et al. (2013).

3.1.2 Phase 2: Cluster Analysis

To address the thesis' research question and identify existing circular business model types, in a second phase, the obtained data were further examined using cluster analysis. According to Sarstedt & Mooi (2011, 238), "cluster analysis is a convenient method for identifying homogenous groups of objects called clusters. Objects (or cases, observations) in a specific cluster share many characteristics, but are very dissimilar to objects not belonging to that cluster." Given this partitioning ability, cluster analysis is commonly applied in studies aiming at the formation of taxonomies (Hair et al., 2014), and Hartmann et al. (2016), Täuscher & Laudien (2018) and Remane et al. (2016) demonstrate that it works well in the context of business models. Cluster analysis can be divided into several steps whereby the thesis at hand broadly adopts the six-step procedure by Hair et al. (2014). While figure 6 provides a brief overview of these steps, the following subsections elaborate on the different choices made. Step five and six are thereby being discussed together.

Step 1: Research objective & variable selection	• Selection of variables:
	    • Definition of approximate number of variables (based on sample size and benchmarking): around 7
	    • Elimination of variables for which sufficient data quality cannot be ensured
	    • Assessment for multicollinearity and elimination of variable combinations with a phi-coefficient >= 0.7
	    • Elimination of variables that were of minor conceptual interest (e.g. given the research objective)
	    • Iteration of clustering procedure with different variable combinations (evaluation criteria in steps 5+6)

Step 2: Research design issues	• No data standardization required due to binary data set
	• Outlier detection during sample construction and via dendrogram in the fourth step
	• Determination of suitable similarity measure:
	    • Definition of data type: non-metric, symmetric
	    • Measurement of clustering performance via cophenetic correlation coefficient c
	    • Resulted in the selection of *Rogers-Tanimoto* (c = 0.7984)

Step 3: Assumptions	• Measures to increase confidence in representativeness of the sample (see phase 1):
	    • Pre-processing of data
	    • Benchmarking of other taxonomy studies
	    • Randomized sampling process via atmospheric noise
	• Measure to reduce potential impact of multicollinearity (see step 1):
	    • Elimination of variable combinations with a phi-coefficient >= 0.7

Step 4: Deriving clusters	• Application of hierarchical and non-hierarchical clustering techniques whereby the former was used to determine the number of clusters and cluster seeds for the latter
	• Selection of clustering algorithms:
	    • Hierarchical clustering (based on cophenetic correlation coefficient): average-linkage
	    • Non-hierarchical clustering (based on conceptual considerations and similarity measure): k-medoids
	• Implementation using existing python packages and modified code by Bauckhage (2015)

Steps 5 + 6: Validation & interpretation	• Interpretation and labeling of technical cluster centroids • Review of descriptive cluster statistics • Comparison with existing circular business model classifications • Performance of stability tests using different clustering algorithms (k-means, k-means++) as well as sample splitting. Results were interpreted based on guideline provided by Hair et al. (2014) • Calculation of silhouette coefficient s (s = 0.53 for final cluster solution indicates reasonable partitioning)

Figure 6. Overview of Phase 2: Cluster Analysis. Based on Hair et al. (2014).

Step 1: Research Objective and Variable Selection

The process outlined by Hair et al. (2014) starts with the identification of the research's objective and the selection of variables. As the former has already been stated at the beginning of this chapter, it is not further discussed at this point. Instead, the focus is set on the selection of clustering variables that represent the objects to be clustered. According to Ketchen & Shook (1996, 443) "choosing the variables along which to group observations is the most fundamental step in the application of cluster analysis, and thus, perhaps the most important." However, as specific approaches differ there does not seem to be a definitive answer on how to exactly choose the variables. Hence, in practice often a multitude of different approaches is combined (Sarstedt & Mooi, 2011). This is also the case in the business model taxonomy studies conducted by Hartmann et al. (2016) and Täuscher & Laudien (2018). Against this background and similar to Täuscher & Laudien (2018), the thesis at hand drew on a combination of conceptual and experimental techniques in order to select suitable clustering variables. Thereby, following Sarstedt & Mooi (2011), the sample size was used to provide a rough indication regarding the number of variables to choose. Based on an equation cited in Sarstedt & Mooi (2011) and originally proposed by Formann (1984)—according to him the relationship between sample size (n) and number of clustering variables (m) can be expressed as $n>=2^m$—as well as practical insights from the studies by Hartmann et al. (2016) and Täuscher & Laudien (2018), the thesis' sample size (n=100) indicated to experiment with around six to nine variables.

To further guide the selection process, the variables were checked on three criteria. First, following Sarstedt & Mooi's (2011) advice to select only variables for which sufficient data quality can be ensured, variables that had been marked during the coding process as being difficult to evaluate—for instance, this particularly concerned variables in the *partners and stakeholders* subdimension—were eliminated from the set of variables to experiment with. Secondly, to prevent cluster results from being skewed due to the impact of multicollinear variables— "multicollinearity acts as a weighting process not apparent to the observer but affecting the analysis nonetheless" (Hair et al., 2014, 437)—all variables were examined for substantial collinearity. Sarstedt & Mooi (2011) suggest determining a potential impact by running a bivariate correlation analysis using *Pearson's R* and checking for values above 0.9. However, as the obtained data is coded in binary, the phi-coefficient was used as a measure of association between the variables (see Gravetter & Wallnau, 2013). While in contrast to Pearson's R the phi-coefficient only attains positive values between 0 and 1, it can be interpreted in a similar way with values between 0.7 and 0.89 indicating a strong and values above 0.89 indicating a very strong relationship (Hinkle et al., 2003). Given this benchmark, a strong association was detected in four cases and particularly concerned the relation between resource value retention activity features and features of the environmental impact dimension. Since factor analysis as a potential approach to account for multicollinearity bears several disadvantages (see Sarstedt & Mooi, 2011) and the number of clustering variables to be selected is being constrained by the sample size, as a consequence the identified combinations of variables with strong similarities were excluded from the experimentation process. Thirdly, following Hair et al. (2014), conceptual considerations were undertaken to further narrow down the remaining variables. Based on the previous variable space creation and coding phase, particularly features in the *value creation and resources value retention* as well as the *value capture* dimensions appeared to be characteristic for clustering circular business models. Using the target range of variables to be selected, the remaining 16 variables were then clustered with the algorithms described below and evaluated based on the validity criteria described in step 5 and 6. This approach resembles wrapper models that are used for feature selection in data mining applications (see Aggarwal, 2015) and finally resulted in the selection of the seven independent variables outlined in section 4.2.

Step 2: Research Design Issues in Cluster Analysis

Following Hair et al. (2014), the second step in cluster analysis concerns sample size, outlier delectation, similarity measures and data standardization. The latter can thereby be neglected as the thesis' dataset only contains binary values so that, per definition, there is no sensitivity to differing scales among the variables. The issue of sample size has already been discussed to a large extent in phase 1 of the research approach. However, the discussion can be complemented with regards to the detection of outliers. In specific, it can be argued that the rather small sample size of n=100 provides sufficient representation as due to the thesis' interest in the formation of relatively generic groups it is less important to differentiate between outliers and representatives of smaller groups. Consequently, besides non-representative outliers, outliers that are representative but do not represent significant segments within the population and with regards to the research objective, are to be removed as they would otherwise distort the clustering structure. As described in phase 1, to prevent non-representative outliers from influencing the clustering process, the sample was constructed in such a way that non-representative observations were already filtered before starting the clustering. In contrast, representative observations of insignificant segments could only be identified during clustering. In specific, such observations reveal themselves graphically in the dendrogram of a hierarchical cluster analysis by forming isolated branches (Soman et al., 2006). As depicted in appendix 1, in the present analysis, this turned out to be the case for one of the sample companies which was subsequently removed from the sample but will be discussed when interpreting the results of the analysis in section 4.2.

Finally, the question of how object similarity should be measured needs to be answered. According to Hair et al. (2014), there are three different forms of similarity measures—correlational measures, distance measures and association measures. While distance measures are the most popular, they are only recommended to use with metric data inputs (Hair et al., 2014; Sarstedt & Mooi, 2011). If the variables' values are non-metric such as in this thesis' dataset, association measures provide a more suitable option as they express the degree of agreement or matching between a pair of variables (Hair et al., 2014; Sarstedt & Mooi, 2011). Within the group of association measures, it is further differentiated between symmetric and asymmetric measures (Tamasauskas et al., 2012). In the case of binary data, symmetric association measures are used when the matching outcomes are equally valuable and asymmetric association measures are preferred when there is a preference for one of the outcomes. Following Hartmann et al. (2016), in the given context of circular business models it can be assumed that values carry the same weight as both business models that have specific feature (represented by a "1") as well as business models that lack a specific feature (represented by a "0") can be understood to have something in common. Hence, only symmetric association measures were taken into consideration when selecting a similarity measure. Two symmetric association measures available in *Python's SciPy* package are *Rogers-Tanimoto* and *Matching*. As cluster solutions tend to differ based on the similarity measure and clustering algorithm chosen, it is recommended to experiment with different combinations (Hair et al., 2014). Following Bonaccorso (2019), the cophenetic correlation coefficient—which indicates how faithfully the final number of clusters in a hierarchical cluster analysis preserves the pairwise associations of the original data points—was calculated to evaluate the best performing similarity measure/clustering algorithm combination. Applying the *SciPy* function *cophenet* revealed the *Rogers-Tanimoto* association measure in combination with *average linkage* to be the highest performant for the given dataset with a cophenetic correlation coefficient of 0.7984.

Step 3: Assumptions

The third stage in Hair et al.'s (2014) cluster analysis procedure is closely related to the first two steps as it focuses on the representativeness of the sample and multicollinearity among selected variables. While cluster analysis as a non-statistical inference technique makes it difficult to ensure that a sample is truly representative, there are measures that help to increase confidence in it. To address potential issues regarding data collection, the data of the initial dataset was obtained from a network dedicated to the Circular Economy and thoroughly pre-processed. Further, to create benchmarks for sufficient sample sizes, the thesis reviewed and evaluated similar taxonomy studies. Lastly, researcher bias in the selection of sample companies was reduced by randomizing the sampling process via atmospheric noise. Regarding the potential issue of multicollinearity, measures have been mainly undertaken during the variable selection process. As described above, the impact of multicollinear variables was reduced by assessing the relationship between variables using the phi-coefficient and only selecting variables without strong associations. Figure 7 provides the phi-coefficients for the chosen variables. As can be seen, there is no variable combination with a phi-coefficient greater than 0.69 which according to Hinkle et al (2003) would indicate a strong or in the case of values above 0.89 a very strong relationship.

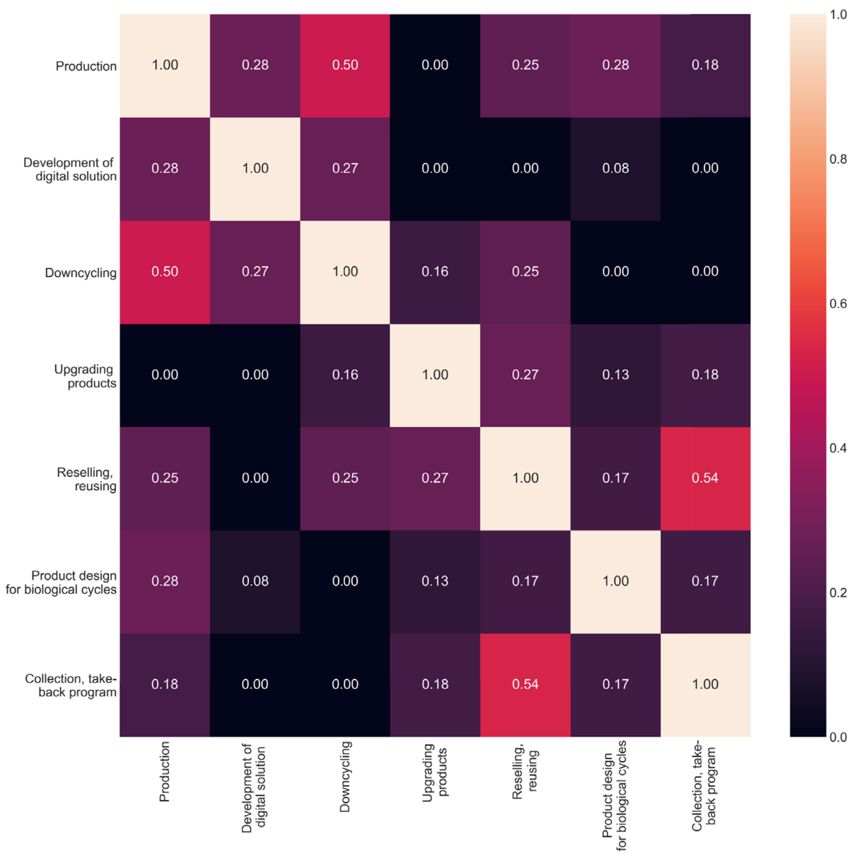


Figure 7. Phi-coefficients of Cluster Variate.

Step 4: Deriving Clusters and Assessing Overall Fit

Having chosen the similarity measure and addressed underlying assumptions, the thesis now turns to the selection of clustering algorithms and the number of clusters to be formed. Based on the recommendations by several researchers (e.g. Hair et al., 2014; Sarstedt & Mooi, 2011; Milligan, 1980; Punj and Stewart, 1983) and practical applications in the taxonomy studies by Remane et al. (2016) and Täuscher & Laudien (2018), a combination of hierarchical and non-hierarchical techniques is chosen. In specific, hierarchical clustering is performed in order to determine the appropriate number of clusters and to identify suitable starting points for a non-hierarchical clustering procedure that then optimizes the final cluster solution in a second step. According to Milligan (1980), in this way the disadvantages of the hierarchical clustering methods that include the tendency to reward outliers and the disallowance of switching cluster membership in the process are compensated by the strengths of non-hierarchical clustering methods whereby the selection of non-random seed points and the determination of the number of clusters to be formed ensure that the benefits of non-hierarchical clustering methods can be realized.

Hierarchical clustering. For hierarchical clustering, the agglomerative approach was followed. As Han et al. (2011, 449) explain, "the agglomerative approach, also called the bottom-up approach, starts with each object forming a separate group. It successively merges the objects or groups close to one another, until all the groups are merged into one (the topmost level of the hierarchy), or a termination condition holds." As there are different ways to measure similarity between the individual observations, there are also several techniques to determine the similarity between the multiple-member clusters that form in the process. As briefly outlined earlier, the average linkage procedure—in combination with the *Rogers-Tanimoto* association measure—proved to be the highest performant hierarchical clustering algorithm for this thesis' dataset and research objective. Using average linkage, "the similarity of any two clusters is the average similarity of all individuals in one cluster with all individuals in another" (Hair et al., 2014, 441) which means that the agglomerative clustering algorithm minimizes average inter-cluster similarity to generate cluster solutions (Bonaccorso, 2019). This set of cluster solutions can be illustrated by a dendrogram. Figure 8 depicts the dendrogram that shows the arrangement of clusters created by applying the average linkage procedure to the seven selected variables of the 99 observations that have remained after outlier removal. The whole process was implemented using the *hierarchy* module available in SciPy's clustering package.

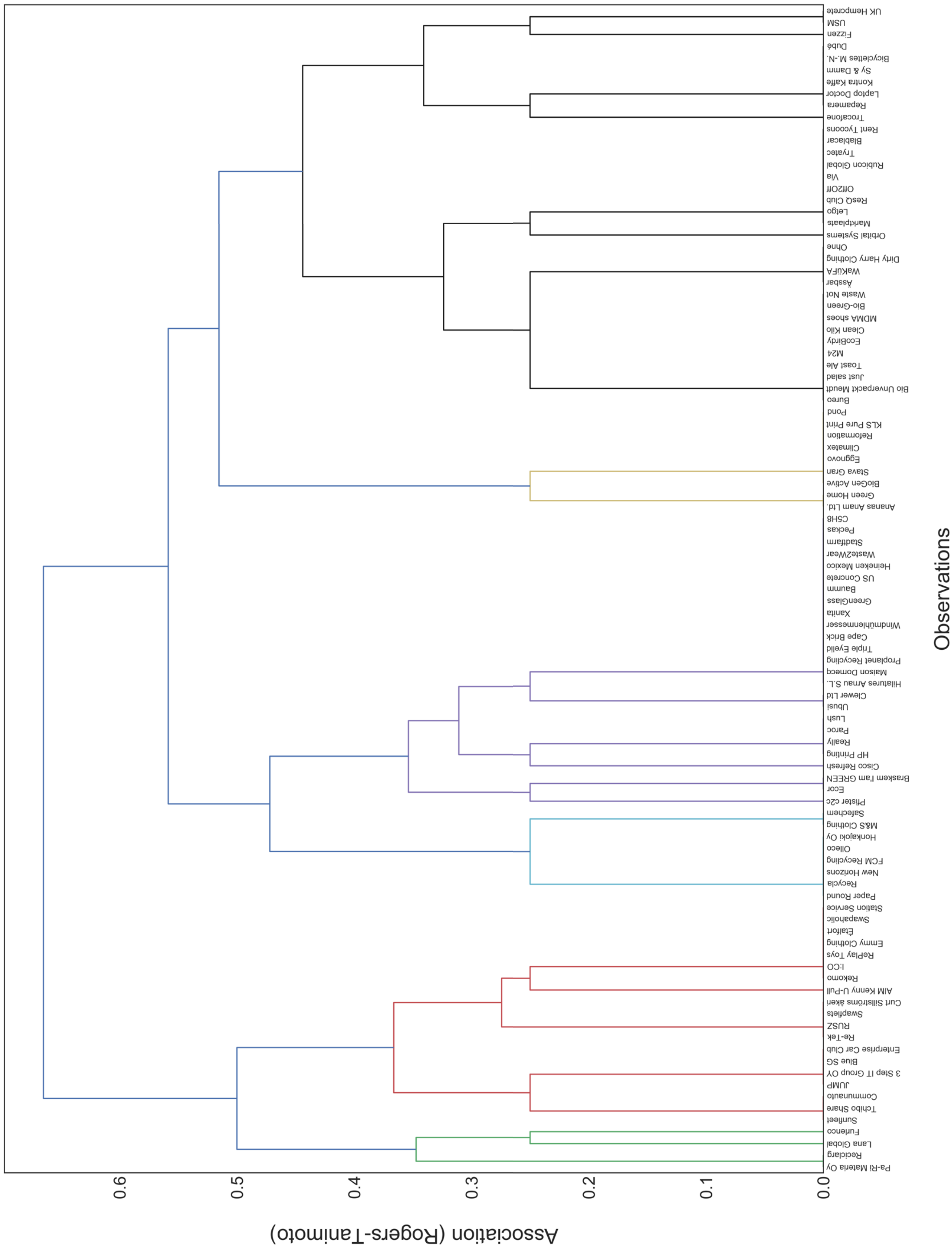


Figure 8. Dendrogram of Hierarchical Cluster Analysis.

When it comes to determining an appropriate number of clusters that represent the sample's data structure, it is generally suggested to apply a blend of different techniques as there is no single technique providing high reliability (Hair et al., 2014; Ketchen & Shook, 1996). A relatively basic technique is to visually evaluate the dendrogram (Ketchen & Shook, 1996). In specific, this is done by searching for relatively large "jumps" in similarities before clusters are merged together (indicated by long, uninterrupted vertical lines) and then placing a horizontal line through it in order to count the number of vertical lines the new horizontal line cuts. Such a line might be drawn at an association level around 0.4 resulting in seven vertical cuts or clusters. This observation is supported by a related technique, the elbow method which "plot[s] the number of clusters on the x-axis (starting with the one-cluster solution at the very left) against the distance at which objects or clusters are combined on the y-axis" (Sarstedt & Mooi, 2011, 254). The number of appropriate clusters then reveals itself at the point where the graph flattens abruptly which corresponds to the strongest acceleration in similarity growth—or in this case association growth. While there is no particularly strong elbow to be identified in figure 9—which is not uncommon in practice and also the case in Hartmann et al.'s study (2016)—smaller elbows can be seen for 2, 7 and 14 cluster solutions whereby a solution with seven clusters is conceptually the most meaningful. Further, also the rule of thumb by Han et al. (2011) which suggests setting the number of clusters to about the square root of the sample size divided by two yields a solution around seven clusters. Lastly, experimenting with a set of different cluster numbers around seven and interpreting the solutions based on the criteria that will be outlined in steps 5 and 6 additionally strengthened the case for setting the number of clusters to seven.

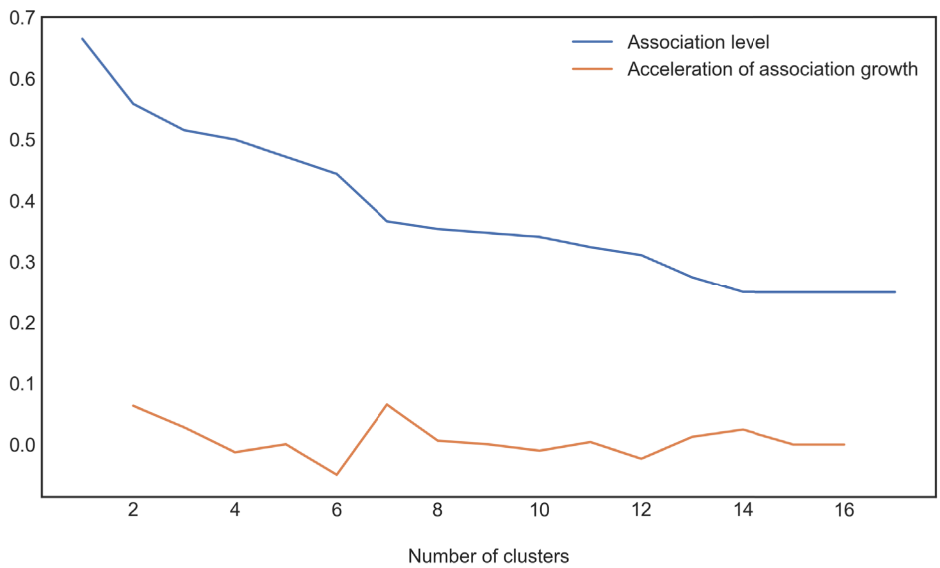


Figure 9. Elbow Diagram of Hierarchical Cluster Analysis.

Non-hierarchical clustering. To determine the final cluster solution non-hierarchical partitioning methods were employed. In contrast to hierarchical techniques, these usually start with an initial solution specified by so-called cluster seeds. The number of cluster seeds is thereby determined a priori and equals the number of required clusters. Subsequently, the observations are assigned to one of the cluster seeds and potentially rearranged several times based on an optimality criterion. This criterion as well as the specification of the seeding depends on the particular portioning method chosen. While Täuscher & Laudien (2018) as well as Remane et al. (2016) use the *k*-means procedure, Hartmann et al. (2016) apply *k*-medoids. The main difference in these techniques is that the seeds and cluster centers in *k*-medoids are always represented by an actual object from the sample while in *k*-means, by definition, the mean value of the observations in a cluster serves as a reference point (Han et al., 2011; Aggarwal, 2015). Along the lines of Hartmann et al. (2016), in the specific case of circular business models, the *k*-medoids partitioning algorithm, therefore, appears to provide more meaning to the cluster solution as the centers of the final clusters can easily be interpreted as representative circular business models. Further, the *k*-medoids algorithm has the advantage "that it can be defined virtually on any data type, as long as an appropriate similarity or distance function can be defined on the data type" (Aggarwal, 2015, 165). Consequently, the optimality criterion according to which dissimilarities between data points and corresponding cluster centroids are minimized can be based on the selected *Rogers-Tanimoto* association measure that is suitable for handling binary data. Against this backdrop, *k*-medoids was chosen as the primary partitioning algorithm in this thesis. However, as the *k*-means algorithm provides valid results in the studies conducted by Täuscher & Laudien (2018) as well as Remane et al. (2016)—despite relying on Euclidean distance and not being suited for clustering binary variables from a statistical perspective (see Sarstedt & Mooi, 2011)—it was also implemented to further validate the clustering obtained through *k*-medoids. Thereby, both algorithms were implemented in *Python*. While for *k*-means the corresponding class in the cluster module in *Scikit-learn* was used, the *k*-medoids implementation was based on the *NumPy*/*SciPy* recipe by Bauckhage (2015).

Following Hair et al. (2014), who highlight that the benefits of non-hierarchical clustering can only be realized when the seed points are selected in a non-random fashion, both procedures were thereby initialized with the cluster centroids obtained from hierarchical clustering. As these centroids were of type float they could be directly used for initialization in *k*-means. When the *k*-medoids algorithm was applied, a representative sample for each of the seven clusters resulting from the hierarchical clustering procedure had to be selected first. Further, the recipe provided by Bauckhage (2015) had to be slightly adjusted as it performs a random initialization in its original version. While the final cluster solution is described in the fourth chapter, in the following it is outlined how this solution has been selected and validated.

Steps 5 + 6: Validation and Interpretation of the Clusters

The fifth and sixth step in Hair et al.'s (2014) clustering procedure are here discussed together and concern the interpretation of the clusters as well as the cluster solution's validity. Apart from establishing confidence in the final solution, the criteria elaborated on in the following provided guidance in selecting between different cluster solutions. First, in order to confirm the clusters' overall coherence and relevance with regards to the thesis' objective, the clusters were interpreted based on their respective cluster centroids as well as a review of descriptive statistics that included the variables not involved in the clustering. Further, as part of this interpretation process, labels were assigned to each of the clusters. Following Hair et al. (2014) and Sarstedt & Mooi (2011), the ability to come up with meaningful and coherent labels thereby served as a criterion for selecting between different solutions. The labels and interpretation of the final clusters are provided in section 4.2. Secondly, in line with Groth & Nielsen's (2015) article on business model taxonomy studies, Hair et al. (2014) advise comparing the cluster solution to existing or preconceived typologies in order to assess the clusters' practical significance and potentially provide some theoretic validity. Such a comparison is performed in section 4.3 finding that almost all existing circular business model types can be expressed with the proposed taxonomy.

Thirdly, the solution's validity was further examined by testing its stability. In specific, two approaches were employed. Following Hair et al. (2014), one test involved the sample's random division into halves and their subsequent clustering, independent analysis and comparison. Following Sarstedt & Mooi (2011), in another test a different clustering algorithm—as described above, the thesis at hand used *k*-means initialized with cluster centroids obtained from the hierarchical clustering procedure—was applied on the full sample. Based on Hair et al.'s (2014) interpretation guideline, the final cluster solution was assessed as being stable given the reassignment of 15% (*k*-means in comparison to *k*-medoids) and 18% (cross-validation with divided sample) of observations, respectively. Further, the stability and reliability of the final solution were proven by generating the same centroids through various iterations with the implementation of a different seed point specification of *k*-means, k-means++. Lastly, to assess internal cluster validity in the absence of ground truth, the silhouette coefficient, which provides an indication on the clusters' densities as well as their separation (Han et al., 2011), was calculated using the *Scikit-learn metrics.cluster* submodule. For the final cluster solution, the silhouette coefficient amounted to 0.53 which indicates a reasonable partitioning of the data according to Kaufman & Rousseeuw (1990).

3.2 Limitations

Despite its merits, the outlined taxonomy development approach is not without limitations. First, there are some general limitations regarding the nature of taxonomies and the empirical data the taxonomy is based upon. With regards to the former, Nickerson et al. (2013) point out that there does not exist any *correct* taxonomy and that it is more reasonable to discuss taxonomies in terms of usefulness. This viewpoint is echoed by Baden-Fuller & Morgan (2010) who highlight that different approaches to classifications may result in different perspectives, of which each itself may reveal new aspects to look at. Consequently, as stated in the introductory chapter, this thesis does not attempt to provide a definitive answer to the question of which types of circular business models exist, but rather one that is useful and complements existing approaches. Further, while Han et al. (2011) and Lambert (2015) underline that the groupings in numerical taxonomy development are found automatically and, hence, potentially reduce researcher bias when compared to typology studies, they also stress that the approach still involves many subjective decisions. Before this issue will be discussed in more detail, it is further of importance to address general limitations with regards to the taxonomy's empirical foundations.

In specific, it has to be acknowledged that the constructed taxonomy is constraint in that it is based on a limited sample of observations drawn from a single database at a specific point in time. Among others, the sample size is limited due to the amount of manual work required to gather and codify data on the sample firms (see Hartmann et al., 2016). Moreover, although the database from which the sample has been drawn was established by a large group of people from various continents, it may still lack diversity and potentially overrepresents some circular business models while neglecting others. This limitation was potentially further aggravated by the circumstance that the sample was restricted only to those companies for which sufficient information was available in English or German.

Additionally, having predominantly been constructed in February 2018, the database only covers circular business models existent at that point in time. Consequently, in line with remarks made by Baden-Fuller & Morgan (2010), the taxonomy does not necessarily account for novel models that have been developed afterwards and, thus, may need to be updated over time. Lastly, although most likely sufficient (see Teece, 2010), information gathered on the sample firms' business models was limited to publicly available information and due to the thesis' resource constraints could not be cross-checked with external analysts or the companies themselves.

Secondly, there exist more specific limitations regarding the first phase of the research approach. As Im & Cho (2013) outline, morphological analysis ideally requires a heterogeneous group of several experts to develop the morphological matrix. The same holds true with regards to the coding process which is preferably handled by at least two independent coders of which at least one is not in involved in the research itself in order to reduce researcher bias (see Täuscher & Laudien, 2018; Hartmann et al., 2016). Additionally, confidence in the final coding can be increased through cross-checking it with a randomly selected set of companies (see Hartmann et al., 2016). However, given how the master's thesis was set up and due to time constraints, these criteria could not be fulfilled. As described, to limit the resulting bias, the construction of the variable space was conceptually grounded, and variables had been clearly defined before the final round of coding. Moreover, while the dimensions' features were not selected in a mutually exclusive manner potentially resulting in the formation of less distinctive clusters during the second phase, overall adherence to Nickerson et al.'s (2013) quantitative and qualitative ending conditions provided at least some validation to the final framework solution.

Thirdly, the clustering process involved a number of subjective decisions that may limit the validity of the final outcome. Due to this inherent subjectivity, Hair et al. (2014, 428) claim that cluster analysis "is as much an art as a science". An example provides the selection of variables which is specified entirely by the researcher and can influence resulting cluster solutions substantially (Hair et al., 2014). To combat the influence of subjectivity and prevent the formation of non-meaningful clusters, the thesis at hand thus applied a range of different techniques to the selection process most importantly including an experimental approach guided by conceptual considerations (section 3.1.2). Conceptual support also played an important role in assessing the final solution's validity. In addition, this assessment included a range of other techniques such as cross-validation with split clusters. However, while the taxonomy appeared to be stable and internally valid, its external and criterion-related validity have not or not sufficiently been tested. Following Ketchen & Shook (1996), one way to address the former would have been to draw another sample from this or a separate database and evaluate whether the initially identified cluster solution is replicated. However, due to the manual work related to the collection and coding of sample data, such a procedure would have been out of the thesis' scope. In contrast, the reasons for not further pursuing criterion-related validity which involves the implementation of significance tests with variables that have not been used in defining the clusters are slightly different. First, the variables required to assess criterion-related validity, i.e. variables that are strongly theoretical or practical supported (Hair et al., 2014) and mostly performance related (Ketchen & Shook, 1996), did not seem to be readily available. Secondly, along the lines of Groth & Nielsen (2015), testing the taxonomy with tools such as ANOVA would constitute a study in its own right with the purpose being rather to test than to develop a circular business model taxonomy. In this regard, the limitations seem to provide ample opportunities for further studies which will be specifically elaborated on in the concluding chapter.

4. Results and Discussion

With the research approach and its limitations elaborated on, the fourth chapter now presents the research findings and discusses them in the light of the reviewed literature. The chapter is thereby divided into three main parts. In the first part, the final version of the variable space is introduced particularly highlighting the features added during the empirical cycles. In the second part, the chapter then presents and interprets the generated circular business model taxonomy. Finally, the chapter concludes by comparing this taxonomy with the existing circular business model classifications reviewed in section 2.2.5.

4.1 Variable Space

The framework or variable space provides the basis to systematically describe circular business models and has been developed using existing circular business model literature as well as empirical data (see section 3.1.1). While Lüdeke-Freund et al. (2018a) create a similar framework in their circular business model typology study, the thesis at hand deliberately decided to create an own one. This is because Lüdeke-Freund et al.'s (2018a) version does not take into consideration any publications made later than 2016 and data collected from Scopus reveals that as of December 2018 about 91% of all publications for the search terms "circular business model" and "circular economy business model" are attributed to the years 2017 and 2018. Still, since Groth & Nielsen (2015) argue that existing (circular) business model frameworks are a useful starting point for the identification of variables in taxonomy studies, Lüdeke-Freund et al.'s (2018a) framework provides an important foundation to build upon. In which way it exactly supports this thesis' framework is described in the upcoming subsections whereby, for the sake of clarity the framework's dimensions and features are discussed separately.

Before this elaboration, a brief overview of the variable space—depicted in figure 10—is provided. As highlighted in the literature review and table 3, most circular business model frameworks are based on or readily adopt the ones developed by Osterwalder & Pigneur (2010) and Richardson (2008). Therefore, also the framework's four dimensions and nine sub-dimensions or components bear a close resemblance. Moreover, the variable space consists of 51 features whereby some of the features can be aggregated. Dimensions and features formed during the empirical cycles are highlighted in grey. Furthermore, in order to support variable selection, features that had been coded based on less reliable data are marked with an asterisk.

Circular Business Model Dimensions		Circular Business Model Features													
Value Proposition	*Value Proposition*	Informational Value			Environmental Value	Emotional Value			Functional Value				Financial Value		
		Customer Education	Unlocking Hidden Information	End-of-life Information		Convenience	Trust and Reliability	Other Emotional Value	Long Product Lifetime	Product Lifetime-enhancing Services	Guaranteed Performance	High or Comparable Performance/ Quality	Affordability	Efficiency-enhancing/ cost-effective Services	Income Generation
Value Delivery	*Customers*	B2B	B2C	C2C											
	Value Delivery Activities	Selling Products	Selling Product/ Service Systems	Selling Pure Services	Communicating Circular Efforts	Distribution through Own Channels									
Value Creation and Resource Value Retention	*Value Creation Activities*	Sourcing Used Supplies	Production	Development of Digital Solutions											
	Resource Value Retention Activities	Downcycling	Upgrading products	Reselling, Reusing											
	Key Supporting Activities	Design for Circularity			Co-creation, Joint Offering	Research & Development	Data Monitoring and Analysis*	Collection, Take-back Program							
		Design for Circular Production*	Product Design for Technical Cycles	Product Design for Biological Cycles											
	Partners and Stakeholders	Suppliers*	Manufacturers*	Retailers, Distributors	Forward Logistics Operators*	Reverse Logistics Operators*	Partners Performing Value Retention Activities*	Insurance Companies*	Other Partners						
Value Capture	*Revenue Streams*	Revenues from Products	Revenues from Services												
			Transaction/ usage-based Revenues	Continuous Service Revenues											
	Environmental Impact within Value Network	Resource Value Retained through Downcycling*	Resource Value Retained through Upgrading*	Resource Value Retained through Reselling/ Reusing*	Impact Savings through Feeding Biological Cycles*	Impact Savings through Displacing New Production*									

Figure 10. Variable Space.

4.1.1 Variable Space Dimensions

Following the majority of circular business model frameworks, the first dimension captures different *value proposition*s. However, in contrast to Manninen et al. (2018) and Bocken et al. (2018), the thesis does not make a specific distinction between customer and environmental value propositions in the sub-dimensions because in line with the outlined circular business model definition and Urbinati et al.'s (2017) empirical findings a circular business model can also exist without making sustainable, or more specifically circular efforts visible. Nonetheless, with the thesis' definition as the backbone of the framework, the circular business model's environmental impact should be measured. Therefore, in addition to financial *revenue streams*, *environmental impact* is added as a sub-dimension to the *value capture* dimension. In contrast to the other dimensions which focus on the firm level, environmental impact is thereby understood to capture the impact generated within a company's value network, i.e. it also accounts for activities a company outsources to partners as part of its operations. As will be seen more clearly when introducing the dimension's features, in this way the sub-dimension reflects this thesis' postulate that circular business models also describe how an organization retains resource value within its transcending system (see section 2.2.3). Moreover, in an earlier version, the value capture dimension additionally encompassed the firm's *cost structure* as a sub-dimension. However, after noticing in the empirical cycles that information on companies' cost structures is particularly difficult to obtain and, if available through annual reports, often duplicates information already presented in other dimensions, it was decided to follow Lüdeke-Freund et al.'s (2018a) framework and eliminate this sub-dimension from the variable space.

To keep the framework simple while highlighting the stakeholder network perspective and the notion that circular business models, as attributes of real firms, involve performing activities, also Lüdeke-Freund et al.'s (2018a) conceptualization of the *value creation* and *value delivery* dimensions is—with some adjustments—adopted. In specific, the components *target customers* and *partners and stakeholders* are directly integrated with the latter also reflecting Ranta et al.'s (2018) *position in the value network* component. Further, the *value delivery processes* sub-dimension is reframed to *value delivery activities* without constraining its potential to represent key customer, partner and stakeholder relationships or channels, if relevant. Similarly, the sub-dimension *value creation processes* becomes *value creation activities*. However, in contrast to Lüdeke-Freund et al.'s (2018a) framework, value creation is thereby understood in a narrower sense, only containing activities that *create* value and excluding activities that *retain resource value*—this distinction is also made later on in Lüdeke-Freund et al.'s (2018a) article but not incorporated into the authors' framework. To integrate *resource value retaining activities,* a central aspect of this thesis' circular business model understanding, the *value creation* dimension is augmented, and an additional sub-dimension is formed (figure 10).

Lastly, a sub-dimension that is not addressed by Lüdeke-Freund et al. (2018a) but present in many of the reviewed circular business model frameworks is *resources and capabilities*. However, as identified in the empirical cycles, some of the features conceptually associated with this sub-dimension, are difficult to code in binary or contain a negligible amount of information, respectively. For example, every company requires financial and human resources which is why the mere presence of the feature, represented by a "1", is not very insightful. Further, due to the vast differences in industries from which the sample companies are drawn, capital and human resource requirements vary substantially so that the issue also cannot be resolved by simply reframing the features in terms of specific thresholds. Still, other features such as capabilities in research and development might provide valuable information during the clustering and can be coded more easily. To acknowledge these capabilities while differentiating their superordinate dimension from the *resources and capabilities* one introduced in other frameworks, the component has been reframed during the empirical cycles. Ensuring terminological consistency and particularly emphasizing that features in this sub-dimension contribute to both value creation and resource value retention activities, the sub-dimension is coined *key supporting activities*.

4.1.2 Variable Space Features

This section elaborates on the dimensions' features and is organized accordingly. While the process of how the features were derived is described in detail in the research design, at this point it additionally needs to be highlighted that in the following—for the sake of simplicity—the term *product* is to be understood quite broadly and can also encompass product components and materials.

Value proposition. As shown in the framework (figure 10), circular business models offer informational, environmental, emotional, functional and/or financial value. Thereby, the latter might be expressed through the marketing of more affordable products. For instance, these can be products that have been repaired, refurbished, remanufactured or recycled

(Lüdeke-Freund et al., 2018a) or used components and materials that are offered as production inputs (Ranta et al., 2018). A financial incentive might also be generated through services that enhance a product's efficiency (Nußholz, 2018), offer underutilized products on a pay-per-use basis (De Angelis, 2018) or lead to a reduction in absolute costs such as waste management services (Ranta et al., 2018). When the take-back of goods is not offered as a service but financially incentivized, for instance through a buy-back program (Lieder et al., 2017), the value offered is rather *income generating*. This is also frequently the case on matchmaking platforms (Nußholz, 2017b) where users can sell their used items. At this point, it is further worth highlighting that for business models with peer-to-peer interactions value propositions for both sides were considered in the coding procedure.

Similar to the offering of financial value, the offering of functional value can be divided into sub-features. One of these is the proposition of *long product lifetime* which, in turn, can be expressed through the offering of superior product durability (Lüdeke-Freund et al., 2018a), enhanced reusability (Lewandowski, 2016), designed-in reparability (Nußholz, 2018) or product upgradability (De Angelis, 2018). Functional value can further be provided through product lifetime-enhancing services such as maintenance (Oghazi & Mostaghel, 2018) or spare part services (Nußholz, 2018). Thirdly, guaranteeing the performance of a product by offering product-/service-based results (Lüdeke-Freund et al., 2018a) or free repairs (Mentink, 2014) is another form of functional value whereas basic warranty promises are intentionally excluded. When not advertising performance guarantees, businesses frequently highlight the high quality of their products or present them as having a comparable performance. Hence, this feature was added during the empirical cycles.

The emotional value feature of the value proposition dimension can be characterized through the offering of convenience (De Angelis, 2018)—for example, in form of the recovery of unwanted equipment (Whalen et al., 2018) or the temporary access to products (De Angelis, 2018)—as well as trust and reliability or other emotional aspects such as an offering's newness or a product's design (Hofmann et al., 2017). Finally, a company may also highlight the environmental value of its offering (Nußholz, 2018) or provide informational value. The latter can be expressed by educating customers (Lüdeke-Freund et al., 2018a)—this mainly concerns consultancy services and workshops—unlocking and potentially selling hidden information (Antikainen et al., 2018) or providing information on products' end-of-life processes, which is common in e-waste recycling companies.

Value delivery. The described value is delivered to customers—who are categorized into business-to-business (B2B), business-to-customer (B2C) and costumer-to-customer (C2C) market segments—through selling products, product-service systems or pure services. On the one hand, product-service systems encompass the provision of access to a product's functionality as well as product-based services and results (Lüdeke-Freund et al., 2018a). On the other hand, following Tukker (2004), product-service systems also comprise product-oriented services in which the business offers value-adding services in addition to selling its products. For instance, these can be product-related maintenance contracts, financing schemes, consultancy services as well as take-back agreements. Regarding the latter, the term *agreement* has to be pointed out as businesses can also operate indirect take-back programs. This is the case when the business acquires used items from customers that it then sells again thereby basically giving customers the opportunity to resell their items to the company after use. The third feature, *pure services,* comprises the connection of suppliers and customers (Lüdeke-Freund et al., 2018a), the virtualization of products (Lewandowski, 2016) as well as the installation, maintenance and repair of products (Nußholz, 2017b), among others. Moreover, value delivery activities may include the communication of circular efforts through information on the company's website and other channels (Urbinati et al., 2017), direct sales (Nußholz, 2018) or the creation of community-based relationships with customers (Nußholz, 2018). Lastly, companies can decide to deliver the offered value through own distribution channels, such as online shops (Goyal et al., 2018) or rather draw on established retailers and external distribution networks.

Value creation and resource value retention. Value creation activities are mainly characterized by the production of new products or input materials (Nußholz, 2018) which then provide the stocks to be managed in the technical and biological cycles of the Circular Economy. Interconnected with production activities is the sourcing of supplies. In circular business models, the usage of used products as inputs thereby plays an important role (Lüdeke-Freund et al., 2018a). A third feature that has been added during the empirical cycles is the development of digital products or services which, for instance, can contribute to the virtualization of goods (Lewandowski, 2016). While, apart from the latter, value creation activities are mainly concerned with the creation of stocks, resource value retention activities focus on the management of these stocks. Features associated with resource value retention activities are primarily organized around the above-mentioned value retention option framework by Reike et al. (2018) (table 2). Consequently, the recycling of products

(Lüdeke-Freund et al., 2018a) is categorized as a downcycling activity while refurbishing, remanufacturing, maintenance and repairing activities (Lüdeke-Freund et al., 2018a) are summarized in the *upgrading products* cluster. However, the third category only comprises the reselling—including rental and reuse—of products (Lüdeke-Freund et al., 2018a). This is because activities that contribute to the reduced consumption of products and make customers refrain from buying are mostly discussed within the value creation, value delivery and key supporting activities—in particular, these are activities revolving around product design, the addressed virtualization of goods and customer education.

The *key supporting activities* sub-dimension reflects additional activities that are performed in order to contribute to the creation and retention of value. One such activity is to design for circularity. First, this includes the design of circular products (Lüdeke-Freund et al., 2018a). According to Sumter et al. (2018, 1), the effectiveness of circular product design is largely depended on a firm's "ability to anticipate how the circular offering will evolve over multiple lifecycles." Thus, to be designed for circularity the product design has to be intentional and depending on the offering the product may need to be designed for longevity, repair, refurbishment and remanufacturing (Ranta et al., 2018) or upgradability, adaptability, dis-and reassembly (Bocken et al., 2016). However, given the differentiation between technical and biological cycles (Ellen MacArthur Foundation, 2015), products may also be specifically designed for biological cycles. For instance, this includes biodegradable products that are designed in such a way that they can be fed back safely into nature at the end of their lives. Secondly, the *design for circularity* feature also comprises certain cleaner production practices (Sousa-Zomer et al., 2017) such as the development of circular production systems in which by-products of the main production process are used to power the production itself. These practices are summarized in the *design for circular production* sub-feature. Additionally, Wastling et al. (2018) discuss the importance of involving customers in the initial design of circular products. The relevance of co-creation is also echoed by Hofmann et al. (2017), and several authors (e.g. Lewandowski, 2016; Oghazi & Mostaghel, 2018; De Angelis, 2018) point out the central role of establishing and managing a collaborative value network. However, since the informational basis for evaluating the strength of such a network during the coding process appeared to be too small, it was decided to narrow the feature scope to the explicit co-creation or joint offering of products or services with customers and partners. Another feature concerns research and development activities (Nußholz, 2017b) which may result in new technologies to retain resource value, enable the production of biodegradable products or enhance production processes that reduce material leakage and emissions (Nußholz, 2017a). Moreover, a feature that underlies many of the stated activities is *data monitoring and analysis*. The ability to keep track of products and analyze customer data may help to predict product return flows (Lathi et al., 2018), provide and optimize value retention activities (Bressanelli et al., 2018), improve product performance (Lewandowski, 2016), enhance energy efficiency (Heyes et al., 2018) or facilitate collaboration within the partner network (De Mattos & de Albuquerque, 2018). However, due to its ubiquitousness, the feature has only been marked during the coding process when it was key to the organization's circular business model, i.e. the basic tracking of website or app usage as well as production processes has not been taken into consideration. Lastly, a feature that provides a direct link between value creation and value retention and is particularly highlighted by Lewandowski (2016) is the operation of a *take-back and collection program*. The feature encompasses both direct and indirect take-backs. While the former is characterized through an agreement that the company recaptures the products at the end of their life or rental (Nußholz, 2017a), the latter represents cases in which a company generally collects or acquires used products in order to resell them thereby also offering customers a channel to return their goods.

In this way, customers may also turn into suppliers of secondary products and raw materials. Other suppliers include product collectors (Lüdeke-Freund et al., 2018a), technology providers (Antikainen & Valkokari, 2016), and raw materials extractors (Hofmann et al., 2017), among others. Moreover, partners and stakeholders may comprise manufacturers (Lüdeke-Freund et al., 2018a) that create commissioned products, retailers and distributors (Lüdeke-Freund et al., 2018a), insurance companies (Whalen et al., 2018) or forward and reverse logistic operators—both of which have been added during the empirical cycles. Additionally worth highlighting are partners that perform value retention activities such as maintenance and repair services or enable the recycling of products at the end of their lifecycle (Nußholz, 2018). As these few examples already indicate, the network of partners and stakeholders in circular business models can be vast. In order to keep the framework generic enough, the thesis thus follows Lüdeke-Freund et al. (2018a) by introducing a *other partners* option including non-governmental organizations (Nußholz, 2018), policy makers (Oghazi & Mostaghel, 2018), research organizations (Nußholz, 2017b), governmental institutions, associations, marketing agencies and design studios, among others.

Value capture. Revenue streams can be split into revenues generated from product sales and revenues generated through services. Apart from the sales of products (Hofmann et al., 2017) the former thereby also includes sales of by-products (Bocken et al., 2016) and replacement parts (Nußholz, 2018) as well as income derived from constructs in which product revenues are shared (e.g. franchising). In contrast, more challenging to define are revenues generated through services as especially in the B2B realm there is little information available on specific contract terms. Hence, revenues from services are generically sub-divided into transaction/usage-based revenues and continuous service revenues. While the former entails pay-per-use pricing models (Lewandowski, 2016) such as pay-per-click advertisements, non-subscription-based rental agreements, brokerage fees (Hofmann et al., 2017) and payments for service units such as workshops, the latter comprises subscription-based rentals (Lewandowski, 2016), other types of subscription fees, annual operation and maintenance as well as performance-based contracts (De Angelis, 2018).

In line with the provided definition of circular business models, features in the environmental impact sub-dimension are primarily developed in accordance with the introduced notion of value retention activities as a proxy for environmental impact (section 2.2.3). Hence, main features are the resource value retained through downcycling, upgrading and reselling. The former is characterized as a *material value retention* effect by Lüdeke-Freund et al. (2018a) and largely corresponds to Bocken et al.'s (2016) *closing loop* and *narrowing loop* effects, while both of the latter match with Lüdeke-Freund et al.'s (2018a) *product value retaining* and Bocken et al.'s (2016) *slowing loop* effects. In line with the arguments made when discussing value retention activities as well as defining *Circular Economy*, the reduction and refuse options of Reike et al.'s (2018) value retention framework are intentionally highlighted. *Impact savings through displacing new production* (Whalen et al., 2018) is the feature that captures impact from the reduction of consumption—for instance, through the virtualization of products or the offering of product access—the refusal from buying—for example, through the promotion of sufficient lifestyles—as well as efficiency gains during product usage—given that there is no rebound effect. While Lüdeke-Freund et al. (2018a) stress that the refusal from buying is not covered by their approach, it is considered in Bocken et al.'s (2016) *slowing loop* effect. Further, the reduction of consumption corresponds to the *intensification* and *dematerialization* effects Geissdoerfer et al. (2018) add to the closing, slowing and narrowing effects outlined in Bocken et al. (2016). Also, note that the upgrading and reselling of products may generate impact savings by displacing new production, too, but that these savings are already fully accounted for within the second and third feature. Furthermore, as Reike et al.'s (2018) framework does rather focus on technical stocks than biological flows a fifth feature, *impact savings through feeding biological cycles,* has been added during the empirical iterations.

Lastly, given the complexity of environmental impact assessments, a few cautionary notes have to be made. First, it has to be highlighted again that the presented features provide a proxy to assess a circular business model's environmental impact and should thus be merely seen as a useful tool in the light of this thesis' purpose. To capture the environmental impact dimension more accurately, other tools and approaches such as life-cycle assessments are needed (Scheepens et al., 2016) and also rebound effects have to be accounted for (Zink & Geyer, 2017). In other words, when the sample companies are evaluated, they are evaluated based on *potential* impact savings not based on whether an actual impact saving has been achieved. Secondly, recall that based on the thesis' circular business model definition the environmental impact dimension is understood to capture the impact generated within a company's value network, i.e. it also accounts for activities a company outsources to partners as part of its operations. Thirdly, there may be many other effects that are not captured by the features such as a decrease in pollution due to clean material cycles (Manninen et al., 2018) as well as other internal impact savings that are not related to water recycling or energy recovery—the latter two are narrowing loop effects and part of the first feature.

4.2 Circular Business Model Taxonomy

With the framework established, cluster analysis was performed following the process outlined in the third chapter. In this section, the final cluster solution will be described, interpreted and compared to the existing typologies introduced in section 2.2.5. The cluster variate of this solution, that is the set of variables that has been selected in order to represent the observations during the analysis, consists of the features *production*, *development of digital solutions*, *downcycling*, *upgrading products*, *reselling and/or reusing*, *product design for biological cycles* as well as *collection and take-back program*.

All companies encompassed in the sample on which cluster analysis was conducted are listed in appendix 2. Similar to the database it was drawn from, the sample is mainly comprised of companies from Europe (60%), followed by firms from North America (16%), Latin America (9%), Asia and Oceania (8%) and Africa (4%). About half of the businesses are small and mid-sized enterprises, 27% are startups, 12% multinational corporates and 9% national corporates. This distribution also aligns well with the one in the original database whereby businesses that were initially labeled "private sector (undefined)" have been assigned to one of the four categories—to further ensure a high degree of coherence in the labeling, the businesses that had already been assigned were rechecked, in addition. Moreover, most of the companies in the sample operate in the fashion industry (18%), followed by a range of other industries including electronics and appliances (11%), furniture (9%), food and beverages (9%), other consumer goods (9%), mobility (8%), industrial services (7%), materials (6%) and construction (5%), among others. Thereby, it has to be noted that in order to provide more nuanced information these industry labels differ from the ones in the original database. Also, as with many industry classifications, there might be overlaps among the categories. Hence, the provided distribution should be primarily regarded as a rough reference point.

4.2.1 Analysis of Technical Cluster Centers

As stated above, a critical part of the clustering process is the analysis of technical cluster centers and their labeling (Hair et al., 2014). The cluster solution displayed in table 7 comprises seven clusters with unique centers whereby, as can be seen through the descriptive statistics in table 8, not every company related to a specific cluster necessarily matches all values of the respective cluster's technical center. While most of these deviations are negligible and naturally also present in the business model taxonomy studies that served as a reference point for this thesis (Lüdeke-Freund et al., 2018a; Hartmann et al., 2016; Remane et al., 2016), the ones that appear to be more profound are particularly highlighted in the following analysis. Other than that, the descriptive statistics will be primarily reviewed in the subsequent section 4.2.2.

Circular Business Model Sub-dimensions	Circular Business Model Features	Technical Cluster Centers						
		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Value creation activities	Production	1	1	1	0	0	0	0
	Development of digital solutions	0	0	0	0	0	0	0
Resource value retention activities	Downcycling	0	1	1	0	0	1	0
	Upgrading products	0	0	1	1	0	0	0
	Reselling and/or reusing	0	0	1	0	1	0	0
Key supporting activities	Product design for biological cycles	1	0	0	0	0	0	0
	Collection and take-back program	0	0	1	0	1	1	0

Table 7. Technical Cluster Centers of *k*-medoids Analysis.

A first look on the technical centers reveals that the clusters can be more or less evenly split between circular business models in which the production of goods presents a key value creation activity and models in which companies do not produce own goods. Against the backdrop of this thesis' Circular Economy and circular business model definitions, which both highlight the retention of resource value along the lines of Reike et al. (2018), the former can be regarded as resource value creators. However, while the creation of resource value as such is rather inherent to a linear economy, circular business models have to feature additional characteristics. In the case of the first cluster, the products created are mainly cradle-to-cradle certified and can be fed back safely into biological cycles. Hence, this cluster will be referred to as *biological nutrient-based value creation.* The second cluster is relatively large comprising a total of 20 companies. Consequently, it is not surprising that it is more diverse. This diversity is reflected in the way the companies downcycle resources including the repurposing of used products or components as well as the recovery of energy and nutrients in the production process. While the different ways of downcycling will be elaborated on when describing each cluster in more depth in the next section, it can be noted that, in general, the downcycling process is interwoven with the creation of new resource value. As the by-products and products that are downcycled are often referred to as "waste" in everyday speech, the second cluster is named *waste-to-resource value creation*. The remaining cluster in which the production of goods presents a key value creation activity is at the same time the one that is based on the fewest sample companies. Forming six out of eight times when testing different centroid combinations as seeds in the *k*-medoids clustering procedure, it is also one of the clusters in which the centroid is less distinctive. However, this mainly concerns the cluster's downcycling aspect. What characterizes this type of circular business models is that resource value is not only created but also managed through the combination of higher order value retention activities and collection or take-back systems. Consequently, the third cluster is labeled *resource value creation and management*.

The next two clusters represent circular business models in which companies do not create resource value themselves but are directly involved in the retention of this value. First, the fourth cluster encompasses models that specialize in providing services to refurbish, remanufacture, maintain and/or repair used goods and is, therefore, named *resource value extension*. Secondly, the technical centroid of the fifth cluster—which comprises 26 companies—mainly reflects models that rent or collect and resell used items. If a product is rented, the service is often complemented with repair and maintenance services which, however, are not a defining characteristic of this cluster. Further, although the cluster includes a number of companies, such as car-and bike-sharing firms, that only make their product-service system available via an application, the same holds true with regards to the development of digital solutions. As stated earlier, with the thesis aiming to identify rather generic types of circular business models, such deviations from the cluster centroids have to be accepted as long as the respective cluster still forms a homogenous entity and can be labeled distinctively. This is the case here as the cluster could also be named *resource value management* even if the described features were part of the cluster's centroid.

The technical center of the sixth cluster represents circular business models in which used goods are collected and subsequently recycled in order to provide secondary supplies for the production of new products as well as models in which biomass is collected and turned into biofuels or fertilizers, among others. While the cluster also contains a relatively high number of companies that produce their own products, these companies can be distinguished from the ones in the second cluster as they all have a take-back program in place so that they recycle their own products. Still, as the table in appendix 2 shows, the clustering procedure based on *k*-means categorizes these companies differently demonstrating some overlap among the clusters. Eventually, the cluster's technical center has shown to be stable, though, as it continuously formed regardless of the clustering approach. Given this circumstance, the cluster is labeled *resource collection and downcycling*. In contrast, the seventh cluster clearly differentiates itself from the others. As the cluster centroid indicates, the cluster encompasses models that are neither creating any resource value nor managing any of this value themselves. Rather, they take the role of orchestrators and enable others to perform resource value creation and retention activities. While there are several companies in this cluster that do so by developing a digital platform that connects buyers and sellers of used items, the cluster is broader which is why the cluster will be referred to as *orchestration*.

All clusters will be elaborated on in the next section using descriptive statistics as well as specific examples. The analysis of the technical cluster centers itself concludes with an illustration that summarizes the findings. The overview depicted in figure 11 thereby takes up Pearce & Turner's (1990) initial Circular Economy conceptualization that illustrates the environment's function as a waste sink, i.e. its capability to take in and convert part of the consumed resources back into useful resources over time. While Pearce & Turner (1990) introduce recycling—which is grouped into the *downcycling* feature—as a way to take load off the environment, figure 11 highlights how other types of circular business models can support the retention of resource value. Moreover, the graphic visualizes the overlap between the second and the sixth cluster. While this overlap is represented by the crisscross blue lines, the overhanging part of the sixth cluster symbolizes collection activities—the same is true for the fifth cluster. Lastly, the illustration emphasizes the observation by Mentink (2014) that companies do not necessarily have to employ fully circular business models (cluster 3) but that different circular business models can also be networked in order to close the loop. This idea will be further outlined when comparing the taxonomy to existing classifications.

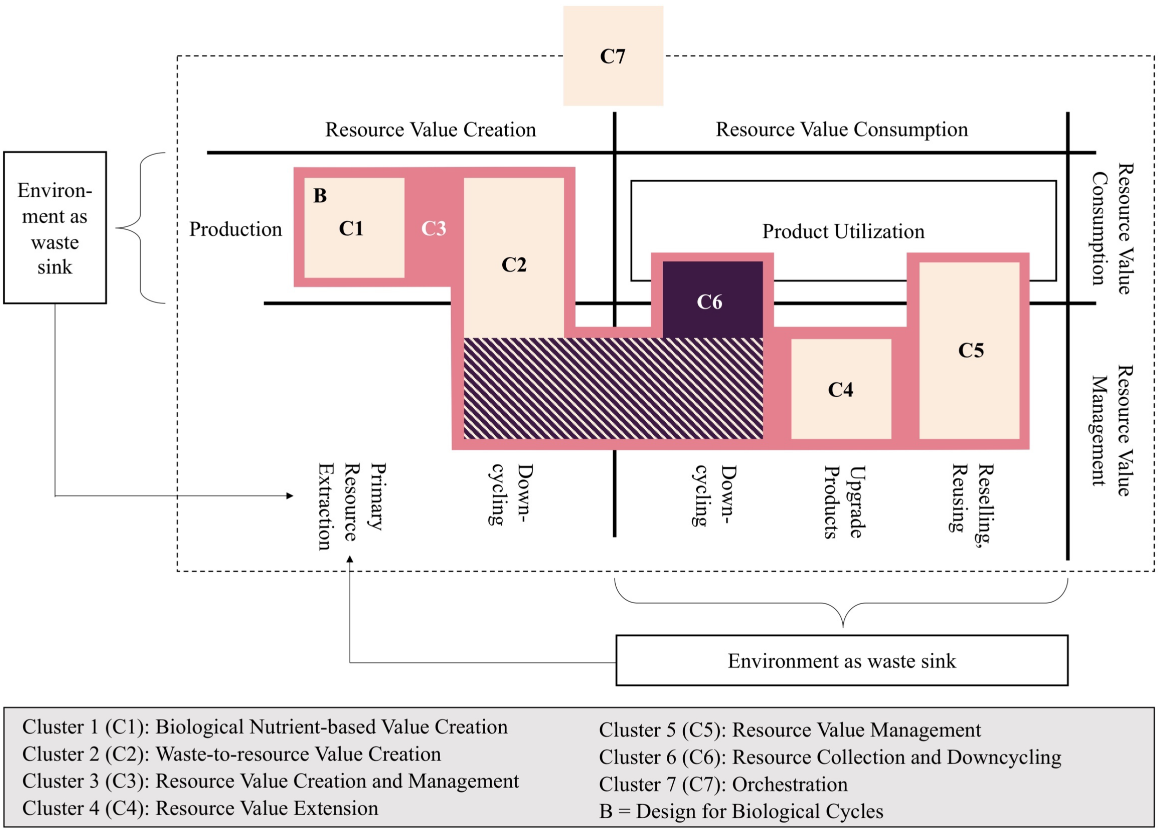


Figure 11. Overview of Proposed Circular Business Model Types.

4.2.2 Description of Clusters

To further interpret the seven clusters, descriptive statistics in the form of variable means as well as the text-snippets used during the coding process are utilized. The variable means for each of the clusters are provided in table 8 whereby the values can be interpreted as the percentage of companies in a given cluster that adopt a specific feature in their business model. For instance, 100% of the companies in the first cluster generate revenues from products. Further, recall that the variables were not treated in a mutually exclusive manner so that variable values within a specific dimension do not necessarily add up to 100% and that, as stated in section 3.1.1, variables that had been coded based on less reliable data are marked with an asterisk. Lastly, it is worth noting that due to the limited sample size the provided statistics are merely indicative and do not express any statistical significance.

Circular Business Model Dimensions and Features		Cluster 1 (n=9)	Cluster 2 (n=20)	Cluster 3 (n=5)	Cluster 4 (n=9)	Cluster 5 (n=26)	Cluster 6 (n=11)	Cluster 7 (n=19)
Value Proposition	Customer Education	0.11	0.20	0.20	0.33	0.12	0.18	0.21
	Unlocking Hidden Information	0.00	0.00	0.00	0.00	0.08	0.00	0.42
	End-of-life Information	0.00	0.00	0.20	0.00	0.08	0.27	0.00
	Environmental Value	1.00	0.95	0.80	0.33	0.62	1.00	0.74
	Convenience	0.00	0.10	0.20	0.11	0.42	0.18	0.37
	Trust and Reliability	0.00	0.15	0.40	0.33	0.50	0.55	0.16
	Other Emotional Value	0.22	0.55	0.40	0.44	0.54	0.27	0.47
	Long Product Lifetime	0.22	0.30	0.20	0.11	0.08	0.18	0.11
	Product Lifetime-enhancing Services	0.11	0.00	0.60	1.00	0.73	0.00	0.37
	Guaranteed Performance	0.00	0.00	0.20	0.11	0.15	0.00	0.05
	High/Comparable Performance/Quality	0.78	0.90	0.40	0.56	0.58	0.82	0.53
	Affordability	0.11	0.00	0.60	0.22	0.50	0.27	0.42
	Efficiency-enhancing/Cost-effective Services	0.00	0.25	0.20	0.11	0.46	0.45	0.32
	Income Generation	0.00	0.00	0.00	0.00	0.08	0.00	0.26
Value Delivery	B2B	0.89	0.85	0.60	0.56	0.54	0.73	0.42
	B2C	0.44	0.35	0.60	1.00	0.77	0.27	0.53
	C2C	0.00	0.00	0.00	0.00	0.00	0.00	0.32
	Selling Products	0.78	0.75	0.40	0.22	0.38	0.36	0.42
	Selling Product/Service Systems	0.22	0.25	0.60	0.56	0.62	0.64	0.11
	Selling Pure Services	0.00	0.05	0.20	0.33	0.19	0.36	0.53
	Communicating Circular Efforts	0.44	0.30	0.60	0.00	0.27	0.55	0.16
	Distribution through Own Channels	0.89	0.80	1.00	1.00	0.92	1.00	1.00
Value Creation and Resource Value Retention	Sourcing Used Supplies	0.44	0.65	0.40	0.11	0.00	0.36	0.26
	Production	0.78	1.00	1.00	0.22	0.04	0.45	0.00
	Development of Digital Solutions	0.00	0.05	0.00	0.00	0.27	0.00	0.47
	Downcycling	0.00	0.85	0.60	0.00	0.04	1.00	0.00
	Upgrading Products	0.00	0.00	1.00	1.00	0.31	0.00	0.00
	Reselling, Reusing	0.00	0.00	0.80	0.00	0.92	0.00	0.00
	Design for Circular Production*	0.11	0.25	0.00	0.00	0.00	0.36	0.00
	Product Design for Technical Cycles	0.00	0.00	0.20	0.11	0.12	0.27	0.05
	Product Design for Biological Cycles	1.00	0.10	0.00	0.00	0.00	0.09	0.00
	Co-creation, Joint Offering	0.33	0.20	0.00	0.22	0.31	0.36	0.21
	Research & Development	0.67	0.55	0.20	0.11	0.19	0.64	0.11
	Data Monitoring and Analysis*	0.00	0.15	0.00	0.00	0.23	0.18	0.26
	Collection, Take-back Program	0.00	0.00	0.80	0.11	0.85	1.00	0.00
	Suppliers*	0.89	1.00	1.00	1.00	1.00	1.00	0.53
	Manufacturers*	0.44	0.00	0.00	0.00	0.08	0.09	0.26
	Retailers, Distributors	0.44	0.50	0.20	0.22	0.23	0.27	0.32
	Forward Logistics Operators*	0.78	0.55	0.60	0.33	0.31	0.55	0.32
	Reverse Logistics Operators*	0.00	0.00	0.20	0.11	0.15	0.27	0.00
	Value Retention Partners*	0.22	0.25	0.00	0.11	0.35	0.45	0.74
	Insurance Companies*	0.00	0.00	0.20	0.11	0.15	0.00	0.05
	Other Partners	0.78	0.85	1.00	0.56	0.73	1.00	0.84
Value Capture	Revenues from Products	1.00	1.00	0.80	0.78	0.69	1.00	0.53
	Transaction/ Usage-based Revenues	0.22	0.25	0.40	0.89	0.73	0.82	0.47
	Continuous Service Revenues	0.00	0.05	0.80	0.11	0.54	0.64	0.21
	Resource Value Retained: Downcycling*	0.11	1.00	0.60	0.00	0.23	1.00	0.37
	Resource Value Retained: Upgrading*	0.00	0.00	1.00	1.00	0.46	0.00	0.11
	Resource Value Retained: Reselling/Reusing*	0.11	0.00	0.80	0.00	0.92	0.09	0.37
	Feeding Biological Cycles*	1.00	0.10	0.00	0.11	0.00	0.09	0.00
	Displacing New Production*	0.33	0.40	0.20	0.22	0.27	0.27	0.37

Table 8. Descriptive Statistics of Final Cluster Solution.

Cluster 1: biological nutrient-based value creation. The first cluster describes businesses that create products which can be fed back safely into biological cycles at the end of their lives. Apart from advertising the environmental value of these products, firms in this cluster particularly highlight the products' quality (78%). In contrast, attributes related to financial values are not emphasized—for instance, only one out of nine companies advertises its products' affordability. A reason that might explain both observations is the circumstance that most of the offerings in this cluster are relatively new. The clients, which are predominantly businesses (89%) and partly process the products further, may first need to be convinced that the products are as functional as traditional alternatives (see Franco, 2017). Additionally, a lack of economies of scale may prevent producers to price their products more competitively. With regards to the value creation activities, it can be noted that the ventures in this cluster are comparatively research and development intensive (67%). Hence, it is not uncommon for them to set up strategic partnerships that support the upscaling of their technologies. An example provides the Danish startup Pond which was founded in 2015. The startup creates biodegradable resin systems that can replace crude oil-based resins used to bind materials in different kinds of applications and recently partnered up with a high-quality fashion brand in order to develop its technology further (Pond, 2018). Given the descriptive statistics, companies in this cluster mainly generate revenue through product sales (100%) and only occasionally complement these revenues through value-adding services (22%). Examples provide KLS Pure Print which complements its offering of fully biodegradable printing products with design services and the producer of chemical-free, whey-based cleaning and skin-care solutions, Bio Gen Active, which offers full technical support, training programs and consulting services, among others.

Cluster 2: waste-to-resource value creation. Similar to the first cluster, the second cluster comprises firms that create resource value. However, in contrast to the first cluster, the production is accompanied by downcycling activities. Analyzing the individual cases related to the cluster shows that a further specification of these activities can be used to form two main sub-categories. First, there are companies that establish circular production processes (25%) such as Stadtfarm or Heineken Mexico. While the former employs a farming system in which water and nutrients are continuously recycled through the symbiotic interplay between farmed fishes and leafy greens, the latter built a plant that recovers water and energy from the production process—through water treatment and anaerobic digestion—and recirculates the resources back to production or other processes. A modification of this sub-category is represented by Clewer and Orbital Systems which do not engage in downcycling activities themselves but rather develop and produce systems others can use in order to recycle water. The second sub-category includes models in which used goods are repurposed into new ones. A representative example is Baumm which creates bags and other products out of old parachutes and advertisement banners. Given that, apart from downcycling activities, the focus of all firms in this cluster remains on the production and sale of products with 100% of companies generating revenues from products, it is less surprising that in its characteristics the cluster is generally very similar to the first one. This is illustrated by the high percentage of companies that perform substantial research and development activities (55%) and emphasize the quality of their products (90%), as well as the low percentage of firms that generate revenues from services (30%).

Cluster 3: resource value creation and management. The third cluster comprises companies that create and manage resource value. As stated above, it only encompasses five firms which is why its descriptive statistics are less useful. Nonetheless, a few remarks, especially in comparison to the first two clusters, can be made. Before turning to this comparison, another characteristic of the cluster is emphasized. While it is common to all firms that they engage in the refurbishment or remanufacturing of products, they also all perform additional value retention activities based on the condition of the products they recollect. Products that cannot be upgraded are recycled by Cisco (electronics), Reciclarg (electronics) and Pa-Ri Materia (furniture). Further, in the same vein as Fizzen (fashion), Pa-Ri Materia and Reciclarg also resell products that do not need to be upgraded. Moreover, Pa-Ri Materia offers rental services for its products. The latter strategy is also pursued by the Indian firm Furlenco (furniture) which, however, offers its products exclusively through a use-oriented product-service system. That it is the only company in this cluster that does so thereby supports existing literature that highlights the adoption challenges related to such systems (e.g. Sumter et al., 2018; Tukker, 2015).

While, as just stated, Furlenco is the only company that generates its revenues exclusively from services, three out of the four remaining companies in this cluster also obtain revenues from services. These services include waste handling as well as maintenance, among others. By having a high percentage of companies generating substantial service revenues the cluster differentiates itself from the product-revenue driven clusters one and two. Additionally, the third cluster differs from these clusters in that firms seem to advertise the financial value of their offerings more strongly. This observation thereby aligns well with existing circular business model literature that identifies the offering of affordable "as new" products as a way to address larger markets (e.g. Bocken et al., 2016; Vogtlander et al., 2017).

Finally, the third cluster could potentially also represent the outlier detected during hierarchical clustering. As stated in section 3.1.2, a company has been removed from the analysis as it appeared to be representative of a small but insignificant segment. While this still might be the case, the company's business model could also be interpreted as a particular variation of the *resource value creation and management* circular business model type. In specific, similar to the other companies in the cluster, Ahrend produces its own products—office furniture—while at the same time providing maintenance and refurbishment services. What sets the company apart is that it also augments its offering digitally by providing asset management and activity tracking services which can be used to optimize the utilization of the work environment. Moreover, Ahrend's products are designed with biological and technical cycles in mind and cradle-to-cradle certified giving it some resemblance to companies in the first cluster. Still, being strongly involved in both resource value creation and management, the thesis at hand finds the *resource value creation and management* label to be most descriptive in Ahrend's case.

Cluster 4: resource value extension. The fourth cluster describes companies that focus on providing services to refurbish, remanufacture, maintain and/or repair used products. In comparison to other clusters, in this cluster the percentage of companies that advertise the environmental value of their offerings is relatively low (33%). Correspondingly, also circular efforts are not highlighted (0%) which fits the narrative discussed in section 2.2.3 that circular business models can arise intentionally as well as unintentionally. Given that 86% of the cluster's companies that generate revenues from products (78%) also generate revenues from product lifetime-enhancing services, it might be just the case that a company started retailing products and then noticed that it can easily increase its revenue by offering services to customers it already had a connection to. In any way, a representative example for this category is Bicyclettes Montréal-Nord which retails and repairs bicycles. Slightly deviating from the cluster centroid are USM and UK Hempcrete which both additionally manufacture their own products. Hence, the two firms are similar to the third cluster although still differ substantially in that they do not recollect their products. This, in turn, aligns well with another observation that characterizes most of the companies in this cluster which is that key supporting retention activities play a rather subordinate role.

Cluster 5: resource value management. The fifth cluster consists of firms that rent or collect and resell used goods. While particularly rental offerings, as product-service systems, are often associated with circular business models (e.g. Urbinati et al., 2017; Bressanelli et al., 2018; Sousa-Zomer et al., 2018), it is surprising that the percentage of companies that communicate its circular efforts is relatively low in this cluster (27%). Further, also the emphasis on the offerings' environmental value is comparatively low (62%). In contrast, a value proposition focusing on the functional and financial benefits of the offering is more common with only one and four out of 26 companies not highlighting these values, respectively. The offerings are thereby marketed to both businesses (54%) and individuals (77%). Looking at the key value creation and resource value retention activities, it stands out that only 12% specifically design for technical cycles. Given that all companies in this cluster are involved in managing resource value, this seems surprising at first appearance as particularly in use-oriented product-service systems downtime can substantially impact the cost structure. Against this background, Jump, a bike sharing startup that was acquired by Uber in 2018, recently worked with its suppliers on a substantial redesign of its bikes including a more resilient bike frame, retractable locks and swappable batteries (The Verge, 2018). While Jump and some other rental services, particularly in the mobility space, rely fully on service revenues, the data in table 8 further reveals that 69% of the cluster's companies generate revenue from selling products. Apart from companies that resell used products on consignment such as Emmy (clothing), this also includes some of the rental companies. An example is Tchibo Share. The service which is operated by Relenda and rents baby and kids clothing made by Tchibo also gives customers the opportunity to buy the borrowed pieces. The price paid for the initial rental is thereby deducted from the sales price incentivizing customers to keep pieces after a certain timespan. While data on the distribution between income from rentals and income from product sales is not available, the example hints at some of the challenges associated with switching to use-oriented product service systems in which the customer does not assume ownership on products she uses (see Sumter et al., 2018; Tukker, 2015). A final example of the fifth cluster presents the Singaporean startup Swapaholic. It provides individuals, who would like to update their wardrobe without having to buy new clothes, the opportunity to swap them. However, in contrast to flea markets or pure marketplaces the offering is curated by Swapaholic and sales are not conducted peer-to-peer. Rather, the venture charges participants a registration fee depending on the number of items the individual likes to swap during so-called "swap parties". In return for the clothes that are stored, sorted and displayed by Swapaholic, the participants receive a certain number of tokens that they can then invest in other items available at the events.

Cluster 6: resource collection and downcycling. The sixth cluster describes businesses that collect and downcycle a range of different products including refuse materials. As stated above, there are two main subcategories. The first one comprises firms that collect used goods, recycle them and subsequently sell or use the obtained materials in the production of new products. Examples include the e-waste handling service Recycla as well as Lush, a cosmetics producer that takes back and recycles most of its cosmetics pods and recirculates the recyclate back into the production of new pods. The second subcategory contains models in which biomass is collected and turned into biofuels, energy and fertilizers. A representative example of this subcategory is Olleco, a company that supplies and collects cooking oil from business clients and, among others, converts it into biogas through anaerobic digestion. It thereby collaborates closely with different firms such as McDonald's and Arla. In this specific case, Olleco turns cooking oil collected from McDonald's restaurants into biofuel that then powers the company's logistics fleet. Further, the cooking oil is converted into energy to process the milk Arla supplies to McDonald's restaurants (Olleco, 2019). This system is also representative for the cluster's relatively high percentage of companies that design intentionally for circularity (64%) in cooperation with partners (36%) and that serve predominantly business clients (73%). Other cluster characteristics are the high degree of research and development activities (64%) and the circumstance that 82% of firms are generating revenue from both products and services. Services thereby particularly include the management of waste as well as consultancy activities.

Cluster 7: orchestration. The seventh cluster comprises businesses that enable others to perform resource value creation and retention activities. Consequently, the percentage of companies with partners that downcycle, upgrade or resell products is comparatively high (74%). In the case of ventures that create digital marketplaces in order to connect individuals who want to buy, sell, share or rent used items, these partners are at the same time customers of the service. Such platforms can be regarded as one of the cluster's subcategories including classified ads (Letgo) as well as peer-to-peer renting (Tryatec) and sharing models

(Blablacar). At their core, these models offer informational value (89%) and often monetize it through transaction and commission fees (67%). By twos out of the nine companies also generate revenue by licensing their technology and offering premium features, respectively.

In contrast, the other companies in this cluster mainly obtain their income from selling products. One such sub-group consists of product retailers and technology distributors. The former mainly include packaging-free shops that focus on promoting sustainability in general—the promotion of circular efforts in specific seems to play a rather subordinate role in the whole cluster (5%)—while the latter can be represented by Bio-Green Africa, a company which enables third parties to recover energy from waste materials by selling waste-to-energy plants and arranging maintenance services. A third sub-group describes firms, that similar to companies in the second cluster, repurpose used items. However, they differentiate themselves in that they do not produce the products themselves. Rather, these companies connect product collectors and manufacturers to produce unique products such as bags made out used tarpaulins (M-24) or shoes made out of used clothes (MDMAshoes).

Two variants of this third approach are particularly worth highlighting and can be represented by the circular business models of Ecobirdy and Bureo. First, Ecobirdy's approach seems special as the startup embeds the repurposing of broken kids toys into an educational school program and storybook for children with the aim to create awareness on the impact of plastics as well as the repurposing process. By donating broken plastic toys during the educational sessions participating children and their parents can thereby become an active part of the story themselves. Through regular updates by Ecobirdy, they subsequently can follow up the journey in which the toys are recycled and repurposed into unique pieces of furniture by Ecobirdy's partners and then sold through the startup's webshop. Secondly, Bureo's approach to repurposing seems unique as the company closely collaborates with established brands and positions itself rather as an ingredient brand. Over the last years, Bureo has built up a network of partners which collect used fishing nets and recycle them into plastic pellets. These can then be used as an ingredient in the production of a wide range of products such as skateboards and sunglasses. The products are sold through Bureo's webshop as well as channels of the collaborating brands. For instance, the sunglasses made with Costa are thereby accompanied by the label "Costa x bureo" on Costa's online shop signalizing customers that these frames have been made out of 100% recycled fishing nets (Costa del Mar, 2019).

4.2.3 Comparison with Existing Classifications

With the clusters described in detail, they can now be compared with the existing circular business model classifications introduced in section 2.2.5. The comparison is supported by mapping the types of circular business models identified during the review to the proposed taxonomy (table 9) and elaborated on in the following.

Proposed Taxonomy / Existing Typologies	Biological Nutrient-based Value Creation	Waste-to-resource Value Creation	Resource Value Creation & Management	Resource Value Extension	Resource Value Management	Resource Collection & Downcycling	Orchestration	Not fully captured
Lewandowski (2016)	Loop, Optimize	Regenerate, Optimize, Loop, Exchange	Sharing, Optimize, Loop, Virtualize	Sharing, Loop	Regenerate, Sharing, Optimize, Virtualize	Regenerate	Sharing	Virtualize
Lacy & Rutqvist (2015)	Circular Supply Chain	Recovery & Recycling	Product as a Service, Circular Supply Chain, Product Life Extension	Product Life Extension	Product as a Service, Product Life Extension, Sharing Platform	Recovery & Recycling	Sharing Platform	
Bocken et al. (2016)		Extending Resource Value, Industrial Symbiosis	Access and Performance, Extending Product Value, Classic Long Life	Extending Product Value	Access and Performance, Extending Product Value	Industrial Symbiosis	Encourage Sufficiency	
Kiørboe et al. (2015)	Product Design	Recycling and Waste Management	Product Design, Service-and Function Based Models, Repair	Repair	Service-and Function Based Models, Reuse	Recycling and Waste Management	Reuse, Collaborative Consumption	
Moreno et al. (2016)	Circular Supplies	Circular Supplies, Resource Value	Circular Supplies, Product Life Extension, Extending Product Value	Product Life Extension	Product Life Extension, Extending Product Value, Sharing Platforms	Resource Value	Sharing Platforms	
Lüdeke-Freund et al. (2018a)		Recycling, Organic Feedstock	Repair & Maintenance, Reuse & Redistribution, Refurbishment & Remanufacturing	Repair & Maintenance, Refurbishment & Remanufacturing	Reuse & Redistribution, Cascading & Repurposing	Recycling, Cascading & Repurposing, Organic Feedstock	Reuse & Redistribution	
Urbinati et al. (2017)	Cannot be compared directly as it rather captures another dimension of circular business models							

Table 9. Comparison between Proposed Taxonomy and Existing Classifications.

First, the mapping indicates that the reviewed traditional and theoretical typologies generally do support the established seven cluster solution. Almost all circular business model types can be expressed with the proposed taxonomy proving its overall comprehensiveness. An exception solely presents the *virtualize* category which describes the “shifting [of] physical products, services or processes to virtual” (Lewandowski, 2016, 9). While it is partially captured in categories such as *resource value management*—for instance, it can be argued that carsharing services such as Sunfleet virtualize the process of renting a car as booking and accessing the car takes place via an application and not through a physical dealership—other cases related to virtualization such as the streaming of music or videos cannot be represented with the proposed taxonomy.

Secondly, the mapping also shows that the reviewed circular business model types can often not directly be related to one of the clusters proposed by this thesis. In other words, it is frequently the case that one of the seven clusters encompasses several existing circular business model types. This underlines the observation by Baden-Fuller & Morgan (2010) that different approaches to classifying business models can result in new perspectives. With regards to further analysis, a question that thereby suggests itself is whether this new perspective just organizes the existing ones in a different way or whether it also augments them. To answer this question, the following paragraphs attempt to crystalize the essence of this new perspective.

In a recent study, Sumter et al. (2018) distill two core design competencies in relation to the creation of circular business models. These "are (1) the ability to concurrently develop the circular business model and the product's design and (2) the ability to anticipate how the circular offering will evolve over multiple lifecycles" (Sumter et al., 2018, 1). These competencies are echoed by Nußholz (2018) who highlights the importance of circular business model lifecycle management. In specific, Nußholz (2018) stresses the point that an effective circular economy requires firms to envision not just one business model configuration but to plan ahead and map out different stages of the product lifecycle (e.g. remanufacturing, material recovery) as well as the changes they require in the business model elements (figure 12). Existing typologies seem to reflect such models indirectly by emphasizing the combinatory power of individual circular business model types. For instance, Bocken et al. (2016) highlight how white good manufacturer Miele combines the models *encourage sufficiency* and *classic long life.*

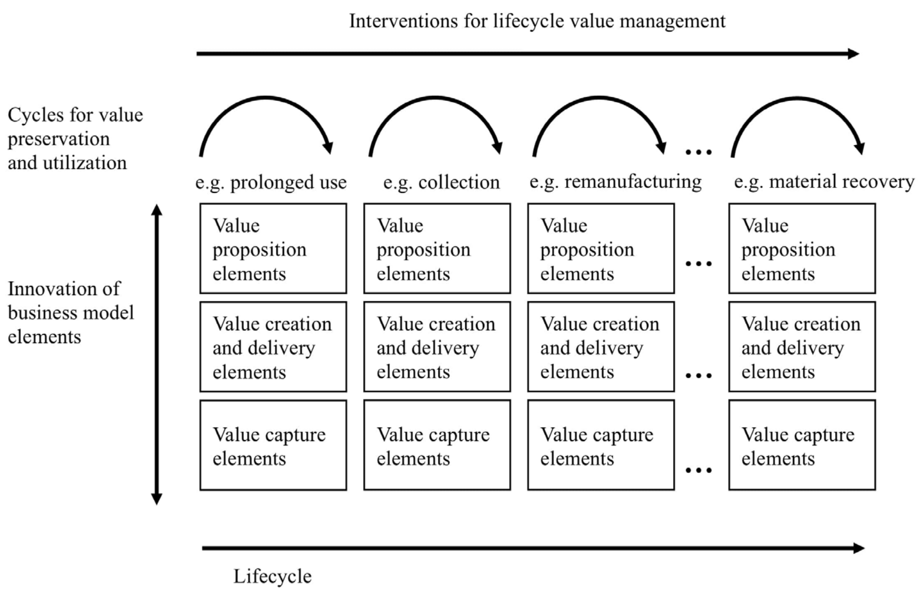


Figure 12. Framework for Circular Business Model Innovation (Nußholz, 2018).

In contrast, the proposed taxonomy captures circular business models that create and retain value along the product lifecycle more directly. Most obviously this is expressed through the clusters that integrate a high number of different circular business model types from the reviewed classifications such as the *resource value creation and management* cluster (see table 9 and figure 11). However, as indicated by the relatively small number of firms included in the cluster, it does not appear to be very common for companies to execute such a lifecycle management approach to circular business models by themselves. This view is supported in the description of Lüdeke-Freund et al.'s (2018a, 17) *cascading and repurposing* circular business model type in which the authors point out "the complexity of coordinating multiple value propositions, material cycles, and related logistics". To address this complexity, the authors emphasize the strategic value of co-operation, among others. With the main unit of analysis being the firm, such an approach is not directly expressible through the proposed taxonomy. However, it is easily conceivable how different companies could work together to recreate a *resource value creation and management* or some other kind of model on a system level.

Another way to address the highlighted complexity on a firm level brings elements of the creation of vertical integrated circular business models and co-operation together. The circular business model of Bureo, which has been introduced above, thereby serves as a first reference point. As stated, the firm has built up a network of partners which collect used fishing nets and recycle them into plastic pellets. These pellets are then used to design a range of different products which as in the case of Costa are ingredient-branded by Bureo (Costa del Mar, 2019). Extrapolating this example, business models could be conceived in which a firm's core activities concern the creation of such partner networks. Access to these curated networks could then be provided as a service to businesses that want to implement circular lifecycle management strategies without the complexity of vertical integration attached. In fact, the Y Combinator-backed venture Sourcify currently does something similar in a linear economy context by creating a platform that connects small businesses with pre-vetted manufacturers (TechCrunch, 2018). As the networks can be broader than the ones Sourcify and Bureo have been built up, such a service not necessarily has to be restricted to material suppliers or manufacturers but could offer a platform that directly connects business to all kinds of different circular value networks. In the same vein as Bureo such services could be explained by the orchestration cluster.

In contrast and regardless of whether one considers Bureo or its extrapolated version, existing classifications tend to solely highlight some of the other sub-categories included in the orchestration cluster. *Sharing platforms* (Lacy & Rutqvist, 2015; Moreno et al., 2016) as well as the *collaborative consumption* (Kiørboe et al., 2015), *sharing* (Lewandowski, 2016) and *reuse and redistribution* (Lüdeke-Freund et al., 2018a) categories can be linked to digital platforms that connect businesses or individuals who want to buy, sell, share or rent used items and the *encourage sufficiency* category of Bocken et al. (2016) aligns well with product retailers such as packaging-free stores that promote sustainability and the reduction of material inputs. Models in which a firm's activities focus on the creation and vetting of value networks that in comparison to industrial symbiosis are not limited geographically do not seem to be captured by existing typologies, though. This is why it appears that the proposed taxonomy not only offers a new perspective on circular business models but also augments the existing solutions in that it enables the expression and explanation of different orchestration models.

Lastly, as pointed out in section 2.2.5, the theoretical typology by Urbinati et al. (2017) presents a perspective on circular business models that differs significantly from the ones discussed above. Thus, it cannot be compared to the taxonomy proposed by this thesis in the same way. In its essence, the classification by Urbinati et al. (2017) rather adds another dimension to the introduced clusters. This dimension reflects the second part of the circular business model definition outlined by this thesis, the degree of circularity. While the thesis at hand postulates that a business model's degree of circularity is influenced by the set of interdependent activities the organization performs and how those contribute to the overall's system effectiveness, Urbinati et al. (2017) define the degree of circularity along the lines of pricing, promotion and circular design features. With respect to the variable space presented in figure 10, the latter criteria could be approximated through the circular business model features *communicating circular efforts* and *design for circularity* as well as the *revenue streams* sub-dimension. In contrast, the criteria introduced by the thesis are more complex and seem to be best represented by features from the *value creation and resource value retention* dimension as well as *environmental impact* sub-dimension. However, since the coding has shown that it is particularly difficult to reliably assess the *environmental impact* sub-dimension—in contrast to the other dimensions this sub-dimension requires an ecosystem level viewpoint—the thesis will not compare the two approaches in more detail. Instead, it moves on to present the final conclusions.

5. Conclusions

The concluding chapter briefly restates the identified research gap and outlines how it has been addressed by the thesis at hand. Subsequently, it summarizes the thesis' main findings and elaborates on how they contribute to existing circular business model literature. Finally, the chapter presents the findings' managerial implications and provides suggestions for further research.

5.1 Main Findings and Theoretical Contributions

Representing a way to decouple economic growth from environmental pressure, over the last decade, the concept of a circular economy has received increasing attention on many levels (Reike et al., 2018; Murray et al., 2017; Kirchherr et al., 2017; Lieder & Rashid, 2016; Blomsma & Brennan, 2017). While circular business models are thereby seen as one of the central constituents that support the shift to a more circular economy (e.g. Bocken et al., 2016; De Angelis, 2018; Antikainen & Valkokari, 2016; Linder & Williander, 2017; Lacy & Rutqvist, 2015; Ellen MacArthur Foundation, 2013), Kirchherr et al. (2017, 228) argue that "much more emphasis on business models will be needed in future discourses if the private sector is supposed to lead the transitions towards CE [Circular Economy]. A CE understanding lacking business models is one with no driver at the steering wheel in our point of view." Being originally driven by practitioner contributions and linked to publications on sustainable business models (Lüdeke-Freund et al., 2018a), research on circular business models has increased significantly over the last two years as a Scopus search on the terms "circular business model" and "circular economy business model" shows. As of December 2018, Scopus listed 80 unique contributions on the terms whereby 19 had been published in 2017 and 54 in 2018. Still, despite the increase in academic efforts, the thesis' literature review highlights that Kirchherr et al.'s (2017) statement remains valid. While there might be a driver now, it is still poorly defined.

According to Lambert (2015, 50), "it is widely recognized that classification is a necessary step in understanding a research area". Early classification schemes thereby often produce traditional typologies (Baden-Fuller & Morgan, 2010), i.e. classifications not based on any explicit classification criteria (Warriner, 1984). This has also been the case in the rapidly growing space of circular business model literature with the first categorizations stemming from practitioner-oriented contributions (e.g. Lacy & Rutqvist, 2015; Kiørboe et al., 2015). Only more recently scholars have started to provide circular business model classifications based on transparent methodological approaches (e.g. Urbinati et al., 2017; Lüdeke-Freund et al., 2018a). These classifications are conceptually derived and can thus be viewed as theoretical typologies (see Rich, 1992; Warriner, 1984). However, while able to simplify complex concepts, classifications in the form of theoretical typologies are less well suited as a foundation for wider generalization since they lack a direct connection to empirical reality and rely on predetermined groupings (Lambert, 2015; Hambrick, 1984). Instead, from a positivistic stance, this power is ascribed to a third type of classifications, taxonomies. In contrast to theoretical typologies, taxonomy studies use statistical tools to derive natural groupings within empirical data and, hence, can provide a basis for mid-range theory development (Lambert, 2015). Still, according to Groth & Nielsen (2015, 17), such taxonomies are "relatively new ground" in business model literature. In fact, this thesis' systematic review of 116 circular business model related publications did not identify a single taxonomy study.

This gap is addressed by the thesis at hand. Broadly following Lambert's (2015) approach to business model classification development and adopting core elements from other business model taxonomy studies (Hartmann et al., 2016; Remane et al., 2016; Täuscher & Laudien, 2018) for its research design, the thesis produces a conceptually grounded and empirically derived circular business model taxonomy. More specifically, building on a literature review and empirical data, the thesis first creates a morphological box-like framework on which basis circular business models can be described. In the process of its development, also a binary-coded matrix expressing the defining business model characteristics of 100 randomly selected firms is generated. In a second phase, hierarchical and non-hierarchical cluster analysis techniques are then used to derive natural groupings from the gathered data. While not generating a definitive answer, in this way the thesis provides a novel perspective to the question of *what types of circular business models exist and how they can be characterized.* The following paragraphs summarize the thesis' main findings and elaborate on how they contribute to the existing body of knowledge.

Using *Rogers-Tanimoto* as an association measure for average linkage-based agglomerative clustering and *k*-medoids centroid-based clustering, the thesis identifies seven types of circular business models. Since it interprets circular business models as *attributes of real firms* (see Massa et al., 2017) they will be presented as such. First, *biological nutrient-based value creating* firms focus on the creation of products that can be fed back safely into biological cycles at the end of their lives. These firms often run research and development activities, predominantly serve business clients and almost exclusively generate revenue from products. Secondly, at their core *waste-to-resource value creating* companies take downcycled resources as an input for the creation of new resource value. However, apart from downcycling activities, their characteristics closely resemble the ones of the first type. Thirdly, *resource value creating and managing* firms extend the production of products with collection and different upgrading activities. Consequently, product revenues are augmented by service revenues whereby some firms offer use-oriented product-service systems. Further, actively managing the created resource value often enables these firms to extend their addressable market by offering more affordable solutions to price-sensitive business clients and individuals. Fourthly, *resource value extending* companies primarily focus on providing upgrading services such as refurbishing, remanufacturing, maintaining and/or repairing used products. However, they often also retail the products they upgrade in order to complement service revenues with product revenues. Clients are mainly individuals while some firms also serve businesses. Fifthly, *resource value managing* businesses rent or collect and resell used goods. Thereby, most firms particularly highlight the financial and functional benefits of their offerings. In contrast, circular efforts are seldom communicated. Revenues are generated from both products and services whereby the percentage of rental firms in the sample that fully rely on service revenues is surprisingly small. Sixthly, similar to firms in the second cluster, *resource collecting and downcycling* companies ensure that devalued goods and materials can be used in the production of new products. Thereby, apart from collection activities, core downcycling activities rather include recycling and energy recovery than repurposing. Unsurprisingly, clients are thus mainly other businesses and revenues are generated from both products and services. Finally, *orchestrating* businesses enable others to perform resource value creation and retention activities. In contrast to other types of circular business models, this type is more often associated with the provision of informational value and the development of digital peer-to-peer platforms. Still, some *orchestrating* firms also operate in business-to-business and business-to-customer markets and generate revenues from selling physical goods.

This final seven cluster solution has proven to be stable given the results from split-sampling and the application of different cluster algorithms. Further, with a value of 0.53 the silhouette coefficient indicates a reasonable partitioning of the data strengthening the cluster solution's internal validity. Moreover, and most importantly, a comparison with existing typologies demonstrates the taxonomy's comprehensiveness and relevance. With exception of the *virtualization* category in Lewandowski's (2016) circular business model typology, the taxonomy is able to express all circular business model types defined by existing classifications. Further, the taxonomy enriches the current body of knowledge in that it provides a novel perspective on existing models. First, instead of only referring to the combinatory power of individual circular business model types (e.g. Bocken et al., 2016), the proposed taxonomy captures circular business models that create and retain value along the product lifecycle more directly. That the share of *resource value creating and managing* firms is thereby relatively small, empirically supports Nußholz' (2018, 192) remark that "it may not be realistic for companies to integrate multiple cycles in their business models". Secondly, by slicing existing circular business model categories in a different way and aggerating some of them, the taxonomy supports Whalen's (2017, 420) observation that "some of the existing archetypes appear to be more suited as subcategories."

Apart from presenting existing circular business model types in a different light, the constructed taxonomy also augments them further proving the taxonomy's usefulness. In specific, while existing circular business model classifications mainly capture sharing platforms as a form of *orchestrators*, the proposed taxonomy also enables the expression and explanation of different orchestration models. As an example, the thesis elaborates on the case of Bureo, a firm which neither performs resource value creation or resource value retention activities nor operates a peer-to-peer sharing platform. Rather the firm manages a network of partners that collect used fishing nets and recycle them into plastic pellets. Others, such as sunglasses manufacturer Costa, then turn these pellets into different products ingredient-branded by Bureo.

While still having to be further tested (see section 5.3), the taxonomy additionally contributes to the evolution of circular business model literature in that it provides a stepping stone for mid-range theory development. Along the lines of Lambert (2015), this contribution is mainly founded in the classification's methodological nature which demands the solution to be conceptually grounded and empirically derived. The taxonomy is thereby further substantiated through the detailed description of how it has been developed. In this way, the thesis also addresses the lack of methodological transparency found in some of the earlier circular business model classification works (see section 2.2.5). Finally, by incorporating elements from existing taxonomy studies (Täuscher & Laudien, 2018; Remane et al., 2016; Hartmann et al., 2016) into Lambert's (2015) taxonomy development method, the research approach provides an example of the method's practical application and can serve as a blueprint for further taxonomy studies to come.

A last theoretical contribution concerns the review of circular business model definitions and frameworks as part of the taxonomy development process. First of all, the thesis systematically analyzes existing circular business model definitions using the traditional business model interpretation schemes of Spieth et al. (2014), Wirtz et al. (2016), Massa et al. (2017) and Demil & Lecocq (2010) as an analytical framework. The results of this review thereby support De Angelis' (2018, 4) observation that "in the academic literature, multiple and divergent constructs are emerging around terms relating to both the circular economy and circular business models." By synthesizing the existing viewpoints into a condensed circular business model definition, the thesis then attempts to clarify its own interpretation and establish common ground for future studies to build upon. Of particular value is thereby the distinction to sustainable business models as it addresses one of the key divides in literature (see Linder & Williander, 2017; Hofmann et al., 2017). Similarly, the thesis offers an overview of existing circular business model frameworks and presents an own one that is consistent with the provided definition. This framework consists of the four dimensions and nine sub-dimensions that span the morphological-box like variable space and addresses calls for more specific circular business model representations (e.g. Antikainen & Valkokari, 2016; Mendoza et al., 2017; Bocken et al., 2016).

5.2 Managerial Implications

In addition to the theoretical contributions, the thesis has two major managerial implications. First, it may serve as a source of inspiration that supports companies in transitioning towards or directly adopting more circular business models. For instance, companies could combine the seven circular business model types as well as some of their sub-categories described in the fourth chapter with proven business model innovation processes such as Gassmann et al.'s (2013) *Business Model Navigator* to systematically rethink their current business models. Alternatively, companies could also tinker with new circular business models more freely by seeking inspiration in the provided circular business model examples—an advantage of the provided set of examples is thereby that it contains several lesser known cases. A concrete illustration of such a novel circular business model idea is provided by extrapolating from the case of Bureo and building on the linear business model of Sourcify.

In specific, the envisioned *orchestration* model proposes the offering of platforms that directly connect businesses to all kinds of different, pre-vetted circular value networks potentially reducing the complexity of coordinating multiple cycles for clients. Both approaches, the process-oriented and the free-form one, could thereby be further complemented through the morphological-box like framework presented in the fourth chapter. When augmented by the dimensions *resource & capability* and *cost structure*—as stated, these were intentionally left out for this thesis' purposes—the framework can be seen as a simple tool that in a similar vein as the Business Model Canvas (Osterwalder & Pigneur, 2010) helps to characterize the envisioned models in greater detail and to generate and test relevant hypotheses.

Secondly, with particular regards to firms that already employ a circular business model, the overview of circular business model types may additionally provide strategic value. A firm may use the taxonomy as a tool to position itself and evaluate with what kind of other firms it could cooperate in order to create a more circular system. In a similar way, the taxonomy could be useful for institutional players and investors that want to map the landscape of firms employing a circular business model. Again, with the support of other existing classifications such as the one by Urbinati et al. (2017), or the morphological-box like framework, these analyses can be easily enriched to provide more detailed insights.

5.3 Limitations and Suggestions for Further Research

Despite its merits, the introduced taxonomy has some limitations which should be addressed in future research. As elaborated on in section 3.1.3 one of the main limitations concerns the taxonomy's external validity. External validity is paramount for generalization and along the lines of Ketchen & Shook (1996) can best be assessed by conducting the same cluster analysis on a different sample. To further increase confidence in the taxonomy, future research that seizes this opportunity, should thereby also consider a larger sample size as well as an improved coding process. The latter is ideally supported by at least one additional and independent coder as well as interviews with representatives of a randomized set of sample firms. Another main limitation of the thesis is the lack of criterion-related validity which represents a taxonomy's usefulness with regards to the prediction of important outcomes (Ketchen & Shook, 1996). Thus, after having externally validated the taxonomy, future research could follow the suggestion by Groth & Nielsen (2015) and conduct studies with the single purpose to test the classification. Criterion-related validity is often assessed with performance-related measures which in this case could be profitability or the degree of circularity. However, it has to be taken into consideration that these criteria have to be well grounded in theory and may first require additional research themselves (Hair et al., 2014). In this regard, it may also be valuable to review research streams that are related to the concept of a circular economy in general and circular business models in specific. Some of these streams have been briefly mentioned in the first and second chapter of this thesis.

Moreover, as the discussion of circular business model types has shown, there appear to exist several sub-categories. For instance, the *waste-to-resource value creation* type can be divided into models that employ circular production processes and models that repurpose used goods, components and materials into new products. Future research could examine these circular business model types more closely and develop nuanced categorizations within individual clusters. Based on this thesis' findings, a particularly interesting circular business model type to explore in more depth thereby seems to be the seventh one which consists of *orchestrating* firms. Apart from creating more nuanced classifications, future research could also conduct longitudinal studies in order to examine how companies' circular business models develop over time. For instance, based on the thesis' findings it is easily conceivable that companies start out as *resource life extenders* or *waste-to-resource value creators* and then transform into *resource value creator and managers.* Against the backdrop of literature that discusses circular business model challenges and barriers (e.g. Whalen et al., 2018; Hopkinson et al., 2018; Rizos et al., 2016) it appears interesting to identify whether a certain evolution of circular business models can help to overcome these and increase the likelihood of success. In this regard, the thesis also suggests conducting studies that compare vertically integrated models to horizontally integrated ones.

Lastly, in their study on the development of business model research, Wirtz et al. (2016) argue that general business model literature converges to a firm-level perspective. While such a perspective has also mainly been taken for the purpose of this study, the study's circular business model definition and findings re-emphasize the importance of systems thinking. Thus, it might be interesting for future studies to not examine the circular business model types solely from a firm perspective but to also explore how systems of circular business models work, how they form and what particular challenges they face.

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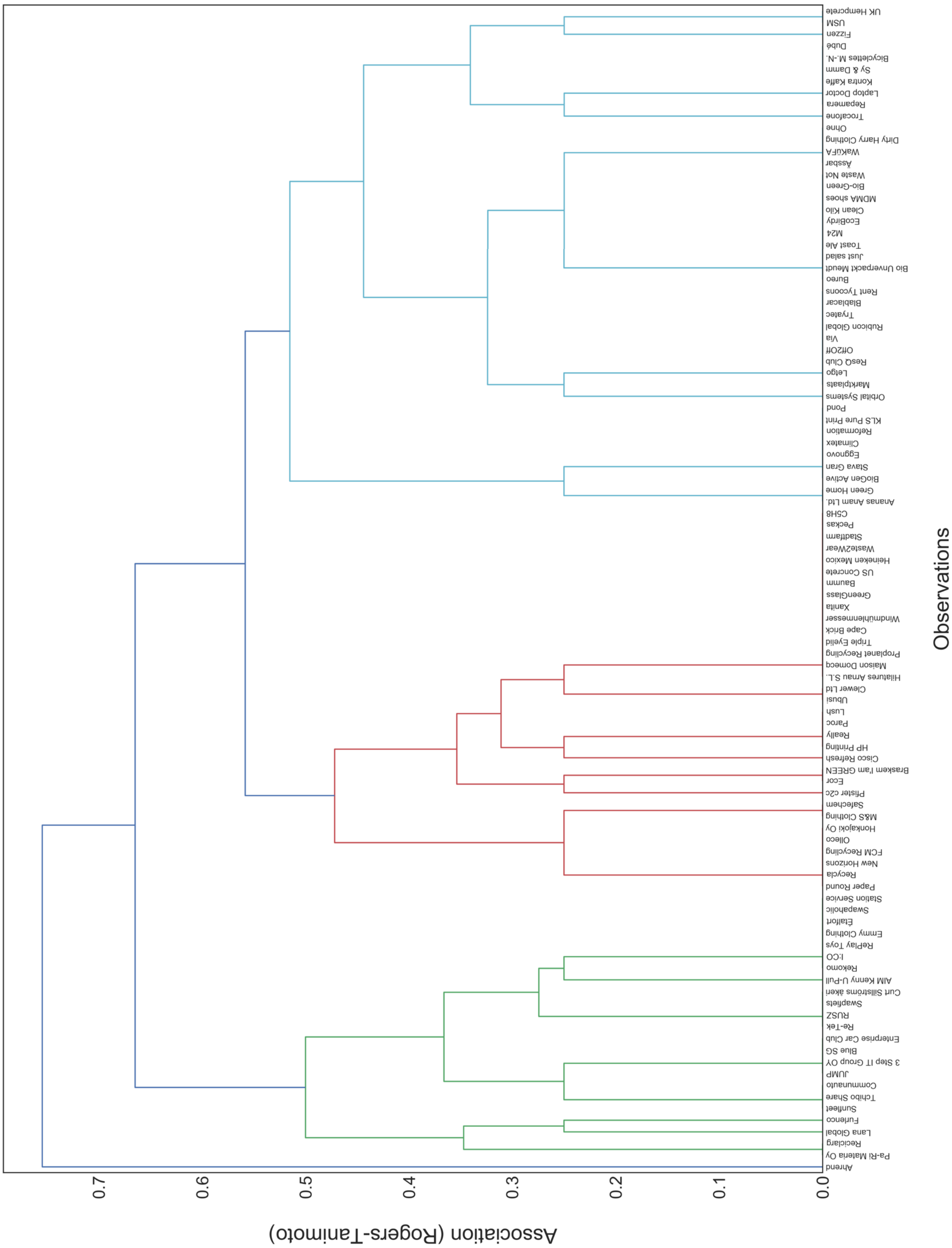
Appendices

Appendix 1. Graphical Outlier Identification.

The following dendrogram illustrates the arrangement of clusters generated via average linkage-based agglomerative clustering using *Rogers-Tanimoto* as a measure of association. As can be seen on the left-hand side of the tree graph, the observation *Ahrend* constitutes an isolated branch which, in turn, is associated with outliers.



Appendix 2. List of Samples.

The following table shows the clustering of sample companies using *k*-medoids and *Rogers-Tanimoto* with the clusters generated by average linkage-based agglomerative clustering serving as seed points. Sample firms highlighted in bold were allocated to different clusters when applying the *k*-means algorithm. Ahrend was excluded from the clustering procedure and hence is put into brackets while being allocated to the cluster that explains it best.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Biological Nutrient-based Value Creation	Waste-to-resource Value Creation	Resource Value Creation & Management	Resource Value Extension	Resource Value Management	Resource Collection & Downcycling	Orchestration
KLS Pure Print	Ubusi	Pa-Ri Materia	Bicyclettes Montréal-Nord	**Dirty Harry Clothing**	**Paroc**	Bio-Green
Pond	Peckas Naturodlingar	Cisco Refresh	Dubé Pneu et Mécanique	Tchibo Share	Olleco	Blablacar
Reformation	C5H8	**Fizzen**	Trocafone	Communauto	Honkajoki	Waste Not
Climatex	Stadtfarm	Reciclarg	USM	**AIM Kenny U-Pull**	**Pfister C2C Products**	MDMAshoes
Eggnovo	Waste2Wear	Furlenco	Sy & Damm	Swapfiets	**Lush**	Rent Tycoons
Ananas Anam.	Heineken Mexico	(Ahrend)	Kontra Kaffe	Swapaholic	**Really**	Tryatec
Stava Gran	US Concrete		UK Hempcrete	Station Service	FCM Recycling	Clean Kilo
Green Home	Ecor		Laptop Doctor	Curt Sillströms Åkeri	New Horizons	Rubicon Global
BioGen Active	Baumm		Repamera	Étalfort	**HP B2C Printing**	EcoBirdy
	Braskem I'am GREEN			R.U.S.Z.	Recycla	M24
	GreenGlass			**Ohne**	Paper Round	Via
	Xanita			Blue SG		Off2Off
	Clewer (Car Wash)			Sunfleet		Toast Ale
	Windmühlenmesser			Emmy Clothing		ResQ Club
	Orbital Systems			**Lana Global**		Letgo
	Cape Brick			**Marks & Spencer Clothing**		Just Salad
	Triple Eyelid			RePlay Toys		Bio Unverpackt Meudt
	Proplanet Recycling			Enterprise Car Club		Bureo
	Maison Domecq			I:CO		Marktplaats
	Hilatures Arnau			3 Step IT		
				Rekomo		
				WaKüFA		
				Ässbar		
				Safechem Metal Cleaning		
				Re-Tek		
				JUMP		