CIRCULAR INDUSTRY 5.0:

REGENERATIVE-DOMINANT (R-D) LOGIC OF VALUE CREATION AND MANUFACTURING

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Abstract

Policymakers and practitioners realize that an industrial revolution isolated from the premises of the Circular Economy (CE) and social well-being wouldn't be viable. Industry 4.0 and its short-term outcomes were proven to be insufficient and found to be a reductionist approach to sustainable manufacturing and development. As an anomaly (only a few years after the advent of Industry 4.0), the European Commission named a new paradigm as Industry 5.0 to re-assign the industry's role to social prosperity. Despite the prolific research attempts to re-iterate the impact of enabling technologies for a sustainable CE, there is an apparent need to level up the discussion with alternative perspectives to value creation. That includes the logic and purpose (raison d'etre) perspective to the synergy between enabling technologies and CE managerial practices and their relevance to sustainable development. Using the conceptual theory-building method, a maturity-based framework of Circular Industry 5.0 is created for a nuanced understanding of the integration of CE and Industry 5.0. As such, four distinct levels of enabling technologies are abstracted and mapped against four levels of CE from the value creation logic perspective. This research adds to the theory by suggesting an alternative and higher-level logic than the Goods-Dominant (G-D) and Service-Dominant logic for value creation, called 'Regeneration-Dominant (R-D)' logic. By utilizing the intersection of different streams of literature with the interpretive power of conceptual theory building, this study aims to guide practitioners to make more informed and revolutionary (challenging the status quo) decisions and innovate their business models towards higher levels of circularity. The implications for manufacturing firms are discussed as Regenerative-Dominant Logic requires challenging the mainstream and linear manufacturing processes primarily built on Goods-Dominant Logic's premises.

Introduction and Motivation

Considering the drastic changes in how manufacturing and resource consumption are organized, many companies have already started adapting and modifying their business models—often called differential value creation and business model innovation. As such, the transition from a linear economy to a circular economy (CE) and the shift from the Fourth Industrial Revolution (Industry 4.0) to the Fifth Industrial Revolution (Industry 5.0) are happening simultaneously, creating both synergies and tensions.

CE is emerging as a more viable industrial paradigm for decoupling economic growth from finite resource constraints by providing opportunities for businesses regarding new ways of value creation, revenue generation, cost reduction, resiliency, and legitimacy (Manninen et al., 2018). On the other hand, Industry 4.0 is initiated mainly due to increasing competition with the rapid uptake of digital technologies to enhance the value-creation process (European Parliament, 2015). Industry 4.0 technologies let businesses achieve competitiveness by realizing time reduction, flexibility, cost reduction, high productivity, and quality (Kache & Seuring, 2017; Liao et al., 2017). However, Industry 4.0 and its short-term outcomes were proven to be insufficient and a reductionist approach to sustainable development. Unlike previous industrial revolutions, which were primarily driven by technology and lasted for decades or even centuries, the European Commission introduced a new paradigm, Industry 5.0, just a few years after the advent of Industry 4.0. The aim was to re-assign the role of industry for social prosperity. Industry 5.0 became the first and only revolution that was driven by the logic of co-existence (of nature, society, and economy). Although there were limited attempts in academic literature to highlight the significance of the new Industrial Revolution and CE, the engagements of practitioners and politicians on these topics are far more developed than academics' engagements (Korhonen, Nuur, Feldmann, & Birkie, 2018). In literature, some contributions have tried to provide roadmaps for sustainable operations in CE through Industry 4.0 (Jabbour, et al., 2018) or to propose conceptual, theoretical frameworks of Industry 4.0 (Müller, et al., 2018), also for improving logistics of products and supply chain efficiency. This is followed by some research on Industry 5.0, highlighting techno-functional principles, enabling technologies, humancentric values, and harmonious collaboration between enabling technologies and humans (Ghobakhloo, M. et.al., 2023). Yet, in theory and practice, the convergence of CE and Industry 5.0 is insufficient despite their strong symbiotic relationships. The research is in its infancy since Industry 5.0 is a recent concept (that was discussed in 2020 at the EU level, accompanied by the creation of the EU Industry 5.0 Community of Practice in 2023). Moreover, Industry 5.0 was still understood as a technocratic approach to CE without enough emphasis on its diverse and evolutionary nature. The co-action of CE and Industry 5.0 is mostly studied based on a single practice (design, product development, manufacturing, logistics, etc.) or a limited number of practices in a relatively isolated manner. Thus, scientific research with a business model and ecosystem view is crucial to reaching both pursuits' intended outcomes. As both CE and Industry 5.0 concern the reasoning and sense-making for conscious resource management, I perceive both paradigms as a business model challenge for value creation. Therefore, I adopt a conceptual theory-building method (Alcayaga, Wiener, & Hansen, 2019; Torraco, 2005) to examine the integration of Industry 5.0 and CE (leading to a potential alternative logic of value creation as an outcome). Thus, this research aims to unite CE and Industry 5.0 within a novel conceptual framework by having a business model innovation and value-creation perspective.

Review of Related Work

Business model innovation is '*initiatives to create novel value by challenging existing industry-specific business models, roles and relations in certain geographical market areas*' (Aspara et al., 2010, p.47). It challenges the existing way of doing business or value creation by introducing some degree of novelty. It leverages a method, philosophy, technology, or even a blend of them as value drivers. In the case of business-as-usual, designing a business model has been recognized as a '*key decision and a crucial - perhaps more difficult - task for managers*' (Zott & Amit, 2010). Given the changing current paradigm of business, from the linear economy with a take, make, and waste approach to a CE with a take, make, regenerate approach, business model innovation has become even more challenging. As such, companies must not solely consider their well-being and economic value creation but also be responsible for the environmental and societal value as an integral part of the business that might embed considerable tensions (Porter & Kramer, 2011).

Understanding the notion of 'value'

The understanding of value creation highly depends on the context, as many scholars have attempted to explain the value creation in different settings. In fact, the notion of value is used in different meanings in several contexts, making it elusive. Amit and Zott (2001) focused on value creation in the context of e-business, and the authors suggest that there is a need for integrating various theoretical perspectives as it is a complex phenomenon. They have suggested four sources (drivers) of value: novelty, efficiency, complementarities, and lock-in. As evident from the value drivers, the term value is mainly referred to as monetary value in strategic management research. As such, Porter defines value as '*the amount buyers are willing to pay for what a firm provides them*' (Porter, 1996).

In the field of economics, according to Schumpeter, value is created through technological change processes and innovation (Schumpeter, 1934). This approach is more in line with the core logic of Industry 4.0. Schumpeter identified several sources of value creation, such as new products or production processes, industry reorganization, and new markets and supply sources. On the other hand, the resource-based view (RBV), the extension of Schumpeterian innovation theory, suggests that firms are made up of unique resources and capabilities, and their combination leads to value creation (Barney, 1991).

Classical economists differentiate the term value into the use value and the exchange value. The use value is evaluated from a customer's perspective, and it is subjective as the customers perceive it with respect to their needs. On the other hand, exchange value (commensurable value) is addressed as the monetary amount, in other words, the price realized at a specific time when the exchange of goods occurs. Likewise, Adam Smith explicated the notion as '*the word VALUE, it is to be observed has two different meanings, and sometimes expresses the utility of some particular object (value in use), and sometimes the power of purchasing other goods which the possession of that object conveys (value in exchange)*' (Smith 1776/2000, p. 31). Smith problematized the contradicting nature of two types of value: '*The things which have the greatest value in use have frequently little or no value in exchange; and on the contrary, those which have the greatest value in exchange frequently have little or no value-in-use'* that highlights the scarcity (and finite resources) problem (Smith, 1776/2000, p. 31).

The traditional view of economics focuses on a Goods-Dominant (G-D) logic for value creation (Vargo and Lusch, 2004) that is derived from the value-in-exchange. On the other hand, having challenged the foundations of economics, a Service-Dominant (S-D) logic for value creation is realized by anchoring on the value-in-use concept (Visnjic, Jovanovic, Neely, & Engwall, 2017). The core contrast between the two logic originates from the basis of exchange: whereas the former (G-D) relies on operand resources (that is, resources that an act or operation is performed on), the latter (S-D) leverages on operant resources (that is, employed to act on operand resources: knowledge and skills) (Vargo, Maglio, & Akaka, 2008). S-D logic requires a higher level of customer involvement in the value creation process; value co-creation becomes prominent by suggesting that the customer is as important as the company for value creation (Payne, Storbacka, & Frow, 2008). Yet, value co-creation encompasses both types of value, as Vargo et al. (2008) stress: '*The process of co-creating value is driven by value-in-use, but mediated and monitored by value-in-exchange*.' (p.150).

In the last decade, Porter and Kramer (2011) introduced the term shared value by connecting strategy and social goals, which boils down to creating a caring or conscious capitalism (O'Toole & Vogel, 2011). The authors suggested changing the role of the corporation to create shared value (Porter & Kramer, 2011), which is defined as: '*policies and operating practices that enhance the competitiveness of a company while simultaneously advancing the economic and social conditions in the communities in which it operates*' (p.6). Although there are several critics of it, such as being unoriginal or ignoring the tensions between social and economic goals, shared value co-creation adds rigor as an umbrella construct to the idea of conscious capitalism (Crane, Palazzo, Spence, & Matten, 2014). As the business-as-usual mandates organizations to prioritize self-interest in value creation, which is not sustainable, the new industrial paradigm of CE necessitates redefining the value from an evolutionary perspective that accounts for technological and social advancements. Furthermore, the value uncaptured concept (which can be considered as another source of waste) has been introduced to business model literature from a sustainability perspective that includes value surplus (existing but not required value), value absence (required but non-existent value), value missed (a value that is not exploited), and value destroyed (negative consequences) (Yang, M. et.al., 2017).

Circular Business Models

CE has emerged as an alternative industrial paradigm to the existing linear take, make, and dispose model (Ghisellini et al., 2014). Thus, CE offers new value creation and capture methods that are decoupled from resource depletion and social impact. According to Murray et al. (2015), '*a true circular economy would demonstrate new concepts of system, economy, value, production, and consumption*' (p. 373) for sustainable development.

The business model is considered a holistic and system-level approach to how firms do business (Zott, Amit, & Massa, 2011). A circular business model (CBM) creates an overall picture of the firm and its operations with a consistent logical structure for executing the strategy for value creation and capture (Richardson 2008, p.141). Accordingly, CBMs are defined as '*business models that aim at solutions for sustainable development by creating additional monetary and non-monetary value by the pro-active management of 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, p. 713). It is noted that the value in the context of circular economy is not only limited to economic one but also includes natural resource regeneration and the wellbeing of the society as an integral part of doing business (Geissdoerfer et al., 2018).

In the emerging field of CBM, Ünal et al. (2019) and Urbinati et al. (2017) proposed a new taxonomy aimed at classifying the degree of adoption of circular economy principles. In particular, they build this taxonomy by leveraging the business model perspective (Osterwalder & Pigneur 2005, 2010; Zott et al. 2011) and identify two major dimensions featuring circular economy business models:

1. The value creation, which refers to the degree a company leverages its key resources, activities and upstream partners to enhance the circularity of its products and processes;
2. The value capture, which regards the degree to which a company makes visible to the customers its compliance to the CE principles. In particular, the authors consider the variables of price (how much of the price is based on pay-per-use) and promotion (how much content around the CE is promoted through marketing campaigns) to measure this dimension.

This research focuses on value creation practices, which include the process of deploying key partners, channels, resources, and practices to form the product (or service) for stakeholders, as depicted in Table 1 below.

Table 1 – CBM value creation practices

Managerial Practices	**Sources**
Energy efficiency-driven practices to reduce emissions and environmental footprint	(Li, Bao, Xiu, Zhang, & Xu, 2010; Parkinson & Thompson, 2003)
Friendly material usage-driven practices, such as natural, recyclable, durable, and easy-to-separate	(McDonough & Braungart, 2002; Zhu, Geng, & Lai, 2010)
DfX Practices (such as design for recycling, design for remanufacturing and reuse, design for disassembly, and design for the environment)	(De los Rios & Charnley, 2017; Go, Wahab, Rahman, Ramli, & Azhari, 2011; Goldsworthy, 2013; Mayyas, Qattawi, Omar, & Shan, 2012)
Support of all partners to develop awareness and new skills, rendering the business model more viable, or circular, for all actors involved in the supply chain	(Bocken, Schuit, & Kraaijenhagen, 2018; De los Rios & Charnley, 2017; Moreno, De los Rios, Rowe, & Charnley, 2016)
Establishment of effective communication with suppliers, retailers, and end-of-life materials managers (such as the waste industry), as well as with all actors involved in the supply chain	(Geissdoerfer et al., 2018; Vermeulen, 2015; Zhu, Geng, & Lai, 2011)

Upskilling and social enhancement as a regenerative business; fairly benefitting the local community (suppliers, workers, and inhabitants) and culture as a part of doing business	(Ünal et.al., 2019; De los Rios et.al., 2017; Mies, A, and Gold, S., 2021)

There are three levels of CBM identified by Urbinati et al. (2017) which guides this research for developing the integrative framework;

1. '*Downstream Circular adoption focuses on the use and re-use of products, yet the company's design practices or philosophy remain linear. Companies at this level focus mainly on a pay-per-use model, while product design, internal activities, or suppliers are mostly unaffected. Here, the main goal is market penetration.*
2. *The Upstream Circular adoption is mainly driven by the efficiencies achieved by changes in the product design and internal activities because of CE adoption. An effective relationship with new suppliers is established. Yet the customers are not actively involved or made aware of these changes.*
3. *The Full Circular adoption is a collective action that involves many actors including the customers, suppliers and the focal firm that internalizes CE principles. The internal and external circular activities are communicated as an added value to the offer*.'

From Industry 4.0 to Industry 5.0

As mentioned in the final report by the EU Industrie 4.0 Working Group, "*in Industrie 4.0, dynamic business and engineering processes enable last-minute changes to production and deliver the ability to respond flexibly to disruptions and failures on behalf of suppliers… Industrie 4.0 will also result in new ways of creating value and novel business models. In particular, it will provide start-ups and small businesses with the opportunity to develop and provide downstream services. In addition, Industrie 4.0 will address and solve some of the challenges facing the world today such as resource and energy efficiency, urban production and demographic change. Industrie 4.0 enables continuous resource productivity and efficiency gains to be delivered across the entire value network. It allows work to be organized in a way that takes demographic change and social factors into account*". Industry 4.0 is an umbrella concept that is made of an integration of a multiplicity of technologies to achieve efficiency and responsiveness (Ahuett-Garza & Kurfess, 2018). Despite the hype around the concept, the EU realized that '*Industry 4.0 is not the right framework to achieve Europe's 2030 goals*' as '*Industry 4.0 lacks key design and performance dimensions that will be indispensable to make systemic transformation possible and to ensure the necessary decoupling of resource and material use from negative environmental, climate and societal impacts*. The lacking dimensions are '***regenerative features of industrial transformation, an inherently social dimension, mandatory environmental dimension***' (European Commission, 2021). Accordingly, the EU modified the concept as '*Industry 5.0 envisions a future where industries go beyond just efficiency and productivity, focusing on worker well-being and using technology for broader prosperity while respecting planetary limits. It places human values at the core of production, driving the digital and green transitions essential for Europe's long-term success.*' (European Commission, 2024).

By building on Industry 4.0, Industry 5.0 aims to harmonize technological developments with human creativity to simultaneously achieve social well-being, resilience, and sustainable development. Therefore, Industry 5.0 reclaims the role and value of people in business and manufacturing and questions how technology can best assist people in achieving prosperity. This includes assigning new roles for people in production by upskilling and leveling up the value creation for the economy, society, and environment. Besides, circular economy is a core element in Industry 5.0 as European Commission (2022) underlines '*A systemic Industry 5.0 approach will also necessitate a realignment of policy, to support business innovation and transformation aligned with regenerative circular economy principles and to encourage all companies to orient away from linear, extractive, wasteful and polluting practices.*' (p.10). At the same time, European Commission (2022) outlines the distinction between Industry 4.0 and Industry 5.0 as '*Industry 5.0 needs to be given clear purpose in enabling the transition to: industry-relevant, intersectoral, regenerative, circular economic pathways. This means moving decisively beyond Industry 4.0 paradigms that encourage digitally-enabled extractive and consumptive economic activity, which results in nothing other than an acceleration of negative climate impacts and ecosystem loss*.' (p.8).

Enabling Technologies for Industry 5.0

Below, I discuss the key enabling technologies for Industry 5.0 under four main categories:
Automation: Robot automation is the combination and configuration of a wide range of technologies (e.g., electrical, computer, mechanic, hydraulic, pneumatic, etc.) that aim to reduce human intervention in the production process and increase efficiency. This can vary based on context and industry and can be named the foundations and start of the first industrial revolution.

Additive manufacturing (3D printing): Additive manufacturing provides foundations for Industry 5.0 by transforming a digital 3D model to a physical object through the material being added together –usually layer upon layer by a 3D printer (Dilberoglu, Gharehpapagh, Yaman, & Dolen, 2017). It enables agile and connected prototyping or large-scale customized production. Furthermore, it can be used to support the design for assembly and re-assembly, by producing modular and customized products for customers also in places that are close to them, thus exploiting a localization advantage. In this way, the manufacturing of products becomes decentralized and allows lower distribution costs and raw materials savings (Nobre & Tavares, 2017).

Internet of Things (IoT) and Cyber-Physical Systems (CPS): In Industry 5.0, the goal of the Internet of Things is to enable things to be connected anytime, anywhere, with anything and anyone by deploying physical devices and extending the connectivity of the Internet to collect and exchange data. It allows communication between objects to achieve a common purpose by considering human values. IoT application's benefits and value creation in an industrial environment originate in different aspects, including visibility identification, safety, the right information, improved industrial operation and flows, reduced production losses, reduced energy consumption, and sustainability. Moreover, IoT can be used as a digital enabler of CE to allow (i) system optimization models, (ii) real-time measurement, (iii) analysis and process control, (iv) smart integration of tools and methods, which help quantify resource efficiency (Reuter, 2016). Similarly, CPS enables the integration of cyberspace, physical processes, and objects to connect machines and devices in production lines as a network, thus making real data available for decision-making (sense-making for a CE), such as prioritizing production orders, optimizing tasks, reporting maintenance needs, etc. (Ahmadov & Helo, 2016; Lee, Bagheri, & Kao, 2015). Sensors and actuators gather and distribute this data in real-time. They enable the automation of the system and an advanced level of monitoring and control and can play a key role in enabling the circular economy transition. As CE indicates larger boundaries of stakeholders, inherent uncertainties, tensions, and high levels of complexity, cyber-physical systems could provide a remedy to manage the process with a systems approach.

Cognitive Computing: It includes Big Data, cloud computing, augmented reality, simulation, and artificial intelligence (AI). The added value for the IoT and CPS can be enhanced with the intelligence. For this purpose, Big Data, cloud computing, augmented reality, simulation, and AI are considered key enabling technologies. In particular, Big Data and cloud computing can support products' monitoring, analysis and control to support their lifecycle and extend their replacement along the entire supply chain. These activities can be also due to the application of Product Lifecycle Management systems (PLMs) (Urbinati, Chiaroni, Chiesa, & Frattini, 2018), which focuses on using IoT to allow intelligent products and devices to interact among themselves to promote environmental benefits such as energy usage optimization and impact reduction of CO2 emissions. As underlined by Tseng et al. (2018, p.146), '*data-driven analysis can potentially be used to optimize the sustainable solutions intended to reduce industrial systems' resource and emission intensities*'. Furthermore, Big Data and its main characteristics of volume, velocity, variety, and veracity (4V) find applicability in the ReSOLVE (i.e., Regenerate, Share, Optimise, Loop, Virtualise, Exchange) framework for circular economy transition (Jabbour, Jabbour, Sarkis, & Filho, 2018). Accordingly, Big Data supports information flows along the supply chain, and the collection and share of data among the stakeholders' network to serve the objectives of circular economy (Despeisse et al., 2017). Cloud manufacturing is a technology that creates a virtual and global space for enabling a shared network of manufacturing resources and capabilities through the internet. The logic of cloud manufacturing is service-based, meaning that suppliers and customers interact in order to sell and buy services—for instance, design simulation, manufacture, and assembly of products. The value creation opportunities of the *augmented reality* lie within their ability to: 1) provide more engaging experiences as well as the possibility to create more engaging content, 2) improve previous graphical user interfaces by eliminating complexity, 3) reduce costs by transforming physical resources to virtual resources, and 4) improve communication and collaboration (Damiani, Demartini, Guizzi, Revetria, & Tonelli, 2018). Simulation is at the heart of Industry 5.0 as it can help to evaluate and compare different value creation models by accounting for human behavior and values. Lastly, AI creates value through the analysis and filtration of huge amounts of incoming information from different types of sensors and assists in the interpretation and suggestion of the most recommended course of action.

Methodology

I leverage a conceptual theory-building approach by deducing from the literature review a set of concepts or models representing or describing an event or process, which enables me to seize the nature of the relevant themes. According to Meredith (1993), it has more interpretive power compared to formal traditional research methods. In strategic management literature, conceptual models and theory-building approaches are widely used for adaptive complex systems. Given the complexity and nature of the relationship between CE and Industry 5.0 paradigms, a systems approach is required to synthesize these research streams and understand the relevance of the proxies that define each paradigm. The literature review is based on an integrative strategy, which is known as an integrative literature review that aims to generate new knowledge. Torraco (2005, p363) suggests integrative literature aims at '*New ways of thinking about the topic addressed by the integrative review. Alternative models or conceptions proposed by the author should be derived directly from the critical analysis and synthesis provided*.'.

Results

Literature analysis shows that several studies examine how new emerging digital technologies can support CE adoption by companies (Nobre & Tavares, 2017) and enhance sustainable competitiveness and smart growth (Gerlitz, 2016; Seele & Lock, 2017). When it comes to value creation, I propose four stages of enabling technologies maturity-wise progression: i) automation, ii) additive manufacturing (3D printing), iii) IoT and Cyber-Physical Systems, and iv) cognitive computing: big data, cloud computing, augmented reality, simulation, and artificial intelligence (AI). These are the technologies that facilitate and contribute to creating economic, environmental, and social value. On the other hand, the maturity-wise progression of CE is understood as i) energy efficiency, ii) materials, iii) design for X (DfX) practices, and iv) upskilling. Consequently, the analysis reveals a pattern of maturity and a corresponding value-creation logic. I propose Figure 1 below as the explanatory framework for Circular Industry 5.0 - a transformation from degenerative to the regenerative dominant logic of value creation.

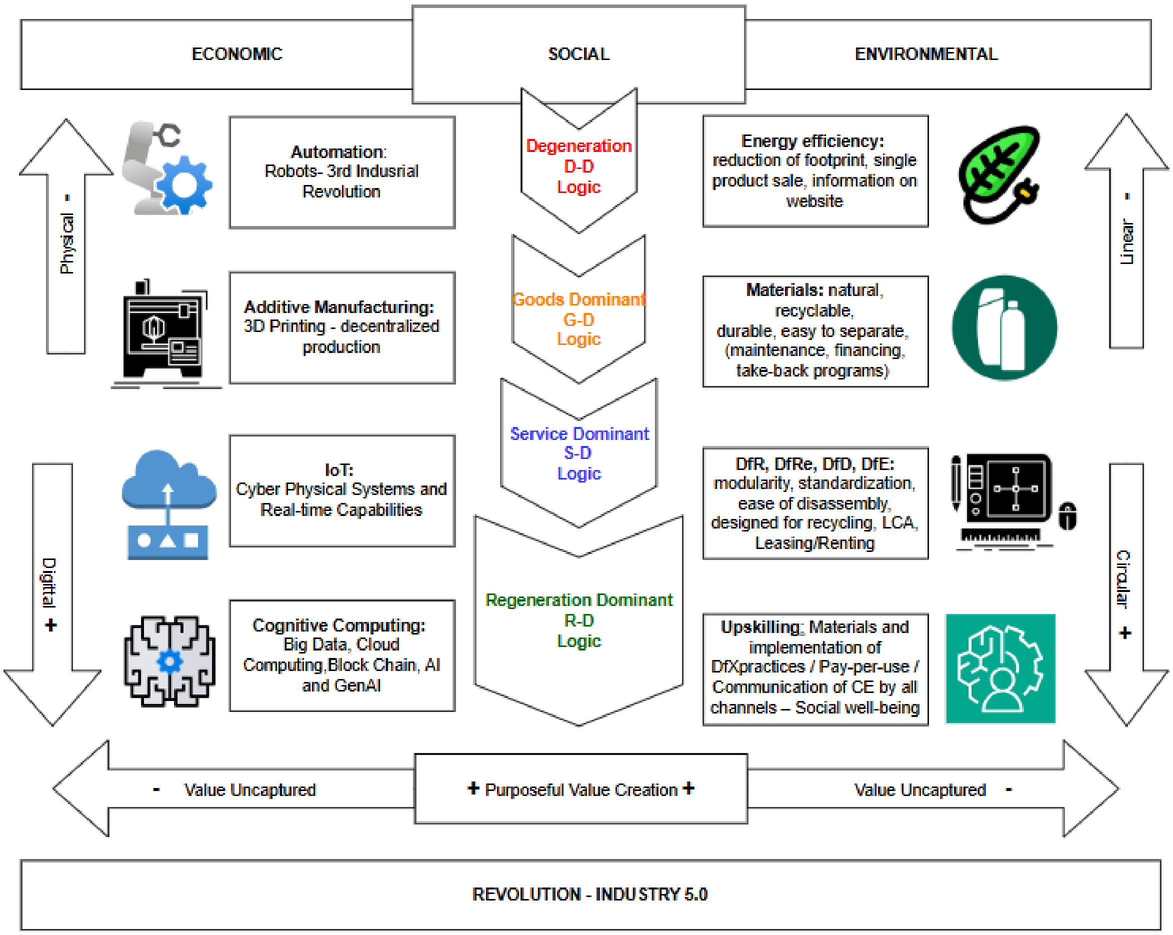

Fig1. Circular Industry 5.0 - a transformation from degenerative to the regenerative dominant logic of value creation

Economic Value Creation and Circular Industry 5.0

Economic value creation refers to the profits and benefits generated due to enabling technologies. For instance, industrial automation enabled by robots, electronics, and information technology provides a foundation for Industry 5.0. It leads to an increase in productivity by reducing waiting times between different production steps in human-centered manufacturing. Furthermore, human-robot collaboration increases the speed of manual production and reduces the complexity of tasks executed by workers (Bahrin, Othman, Azli, & Talib, 2016). Similarly, additive manufacturing enabled by 3D printing allows the offering of customized products while at the same time reducing time to market through rapid prototyping (Weller, Kleer, & Piller, 2015). Accordingly, industrial automation and additive manufacturing provide a platform on which IoT and Cyber-Physical Systems are built by deploying different types of sensors along with computing devices, controllers, actuators, and wireless communication networks. As an important pillar of Industry 5.0, these technologies enable to creation of economic value through the optimization of processes and material consumption, proper management of inventories, improvement of product and process quality, flexible and small batch production, optimal utilization of manufacturing assets, aftersales services and innovative service business models (Tai Angus Lai, 2018). Once the IoT and Cyber-Physical Systems are in place, they can harness the power of big data and cloud computing through data capture, storage, and analysis. Big data and cloud computing enable the creation of economic value through accurate forecasting, planning, diagnosis, and maintenance (O'Donovan, Leahy, Bruton, & O'Sullivan, 2015).

At the same time, AI expedites new product or service development (Binns et al., 2023), creating new and more sustainable materials and business models (Ellen MacArthur Foundation & Google, 2023) that can serve circular economy purposes. AI algorithms are leveraged for predictive maintenance to detect potential machinery failures before they happen and retain their value for longer periods of time (Brennan et al., 2022). Al-kahtib, Alghababsheh, and Khattab (2025) discuss that artificial intelligence capabilities (design, forecast and risk analysis, creating regenerative cycles, etc.) are positively associated with circular supply chain practices by exploiting frugal innovation opportunities.

Environmental Value Creation and Circular Industry 5.0

Environmental value creation refers to environmental benefits generated by Industry 5.0 technologies. Industrial automation and additive manufacturing play an important role in creating environmental value through enhanced resource efficiency and by using less resources (material and energy) and producing less waste (Lopes De Sousa Jabbour, Jabbour, Foropon, & Filho, 2018). Within Industry 5.0, the IoT and Cyber-Physical Systems enable real-time synchronization of physical flows with information flows. Due to this, the processes become more transparent, which leads to transparent and optimized material consumption and holistic resource efficiency (Blunck & Werthmann, 2017). Furthermore, these technologies enable carbon footprint analyses, which can impact greenhouse gas emissions. The real-time data from IoT and Cyber-Physical Systems help make more sustainable manufacturing decisions to eradicate waste and to use material, energy, water, and assets in a more sustainable fashion (Stock & Seliger, 2016). In addition, these technologies create environmental value through the optimization of inventories, leading to decreased energy and space requirements for storage as well as less waste created by materials turning old or outdated due to technical progress (Song & Moon, 2017). With IoT and Cyber-Physical Systems, the operational/useful life of the product is increased due to their high manufacturing quality as well as the monitoring and maintenance during their use phase. Lastly, IoT and Cyber-Physical Systems can support material tracking, facilitating collection points for reuse and recycling. Big data and cloud computing create value mainly through process monitoring, predictive maintenance, and repair, which helps extend the use phase of products (Zhang, Ren, Liu, & Si, 2017). Lastly, AI can help mitigate climate change by enabling upskilling and informed policymaking focusing on less resource-intensive and high-impact upstream interventions. For example, employing AI can give more accurate predictions on the climate patterns and the externalities we will face to develop more proper mitigation and adaptation strategies (Cowls et al., 2023). It enables informed decision making and policy making for sustainability in shorter time frames.

Social Value Creation and Circular Industry 5.0

On the social part, variables such as employee satisfaction, health & safety, and community initiatives become important for the full performance of the firm. While the broader context of performance is considered, social value has been less discussed, especially in the context of enabling technologies. In the digital transformation era, it is important to explore how Cyber-Physical Systems, Cloud Manufacturing, the Internet of Things –IoT, and *Additive Manufacturing* could facilitate the social value creation. This is important for digital transformation as it helps to understand and account for digital strategies in social value creation. From this review, I found several authors pinpointing how social value is co-created in such contexts. Ismagilova.et.al. (2019) shows how smart cities have enabled a better quality of life by enabling transport through traffic management, environment, and interaction with the government. Similarly, Leviäkangas (2016) shows how digitalization socially enhances transport networks through intelligent transport systems and high levels of connectivity, thus reducing traffic and smoothening the flow of passengers, which provides safety. Another key value for the social dimension is conserving social and natural capital; by advocating agility and flexibility, 3D printing removes assembly steps and reduces the global manufacturing footprint. In another important study, it was found by Frazzon (2013) that Socio-Cyber-Physical Systems (SCPS) applied to production networks enable behavioral aspects and implications related to the human stakeholders to be delimitated, which fosters better stakeholder relationships. Previous research in operations has documented a lot about customization and customer satisfaction. With 3D printing, the social value to customers is seen in personalized and more effective solutions in medicine, including dental and orthopedic implants. This means that everyone in society could be treated and attended to with personalized and customized products. Social innovation is also another important element realized through Service 4.0. Through calculative practices and storage of data, social innovation starts to spring up. (Morrar, R., et.al., 2017). Due to the Internet of Things, companies are now able to communicate with their social communities, especially with the new data protection regulation. This means the interaction between each individual and societal determinants of online privacy concern (OPC) and behavioral intention of internet users are much more factual and better for society. Acquiring real behavior data for vast societal research will then be possible, which can lead to enabling regenerative behavior patterns.

From the sustainability and economic point of view, the food sector is one of the most wasteful industries, as 1.3 billion tons of food are wasted every year, which corresponds to 30% of yearly food production worldwide - costing around US$ 900 billion to the world economy (UN Food and Agricultural Organization). The Internet of Things has enabled the retail industry to value co-creation. For example, larger quantities of wasted production in distribution centers and on grocery store shelves were massive. Still, due to IoT, it is expected to change the way customers experience shopping. Drawing on the service-dominant logic, this study proposes that customer interaction with IoT retail technology results in value co-creation in reducing food waste but also has a broader societal impact with Efficient Markets. Goods and services that add value to the ecosystem could freely trade at their fair market prices and quantities without tampering from biased third parties and, hence, less monopoly pricing, bringing back power to the people. Accordingly, many entrepreneurs, incubation centers, and innovation support funds have started to address the issue of food waste, surplus food, tractability, and, more importantly, food innovation (lab-grown meats, etc.) by involving the customers effectively -e.g., upskilling- (permaculture, grow your own food initiatives, etc./ as upstream interventions). Given the above-mentioned premises, the food industry constitutes a promising research direction and opportunities for CE-oriented innovations.

AI has surpassed human intelligence in certain areas, such as comprehension, image recognition, predictive reasoning, and language understanding. Artificial General Intelligence is predicted to outsmart people in most areas soon and can be employed as **cognitive labor** to deal with the unsustainability crisis. Furthermore, Gen AI allows **proactive measures** in Circular Supply Chains by simulating and predicting the safety scenarios (Zhang et al., 2024). It has great potential to actively involve the public in decision making, design, and production of products and services for circular economy and challenge the monopoly and status quo.

Discussion

Regeneration refers to the restoring, renewing, and revitalizing qualities of a process in a system that maintains a balance between society, nature, and resources (Lyle, 1994). The word regeneration emerges from the Latin 'regenerāre' and conveys the idea of being born/created and brought forth again. In the context of the economy, it depicts the characteristics of business that help improve the re-utilization of material and information flows and the socio-economic conditions of the locale. Since the emergence of enabling technologies lacks societal and environmental priorities, leveraging it for CBM would lead to more balanced and amplified prosperity. Regarding the innovation theories, R-D logic can also be considered from a sustainability-oriented innovation (SOI) perspective (Klewitz & Hansen, 2014) That identified three stages of innovation for sustainable development that align with the proposed framework: operational optimization, organizational transformation (CBM becomes part of the equation), and finally, system building (a societal change with the new logic of production and consumption). The framework perceives the degree or maturity of CBM and Industry 5.0 as crucial as the value created differs exponentially between the levels. In other words, the goal is to contribute to sustainable development by advancing the degree of maturity at both CBM and Industry 5.0 and eventually moving from G-D and S-D logic to R-D logic. Therefore, the simultaneous realization of cognitive computing (especially AI) and upskilling for CE can provide unprecedented opportunities to restore and regenerate the biosphere and create irreversible positive impacts (realizing positive tipping points for self-reinforcing co-existence).

The multiple theoretical perspectives addressed throughout the research of this study show how the concept of value in the research stream of CE and Industry 5.0 is more collaborative (social), holistic (interdependent), and meaningful (symbolically and emotionally). How the value creation in CBM leveraging Industry 5.0 differs from conventional business models can be explained from internal and external perspectives. First, the companies embarking on CBM justify their existence based on CE principles (biocentric) rather than sole economic concerns (degeneration/downstream). Secondly, CBM requires higher levels of dependence on the wider ecosystem. This indicates that the boundaries of the systems in CBM can extend beyond that of conventional BM, as CBM requires interconnectedness with disparate industries with cascading and regeneration logic. Therefore, the current logic of doing business, a goods-dominant (G-D) logic (Vargo and Lusch, 2004) and a service-dominant (S-D) (Visnjic et al., 2017; Wilden et al., 2017), are insufficient to explain completely the value creation through CBM leveraging Industry 5.0. Whether it is a product or service (as CBM is a generic model for both), the core idea of regeneration governs the value creation as a higher-level logic. Accordingly, without denying the foundational premises of (S-D) logic and (G-D) logic, given that these two logics are interdependent, CBM pursues a logic that can be said to

be a ‘*metamorphosis*’ of (S-D) and (G-D). This study has synthesized the existing body of knowledge by integrating two streams, suggesting the regeneration dominant (R-D) logic for CBM. The R-D Logic of value creation manifests that a sole technocratic approach to CE wouldn’t be sufficient and should be supported by a reasoning for co-existence.
An Industry 5.0 initiative lacking a CE perspective would eventually be self-destructive and unviable. On the other hand, one should be aware of the tensions and externalities that even CBM leveraging Industry 5.0 might embed. For instance, it might lead to induced production and consumption as the rapid pace of innovation makes current goods or services obsolete by creating new needs. A critical stance towards both paradigms would help effectively mitigate externalities and prevent forms of uncaptured value.

Conclusions

This study's purpose was to create foundations for further research at the intersection of enabling technologies and circular business models from the logic of value creation perspective. An alternative and higher-level logic of value creation is proposed as Regenerative-Dominant (R-D) Logic. As the degree of circularity advances with the digital enabling technologies, the potential for purposeful value creation for regeneration increases. As such, the rapid developments in AI and Gen AI space provide unprecedented opportunities to realize circular business models for the environment, society, and economy. Future studies should empirically test the emerging applications of recent enabling technologies in the circular economy context. Given the limited time before critical environmental and social tipping points are reached, the potential of new digital technologies—particularly various types of AI—to amplify and expedite the impact of the circular economy and enable leapfrogging scenarios should be prioritized.

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