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Introduction Chapter 1: Circular Economy and Technological Innovations: Synergies and Regional Implications

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1. Circular economy and the promise and challenge of technological innovations

The sustainability agenda has taken the central stage on the global agenda amid heightened concerns that the planet's resources are being stretched to the limit. In the past few centuries, and especially since the beginning of the 20th century, the global economy has seen astronomical industrial growth powered by advances in technological innovations across a whole spectrum of industries. These technologies have revolutionized mass production, created new markets, and instigated new habits of consumption across the countries of the world. As corporate industrial giants sought to consolidate their gains and expand market opportunities, they instigated new production processes and market dynamics underpinned by strategies such as planned obsolescence, vertical and horizontal integration, monopolization and cartel formation, and tied selling and bundling. Geopolitical forces and interests also reinforced this evolution of the global economy as leading countries seek to outrun one another in a frantic race to the bottom.

The result of this is a linear economy characterized by centralized mass production and large inventory stocking powered by the economy of scale. This make-take-dispose paradigm has invariably instigated increased waste production and associated waste management problems that have increasingly worsened as more countries industrialize and harness the benefits of existing technologies. The lock-in to the linear economy technologies continued apace as creators and adopters of the technologies aggressively promoted them and influenced later adopters. The aggregate of the ensuing network externalities and the increasing returns associated with these old technologies have induced the global economy to outcomes that are at once inferior and difficult to alter. With considerable capital sunk into these linear technologies and the significant political capital that comes with the investments, along with entrenched consumption habits associated with them in the absence of attractive market options, the linear economy has become a difficult nut to crack.

The promise of the circular economy is set against this backdrop of the entrenched linear economy. In place of the make-take-dispose paradigm associated with the linear economy, the circular economy is underpinned by three core R's: Reduce, Reuse, Recycle; or, in its more expanded form, include other R's such as recover, re-manufacture, repair, repurpose, and refurbish (Zhang et al., 2024). By prioritizing resource efficiency and waste minimization, the circular economy is seen by many stakeholders as the economy of the future. At the heart of this paradigm is the prioritization of planetary health and human needs in a positive sum game

in which one outcome does not have to suffer to realize the other: that humans produce what they need while taking care of the planet and considering the needs of future generations.

The circular economy, thus, sets a new agenda for technological progress. It does not advocate for a drawdown on technological ambitions. Instead, it sets a new direction and target for it—underpinned by the mutually reinforcing pillars of human-centric and eco-priority. Technology has, therefore, emerged as a principal ally, rather than an adversary, in the drive to break the lock-in to the linear economy. It is this theme that this book draws its attention. Across the globe, technological innovations are playing a critical role in the campaign to drive the transition to the circular economy (Hassan et al., 2023). The outcomes and challenges are not homogenous. Still, the emerging directions of impact offer a window into key areas that should attract the attention of scholars, policymakers, and practitioners.

1.1 Breaking free from the linear Model: digital innovations in action

The advent of digital transformation, accelerated since the beginning of the millennium, provides an auspicious opportunity to upend the linear economy in this age of disruptions. Old technologies are falling apart at a rapid pace, and new ones are taking command at the forefront of the global economy. These disruptive technologies are not necessarily eco-friendly and, in some cases, have exacerbated the challenges and problems of the linear economy as they push the frontiers of efficiency of mass production, promote shortened product lifespan, and make worse an endemic global waste problem. Still, others are eco-oriented technologies, prioritizing resource efficiency over production maximization. In effect, digital transformation is a battleground of disruption, where ambitious eco-friendly innovations challenge the onslaught of a digitally powered linear economy for market leadership. The following is a highlight of key areas where circular innovations are gaining traction:

Firstly, as linear economy technologies prioritize resource extraction and disposal, they invariably create inefficiencies and environmental burdens. In response, digital technologies such as IoT and blockchain prioritize the optimization of material flows, thereby minimizing waste and maximizing reuse. The second example contrasts centralized high-volume production with decentralized, customized manufacturing. The former, underpinned by traditional manufacturing, creates waste from inefficient resource use but is also more intensive in energy and ancillary resource consumption associated with long supply chains and economies of scale. On the other hand, frontier digitally enabled technologies like 3D printing to minimize resource use and disrupt traditional supply chains through decentralized manufacturing and the economy of one (Oyinlola et al., 2022). Thirdly, digital innovations are challenging ownership-based consumption by enabling servitization models where consumers can access services without ownership, thereby reducing waste while extending the product lifecycle. The past decade has seen a remarkable growth of multi-sided digital platforms powering collaborative consumption in what has been described as the sharing economy (Oyinlola et al., 2022). Fourthly, while linear economies typically operate reactively, the boom in AI and machine learning technologies has driven new predictive applications in predictive maintenance, thereby reducing time and material use and addressing problems in advance before they escalate.

1.2 Challenges to technology-enabled circularity

While the potential of digital innovations to drive the CE transition is evident, numerous challenges hinder their widespread adoption and effectiveness. First, the digital divide remains

a significant barrier, particularly in developing regions. The ability of many countries and communities to realize benefits from the technologies is limited by inadequate digital infrastructures, lack of meaningful internet connectivity, and inadequate digital literacy. This is exacerbated by the uneven distribution of technological expertise and financial resources, further marginalizing disadvantaged regions and populations. Regulatory and institutional barriers also pose significant challenges. Globally, many countries lag in the policy frameworks required to incentivize circular economy practices. For instance, the lack of extended producer responsibility regulations in several African countries undermines efforts to hold manufacturers accountable for the lifecycle impacts of their products.

The given regulatory frameworks need to understand the utility of technology-led solutions in the given geographical proximity. Meanwhile, firms that have spent money on traditional operational formations are usually reluctant to adopt emerging technologies, considering the cost and risk associated with them. Likewise, the global corporate landscape also reflects stats in line with linear technologies, with a slight tilt in favour of emerging circular sustainable technologies (S. A. R. Khan, Tahir, et al., 2024). Conversely, to counter the prevailing linear technology-led mindset, there is a dire need for public-private collaboration (Kolade et al., 2024).

1.3 Regional nuances and progress in the circular economy transition

The advancements and developments surrounding the circular economy process vary from one region to another. These variations are developed due to several factors, including the level of economic development, the nature of industrial frameworks, and the unique sociocultural environments. In Europe, the concept of circular economy has its place within regional policy frameworks because of initiatives like the European Green Deal. This policy framework focuses on the need to adopt circular practices across industries to emphasize a collective commitment to sustainability. Digital innovations receive substantial backing from funding initiatives such as Horizon Europe, which offers vital resources for the research and development of circular technologies.

Initiatives such as Woelabs in Togo, which focuses on constructing 3D printers from electronic waste, have achieved impressive results. They highlight the potential of resource-limited settings to foster innovative solutions and promote circular economy principles. Southeast Asia faces the significant challenge of addressing both the substantial amounts of plastic waste generated and the need to shift towards more sustainable circular systems.

In the same way, geographical areas like Africa and Southeast Asia are faced with challenges of varying nature and intensity, which set the direction for its development. According to the article, grassroots support and informal industrial formations for circular economic nourishment. Similarly, the stated grassroots initiatives hold notable strength in causing a change in Favor of a circular economy. However, challenges prevail, including the availability of supporting policies, infrastructure, and financial subsidies. There are also signs of slow yet steady technological growth within the developing region for the adoption of sustainable business practices.

Likewise, Indonesia and Vietnam have also adopted digital technologies for managing their waste, which marks a significant step in the direction of sustainable development. Though corresponding challenges, including non-existent policies and social support, do undermine the positive, sustainable step, the given limitations also underscore the developments in Favor of

technological advancements and ask for prompt community engagements and mass education in Favor of the subject matter.

1.4 A multi-sectoral, multi-stakeholder approach to circular economy transitions

The intermix of technological advancements and circular economic development has a promising prospect for sustainable orientation. Yet, to make the maximum of the given potential, there is a dire need for coordinated efforts across the layers of the social fabric. Public offices are required to legislate in Favor of circular economic practices and related technological adoption. It also asks for formalizing the public and private partnerships for digital infrastructure development, which in turn encourages sustainable consumption practices. Businesses, still sticking with conventional value chains, are supposed to rethink their corporate formations for improved performance outcomes. Firms are required to absorb technologies that facilitate the optimum utilization of resources, which ignites efficiency. This leads to rethinking products, with increased reliability and reusability, through effective integration with chain-wide stakeholders.

Academic institutions do have a role to play in pursuit of shaping the future, which would be sustainable. Developing a curriculum that will focus on developing digital competencies will surely play its part in nurturing generations that will be more innovative and would have more inclination toward sustainable innovation (Okoya et al., 2024). Similarly, the influx of 3D printing within the given education landscape has the potential to cause sustainable transformation (Bañón & Raspall, 2022).

The integration of technological advancement and the emergence of circular economic principles hold the definite potential to address sustainable issues faced by the present-day world. With the effective use of emerging technologies, firms can likely ensure the transition towards circular economic systems, which ensures optimum utilization of resources, reduced waste, and the development of self-sustaining systems. The materialization of the given sustainable aspirations demands countering the regulatory, technological, and industrial challenges at hand. Varying geographical formations ask for tailored policies that propagate the practical usage of prevailing advantages in order to counter existing challenges. The given intellectual compilation digs deep into the process, which aspires to craft a sustainable future with a reasonable focus on innovation and circular corporate formation.

The upcoming sections present an overview of the chapters, emphasizing the connections and complementary insights that exist among them. Additionally, they will address the gaps and opportunities that arise in the context of circular economy transitions across various regional and geopolitical landscapes.

2. Introduction to the chapters

The given edited compilation presents a mindfully crafted list of chapters that explore the interrelationship between the concepts of circular economy and technological enhancement. The dispersed contributions highlight the utility of nexus in encouraging sustainable development across the region. Chapters also unbox the challenges posed and prevailing opportunities, which are both the by-products of the transition from linear to comparative circular and resource-smart systems.

Similarly, the initial chapters, titled Circular Economic and Technological Innovation in Industry 4.0 and 5.0 Revolution, which proves to be the stepping stone that sets the tone for

discovering the connection between technological enhancement and the idea of circular economic development, the given book also explores the actions, through which AI, blockchain, and Internet of things (IoT), contributes towards transparent supply chains. Therefore, the given industrial developments are critical for transforming industries by reducing their carbon footprints. This sets the robust foundation for the book's exploration of innovative circular practices.

Expanding on this foundation, the third chapter, *Insights into Eco-Product Designs and Eco-Business Model Strategies*," examines the design strategies and business models that underpin the circular economy. With the traditional "take-make-dispose" model proving unsustainable, the chapter demonstrates how industries can adopt circular product design and eco-business strategies to mitigate resource depletion and environmental degradation. This resonates with the practical deployment of Industry 4.0 tools discussed in this chapter, which highlights the interaction between technological and design innovations.

The initial chapters investigate behavioral and logistical aspects of circular economy practices. The chapter title, *Online to Offline Recycling - An Analysis of Recycling Waste in an Internet-Integrated World*, explores how digital platforms influence consumer recycling behavior, demonstrating the role of Internet-enabled services in promoting sustainability. This is especially true among younger demographics, who are strongly represented in the frontline of sustainability and circularity campaigns. The chapter titled *Environmental Sustainability: Nexus between Green Conscientiousness, Green Motivation, Green Altruism, Green Attitudinal Purchase Intention, and Green Brand Evangelism*, analyses consumer attitudes and motivations. The authors underline the effective role of "green evangelists" and promoters of circular consumption habits among the population. Together, these chapters connect technological infrastructure with consumer-centric insights, illustrating the behavioral and digital dimensions of circular transitions.

Higher education emerges as a pivotal actor in the other two chapters. Chapter title, *Circular Economy and Commitment of Asian, South American, and Middle Eastern Higher Education Institutions to Sustainability Agenda*, investigates how regional higher education institutions (HEIs) embed sustainability principles into their strategies. Using content analysis, the chapter identifies regional variations in how HEIs align with Sustainable Development Goals (SDGs). Chapter title, *Assessing Publication Trends in MIS, Economics, and Management: Exploring the Impact of Sustainable Practices, Circular Economy, and Digitalisation*, underscores the intellectual contributions of academia to advancing circular economy research, tracing publication trends and emerging themes in sustainability and digitalization. These chapters highlight the role of knowledge systems and education in driving systemic change.

Two chapters focus on organizational and consumer dynamics within circular transitions. Chapter title: *The Impact of Integration, Hyper Agility, and Resilience Capability on Agile Strategy: Leading Towards Firms' Sustainable Performance*, examines how firms navigate global supply chain disruptions using agility and resilience capabilities. The findings underscore the necessity of dynamic capabilities to achieve sustainable performance. Chapter title, *Determinants of Consumer Green Product Consumption: Analysing the Role of Green Marketing and Consumer Attitudes*, explores the factors driving consumer preferences for green products. These chapters emphasize the interplay between organizational strategies and consumer engagement in fostering circular economies.

The following three chapters offer insightful regional perspectives that focus on the sustainability challenges and opportunities. The chapter titled "The Complex Nexus of Military

Spending, Economic Growth, Energy Consumption, and Environmental Sustainability: Insights from India and China" focuses on the intricate association between economic development and environmental impact, specifically on India and China. A chapter titled "A Multivariate Analysis of Economic Growth, Energy Consumption, and Carbon Emissions in Highly Mountainous Economies: An Empirical Evidence" focuses on the environmental Kuznets curve within mountainous regions. The chapter examines the intricate association between economic activities and their influence on carbon emissions by providing valuable insights. Chapter titled "Environmental Kuznets Curve in Pacific Nations: ICT and Renewable Dynamics" delves into the intricate association between information and communication technology (ICT) and renewable energy by exploring their roles in shaping environmental sustainability across East Asia and the Pacific region. These chapters together highlight the specific details of regional paths, demonstrating how socioeconomic and environmental contexts bring circular economy practices in the implementation process.

The concluding chapters focus on transformative opportunities. *Revolutionising Agriculture: Harnessing High-Performance Computing and Artificial Intelligence for Innovative Farming Practices* explores how AI and high-performance computing can transform agriculture, enhancing resource use efficiency and reducing environmental impacts. The next chapter, *Revolutionising Sustainability: The Impact of Circular Economy Innovations on CO2 Emissions*, examines circular economy innovations' macroeconomic and environmental benefits, particularly in reducing carbon emissions. Further, in a chapter titled: *3D Printing and the Circular Plastic Economy: Challenges and Opportunities in Nigerian Universities*, the authors explore how universities can drive sustainability through 3D printing technologies. Analyzing data from 151 students in Nigeria, the chapter highlights the critical role of knowledge in plastic waste management while uncovering systemic gaps in infrastructure and policy. It advocates multi-sectoral partnerships to enhance innovation and entrepreneurship in resource-constrained settings

In the last chapter, *Greening the Workforce for Product Recycling and Energy Conservation*, addresses the human capital dimension, highlighting the importance of workforce greening and green human resource management practices in achieving organizational sustainability goals. While these chapters span diverse topics, they are united by a common thread: the recognition that technological innovations are indispensable for advancing circular economy principles. The role of digital platforms in recycling and AI-driven agricultural solutions highlights the importance of integrated approaches in achieving circular transitions. These contributions illustrate that such transitions necessitate a harmonious blend of technological, organizational, and behavioral dimensions. The chapters simultaneously highlight the difficulties posed by established linear economic models, the variations across regions, and the pressing requirement for both policy and educational interventions.

3. Introduction to Book Sections

The following sections represent three emerging domains that capture the interconnectedness and critical aspects of circular economy and technological innovation discussed in the above-mentioned chapters. The transformative potential of digital technologies in circular practices is significant. Themes such as these serve as a guide for comprehending and tackling the intricate challenges associated with implementing a circular economy in various settings.

3.1 Foundations of Circular Economy and Technological Innovation

The foundational chapters of this book revealed that technological innovations have considerable potential in the enhancement of circular economy (CE) practices. These innovative technologies have the potential to deal with inefficiencies found in traditional business models and to leverage sustainable resource utilization. Innovations concerning circular practices play a significant role in the design, implementation, and scaling of circular business models by transforming global economies and shifting to sustainability initiatives. Other researchers have indicated that the incorporation of digital solutions within circular economy frameworks improves resource efficiency, aids in waste reduction, and encourages innovative opportunities for reuse, reform, and recycling (Khan et al., 2024; Khan, Sheikh, et al., 2024; Khan, Tahir, et al., 2024; Zhang et al., 2024).

Furthermore, the first section of the book discusses the growth and development of the circular economy and innovations in technology, particularly their use in industries 4.0 and 5.0. This section also emphasizes insights into eco-product designs and eco-business model strategies. Additionally, it emphasizes the trends in MIS, economics, and management by Redefining the role of sustainable practices, circular economy, and digitalization. Innovative technologies such as Industry 4.0 and 5.0 possess the capacity to disrupt and transform conventional industrial methods. Innovative tools like AI-enabled blockchain technologies enhance supply chain visibility and transparency.

Meanwhile, additive manufacturing plays a significant role in remanufacturing, showcasing its practical relevance in promoting circularity. Similarly, recent studies have highlighted that the transparency offered by blockchain technology plays a crucial role in enabling closed-loop supply chain systems, thereby ensuring traceability throughout the recycling and remanufacturing processes (Khan, Tahir, et al., 2024; Rehman Khan et al., 2022). Despite these challenges, significant opportunities for innovation can arise. Digital technologies have the potential to connect infrastructural gaps and inspire local innovations by encouraging collaborations among various stakeholders and incorporating circular economy practices into broader socio-economic strategies. Current research shows that these methods enable informal and small-scale participants to engage in circular value chains, fostering inclusive economic ecosystems. The literature highlights the crucial requirement to leverage digital technologies for logical systemic change. However, this approach fosters not only strong circular economy practices but also tackles global sustainability concerns affecting us all.

3.2 Sustainability Practices Across Industries and Regions

As global challenges like the climate crisis and the ongoing pandemic intensify, scholars are calling for modernizing regional development strategies. Issues such as rising inequalities and the depletion of critical resources have often been overlooked in mainstream economic discussions despite their profound socio-spatial impacts. To address these challenges, we propose a framework for transformative regional development. This approach emphasizes innovation and socio-technical system changes that align with ecological boundaries and address major crises like climate change. It adopts a clear normative stance, integrating ecological and social dynamics into regional development concepts.

A connection is made between the principles of regional industrial growth and the objectives of transitions toward sustainability through transformative regional development. Even though recent research has shed light on the overlap between these domains, there is still a lack of

comprehensive and integrated approaches. There is an urgent requirement for a comprehensive plan that investigates the dynamic relationship between regional industrial pathways and the broader sociological and spatial environments in which they are situated. The trajectories of regions are interrelated and influence one another across various spatial scales. Regions do not exist in isolation from one another. Even while there is a growing awareness of these interdependencies, the crucial role that natural resources play in supporting economies and lifestyles is sometimes underestimated. The true meaning of transformative regional development is acknowledging the profound interconnectedness of ecological boundaries with human systems while respecting those boundaries.

3.3 Innovations Driving Green Transformation

A core idea of circular economy models is optimizing product use, not just production, with consumer behaviour playing a crucial role in the adoption of green and innovative products. This shift emphasizes an "attitude to care," treating end-of-life goods as items for reuse rather than waste. Reintegrating these goods into new cycles reduces waste and promotes sustainability. Studies explore what influences consumers' attitudes toward product care, and green marketing has fostered a segment of environmentally conscious consumers. These individuals consider the ecological impact of their choices, challenging traditional views by recognizing humanity's connection with nature and prioritizing sustainability in their decisions. Green consumers embody a sense of responsibility at three levels: to themselves, others, and the environment (Strong, 1996). This convergence between green and ethical consumerism underscores the link between self-care, health, and a shift toward sustainable consumption. However, challenges remain, such as the "rebound effect," where access to eco-friendly products may encourage overconsumption, offsetting environmental benefits. Sustainable marketing highlights that consumer responsibility extends beyond personal actions, emphasizing choices' broader societal and environmental impact. Principles like fairness, respect, and justice define the consumer-citizen, whose decisions aim to create a positive social and ecological balance within a win-win framework

4. Conclusion

This introductory section explains the essential relationship between the concepts of a circular economy, technological innovation, consumer responsibility, and regional development concerning sustainability and circular economy practices. The book chapters majorly focus on addressing pressing global issues like technology and green transformation, climate change, resource depletion, responsible consumption, environmental impacts, industry transformation, circular product designing, green workforce, and many other insights. This book majorly focuses on the importance of circular economy practices in changing the production paradigms from traditional production to the optimum utilization of resources to reduce wastage and make materials reusable to conserve natural resources and achieve sustainable development goals. Further, the circular economy encourages us to view products that have completed their lifecycle not as waste but as a valuable opportunity to reuse such products and to conserve resources by optimizing the use of raw materials through the concept of recycling and reform. The emergence of technological innovations and depletion of resources has raised a lot of environmental concerns and led consumers to be more environmentally conscious, specifically enabling them to make responsible decision-making. Therefore, in this book, chapters address a comprehensive framework for tackling the sustainability issues offered based on regional

development. Collectively, these concepts chart a pathway toward a future that is more sustainable, balanced, and resilient.

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