Enabling sustainable economic transition through open innovation and emerging technologies

Rana Muhamamd Sohail Jafar
College of Business, Al Yamamah University, Saudi Arabia.

Keyword
Circular economy, PLS-SEM, Open innovation, Technology, Sustainability.

Abstract
The transition from a linear to a circular economy is essential for reducing resource depletion, improving resource efficiency, and minimizing waste generation. This study examines the role of open innovation and technological advancement in supporting this transition. Open innovation is driven by resource availability, governance infrastructure, willingness to adopt change, and knowledge-sharing practices. At the same time, technologies such as big data analytics, the Internet of Things, and additive manufacturing contribute significantly to the development of circular economy practices. Using the frameworks of open innovation and circular economy theories, data were collected from 1,001 participants across different professions and age groups. Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied to analyse the relationships among variables. The findings show that both open innovation and technological capabilities have a significant positive effect on the adoption of circular economy practices. The study offers practical insights for businesses, organizations, and policymakers seeking to accelerate sustainable development through circular economy strategies.

Introduction

The circular economy has emerged as an important framework for achieving sustainable development through efficient resource utilization, waste minimization, and environmental protection. Unlike the traditional linear economic model based on the "take–make–dispose" approach, the circular economy emphasizes reducing waste, extending product life cycles, and reusing materials through recycling, repairing, and regeneration processes (Geissdoerfer et al., 2017). This model promotes a closed-loop production and consumption system in which resources are continuously reused to reduce environmental degradation and improve long-term sustainability (Elisha, 2020). Core principles of the circular economy include reducing resource consumption, improving product durability, encouraging repair and remanufacturing, and integrating recyclable materials into production systems (Kirchherr et al., 2017). Such practices help preserve natural resources, lower pollution levels, and decrease ecological pressure caused by excessive industrial activities (Morseletto, 2020).

In addition to environmental benefits, the circular economy also creates economic opportunities by encouraging innovation, supporting new business models, and promoting industries based on recycling and sustainable production practices (Murray et al., 2017). The shift toward circular systems encourages businesses and consumers to adopt responsible production and consumption behaviours while improving resource efficiency and reducing operational costs (Hernandez et al., 2020). Technological advancement further strengthens circular economy initiatives by enabling efficient waste management, product tracking, resource recovery, and sustainable manufacturing processes. Open innovation has also become a significant driver of the circular economy transition. Unlike conventional innovation systems that rely mainly on internal knowledge, open innovation promotes collaboration among firms, researchers, customers, and other stakeholders to generate sustainable solutions and share expertise (Chesbrough, 2003). Through collaborative networks, organizations can exchange ideas, accelerate innovation, and develop environmentally responsible products and processes that support circular economy goals (Geng et al., 2019). Different forms of open innovation, including collaborative partnerships, crowdsourcing, and knowledge-sharing practices, help organizations improve resource management, reduce production costs, and strengthen sustainable development effort (Rajput & Singh, 2019).

Problem Statement

The circular economy has emerged as an important approach for improving resource efficiency, reducing waste, and promoting sustainable production and consumption. Open innovation and technological advancement are considered key drivers in supporting the transition from a traditional linear economy to a circular economy model. Open innovation encourages collaboration, knowledge sharing, and partnerships among organizations, while technology enables efficient product design, recycling, and resource management. However, limited empirical research explains how open innovation and technology collectively facilitate the implementation of circular economy practices. Therefore, this study examines the relationship between circular economy, open innovation, and technology to provide insights for policymakers, industries, and researchers in promoting sustainable development.

Research Questions

1. What key factors influence the relationship between open innovation, technology, and the adoption of circular economy practices?
2. How does open innovation contribute to the implementation of circular economy principles across industries?
3. How does technology enhance resource efficiency and support circular economy initiatives?

Research Objectives

- To identify the main enablers linking open innovation, technology, and circular economy adoption.
- To examine the contribution of open innovation to the implementation of circular economy practices.
- To assess the role of technology in improving resource efficiency within the circular economy

In conclusion, circular economy is recognized as a revolutionary approach to production and consumption practices. It sustained the resource allocation, resource efficiency and waste reduction. While integrating with the open innovation & technology adoption, businesses can enhance the transition toward the circular economy. It not only promotes environmental sustainability but also drives the economic growth, employment generation and technological advancement. As the stakeholders continue to evolve, adopting the circular economy practices and engaging with open innovation, the global challenges can be addressed and sustainability can be achieved.

Review of Literature

Linear to Circular economy

Economic sustainability focal the economic needs of the economic man without affecting his future potential to satisfy the needs (Rennings & Wiggering, 1997). The traditional "take-make-dispose" approach of linear economy has resulted in significant environmental problem, influencing resources availability and the quality. This leads to sustainability threats. The resource depletion and environmental degradation as an outcome of the traditional economic linear approach, highlight the demand for a worthy liveable model and transition to it is the need of the time. This provides with the foundation that why we should try to adopt a more sustainable solution to overcome the challenges of the linear economy. The circular economic model focus on the efficient and optimal use of resources with little generation of waste by employing 3R strategy (reuse, recycle and reduce). This approach helps in creating the closed system where the materials are reprocessed and remodelled reducing utilization of new resources, recycling the product and conserving the ecosystem by reducing the environmental impact. The sustainability crafted by this approach assists in separating the economic wellbeing from the consumption of resources. The new circular business models are adopted in the corporate environment that support the circular economy (Awan & Sroufe, 2022; Urbinati et al., 2017). Companies are leasing products rather than selling, service-based economy is growing, products that ensure durability are designed to ensure the reduction of the resource utilization and the resources on repair. If such practices penetrate into the society the environmental damages of the firms can be reduced. Moreover, the social sustainability as one of the understated outcomes of the circular economy. As the stakeholder engagement approach, community integration approach and inclusive approaches help in creating stronger relations and ensure the practices that beneficial to all participant. Academia and researchers can play a significant role in stimulating the open innovation and advocating the circular economy. They help in providing with the tools and the knowledge that industries could implement to promote the circular economy. Thus, a collaboration between the education and the industry leads to sustainability (Jesus & Jugend, 2023). Lastly the government as a main player in most economies- can provide with the regulations, incentives and the funding that create the institutions the hub of the innovation and accelerate the transformation toward the circular economy (Li & Maskin, 2021).

Technological Advancements Facilitating the Shift to Circular Economy

Technology enables transformation in the economy by shifting toward the efficient resource allocation and adoption of innovative ideas. Technologies comprising of internet of things, block chain and artificial intelligence are central to the adoption of the circular economy. IoT assists in product lifecycle monitoring, by improving its design, using efficiency and traceability. AI assists in optimal allocation of the resources, forecasting the future needs of maintenance and reducing waste. Block chain technology help in improving supply chains by ensuring transparency and trust and collaboration among stakeholders (Chishty, 2023). Kirchherr et al., (2023) identified 3D Printing and additive manufacturing is also form of the technological advancement that leads to the promotion of circular economy. It ensures that the waste or by-product is reduced during production process. Further the 3D printing can build objects by using recycled material contributing to resource efficient utilization and optimization (Kirchherr et al., 2023). Online marketplaces dedicated to selling second-hand goods extend the life of products and reduce the need for new manufacturing. Circular business models are easier to adopt due to digital technologies (Corvellec et al., 2022). Examples include "product as a service," in which customers pay to use a product rather than purchase it, and "take-back" programs, in which businesses collect and refurbish products for resale or recycling (Mendoza et al., 2022). Thus, the technological advancement facilitates the circular economy by advancing the manufacturing processes, creating new business models, reducing the waste in manufacturing, recycling and reusing, all of which help in creating a sustainable future. Continuous promotion and adoption of these technologies help in development of resilient economy.

Barriers to Adopting Circular Economy Open Innovation

Open innovation is significant in promoting the open economy beyond organizational boundaries, sometime is identified as a measure to overcome the barriers to adoption of circular practices. AlJaber et al. (2023) highlights the regulations unavailability, fragmented supply chains and high upfront investment cost as the prime obstacles to implementation of the circular economy practices. Their findings indicate that the financial incentives, proper legislation and regulatory framework and innovation can act as driver of circular economy. Jaeger and Upadhyay (2020) emphasize the insufficient technological tools and infrastructure as the prime barrier to the circular economy. The lack of the technologies, innovations and development of advance methods is barrier to it. According to them the gap limits the efficient allocation, optimal utilization and reuse & recycling of resources making it challenging in various sectors to be implemented. Mhatre et al., (2023) highlighted the importance of environmental barriers that are prevalent in the various sectors of economy, like the construction sector of India. The lack of environmentally safe material for construction, environmentally unfriendly supply chains and high operating costs are significant barriers. The integration of the open innovation with the CE provides with course to subdue the limitations to its implementation. Continued innovation, cooperation, shared learning and participation leads to various economic as well as environmental benefits.

Theoretical Framework & Hypothesis Building

This study is based on Open Innovation Theory (Chesbrough, 2003) and Circular Economy Theory (MacArthur, 2013) to examine how innovation and knowledge sharing support circular economy practices. Open innovation emphasizes the use of both internal and external ideas to improve innovation and sustainability. It encourages collaboration, knowledge exchange, and stakeholder engagement, which can help organizations shift from a linear to a circular economy model. Previous studies also suggest that open innovation plays an important role in developing sustainable systems and infrastructure that support circular economy practices.

Conceptual Framework

The conceptual framework explains the key factors influencing the adoption of circular economy practices. The independent variables include governance, willingness to adopt new market strategies, knowledge sharing culture, availability of resources, Internet of Things (IoT), big data analytics, and additive manufacturing. These factors directly support the development of circular economy practices. Open innovation and technology act as mediating variables by strengthening the relationship between these factors and the circular economy. The dependent variable, circular economy, focuses on reducing waste, improving resource efficiency, and promoting sustainable production through recycling and reuse. Understanding these relationships helps explain how organizations can successfully adopt circular economy models.

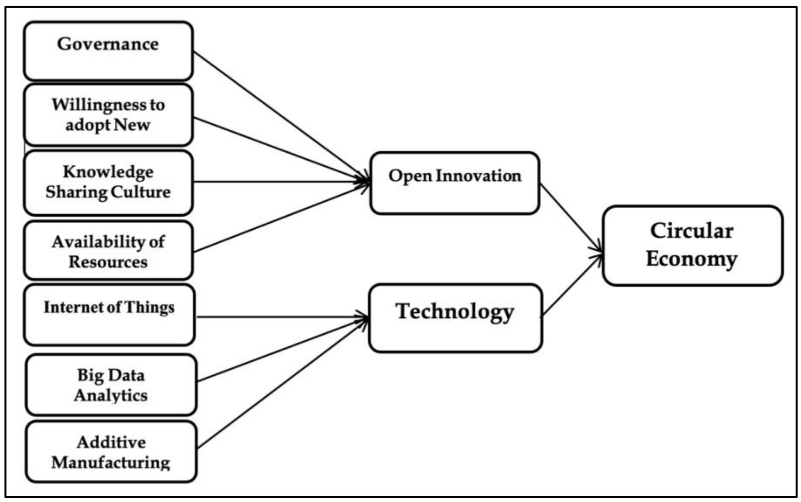


Figure 1: Research Model

Thus, it is hypothesized that;
H1: Open innovation is significantly related to the circular economy.

Additionally, Lee et al. (2010) highlight that how effective governance can facilitates the open innovation by promoting engagement among stakeholders, collaboration and exchange of ideas. Thus, governance can create a conductive environment to sustainability. Chesbrough (2003) discuss that how governance framework influences the adoption of the open innovation principles. The relation can be hypothesized as;

H2: Governance is significantly associated with the open innovation.

The role of the SME's in adoption of the open innovation practices. It is identified that the willingness of the firms to adapt new market trends, making it critical component of the innovation. (Lichtenthaler & Ernst, 2009) analyze the willingness to explore the new ideas as a crucial component to open innovation. Thus, it can be hypothesized that;

H3: Willingness to adopt new is significantly associated with the open innovation.

Creating a knowledge sharing culture also facilitates the open innovation practices. A study by Huang & Rice (2009) highlights the importance of the knowledge sharing culture in facilitating the open innovation by emphasizing on the internal and external knowledge flow to succeed the innovation (Huang & Rice, 2009). Cumming &Teng (2003) also focus on enhancing the open innovation by improving collaboration, exchange of ideas and flow of information (Cummings & Teng, 2003). Thus, it can be hypothesized as;

H4: Knowledge sharing culture is significantly associated with the open innovation.

A study by Dahlander and Gann (2010) investigate the importance of financial, human and technological resources in influencing open innovation practices. It highlights that the resources enable organization to develop new ideas, experiment new methods and practice new knowledge (Dahlander & Gann, 2010). Research by West & Gallagher (2006) explore the role of resources in supporting innovation by increase the probability of engagement with the new stakeholders and resources (West & Gallagher, 2006). Thus, relation can be hypothesized as;

H5: Availability of resources is significantly associated with the Open innovation.

Circular economy theory focuses on minimizing the waste and maximizing the resource use efficiently by reuse, regenerate and recycle principles. This contributes to the overall sustainability and reduce the environmental degradation (Ghisellini et al., 2016). Technology play and important role in create such mechanism that ensure the product recovery and recycling, extending its lifecycle (Lieder & Rashid, 2016). The role of additive manufacturing in supporting the circular economy by enabling the use of waste in recycling, repairing of product and localizing the production processes (Ford & Despeisse, 2016). Study by (Jia et al., 2020) examine the role of technological advancement supporting the development of closed loop system, creating the supply chains, internet of things and the blockchain as a critical component of circular economy. Thus, relationships can be hypothesized as;

H6: Technological advancement is significantly related to the circular economy.

Similarly, McAfee &Brynjolfsson (2012), discusses how the big data analysis transforms the organizations and industries toward the informed data-based (Berman, 2012) decisions and harness the sustainability (McAfee et al., 2012). Berman (2012) highlights the importance of 3D printing in creating technological revolution and developing customized products, thus, additive manufacturing has affected the product development, supply chains and innovation. There are strong implications of the additive manufacturing on technological advancement including development of new business models to limiting orthodox manufacturing practices (Petrick & Simpson, 2013).

H7: Big data analysis is positively associated with the technology.
H8: Additive manufacturing is positively associated with the technology.
H9: Internet of things are positively associated with the technology

Materials and Method

Data collection

This study utilized purposive sampling to select participants with in-depth knowledge and experience in the field. The study selects a set of organizations known for their effective circular economy practices and significant utilization of technology. To achieve the objectives, this study administered structured surveys. This study design and distribute structured questionnaires to diverse organizations representing broad-spectrum industries and sectors in Guangdong Province in P.R. China. The study employs stratified random sampling for the second objective to ensure proportional representation from each sector. The survey measures the extent of open innovation practices and their correlation with circular economy adoption. The response of 1001 respondent's is recorded for the estimation of the research model based on the variables and their items are mentioned with the statements.

Data analysis

The Structure Equation Modelling (SEM) approach has been used to analyse the hypothesis. The process of conducting SEM involves several key stages to ensure the accuracy and reliability of the analysis. The collected data is carefully prepared in line with the assumptions of the selected SEM model. The reliability of data examined through Cronbach's alpha (Hair Jr, Hult, Ringle, Sarstedt, Danks, Ray, et al., 2021). The model is then estimated using SEM analysis, which evaluates how well the model fits the data by establishing the relationships between latent variables and observed indicators (Singh et al., 2021). The findings of the SEM analysis, including parameter estimates, and significance levels presented in this study.

Results and Discussions

Measurement model

The evaluation of measurement model includes assessing the reliability of the variables and their items including the internal consistency by using Cronbach Alpha and composite reliability rho_A, convergent validity by using Average variance extracted (Chin, 1998). Composite reliability represents the internal consistency of the items in the variables. Its value should be greater than 0.7. Table 1 show that the value of composite reliability (rho_a) is between 0.8 to 0.9 highlighting good reliability. The internal consistency reliability of model also presented by Cronbach's Alpha given in the table1, indicating the consistent reliability, as their values are above threshold of 0.7. Average Variance Extracted show the strength of linkage between the variable and its items. Average Variance Extracted is higher than the threshold of 0.5. All the value for VIF is less than 5 indicating that the model is free from multi-collinearity. When item loadings are higher or equal to 0.7, there is more shared variance between the construct and its error variance. The loadings ranging from 0.7 to 0.8. The outer loadings for the variables are higher than 0.7 (Gefen & Straub, 2005).

VARIABLES	ITEMS	LOADINGS	VIF	C.A	C.R	AVE
Additive Manufacturing	ADM1	0.810	1.524	0.793	0.802	0.707
	ADM2	0.825	1.743			
	ADM3	0.886	1.965			
Availability of Resources	AOR1	0.828	1.767	0.827	0.833	0.743
	AOR2	0.897	2.218			
	AOR3	0.860	1.859			
Big Data Analytics	BDA1	0.726	1.439	0.807	0.814	0.634
	BDA2	0.824	1.748			
	BDA3	0.813	1.752			
	BDA4	0.818	1.721			
Circular Economy	CE1	0.919	1.809	0.802	0.803	0.834
	CE2	0.908	1.809			
Governance	GOV1	0.863	2.659	0.871	0.878	0.611
	GOV2	0.858	2.534			
	GOV3	0.772	1.871			
	GOV4	0.718	1.657			
	GOV5	0.713	1.579			
	GOV6	0.752	1.681			
Internet of Things	IoT1	0.782	1.680	0.812	0.822	0.64
	IoT2	0.867	2.054			
	IoT3	0.772	1.527			
	IoT4	0.776	1.609			
Knowledge Sharing Culture	KSC1	0.738	1.497	0.831	0.842	0.666
	KSC2	0.857	2.122			
	KSC3	0.781	1.664			
	KSC4	0.879	2.331			
Open Innovation	OI1	0.811	1.738	0.823	0.825	0.653
	OI2	0.783	1.649			
	OI3	0.819	1.791			
	OI4	0.819	1.739			
Technology	TECH1	0.785	1.651	0.829	0.834	0.661

	TECH2	0.874	2.227			
	TECH3	0.791	1.695			
	TECH4	0.800	1.722			
Willingness to Adapt New	WANM1	0.824	1.907	0.854	0.858	0.696
	WANM2	0.882	2.392			
	WANM3	0.824	1.894			
	WANM4	0.804	1.808			

Table 1: Specification of outer model

The discriminate validity is tested by using the Heterotrait- Monotrait (HTMT) ratio presented in table 2. The maximum value obtained by applying the test is 0.622 which is less than the threshold value of 0.90. The values highlight the validity of the variables (Hair Jr et. al., 2021). The analysis of measurement model exhibit that variables are internally consistent, convergent validate, discriminant validate and the items are reliable.

	ADM	AOR	BDA	CE	GOV	IoT	KSC	OI	TECH	WANM
ADM										
AOR	0.239									
BDA	0.419	0.356								
CE	0.479	0.442	0.541							
GOV	0.396	0.425	0.332	0.571						
IoT	0.267	0.191	0.419	0.432	0.385					
KSC	0.213	0.518	0.354	0.428	0.423	0.138				
OI	0.230	0.654	0.385	0.447	0.444	0.186	0.571			
TECH	0.248	0.204	0.446	0.504	0.411	0.622	0.212	0.236		
WANM	0.387	0.340	0.592	0.480	0.282	0.377	0.357	0.356	0.408	

Table 2: HTMT ratio

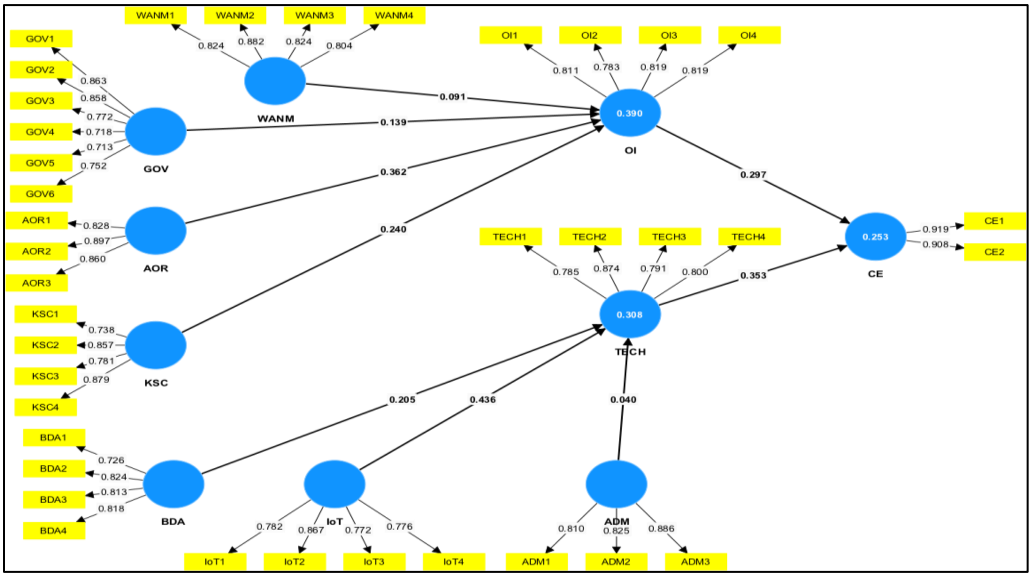
Structural model

The hypothesizes are tested using the PLS-SEM method and relationship between the variables are identified based on the model (figure 2). The structural model is evaluated by using the significance and relevance of the model and assess the R square of the model (Hair & Alamer, 2022). The first hypothesis predict that the open innovation is related positively to the circular economy. Governance, Availability of resources, Knowledge sharing culture, willingness to adopt new are significantly related to open innovation, highlighting the hypothesis 2 to 5. The sixth hypothesis states that the technology is associated (positively) to the circular economy. Additive manufacturing, Big data analytics, Internet of things are significantly related to the technology, accepting the hypothesis 7-9.

Direct effect	(O)	(STDEV)	T statistics	P values	Results
ADM -> TECH	0.040	0.028	1.426	0.154	Accepted
AOR -> OI	0.362	0.028	12.897	0.000	Accepted
BDA -> TECH	0.205	0.030	6.821	0.000	Accepted
GOV -> OI	0.139	0.029	4.746	0.000	Accepted
IoT -> TECH	0.436	0.027	16.168	0.000	Accepted
KSC -> OI	0.240	0.029	8.171	0.000	Accepted
OI -> CE	0.297	0.027	10.859	0.000	Accepted
TECH -> CE	0.353	0.027	12.848	0.000	Accepted
WANM -> OI	0.091	0.027	3.304	0.001	Accepted

Table 3: PLS bootstrapping result

Figure 2: Structural Model
Discussion and Conclusion



The findings confirm that open innovation significantly promotes the circular economy, supporting the transition from a linear to a sustainable economic model. This result is consistent with prior studies emphasizing the importance of collaboration, knowledge exchange, and innovative practices in achieving circular economy objectives (Jesus & Jugend, 2023; Kohler et al., 2022; Sergianni et al., 2024). The results of H2–H5 further indicate that governance, networking and monitoring capability, knowledge-sharing capability, and adoption readiness positively influence open innovation. These factors strengthen organizational collaboration, improve information exchange, and enhance firms' ability to adopt sustainable innovation practices (Lam et al., 2021; Sivam et al., 2019). Additionally, H6 demonstrates that technology positively affects the circular economy by improving resource efficiency, waste reduction, and sustainable production processes. Emerging digital technologies support recycling, reuse, and circular business practices (Bressanelli et al., 2017). Finally, H7–H9 reveal that additive manufacturing, big data analytics, and the Internet of Things significantly contribute to technological advancement. These technologies enhance decision-making, operational efficiency, and sustainable resource management, thereby facilitating the implementation of circular economy practices (Awan et al., 2021).

Conclusion

The findings of this study highlight the significance of the research questions and confirm that Internet of Things big data analytics, and additive manufacturing play a crucial role as enablers in shaping the relationship between technology and the transition toward a circular economy. The results indicate that organizations that actively pursue circular business models are more likely to achieve successful adoption of sustainable practices, improved resource efficiency, and stronger environmental performance. In this regard, open innovation emerges as a key mechanism that enhances the effectiveness of circular economy implementation by facilitating collaboration, knowledge exchange, and better access to internal and external resources.

The empirical results further demonstrate that technological advancement is a strong driver of circular economy practices. Big data analytics supports informed decision-making by enabling organizations to analyze large volumes of data for optimizing resource use and reducing waste. Additive manufacturing contributes to sustainability by minimizing material consumption, reducing production waste, and enabling localized and efficient production systems. Similarly, IoT enhances connectivity across systems, allowing real-time monitoring, improved coordination, and efficient resource management. Together, these technologies strengthen operational efficiency and significantly contribute to the transition from linear to circular economic systems. The study also confirms that open innovation is strongly influenced by key organizational and institutional factors such as governance, resource availability, knowledge-sharing capability, and willingness to adopt change. These factors collectively enhance organizational readiness for innovation and improve the capacity to implement sustainable practices. Knowledge-sharing practices further strengthen collaboration, and willingness to adopt change reflects organizational adaptability in response to evolving sustainability demands. These findings reinforce the importance of an enabling environment for fostering open innovation and sustainable development.

Theoretical Implications

The theoretical contribution of this study lies in extending the understanding of how open innovation and technological advancement jointly influence the transition toward a circular economy. It provides empirical evidence supporting the idea that innovation networks and digital technologies are critical drivers of sustainability-oriented transformation. By integrating open innovation theory with circular economy principles, the study contributes to a more comprehensive understanding of how organizational and technological factors interact to promote sustainable economic systems. The findings also provide a foundation for future research exploring these relationships in different industries, regions, and technological contexts.

Practical Implications

From a policy perspective, the study suggests that governments and relevant stakeholders should prioritize strengthening governance frameworks that actively encourage circular economy practices. Regulatory systems should be designed to facilitate innovation rather than hinder it. Organizations are encouraged to invest in research and development activities, strengthen digital capabilities, and promote a culture of collaboration and knowledge sharing. Moreover, strategic investment in digital and technological infrastructure—particularly IoT systems, big data analytics platforms, and additive manufacturing technologies—should be promoted through funding initiatives, incentives, and awareness programs. In addition, fostering societal awareness and willingness to adopt sustainable consumption and production practices is necessary to ensure long-term success of circular economy initiatives.

Limitations and direction for future research

Despite these contributions, the study has certain limitations. The use of cross-sectional data limits the ability to capture long-term causal relationships between variables. Future studies could adopt longitudinal research designs to better understand how these relationships evolve over time. Additionally, the study focuses on a limited scope of industries and contexts, which may restrict generalizability. Expanding the research to different sectors and geographical regions would provide more robust insights. Furthermore, as technological innovation continues to evolve rapidly, future research should incorporate emerging technologies and examine their role in enhancing circular economy transitions.

Reference

Adams, R., Bessant, J., & Phelps, R. (2006). Innovation management measurement: A review. International journal of management reviews, 8(1), 21-47.

AlJaber, A., Martinez-Vazquez, P., & Baniotopoulos, C. (2023). Barriers and enablers to the adoption of circular economy concept in the building sector: a systematic literature review. Buildings, 13(11), 2778.

Almaiah, M. A., Al-Rahmi, A. M., Alturise, F., Alrawad, M., Alkhalaf, S., Lutfi, A., Al-Rahmi, W. M., & Awad, A. B. (2022). Factors influencing the adoption of internet banking: An integration of ISSM and UTAUT with price value and perceived risk. Frontiers in Psychology, 13(1), 1-23.

Antikainen, M., Uusitalo, T., & Kivikyto-Reponen, P. (2018). Digitalisation as an enabler of circular economy. Procedia CIRP, 73, 45-49.

Awan, U., Shamim, S., Khan, Z., Zia, N. U., Shariq, S. M., & Khan, M. N. (2021). Big data analytics capability and decision-making: The role of data-driven insight on circular economy performance. Technological Forecasting and Social Change, 168, 120766.

Awan, U., & Sroufe, R. (2022). Sustainability in the circular economy: insights and dynamics of designing circular business models. Applied Sciences, 12(3), 1521.

Berman, B. (2012). 3-D printing: The new industrial revolution. Business horizons, 55(2), 155-162.

Bressanelli, G., Perona, M., & Saccani, N. (2017). Reshaping the washing machine industry through circular economy and product-service system business models. Procedia CIRP, 64, 43-48.

Chesbrough, H. W. (2003). Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. Modern methods for business research, 295(2), 295-336.

Chishty, S. K. (2023). Economic and environmental efficiencies of organizations: role of technological advancements and circular economy practices. Sustainability, 15(22), 15935.

Corvellec, H., Stowell, A. F., & Johansson, N. (2022). Critiques of the circular economy. Journal of industrial ecology, 26(2), 421-432.

Cummings, J. L., & Teng, B.-S. (2003). Transferring R&D knowledge: the key factors affecting knowledge transfer success. Journal of Engineering and technology management, 20(1-2), 39-68.

Dahlander, L., & Gann, D. M. (2010). How open is innovation? Research policy, 39(6), 699-709.

Elisha, O. D. (2020). Moving beyond take-make-dispose to take-make-use for sustainable economy. Int. J. Sci. Res. Educ, 13(3), 497-516.

Ford, S., & Despeisse, M. (2016). Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. Journal of Cleaner production, 137, 1573-1587.

Gefen, D., & Straub, D. (2005). A practical guide to factorial validity using PLS-Graph: Tutorial and annotated example. Communications of the Association for Information systems, 16(1), 5.

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm? Journal of Cleaner production, 143, 757-768.

Geng, Y., Sarkis, J., & Bleischwitz, R. (2019). How to globalize the circular economy. Nature, 565(7738), 153-155.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. Journal of Cleaner production, 114, 11-32.

Hair, J., & Alamer, A. (2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. Research Methods in Applied Linguistics, 1(3), 100027.

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., & Ray, S. (2021). Partial least squares structural equation modeling (PLS-SEM) using R: A workbook. Springer Nature.

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., Danks, N. P., Ray, S., Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). An introduction to structural equation modeling. Partial least squares structural equation modeling (PLS-SEM) using R: a workbook, 1-29.

Hassandoust, F., & Techatassanasoontorn, A. A. (2020). Understanding users' information security awareness and intentions: A full nomology of protection motivation theory. In Cyber influence and cognitive threats (pp. 129-143). Elsevier.

Hernandez, R. J., Miranda, C., & Goñi, J. (2020). Empowering sustainable consumption by giving back to consumers the 'right to repair'. Sustainability, 12(3), 850.

Huang, F., & Rice, J. (2009). The role of absorptive capacity in facilitating" Open innovation" outcomes: A study of Australian SMEs in the manufacturing sector. International journal of innovation management, 13(02), 201-220.

Jaeger, B., & Upadhyay, A. (2020). Understanding barriers to circular economy: cases from the manufacturing industry. Journal of Enterprise Information Management, 33(4), 729-745.

Jesus, G. M. K., & Jugend, D. (2023). How can open innovation contribute to circular economy adoption? Insights from a literature review. European Journal of Innovation Management, 26(1), 65-98.

Jia, F., Yin, S., Chen, L., & Chen, X. (2020). The circular economy in the textile and apparel industry: A systematic literature review. Journal of Cleaner production, 259, 120728.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, conservation and recycling, 127, 221-232.

Kirchherr, J., Yang, N.-H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the circular economy (revisited): an analysis of 221 definitions. Resources, conservation and recycling, 194, 107001.

Kohler, J., Sonnichsen, S. D., & Beske-Jansen, P. (2022). Towards a collaboration framework for circular economy: The role of dynamic capabilities and open innovation. Business Strategy and the Environment, 31(6), 2700-2713.

Lam, L., Nguyen, P., Le, N., & Tran, K. (2021). The relation among organizational culture, knowledge management, and innovation capability: Its implication for open innovation. Journal of Open Innovation: Technology, Market, and Complexity, 7(1), 66.

Lee, S., Park, G., Yoon, B., & Park, J. (2010). Open innovation in SMEs—An intermediated network model. Research policy, 39(2), 290-300.

Li, D. D., & Maskin, E. S. (2021). Government and economics: An emerging field of study. Journal of Government and Economics, 1, 100005.

Lichtenthaler, U., & Ernst, H. (2009). Opening up the innovation process: the role of technology aggressiveness. R&d Management, 39(1), 38-54.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry. Journal of Cleaner production, 115, 36-51.

MacArthur, E. (2013). Towards the circular economy. Journal of industrial ecology, 2(1), 23-44.

McAfee, A., Brynjolfsson, E., Davenport, T. H., Patil, D., & Barton, D. (2012). Big data: the management revolution. Harvard business review, 90(10), 60-68.

Mendoza, J. M. F., Gallego-Schmid, A., Velenturf, A. P., Jensen, P. D., & Ibarra, D. (2022). Circular economy business models and technology management strategies in the wind industry: Sustainability potential, industrial challenges and opportunities. Renewable and Sustainable Energy Reviews, 163, 112523.

Mhatre, P., Gedam, V. V., Unnikrishnan, S., & Raut, R. D. (2023). Circular economy adoption barriers in built environment-a case of emerging economy. Journal of Cleaner production, 392, 136201.

Morseletto, P. (2020). Targets for a circular economy. Resources, conservation and recycling, 153, 104553.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: an interdisciplinary exploration of the concept and application in a global context. Journal of business ethics, 140, 369-380.

Petrick, I. J., & Simpson, T. W. (2013). 3D printing disrupts manufacturing: how economies of one create new rules of competition. Research-Technology Management, 56(6), 12-16.

Rajput, S., & Singh, S. P. (2019). Connecting circular economy and industry 4.0. International Journal of Information Management, 49, 98-113.

Rennings, K., & Wiggering, H. (1997). Steps towards indicators of sustainable development: linking economic and ecological concepts. Ecological economics, 20(1), 25-36.

Sergianni, L., De Chiara, A., & Mauro, S. (2024). Open Innovation as Fuel for the Circular Economy: an Analysis of the Italian Context. Journal of Innovation Management, 12(1), 188-204.

Singh, S., Babbitt, C., Gaustad, G., Eckelman, M. J., Gregory, J., Ryen, E., Mathur, N., Stevens, M. C., Parvatker, A., & Buch, R. (2021). Thematic exploration of sectoral and cross-cutting challenges to circular economy implementation. Clean technologies and environmental policy, 23, 915-936.

Sivam, A., Dieguez, T., Ferreira, L. P., & Silva, F. J. (2019). Key settings for successful open innovation arena. Journal of Computational Design and Engineering, 6(4), 507-515.

Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. Journal of Cleaner production, 168, 487-498.

Van de Vrande, V., De Jong, J. P., Vanhaverbeke, W., & De Rochemont, M. (2009). Open innovation in SMEs: Trends, motives and management challenges. Technovation, 29(6-7), 423-437.

West, J., & Gallagher, S. (2006). Challenges of open innovation: the paradox of firm investment in open-source software. R&d Management, 36(3), 319-331.

West, J., Salter, A., Vanhaverbeke, W., & Chesbrough, H. (2014). Open innovation. Open Innovation Community.