

**THESES OF THE DOCTORAL (PhD)
DISSERTATION**

**EFFECTS OF GREEN TECHNOLOGY ADAPTATION AND
GREEN INNOVATION ON CIRCULAR ECONOMY
PERFORMANCE OF MINING SECTOR IN MONGOLIA**

ERDENEBAYAR CHULUUNBAATAR

Supervisor:

PROF. DR. JUDIT OLÁH

Full Professor, Doctor of the Hungarian Academy of Sciences (DSc)



UNIVERSITY OF DEBRECEN

Doctoral School of Management and Business

Debrecen

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1. INTRODUCTION

1.1 Justification for the study and Research Gap

The adoption of green technology in organizational operations involves complex decision-making that engages both internal and external stakeholders. While previous studies, such as HONG *ET AL.* (2024), have examined green technology adoption, they primarily focus on the individual level. This leaves a research gap at the organizational operational level—specifically in understanding how green technology is implemented and how resources are utilized within firms. Moreover, the influence of external factors on operational performance and the relationship between green technology adoption and circular economic outcomes remain insufficiently explored.

The current study addresses this gap by emphasizing the need to establish a comprehensive framework that captures how public opinion, and external mechanisms can enhance sustainable firm operations and drive circular performance through green technology. Additionally, green innovation—closely related to green technology—is identified as a key but under-researched factor. Research by KHAN *ET AL.* (2024) reveals a strong link between green innovation and environmental performance within circular economy systems. Similarly, YAOTENG AND XIN (2022) affirm that the effectiveness of circular economic performance is dependent on the quality of green innovation and ecological sustainability. ABDALLAH *ET AL.* (2024) further argues that leadership priorities significantly influence green innovation outcomes, enhancing firms' capacity to participate effectively in the circular economy while improving environmental efficiency.

The significance of this research is particularly relevant to Mongolia, where approximately half the population are nomads, and a major portion of exports derive from mining. Rapid urbanization and limited resources have led both the government and citizens to recognize the value of adopting circular production systems, even within traditionally resource-intensive sectors like mining (SODNOMDARJAA *ET AL.*, 2024). The growing migration of nomads to urban centers and mining jobs has prompted a national push for green skill development, supported by the implementation of green innovation and green technologies. Organizations, as a result, are achieving improved performance aligned with circular economic principles (MA *ET AL.*, 2024b).

Despite this momentum, there is a noticeable absence of prior empirical studies specifically addressing Mongolia's mining sector in the context of green innovation and circular economy. This study aims to fill that research gap by providing insights tailored to Mongolia's unique socio-economic and environmental conditions, thereby justifying its relevance and importance.

1.2 Research questions and objectives

To contribute to the academic debate and to provide useful insights to practitioners, the present study aims at evaluating the effect of green technology adaptation and green innovation on circular economic

performance. In the present model, green technology adaptation presents as exogeneous construct, circular economy performance as the endogenous construct, whereas green innovation applied as a mediating factor. Based on this, the current study indicates the following research questions represented in section 1.3.1 and research objectives in section 1.3.2.

1.2.1 Research Questions

RQ1: Does green technology adaptation have a relationship with circular economic performance?

RQ2: Have green technology adaptation a relationship with green innovation?

RQ3: Does green innovation have an association with circular economic performance?

RQ4: Have green innovation a mediating effect on the relationship between green technology adaptation and circular economy performance?

1.2.2 Research Objectives

RO1: To assess the impact of green technology adaptation on circular economic performance.

RO2: To evaluate the effect of green technology adaptation on green innovation.

RO3: To measure the relationship between green innovation and circular economic performance.

RO4: To investigate the mediating effect of green innovation on the relationship between green technology adaptation and circular economy performance.

2. CONCEPTUAL FRAMEWORK

2.1 Green Technology Adaptation

Green technology plays a pivotal role in promoting efficient resource use and reducing the environmental impact of supply chains. ISLAM *ET AL.* (2024b) argue that emerging economies face challenges in adopting green technologies due to managerial inefficiencies and limited spatial resources. To support sustainable development, it is essential to understand the enablers of green technology, as sustainability enhances competitive advantage across all organizational types (BRUCE *ET AL.*, 2022). Companies are increasingly integrating green technologies to meet social and environmental goals (IKRAM *ET AL.*, 2021). These technologies support eco-innovation and provide actionable strategies for practitioners. XIA *ET AL.* (2022) describe green technology adoption as encompassing product development, manufacturing, employee training, and consumer engagement. They emphasize the importance of extending these innovations beyond organizational boundaries to include stakeholders.

Despite the benefits, several barriers hinder widespread adoption. ZENG *ET AL.* (2022) identify structural constraints—such as limited financial access, fuel price distortions, and regulatory issues—and behavioral constraints, including consumer hesitancy due to high upfront costs. These factors complicate the perceived profitability of energy-efficient investments (CHOWDHURY *ET AL.*, 2024; DEY *ET AL.*, 2021).

MING *ET AL.* (2022) highlight the potential of green technologies to reduce energy consumption but caution that hidden costs—like training and opportunity costs—may deter adoption. Consumer heterogeneity further complicates the evaluation of green technology efficiency, making it less appealing for some businesses. USMAN (2023) provides a practical example: installing energy-saving heat pumps can reduce heating costs by 30–40%, improve indoor climate, and lower emissions. These benefits extend beyond private gains to societal advantages, particularly when electricity is sourced from renewable hydroelectric power. Reduced residential energy use can free up resources for sectors with higher emission reduction potential.

In conclusion, while green technologies offer significant environmental and economic benefits, their adoption is influenced by a complex interplay of structural, behavioral, and economic factors. Addressing these barriers is crucial for achieving broader sustainability goals.

2.2 Green Innovation

Green innovation varies in type and novelty, leading companies to pursue it for diverse reasons. The primary drivers of green innovation are associated with regulatory frameworks and market demand (ULLAH *ET AL.*, 2023); and the other drivers include the enhancement of efficiency, the expansion of market share, collaboration with a broader array of stakeholders, and shifts in the technological landscape at the industry

level (QIU *ET AL.*, 2023). While green innovation is integral to the identity of certain companies and serves as a fundamental aspect of their competitive advantage, other companies restrict their efforts to mere compliance with environmental regulations to achieve legitimacy (TU–WU, 2021). Green innovation, while promising, presents various challenges. Initially, its diverse forms encompass incremental, radical, and systemic change (ZHANG *ET AL.*, 2020). This introduces complexity at the individual company level, because of the necessity to align and coordinate various innovation activities (ULLAH *ET AL.*, 2023).

The notable point is that green innovation requires innovative organizational strategies to switch their classical and traditional means of production to novel and sustainable operations (GAZI *ET AL.*, 2024H). Nevertheless, transformation into sustainable operations remains difficult for organizations because multiple uncertainties and complexities are involved in the transformation procedure (ZHANG *ET AL.*, 2022). Different sectors and organizational activities have accepted and transformed their operations into green operations through various green innovations. However, for sustainable performance at the organizational level, the dimensions of performance i.e., environmental, social, and economic performance has been indicated by AMIN *ET AL.*, (2024).

2.3 Circular Economy

The global environmental crisis has led to the development of policies promoting sustainable production and consumption, with the circular economy (CE) emerging as a key strategy. Germany pioneered CE implementation in 1996 through the "Closed Substance Cycle and Waste Management Act," which established a framework for closed-loop waste management. Japan followed with its 2002 Basic Law for a Recycling-Based Society, setting measurable recycling goals and aiming for long-term dematerialization (MONTAG, 2023).

China adopted a more gradual approach, initiating CE through pilot programs to evaluate its broader applicability, similar to its phased economic liberalization. Sweden and other European nations have implemented long-term incentive schemes and public education to improve recycling rates. These efforts have been supported by political integration of green parties, fostering systemic shifts toward CE. The European Commission has called on industry, labor, and civil society to champion resource efficiency and CE, offering a strategic roadmap for a regenerative, resource-efficient Europe (CASTILLO-DÍAZ *ET AL.*, 2024). Common elements across national CE strategies include reducing environmental degradation, conserving finite resources, and managing waste through integrated solid waste systems. In China and elsewhere, CE aligns closely with industrial ecology, emphasizing the reuse and recycling of materials, energy, water, and knowledge (Rabbi–Amin, 2024). The concept of industrial symbiosis—where economic

and environmental benefits arise from inter-firm collaboration—supports CE by clustering businesses to share resources, reduce costs, and enhance productivity (ISLAM *ET AL.*, 2024b).

Economic advantages include reduced transportation and transaction costs, and technology spillovers (AL AMIN *ET AL.*, 2024B; AZAD *ET AL.*, 2012; AMIN *ET AL.*, 2012; AZAD *ET AL.*, 2023; ALI *ET AL.*, 2024). Ecologically, CE reduces waste generation and virgin resource consumption (HAMADA *ET AL.*, 2024), reinforcing its role as a sustainable development strategy.

3. HYPOTHESES DEVELOPMENT

3.1 Green technology adaptation and circular economic performance

The circular economy (CE) is a transformative economic model that emphasizes innovation, technological advancement, responsible resource management, and the reduction of environmental degradation, including global warming and pollution of natural elements like water, soil, and air. Leading global consulting firms such as McKinsey, Ernst & Young, KPMG, Deloitte, and PWC support the principles of CE due to its promising potential. Moreover, major corporations—including the MacArthur Foundation, Philips, Statoil, Unilever, and Accenture—have integrated CE principles into their operational strategies. Countries like Denmark, Scotland, and Finland are actively striving for leadership in CE, while China is promoting it through national programs like the Belt and Road Initiative (HOSAIN *ET AL.*, 2024b).

Despite the momentum, CE implementation faces challenges including complexity, manufacturability concerns, and high initial costs. Adopting a CE requires not just systemic economic reforms but also changes in producer and consumer mindsets. At the core of CE is the emphasis on extended product life cycles and high-quality production standards that support recycling and reuse. However, in practice, many manufacturers avoid additional costs, indicating the need for stronger regulatory and fiscal frameworks. Green technology development also faces resistance due to prevailing consumption habits, pressure from the mining sector, and the growing demand for rare earth metals driven by digital technologies.

ROZHNOV *ET AL.* (2020) emphasize Russia's untapped potential in modern, high-tech sectors like nuclear and space industries. IVANOVA–CHIBEVA (2021) highlights the technological competency of Russia's workforce. ROZHNOV *ET AL.* (2020) also foresee significant growth in Russia's non-primary, non-energy exports, including Industry 4.0 products, by 2025. The CE, thus, offers an opportunity for economies like Russia to diversify and modernize.

Fundamentally, the CE is a restorative and regenerative system that aims to maintain product, material, and component utility by keeping them in circulation. It differentiates between technical and biological cycles and supports sustainable resource flows. According to BAAH *ET AL.* (2024), CE is no longer a theoretical framework; it is actively influencing traditional linear economies and enabling innovative products and services such as biodegradable packaging, modular office equipment, and subscription-based models for tires. These strategies focus on optimizing systems rather than individual products.

BAAH *ET AL.* (2024) also emphasize that the pace of transition to CE affects the cost and success of implementation. Accelerating the transition may increase temporary investments in infrastructure, digital systems, and workforce retraining, potentially leading to stranded assets. KHAN *ET AL.* (2023) caution that these systemic shifts could cause economic redistributions, hence a balanced transition is crucial.

Both businesses and governments play critical roles in this transformation. Governments must set enabling conditions and implement strong policies, especially through procurement and public investment. TANVEER ET AL. (2022) cite a UN finding that 83% of business leaders believe governments must enhance support for sustainability to move beyond fragmented efforts. Shah and DAS (2024) advocate for robust policies to stabilize long-term investments and align CE efforts with global sustainability goals.

In Europe and other developed regions, CE is being advanced through legal regulations, tax incentives, and financial support for innovation (KHAN ET AL., 2022). The concept is also applied in digital formats such as virtual exhibitions, e-commerce, and public-private financing schemes (GAZI ET AL., 2024F; GAZI ET AL., 2024D; ISLAM ET AL., 2023). These reflect the integration of CE principles into various facets of modern economic activity.

CE's success heavily depends on green technology. BAAH ET AL. (2024) describe CE as a system that adds value by reducing, slowing, or closing resource loops. ÜLKÜ ET AL. (2022) affirm that CE helps minimize waste, reduce emissions, and integrate stakeholder values into production. ESPOSITO ET AL. (2024) outline CE as a model centered on reduction, reuse, and recycling. When paired with green technology, CE not only optimizes sustainability but also transforms organizational operations and promotes innovation.

The synergy between green technology and CE leads to improved organizational sustainability practices (LIM ET AL., 2022; ISA ET AL., 2021). TANVEER ET AL. (2022) note that this combination drives improvements in resource use and efficiency. Consequently, exploring the relationship between green technology adaptation and CE performance is essential for sustainability-driven organizations (KHAN ET AL., 2022).

In conclusion, this study identifies the need to empirically assess the proposed hypothesis:

H1: Green technology adaptation has a positive relationship with circular economic performance.

3.2 Green technology adaptation and green innovation

Numerous studies have demonstrated a correlation between technology adoption and improved innovation capabilities within firms (for example, SHAHZAD ET AL., 2022; LISI ET AL., 2020; ZHANG ET AL., 2020; WANG ET AL., 2019; WANG ET AL., 2024). The integration of new technologies facilitates green innovation by enhancing resource efficiency, minimizing waste, and enabling the development of sustainable products (WANG ET AL., 2024). In this pertinent, empirical study of LI ET AL. (2022) examined the factors influencing a firm's adoption of green innovation behavior through the adaptation of green technologies. On the other hand, LIAN ET AL. (2022) examined the impact of legislation and customer pressure on research and development expenditure, which subsequently affects the adoption of the green

innovation process. The environmental management system along with the research and development wing of the organizations facilitates the process of green innovation (LIAN *ET AL.*, 2022).

However, LIAN *ET AL.* (2022) additionally concluded that while environment management significantly affects the innovation process, it has an insignificant association with product innovation. Besides, environmental regulation, management tools, and organizational factors promote environmental innovation. Similarly, the study of LI *ET AL.* (2022) indicated that customer benefits, environmental regulations, and technological capabilities of research and innovation significantly influence the green innovation process. The authors further indicated, the environmental factors and innovation processes have influences on market pressure, government environmental regulation, and the internal conditions of the firm (WANG *ET AL.*, 2024).

In another similar study by LISI *ET AL.* (2020) have examined the impact of internal factors within firms and technological factors on the adoption of green innovation. On the other hand, the examination of SHAHZAD *ET AL.* (2022) identified environmental regulation as a determinant of green innovation adoption. Moreover, this study considers government regulation as a moderating variable, which does not directly influence adoption behavior but rather affects the relationship between technological factors and the adoption of green innovation. Thus, the above discussed studies have identified various technological factors, including ease of use, observability, richness of information, and uncertainty that influence a firm's cognitive beliefs regarding the adoption of green innovation.

The research of LI *ET AL.* (2022) examined complexity, compatibility, relative advantage, and reliability, as various multifaceted characteristics that are identified as significant technological factors influencing a firm's behavior toward innovation adoption. The complexity of innovation indicates the degree to which an organization perceives technology as challenging to comprehend and utilize. The hypothesis posits that an increase in technological complexity correlates with a decrease in the likelihood of innovation adoption. Besides, challenges in innovation diffusion and knowledge sharing contribute to the complexity of technology (ZHANG *ET AL.*, 2020). Consequently, organizations are more inclined to adopt an innovation when knowledge sharing regarding that innovation is facilitated within the organization.

Efficient knowledge sharing within an organization enhances the adoption of innovations that improve financial performance and support effective environmental management (LIAN *ET AL.*, 2022). Additionally, the authors indicated that an innovation necessitates extensive efforts for learning and diffusion, the complexity level rises, thereby reducing the likelihood of adopting that complex technology. However, WANG *ET AL.* (2024) identified several factors influencing firm behavior regarding the adoption

of green innovation, including insufficient private incentives, the complexity of technology replacement processes, and inadequate information about green innovation. The study concluded that financial incentives, policy interventions, training, and information on the benefits of green innovation significantly decrease the reliance on polluting technologies.

Compatibility denotes the organization's assessment of how well technology aligns with its established values, experiences, and requirements (WANG *ET AL.*, 2024). Besides, if a firm perceives that technology aligns with its existing knowledge, the organization is more likely to adopt the technical innovation. In a similar vein, when green innovations build upon a company's existing knowledge, the diffusion of these innovations is facilitated and streamlined. In this pertinent, the research of LISI *ET AL.* (2020) highlighted technological changes and environmental policy specifically in the organic chemical industry, finding that innovations that augment existing technology are diffused more rapidly and easily within organizations than technologies that do not align with the firm's existing knowledge and production processes.

However, innovations aligned with a firm's capabilities demonstrate more significant positive effects on the environment (SHAHZAD *ET AL.*, 2022). Relative advantage denotes an organization's assessment of the benefits of innovation in comparison to its costs. If a firm believes that the relative advantages of innovation surpass both the costs and the current technology, it is more likely to adopt the innovation. The relative advantage may be assessed in terms of price, quality, ease of use, lifespan, and the satisfaction a firm derives from utilizing the innovation. If the relative advantages of innovation are greater, companies are more inclined to adopt the innovation and pursue higher economic gains (WANG *ET AL.*, 2024).

Organizations adopting green innovations may experience several benefits, including reduced consumption of energy and natural resources, decreased greenhouse gas emissions, improved environmental and financial performance, and enhanced responsiveness to social and environmental expectations (ZHANG *ET AL.*, 2020). In this regard, WANG *ET AL.* (2024) highlighted green technology as the notable factor that influencing the adoption of green innovation in the pulp and paper industry, finding that financial benefits are significant technological characteristics impacting this adoption. The perceived net benefits drive the organization to adopt the technology and realize the associated advantages.

Tri-ability indicates that organizations are more inclined to adopt innovations that can be tested in advance, particularly when such innovations involve a significant level of uncertainty. Previous studies have indicated that various technological factors, such as relative advantages, complexity, and compatibility of innovations, influence the adoption of green innovations in the transportation sector in China (WANG *ET AL.*, 2024). In their study, the authors found that Chinese logistic companies widely adopt green technologies, as they

perceive significant benefits for both environmental sustainability and economic performance. Based on transportation industry, the research of ZHANG *ET AL.* (2020) revealing that human capital, customer pressure, and environmental uncertainty significantly influence the adoption of green technology and innovation, whereas organizational and governmental support show an insignificant relationship with this adoption.

The examination of WANG *ET AL.* (2024) found significant correlations between green innovation and the adoption of environment-focused technologies in the manufacturing sector, revealing a positive association between these variables. Similarly, the research of ZHANG *ET AL.* (2020) examined the determinants of green information technology adoption within organizations, identifying various economic, ethical, and regulatory factors influencing this adoption. However, this technology can be adapted through green innovation. The authors additionally noted that a firm readily adopts new technology which is green based when it is easy to learn; otherwise, adoption is hindered; and in that case green innovation can support facing the challenge. Thus, the findings of the above discussed literature indicate that the adoption of green innovation is essential to mitigate the challenges related to the instilment of green technologies. Therefore, the abovementioned literature supports developing the hypothesis below.

H2. Green technology adaptation has a positive relationship with green innovation

3.3 Green innovation and circular economic performance

Since the start of the twenty-first century, the development and growth of environmental concerns that have significantly altered every facet of human existence; it has improved the processes for product and service conception, manufacturing, and delivery (ALI *ET AL.*, 2024). On the other hand, the recent integration of innovative digital manufacturing technology and precision equipment into these processes has facilitated new avenues of innovation in production and delivery (KHAN *ET AL.*, 2024). These novel technologies have enhanced quality and value, expedited development and market entry, and promoted sustainable manufacturing. Innovation for green manufacturing thoroughly acknowledges the environmental impact and resource efficiency in production. The primary characteristics of innovation to green technologies include systematic organization, eco-prevention emphasis, economic adherence, and improved efficiency (ABDALLAH *ET AL.*, 2024). In the past decade, sustainable development has garnered significant attention in the industrial sector owing to heightened awareness and recognized advantages of green technologies for society (JOHL–TOHA, 2021).

Innovation, as the paramount catalyst for growth, accelerates a corporation toward excellence and ensures a competitive edge; it also improves environmental efficiency, so facilitating the accumulation of social

capital essential for future advancements (SIEDSCHLAG *ET AL.*, 2022). The authors additionally indicated that an increasing number of organizations have incorporated green innovation as a fundamental element of their strategy to alleviate the adverse effects of conventional growth models. The Chinese government incorporated green innovation for establishing a foundation for the promotion of a green technology bank to facilitate the adoption of green technologies (LIU–WANG, 2022).

Numerous countries have recently established state-level financial institutions to advance sustainable development and implement the plan for green industry, such as Japan and Canada (LIU–WANG, 2022). These institutions can utilize public-private partnerships (PPPs) to promote green infrastructure and technology innovation. Moreover, this environmental innovation facilitates organizations in producing environmentally sustainable products by reducing resource consumption and waste to achieve sustainable development (ABDALLAH *ET AL.*, 2024). Researchers such as UL-DURAR *ET AL.* (2024) have identified green innovation as a crucial catalyst for sustainable development, asserting that environmentally friendly processes and products deliver comparable value to consumers while minimizing social and environmental repercussions. Moreover, UL-DURAR *ET AL.* (2024) further indicated that the principal advantages of green innovation can be capitalised if circular production system is implemented; and there are numerous stakeholders also supported for its adoption and implementation. While radical transformation is essential at the ecological, cultural, and social levels, organizations must fulfil their specific role in circular economy-based performance (BAG *ET AL.*, 2022).

Nonetheless, the adoption of green innovation encounters considerable obstacles in attaining circular economy-based performance within manufacturing organizations due to several decision-making considerations. Due to escalating commodity prices and apprehensions about sustainable sourcing, organizations may choose for cutting-edge, eco-friendly technology to reduce waste and expenses, hence gaining a competitive edge (AI *ET AL.*, 2024). However, there are no definitive criteria for the global categorization of the adoption of circular economy-based performance (SIEDSCHLAG *ET AL.*, 2022). In addition to that SIEDSCHLAG *ET AL.* (2022) highlighted numerous apprehensions persist regarding the adoption of green and innovative technologies, including financial obstacles, environmental regulations, market demand, knowledge, and awareness. From a financial standpoint, acquiring essential precision equipment and skills may represent a significant share of organizational expenditures; thus, organizations must ensure the viability of such investments (UL-DURAR *ET AL.*, 2024).

Green and environmental policies and activities are believed to enhance company success only when universally implemented, with endorsement and backing from all stakeholders. Studies indicate that insufficient consumer interaction and acknowledgment result in a depletion of investments and resources

(VENCE–PEREIRA, 2019). In this pertinent, JOHL–TOHA (2021) have determined that over reliance on coal energy is the principal contributor to harmful emissions; enhancing energy efficiency can mitigate this through green technical innovation and activities. Consequently, it is essential for organizations to assess the social, economic, and environmental dimensions of circular economy-based performance (LIU–WANG, 2022).

Because of climate change, developing and underdeveloped nations must pursue sustainable and green technical solutions, green innovation, and circular economic system (KHAN *ET AL.*, 2024); specially some Southeast Asian and African countries are the least innovative countries, with a low rating both in Asia and globally. For example, the renowned industrial city of Lahore in Pakistan was designated as the most polluted city in the world due to inadequate air quality. To address these environmental issues and promote green innovation and circular production process, the current leadership of Pakistan has enacted rigorous environmental legislation to mitigate ecological degradation and has endeavoured to assist organizations in reducing their reliance on fossil fuels while harnessing renewable energy resources. The rigor of environmental plans, environmental taxation, and diminished hazardous emissions positively influences the green innovation more (ABDALLAH *ET AL.*, 2024). Nonetheless, renewable energy resources are likewise finite. That is why the present study indicates that emerging nations like Mongolia may provide deeper insights on how green innovation and circular production policies might mitigate environmental degradation and promote eco-friendly products that reduce pollution and minimize industrial waste.

Following the theory on natural resource-based view, scholars acknowledged the significance of the adoption of green innovation and technology to maximum utilization of resources (ALI *ET AL.*, 2024). These characteristics significantly influence the performance which is focusing on circular economy. While it may be contended that green innovation parallels all the new green technologies, the implementation of circular system and conditions of various technologies will differ markedly, leading to discrepancies in adoption factors based on the type of technologies (KHAN *ET AL.*, 2024). Consequently, for a corporation to effectively implement a circular economy-based project, it must understand the factors that would enhance social acceptance among stakeholders. Therefore, it is essential to rigorously examine the implementation issues and adoption concerns by analysing these circular economy performance challenges. According to the support of above literature discussion, this study proposes the following hypothesis.

H3: Green innovation has a positive relationship with circular economy performance

3.4 Green Innovation as a Mediator

In their study, RODRÍGUEZ-ESPÍNDOLA *ET AL.*, (2022) highlighted the relationships among circular economy, green innovation, and sustainable performance was supported by natural resource-based view (RBV) theory. Based on their findings, RBV theory supported the interactions between parties or stakeholders that are involved in the companies' green innovation process will create more circular economy to comply with the sustainable performance factors, specifically environmental, economic, and societal. In another similar research, KHAN *ET AL.* (2025) posited that circular economy contributes to more green innovations, which suggests that green technology adaptation are the key drivers in inducing green innovation practices. Similarly, ZAMEER *ET AL.* (2022) confirmed the mediating role of green innovation in generating circular economy, but they have not considered the comprehensive impacts of green technology adaptation on green innovation. Similarly, the study by RODRÍGUEZ-ESPÍNDOLA *ET AL.*, (2022) showed that green innovation can be stimulated through environmental cooperation among companies and their important suppliers in developing a new green product.

However, the findings of RODRÍGUEZ-ESPÍNDOLA *ET AL.*, (2022) were confirmed by other research indicating that greening the suppliers will positively lead to green innovation. In addition, a study conducted by LIU–WANG (2022) in Taiwan implied that business environmental management such as green innovation is positively linked to green product and process innovation. The rationale behind the relationship between circular economy and green innovation can be justified. The rising concern on environmental issues and regulations from many stakeholders (such as suppliers, customers, and community) urge companies to work closely with them in the product development processes. This collaboration will then be beneficial to companies in creating innovation, enhancing the product design and manufacturing process, and developing overall compliance with environmental regulations (KANAN *ET AL.*, 2023). Green innovation concept can help the implementation of circular economy by offering new ideas, approaches, and/or technologies to manufacturers in developing new products. Finally, green innovation is believed to provide continuous ways to innovate each stage of supply chain to attain competitive advantage and decrease the environmental problems in the industry (AWAN *ET AL.*, 2023).

A review of literature on circular economy conducted by RODRÍGUEZ-ESPÍNDOLA *ET AL.*, (2022) suggested that the implementation of circular economy practices in an organization ultimately influences organizational environmental performance. However, to measure the direct effect of circular economy adaptation on the organizational environmental performance, it is necessary to take into consideration a third i.e., mediating variable. Green innovation has also been known as a mediator in the relationship between green technology Adaptation and organizational environmental performance (ZAMEER *ET AL.*, 2022). In other words, instead of a direct influence from green technology adaptation on organizational

environmental performance, green technology adaptation first affects green innovation that, in turn, influences the organizational environmental performance. These are known as the direct and indirect effects (RODRÍGUEZ-ESPÍNDOLA *ET AL.*, 2022). According to BONSU *ET AL.* (2024), strict environmental regulations that elicit innovation may balance the costs of complying with these regulations and positively affect the business performance of these organizations.

The study of AL-KHATIB (2022) recommended that environmental regulations not only affect the business performance of the organization, but also indirectly encourage these organizations to adopt the green innovation strategy. Such indirect effect is often referred to as the mediated effect. Thus, green innovation may be viewed as a mediating variable, wherein the green innovation strategy becomes the mediator between the environmental regulation and environmental performance of organization. Using this as a benchmark, the present study assumed that green innovation is potentially a significant mediator between green technology adaptation and circular economy performance. Following that, this study extended the direct relationship between green technology adaptation and circular economy performance through the mediation of green innovation.

Despite the limited number of studies performed in this context, the current research considers different aspects of organizational performance focusing on circular economy and discussed the role (mediating) of green innovation. In this pertinent, LIU–WANG (2022) examined the relationship between the adoption of environmental innovation strategy and organizational business performance in the chemical industry in China, which confirmed that the environmental innovation strategy mediates the relationship between relevant environmental pressure forces (such as governmental regulations, managerial environmental concerns, and perceived importance of stakeholder pressures) and organizational business performance.

Additionally, JUO–WANG (2022) examined the positive effects of corporate environmental ethics on the competitive advantage through the mediating effect of green innovation performance in the manufacturing industry in Taiwan. The findings confirmed that green product innovation mediates the positive relationship between corporate environmental ethics and competitive advantage, with the exception for green process innovation. In other words, this suggests that the competitive advantage is directly affected by the corporate environmental ethics and indirectly affected through green product innovation in the manufacturing industry. Moreover, the mediation model proposed by YOUSAF (2021) revealed that the green suppliers contribute to internal green product innovation, green process innovation, and green managerial innovation, which in turn increases the environmental performance and competitive advantage. This significant finding suggests that greening the suppliers and green innovation may be highly linked to the organizational circular economic performance and competitive advantage, which verifies the mediating role of green innovation

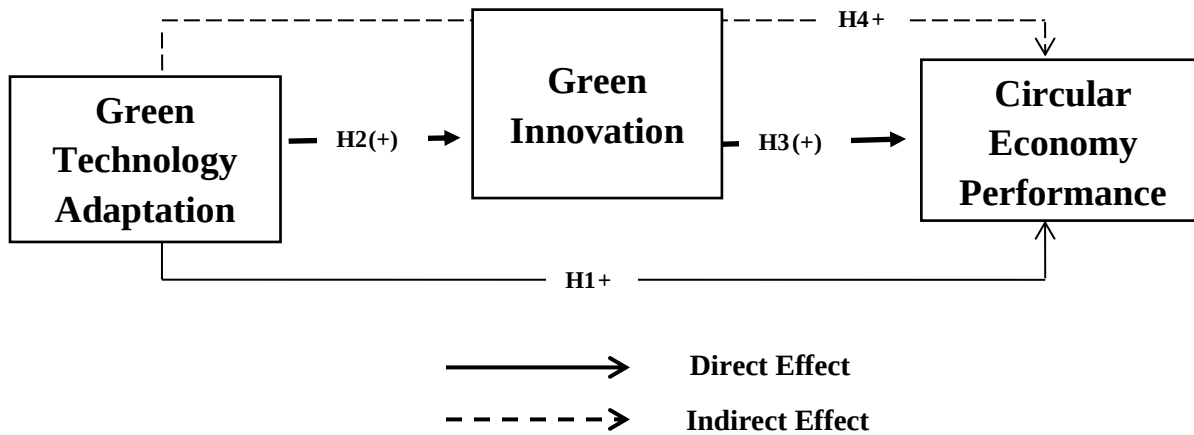
between green technology adaptation and circular economy performance. Based on the above discussion, this research develops the following hypothesis.

H4: *Green innovation has a mediating effect between the relationships of green technology adaptation and circular economy performance*

3.5. Conceptual Model of this Research

Based on the above discussion, literature supports, to attain the present research objective, and to address the current research questions, this study proposes the following conceptual framework demonstrated in Figure 1 below.

Figure 1. Conceptual Model of this study



4. METHODOLOGY

4.1 Introduction

This chapter discusses the research methodologies and instruments used to investigate the correlation between the adoption of green technology, green innovation, and circular economy performance in the mining industry of Mongolia. This study examines how adopting green technology impacts the performance of the circular economy, with green innovation playing a mediating role. This chapter elucidates the research approach devised to examine the hypothesized correlation between the variables in accordance with the proposed framework. In addition, this chapter covers the various aspects of research methodology, including research design, population and sample selection, sampling frame, sampling technique, sample size determination, measurement and questionnaire design, and data analysis techniques.

4.2 Research Design

According to CRESWELL (2009), research design is a set of planned techniques for conducting research investigations that disseminate the findings derived from extensive postulations through various data collection and analysis methods. Based on the following considerations, the methodology has been designed for this study:

4.2.1 Research Nature

The objective of this study is to examine the performance of the circular economy as an organizational-level outcome in the mining industry in Mongolia. This research intends to investigate the relationship between uni-dimensional green technology adoption and the performance of a single-dimensional circular economy, considering the role of green innovation as a mediator. The present study adopted a quantitative research approach, using a structured questionnaire as the core research instrument. The research conducted was quantitative in nature, involving the collection of relevant data and the analysis of the relationship between variables, as outlined in a theoretical framework. In this pertinent, SALKIND (2006) proposed using a questionnaire as a survey approach to examine the relationship between various categories of constructs such as adaptation, organizational performance, company values, and individual perceptions in diverse contexts.

The current research is a cross-sectional study that involves the integration of data at a given moment in time and drawing conclusions through inspection at the same point in time (SEKARAN–BOUGIE, 2010). The present research included data and information on the perspectives of mining industry managers

regarding the adoption of single-dimensional green technology, green innovation, and circular economic performance at the organizational level.

4.2.2 Data Sources

In this research, both primary and secondary sources of data were used. The main sources consist of thirty mining factories or enterprises, the perceptions of their managers, and all the data have been acquired with the use of a structured questionnaire, which was regarded to be primary data. In addition, secondary sources were used for the purpose of conducting the literature discussion for the present research. The term secondary data refers to information that has been gathered from personnel of selected organizations for objectives that are not related to this present research study specifically. There is a possibility that secondary data is accessible, which is completely suitable and completely sufficient for drawing conclusions, answering the issue, or finding a solution to the problem. In many circumstances, the collection of original data is not required. Secondary sources will be used in the process of doing empirical research to provide an explanation of the literature review, background literature for developing the hypotheses, a justification of the research gap, and a rationale for the hypothesized relationships among variables. Several journals, websites, organizational data sources, national data, books, periodicals, and newsletters were regarded as secondary sources for the purpose of providing information that was pertinent to the explanation of the literature and other material that was connected to it in the present research.

4.3 Population and Sample Design

4.3.1 Population and Sampling Frame

According to SEKARAN–BOUGIE (2010), the term 'population' is defined as the entire group of people, events, or things of interest that the researchers target to investigate. In any study, clarification of the population is necessary since it enables the researchers to avoid making mistakes while selecting the appropriate samples. In this regard, CAVANA *ET AL.* (2001) elucidated that if the researchers are able to get the appropriate sample, they would be able to demonstrate an assumption that would make it simpler to generalize to the full population. All of the personnel who were working in management positions in mining organizations in Mongolia were regarded to be part of the target population for this study. According to KARIM *ET AL.* (2023A), managers are groups of individuals who are responsible for carrying out their duties within their organization. These individuals are responsible for planning, making decisions, coordinating, motivating, and managing other activities that are pertinent to their work. Based on this study, it is assumed that managers possess the necessary qualifications, capabilities, and experience to comprehend and respond effectively to the research criteria given. In order to generalize the findings of the research, the present study looked at all types of managers and classified them into three distinct classes: upper-level

managers, middle-level managers, and lower-level managers (operator managers). In addition, all three categories are taken into consideration in this research since it will provide the opportunity to assess the perspectives of all the different kinds of managers.

Furthermore, according to CUI *ET AL.* (2025), there are around 130 mining organizations that are now active in Mongolia, most of which are privately held. In order to determine the organization and its size, the present research divides the organization into three primary groups: big, medium, and small. These categories are used to identify the organization. For categorizing organizations, the number of workers working for the organization was taken into consideration. According to DAMIRAN *ET AL.* (2025), the mining organizations in Mongolia are classified as big when they have more than 500 workers, medium when they have more than 200 employees, and small when they have more than 100 employees. As a result of this conception, the current study takes into consideration the first ten (ten) organizations from each category for the purpose of data collection. This is due to the fact that these 30 (thirty) organizations contribute more than sixty percent to the gross domestic product of the mining industry in Mongolia (DAMIRAN *ET AL.*, 2025). The names of these organizations are included in Appendix B for your convenience.

4.3.2 Sampling Design

The current study employed judgmental sampling. Judgmental sampling is a part of the purposive sampling of non-probability sampling design.

4.3.3 Sample Size

Various approaches have been proposed by researchers to determine the necessary sample size, including well-established formulas and references to past research. The current study emphasized both perspectives in establishing the necessary sample size. The formula utilized in the present investigation applies to the specified population. This formula is recommended for researchers when a comprehensive list of the population is unavailable. The formula utilized in this study was selected due to the lack of information on demographics.

$$P = p(1 - p) \left(\frac{z}{E} \right)^2$$

Where:

- P is the sample size
- p is the proportion (0.5)
- z is the confidence interval according to the table and the value is 1.96 (0.05)

- E is the accepted error and the value is 0.05.

Therefore, based on the above formula the required sample size will be 384.

In addition, scholars have provided several suggestions for estimating sample size. For instance, SEKARAN–BOUGIE (2010) stated that, in order to estimate the minimum required sample size for multivariate analysis, the number of variables in the study should be at least ten times the number of variables. Hence, the minimum sample size for this research is 80 (8 multiplied by 10). (HOE, 2008) suggests that a sample size of 200 or more is adequate for data analysis. According to (HAIR *ET AL.*, 2014), it is recommended that the minimum sample size for PLS-SEM should be at least ten times the number of structural paths in the model. In addition, HAIR *ET AL.* (2014) demonstrated that a sample size of 100 is adequate for data analysis using SEM-PLS. In another study based on a similar developing nation, KARIM *ET AL.* (2023B) utilized a sample size of 395 for data analysis and obtained favorable outcomes. Therefore, building on the existing literature, the present study identified 475 valid samples for efficient data processing.

4.3.4 Unit of Analysis

The unit of analysis in this study is comprised of managers at various levels (top-level, mid-level, and lower level) employed in the mining business. In this pertinent, SEKARAN–BOUGIE (2010) stated that individuals and groups possess distinct qualities that set them apart from each other. Furthermore, there exists a divergence in perceptions, attitudes, and behaviors exhibited by individuals belonging to distinct groups. Therefore, the type of information collected and the level at which it is combined for analysis are crucial factors in determining the unit of analysis for decision-making. Thus, in order to assess how individual managers perceive the research objective, each individual operator was selected as the unit of analysis. Purposive sampling is a method that involves selecting individuals who possess the specific information needed for a study, either because they are the only ones who have it or because they meet specific criteria established by the researchers (SEKARAN–BOUGIE (2010)). In this regard, COOPER–SHINDLER (2011) stated that judgmental sampling is employed when a researcher selects a sample that meets specific criteria. The purpose of its utilization was to selectively gather data from a specified group. The selection of respondents in this study will be based on two factors. The questionnaire also specifies the inclusion requirements.

- i) Managers who have at least five years of experience in the mining organization and
- ii) Managers who have at least one year of job experience in their present working place.

4.4 Research Instruments

A well-structured questionnaire can be used in any study as a data-gathering technique. The questionnaire used in this research typically consists of four basic parts: Part I consists of five items designed to assess the adoption of green technology as a unidimensional independent variable. Similarly, part II focuses on the measurement of the mediating variable, i.e., green innovation, using five items, as well as a unidimensional construct. Additionally, part III assesses the measurement of unidimensional circular economic performance using six items. Lastly, Part IV includes items that pertain to the demographic factors of the respondents, with a total of 8 items. The elements of the various variables were derived from pre-existing recognized, reliable, and valid scales. The measurement tools utilized in this study are summarized in the following Table 1.

Table 1 Measurement instrument of the research variables

Variables	Items	Sources
Green Technology Adaptation	5	AFUM <i>ET AL.</i> , (2021) and XIA <i>ET AL.</i> , (2022)
Green innovation	5	SHAHZAD <i>ET AL.</i> , (2020) and SONG–YU (2018)
Circular Economy Performance	6	MARRUCCI <i>ET AL.</i> , (2021)
Demographic Variables	8	Age, Gender, Religion, Marital Status, Education, Monthly Income, Current organizations experience, and Industry Experience.
Total	24	

4.5 Data Collection Techniques

At the beginning of the research project, a formal request was sent to the mining organizations to solicit their participation in the study. A request letter, including research questionnaires, was sent to individual organizations at the beginning of the data-collecting procedure. In order to facilitate the administration of the structured questionnaire survey, the organizations were requested to provide their personnel authorization to contribute contributions. The letter of request includes a short summary of the study, the research objective for the questionnaire survey, and a rough data collection schedule plan for completion. A method known as drop-off and pick-up (DOPU) was used to administer the questionnaires. According to LANGLEY–KYPRI (2011), a DOPU technique enables respondents to fill out fields at their own

convenience while also reducing the interviewer's potential for bias. Previously, AMIN–RUBEL (2020) conducted research that used this similar identical method for the purpose of data collection.

4.6 Data Analysis Techniques and Tools

Various statistical approaches and tools, including SPSS for data input descriptive analysis and structural equation modeling with Partial Least Square (PLS) for hypothesized relation, were employed in hypothesis testing. Structural equation modelling (SEM) aids in elucidating the connections among numerous variables (HAIR *ET AL.*, 2014). SEM is essential for modelling applied multivariate analysis (REISINGER–MAVONDO, 2007).

Structural Equation Modelling (SEM) is a statistical methodology that enables the examination of relationships between independent variables (which can be continuous or discrete) and dependent variables (which can also be continuous or discrete). It is a collection of tools that facilitate this analysis (HAIR *ET AL.*, 2017). It is a statistical method that combines elements of multiple regression and component analysis to concurrently estimate a set of interrelated dependent relationships. Multiple regression examines the relationship between variables, while factor analysis represents unmeasured ideas with numerous variables. This technique, known as multivariate analysis, is used to analyze complex data sets (HAIR *ET AL.*, 2014). Furthermore, SEM focuses on examining hidden variables, specifically the examination of causal relationships between hidden variables (HOOPER *ET AL.*, 2008). Structural equation modelling or route modelling is a statistical technique used to analyze the relationships between constructs and variables (HOOPER *ET AL.*, 2008).

Structural Equation Modelling (SEM) is classified as a second-generation technique of multivariate analysis (CHIN, 2010). Previous methodologies, including analysis of variance, logistic regression, and multiple regressions, had certain limitations. These constraints included the assumption of a simplistic model structure and the requirement that all variables be observable and measured without any errors (HAENLEIN–KAPLAN, 2004). Furthermore, these preconceptions may be excessively limited when evaluating any intricate and authentic circumstances. In addition, while assessing the accuracy of variables, it is necessary to account for both random and systematic errors included in the observations (BAGOZZI *ET AL.*, 1991). The mistakes in the 1st generation approaches are inadequate in accurately explaining the reality (HAENLEIN–KAPLAN, 2004).

5. FINDINGS OF THE ANALYSIS

5.1 Introduction

The current chapter reports the findings of the data analysis and hypothesis testing of the study. Data analysis starts with descriptive statistics, where the characteristics of the respondents were explained. Later, Harman single factor test was conducted to examine the common method variance (CMV). After assessing the acceptability of the data set based on the CMV, the research framework was examined using SMART-PLS 4 software. In this phase, both measurement and structural model were reported. In the measurement model both reliability and goodness of measure were assessed and in the structural model path coefficient, determination of R^2 and hypothesis testing were reported. Lastly, this chapter demonstrates the hypothesis results of the studied variables of the current research.

5.2 Response Rate

Table 2 clarifies the response rate of the current research. In total 500 questionnaires were disseminated from the different mining organizations. Among these 500 questionnaires 407 questionnaires were returned within two months duration, where 21 questionnaires were found incomplete and not acceptable. Therefore, the usable questionnaires were found 386 that were suitable for data analysis with a response rate of 77.2%. In this regard, HAIR *ET AL.* (2017) recommended that in case of PLS-SEM analysis, a minimum of 100 sample size is suitable for getting accepted outcome. In support to that previously, in the context of Mongolia, KIM *ET AL.* (2016) could attain 74.1% response rate for their research and found suitable outcome. Therefore, from the previous explanation 386 sample size for the current study is considered acceptable.

Table 2: Response Rate

Questionnaire	Number	Percentage
Distributed Questionnaires	500	
Returned Questionnaires	407	81.4%
Usable Questionnaires	386	77.2%
Unusable Questionnaires	21	4.2%

5.3 Profile of Respondents

The current section talked about the demographic profile of the respondents. The demographic section covers the gender of the respondents, marital status, age of the respondents, educational qualification of the respondents, experience of the respondents in the present organization, and experience of the respondents

in the industry. The following table provides detailed information of the respondent's demographic information of the current study.

Table 3: Descriptive Analysis of Respondents' Demographic Data

Demographic Data	Frequency (N= 275)	Percentage (%)
Gender		
Male	264	68.4
Female	122	31.6
Total	386	100%
Age		
16-25 years	56	14.5
26-35 years	88	22.8
36-45 years	132	34.2
46-55 years	91	23.6
56 years and above	19	4.9
Total	386	100%
Marital Status		
Single	71	18.4
Married	275	71.2
Divorced	32	8.3
Widowed	8	2.1
Total	386	100%
Educational Qualification		
Below Secondary	6	1.6
Secondary (SSC)	30	7.8
College diploma	78	20.2
Bachelor	216	56.0
Master	51	13.2
PhD	5	1.2
Others		
Total	386	100%
Total Experience in Current organization		
01 – 05	160	41.5
05 – 10	108	28.0
10 – 15	77	20.0
More than 15	41	10.5
Total	386	100%
Industry Experience		
01 – 05	62	16.1
05 – 10	78	20.2
10 – 15	131	33.9
More than 15	115	29.8
Total	386	100%

5.4 Common Method Variance

When data are collected using a cross-sectional survey method, common method variance may be a problem (PODSAKOFF *ET AL.*, 2003). According to PODSAKOFF *ET AL.* (2003), common method bias arises in the dataset if:

- 1) a single factor appears from a factor analysis of all survey items, and
- 2) a single factor reports for most of the common variance existing in the data.

To address this potential problem, Harman Single factor test was employed. An un-rotated factor analysis conducted on all measurement items extracted 16 factors with eigenvalues greater than one (Table 5.3). According to PODSAKOFF *ET AL.* (2003), the un-rotated single latent component accounts for less than 50% of the observed variance. Factor one accounted for only 34.29 percent of the variance, thus common method was not a persistent dilemma in this study. Since a single factor did not emerge and the first factor did not account for most of the variance, therefore this study concludes that the common method bias was not a major concern in this study. The next section of this study reveals other related descriptive statistics and the analysis obtained by PLS method. The following Table 4 represents the results from Harman's Single factor test.

Table 4: Harman's Single factor test: Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.486	34.289	34.289	5.486	34.289	34.289
2	2.933	18.334	52.623			
3	2.237	13.979	66.601			
4	1.025	6.403	73.005			
5	.650	4.066	77.070			
6	.597	3.733	80.803			
7	.488	3.052	83.855			
8	.434	2.712	86.567			
9	.415	2.594	89.162			
10	.327	2.045	91.207			
11	.311	1.943	93.150			
12	.298	1.862	95.012			
13	.265	1.657	96.669			

14	.231	1.446	98.115			
15	.166	1.035	99.150			
16	.136	.850	100.000			
Extraction Method: Principal Component Analysis.						

Subsequently, KOCK (2015) proposed that Variance Inflation Factor (VIF) values obtained from an extensive collinearity test might indicate pathological collinearity and a potential intrusion of a model by common method bias. If all the VIF values derived from SEM analysis in the inner model are less than or equal to 3.3, it indicates that the model does not possess any common method bias (KOCK, 2015). Thus, based on the VIF values shown in Table 5, this study is not affected by common methos bias.

Table 5: VIF values

	CEP	GI	GTA
CEP			
GI	1.124		
GTA	1.124	1.000	

5.5 Assessing Structural Model

5.5.1 Direct Effect

A relationship between latent variables or constructs which are hypothesized in research models is represented through the structural model (DUARTE–RAPOSO, 2010). Main objective of PLS is prediction (HAIR *ET AL.*, 2014). Through the variance that is explained (R^2) of the endogenous constructs and the importance of all path estimates, the principle of the theoretical model is understood (CHIN, 2010). After determining the path estimates, a bootstrap analysis was applied to find out the statistical significance of path coefficient. According to CHIN (2010), 500 re-samplings are recommended while using bootstrapping for estimating parameters. But according to HAYES (2009), at least 1000 re-sampling is recommended though 5000 re-sampling is alright for bootstrapping. In this study, 1000 re-samplings were applied for bootstrapping analysis to examine the significance of regression coefficients.

Here, there was one dependent variable i.e., circular economy performance having R^2 value 0.125 (moderate) and one mediating variable i.e., green innovation showing R^2 value 0.110 (weak). According to COHEN (1988), this value of R^2 can be taken as moderate because he recommended R^2 having range 0.02 – 0.12 as weak, 0.13 – 0.25 as moderate and 0.26 and above as substantial.

The value of R^2 for dependent variable i.e., circular economy performance having R^2 value 0.125. This suggested that green technology adaptation explains 12.5% of the circular economy performance. On the other hand, the value of R^2 for mediating variables, i.e., green innovation having R^2 value 0.110. This suggested that green technology adaptation explains 11% of the green innovation. The following Table 6 shows the R^2 and adjusted R^2 values of the dependent variables.

Table 6: R^2 and adjusted R^2 values

Variable	R^2 value	Adjusted R^2
CEP	0.125	0.121
GI	0.110	0.108

Moreover, in this study, blindfolding technique was applied using omission distance 7 to assess the path model's predictive relevance. It was found that Stone-Geisser's Q^2 value (STONE, 1974; GEISSER, 1975) for both the endogenous constructs were above zero ($Q^2_{\text{CEP}} = 0.095$ and $Q^2_{\text{GI}} = 0.070$) in Table 7 below, indicating acceptable cross validated predictive relevance of the path model.

Table 7: Q^2 values

Variable	Q^2 value
CEP	0.095
GI	0.070

Analysis showed that GTA to CEP ($\beta = 0.218$; $p < .05$; T value 4.048; P values 0.000) is positive and statistically significant. Therefore, H1 is strongly significant. Similarly, GTA to GI ($\beta = 0.332$; $p < .05$; T value 7.125; P values 0.000) is positive and statistically significant. Therefore, H2 is strongly significant. On the other hand, GI to CEP ($\beta = 0.216$; $p < .05$; T value 4.571; P values 0.000) is positive and statistically significant. Therefore, H3 is also strongly significant. Based on the above outputs, this study confirms that greater degree of green technology adaptation leads to higher degree of circular economy performance by the mining organizations in Mongolia. On the other hand, favorable perception about green technology adaptation leads to higher degree of green innovation by the mining employees in Mongolia. Additionally, greater degree of green innovation leads to higher degree of circular economy performance by the mining organizations in Mongolia. Table 8 shows the results of direct hypotheses test.

Table 8: Results from Hypotheses Testing (Direct Effects)

Hypotheses	Paths	Std. Beta	Std. Error	T Statistics	P Values	2.5% LLCI	97.5% ULCI	VIF	Decision
H1	GTA → CEP	0.218	0.216	4.048	0.000	0.109	0.312	1.124	Significant
H2	GTA → GI	0.332	0.337	7.125	0.000	0.241	0.419	1.000	Significant
H3	GI → CEP	0.216	0.224	4.571	0.000	0.129	0.313	1.124	Significant

Notes: GTA = Green Technology Adaptation, GI = Green Innovation, CEP = Circular Economy Performance.; VIF= Variance Inflation Factor; LLCI = Lower Limit Confidence Interval; ULCI = Upper Limit Confidence Interval; S = Supported

5.5.2 Indirect Effect

However, the analysis of this study further shows that the indirect relationships between GTA to GI to CEP ($\beta = 0.072$; $p < .05$; T value 3.346; P values 0.000) is positive and statistically significant. Therefore, H4 is strongly significant. This result represents that GI is partially mediating between GTA and CEP. Table 9 below shows the results from indirect hypothesis testing.

Table 9: Results from Hypotheses Testing (Indirect Effect)

Hypotheses	Paths	Std. Beta	Std. Error	T Statistics	P Values	2.5% LLCI	97.5% ULCI	Decision
H4	GTA → GI → CEP	0.072	0.076	3.346	0.001	0.037	0.120	Significant

Notes: GTA = Green Technology Adaptation, GI = Green Innovation, CEP = Circular Economy Performance.; VIF= Variance Inflation Factor; LLCI = Lower Limit Confidence Interval; ULCI = Upper Limit Confidence Interval; S = Supported

5.6 Summary of Hypotheses Testing

The results of the hypothesis are summarized in Table 10. A total of 4 hypotheses were tested and all were supported. The findings from all analysis were deliberated after the data presentation.

Table 10: Summary of Hypotheses Test Results

Hypothesis	Direct Path	Decision
H1	Green Technology Adaptation → Circular Economy Performance	Significant
H2	Green Technology Adaptation → Green Innovation	Significant
H3	Green Innovation → Circular Economy Performance	Significant
H4	Green Technology Adaptation → Green Innovation → Circular Economy Performance	Significant

5.7 Results and Discussions

This section discusses the main findings of the study on the effects of green technology adaptation and green innovation on circular economy performance in Mongolia's mining sector. The results confirm that green

technology adaptation positively influences circular economic performance, supporting previous research that highlights the role of green technologies in optimizing resource use, reducing waste, and improving operational efficiency. The adoption of green technologies, such as renewable energy systems and advanced recycling methods, enables mining companies to minimize environmental impacts and enhance sustainability.

The study also finds a significant positive relationship between green technology adaptation and green innovation. Integrating green technologies encourages innovation within organizations, leading to the development of new products, processes, and business models that further support circular economic goals. This synergy is particularly important in the mining sector, where environmental challenges and resource constraints are prominent.

Green innovation itself is shown to have a direct positive effect on circular economic performance. By fostering eco-friendly practices, improving resource efficiency, and reducing waste, green innovation helps organizations gain a competitive advantage and meet sustainability targets. The mediating role of green innovation between green technology adaptation and circular economic performance is also confirmed, indicating that innovation acts as a bridge that amplifies the benefits of technology adoption.

The discussion acknowledges some challenges, such as high initial costs, regulatory barriers, and the need for supportive policies and infrastructure. It also notes potential negative impacts, including technological lock-in, rebound effects, and social or ethical concerns related to resource extraction and community impacts. Despite these challenges, the study emphasizes the importance of a holistic approach that combines technological, organizational, and policy interventions to maximize the positive outcomes of green technology and innovation.

In conclusion, the findings highlight the critical role of both green technology adaptation and green innovation in driving circular economy performance in Mongolia's mining sector. The study suggests that policymakers and industry leaders should focus on fostering innovation, investing in green technologies, and creating enabling environments to achieve sustainable development and long-term competitiveness.

6. IMPLICATION, LIMITATION, AND CONCLUSION

6.1 Theoretical Contributions

This study advances the academic literature by proposing and empirically testing a conceptual model that clarifies how corporations can enhance circular economic performance through green technology adaptation and green innovation, specifically within Mongolia's mining sector. Building on the resource-based view (RBV) theory, the research demonstrates that green technology and innovation are critical organizational resources that generate value and competitive advantage. The findings highlight that integrating green technology with green innovation is essential for achieving higher levels of circular economic performance. The study also addresses a gap in the literature by empirically examining the interplay between these factors, rather than treating them in isolation. It shows that organizations can leverage insights from green innovation to better adapt green technologies, and that a holistic approach—encompassing human, technological, and innovative resources—is necessary for optimal performance. While previous research has discussed the benefits of green technology and innovation, this study uniquely emphasizes their combined effect and the importance of internal processes and expertise in driving circular outcomes. Ultimately, the research enriches the understanding of how dynamic capabilities and resource-based strategies can be harnessed to achieve sustainability goals in resource-intensive industries.

6.2 Managerial Implications

The study provides actionable guidance for managers and organizational leaders, particularly in the mining and manufacturing sectors, on leveraging green technology and innovation to improve circular economic performance. It underscores the importance of transitioning from linear to closed-loop production systems, where technical skills and innovative thinking are vital for reusing and recovering materials. The research highlights that simply adopting green technology is not enough; managers must also foster a culture of innovation and utilize analytics to identify and address performance gaps. Senior management should go beyond compliance, actively seeking to integrate green innovation into business strategies to achieve superior circular outcomes. The findings suggest that overreliance on technology without innovation may limit potential gains, while a balanced approach can drive sustained improvements. The study also stresses the need for continuous learning and skill development among all employees to operate effectively within a circular economy framework. By adopting these strategies, firms can enhance efficiency, competitiveness, and environmental stewardship, positioning themselves as leaders in sustainable business practices.

6.3 Limitations

While this research makes significant contributions, it acknowledges several limitations. First, the findings are specific to Mongolia's mining sector and may not be directly transferable to other industries or regions.

The study's focus on a single sector and country limits the generalizability of its conclusions. Second, the cross-sectional design captures data at one point in time, which may not fully reflect the long-term impacts of green technology and innovation on performance. Future research should consider longitudinal studies to observe changes over time. Third, the reliance on quantitative data from managerial respondents may overlook deeper insights that could be gained from mixed method approaches or by including other organizational levels. Additionally, the study does not assess the effectiveness of each variable in detail, suggesting that future research should use performance matrix analysis and expand to other industries and geographies. Lastly, the focus on managers' perspectives excludes the broader workforce, indicating a need for future studies to explore employee behaviors and organizational initiatives aimed at fostering sustainable practices.

6.4 Conclusion

This research demonstrates that the adaptation of green technology, combined with green innovation, significantly enhances circular economic performance in Mongolia's mining industry. The study finds that green innovation not only directly improves performance but also mediates the relationship between technology adaptation and circular outcomes, making the combined approach more effective than either strategy alone. The results highlight the importance of organizational learning and investment in both technological and human resources to achieve sustainable business success. By integrating green technology and innovation, companies can boost productivity, efficiency, and environmental responsibility, contributing to long-term competitiveness and sustainability. The study provides a robust empirical foundation for future research and practical strategies for organizations aiming to excel in the circular economy.

7. NOVEL FINDINGS

7.1 Novel Findings

Novel Finding # 1: The novel finding of this research is that green technology adaptation through green innovation boosts circular economic performance, i.e., efficiency, productivity, and creativity. Understanding how green technology adaptation affects circular economic performance is vital for Mongolia's mining industry's future. Theory emphasizes organizational and industrial adoption of green technology and green innovation, and the current study proves it through its empirical findings. The research examines perception-based circular performance, evaluating green technology adaptation and green innovation, whereas prior studies discussed basic literature only. This procedure reveals existing knowledge, discrepancies, and research needs for empirically examining Mongolia's mining sector.

Novel Finding # 2: The second novel finding of this study reveals that the adoption of green technology significantly enhances the performance of circular processes. This finding explains that the perception of the managers of the mining sector of Mongolia that an increase in green technology adaptation positively affects the productivity, efficiency, and overall circular-based performance of the company. Therefore, green technology adaptation significantly enhances the circular performance of Mongolia's mining industry.

Novel Finding # 3: This research indicates that the adoption of green technology significantly boosts green innovation. The third novel finding of this study is that management in Mongolia's mining industry believes that embracing green technology enhances green innovation. Consequently, the more they utilize green technologies, the more significantly they advance the green innovation of the mining sector in Mongolia.

Novel Finding # 4: According to the fourth novel finding of this research, green innovation has a significant and favorable effect on circular performance. It may be inferred that the managers of the mining industry in Mongolia have the opinion that a rise in green innovation by the employees of the organization has a favorable impact on the organization's overall performance in terms of productivity, efficiency, and circularity. As a result, the mining sector in Mongolia can accelerate more green innovation to attain outstanding circular performance.

Novel Finding # 5: In terms of the environmental and economic aspects, the study investigated whether the integration of green technology adaptation and circular performance demonstrates a notable positive mediating impact of green innovation, indicating a significant interaction effect. This study reveals a novel finding that green innovation has partial mediation between green technology adaptation and circular performance. So, policymakers can incorporate innovation in the adaptation of green technologies to achieve extreme circular performance.

SUMMARY

Green technology and the circular economy have become central themes in sustainability research, offering a transformative alternative to traditional linear economic models. The circular economy seeks to slow, close, or regenerate resource cycles, thereby reducing waste, preserving the environment, and fostering systems that prioritize stakeholder engagement. Achieving strong circular economic performance requires organizations to adopt innovative business models and operational strategies, often underpinned by advanced technologies. Green technology, in this context, refers to the strategic use of existing resources to develop new products, processes, and avenues for resource development. However, the transition to green technology is not without challenges—companies must overcome barriers related to education, training, organizational change, and coordination. The adoption of sophisticated environmental technologies, such as advanced wastewater treatment, is influenced by a combination of internal factors (like corporate knowledge and alliances) and external factors (such as public involvement and regulatory frameworks).

This study finds that senior management plays a pivotal role in driving the adoption of green technology, which in turn is propelled by market dynamics, environmental awareness, and the rise of green entrepreneurship and innovation. The integration of green innovation into business practices has provided firms with a competitive edge, enabling them to optimize productivity and resource use while reducing environmental costs. Green innovation not only supports sustainable management but also allows companies, especially in emerging economies, to command premium prices for eco-friendly products, enhance brand reputation, and access new markets. The research highlights that green innovation is a key enabler for maintaining competitiveness and delivering sustainable value, with additional benefits identified by experts in the field.

The Mongolian mining industry serves as a compelling case study for the circular economy in action. Mining companies have become influential in shaping local policies on green technology adoption, and their operations have had complex effects on rural communities. Initially, many rural and nomadic inhabitants viewed mining as a threat to their environment and traditional livelihoods. Over time, however, as climate-related disasters impacted livestock, mining became a critical source of employment and economic stability for many. The sector's growth has spurred the development of related industries and infrastructure, improved access to services, and contributed to rising educational attainment in mining towns, despite some negative health and environmental impacts.

The research model positions green technology adoption as the independent variable, green innovation as the mediating variable, and circular economic performance as the outcome. The study's first major finding is a significant positive relationship between green technology adoption and circular economic

performance—companies that embrace eco-friendly technologies reduce resource consumption, waste, and environmental impact. The second finding is that green technology adoption stimulates green innovation, fostering creativity and enabling the implementation of circular practices across sectors. This includes the adoption of renewable energy sources, which help mitigate climate change and reduce industrial pollution. The third finding is that green innovation itself directly enhances circular economic performance, strengthening the link between sustainable practices and competitive advantage.

A particularly important result is the mediating role of green innovation: it not only supports but amplifies the positive effects of green technology adoption on circular economic performance. Recognizing this intermediary role is crucial for stakeholders seeking to maximize the benefits of circular economy initiatives. The study calls for comprehensive strategies to address challenges such as resource allocation, technological lock-in, rebound effects, and regulatory barriers, ensuring that green innovation can fully contribute to circular economy goals.

The primary contribution of this research is the development and empirical testing of a conceptual model that clarifies how corporations can improve circular economic performance through the integration of green technology and innovation. By applying the resource-based view (RBV) framework, the study demonstrates that dynamic capabilities—such as technological assets and employee creativity—are essential for achieving superior performance. This approach enriches the literature by showing that a resource-based perspective is particularly effective in explaining how green technology and innovation drive circular economic outcomes.

For practitioners, the study offers practical guidance on managing green technology and innovation to achieve circular economy success. It emphasizes the need for technical expertise, organizational learning, and the effective reuse and recovery of resources. Managers are encouraged to move beyond linear production models and adopt closed-loop systems, leveraging analytics to identify and address performance gaps. The research also highlights the importance of aligning green technology initiatives with broader innovation strategies to maximize impact.

In conclusion, the study finds that the combination of green technology adaptation and green innovation provides the most accurate prediction of circular economic performance, while green technology adaptation alone is a strong predictor of decision-making quality. Green innovation strengthens both the direct and indirect effects of technology adoption on circular economic success, making it a critical factor for organizations aiming to enhance productivity, efficiency, and sustainability. The findings underscore the need for integrated, innovation-driven approaches to achieve the full potential of the circular economy, particularly in resource-intensive sectors like mining.

REFERENCES

- ABDALLAH, A. B. – AL-GHWAYEEN, W. S. – AL-AMAYREH, E. A. M. – SWEIS, R. J. (2024). The Impact of Green Supply Chain Management on Circular Economy Performance: The Mediating Roles of Green Innovations. *Logistics*, 8(1), 20.
- AI, H. – ISLAM, N. – MANGLA, S. K. – SONG, M. – TAN, X. (2024). Circular economy, open innovation, and green innovation: Empirical evidence from prefecture-level cities in China. *IEEE Transactions on Engineering Management*, 71, 5706-5719.
- ALI, Z. A. – ZAIN, M. – PATHAN, M. S. – MOONEY, P. (2024). Contributions of artificial intelligence for circular economy transition leading toward sustainability: an explorative study in agriculture and food industries of Pakistan. *Environment, Development and Sustainability*, 26(8), 19131-19175.
- AWAN, F. H. – DUNNAN, L. – JAMIL, K. – GUL, R. F. (2023). Stimulating environmental performance via green human resource management, green transformational leadership, and green innovation: a mediation-moderation model. *Environmental Science and Pollution Research*, 30(2), 2958-2976.
- BAAH, C. – RIJAL, A. – AGYABENG-MENSAH, Y. – AFUM, E. – ACQUAH, I. S. K. (2024). Does circular economy entrepreneurship drive technical capabilities for circular economy performance? The moderating role of environmental dynamism. *Management of Environmental Quality: An International Journal*, 35(3), 567-586.
- BAG, S. – DHAMIJA, P. – BRYDE, D. J. – SINGH, R. K. (2022). Effect of eco-innovation on green supply chain management, circular economy capability, and performance of small and medium enterprises. *Journal of Business Research*, 141, 60-72.
- COOPER, D. R., – SCHINDLER, P.S. (2011). *Business Research Methods* (11th ed.). New York: McGraw-Hill.
- CRESWELL, J. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches*: SAGE Publications, Incorporated.
- ESPOSITO, B. – SICA, D. – SUPINO, S. – MALANDRINO, O. (2024). Measuring the impact of circular economy performance on financial performance: The moderating role of stakeholder engagement. *Business Strategy and the Environment*, 33(6), 5109-5126.
- GAZI, M. A. I. – MASUD, A. A. – AMIN, M. B. – HOSSAIN, M. A. – BIN S SENATHIRAJAH, A. R. – ABDULLAH, M. (2024D). Evaluating customer satisfaction with the quality of online banking services after COVID-19: developing country perspective. *Cogent Business & Management*, 11(1), 2423057. <https://doi.org/10.1080/23311975.2024.2423057>
- GAZI, M. A. I. – MIM, A. T. – MASUD, A. A. – RAHMAN, M. K. H. – AMIN, M. B. – SENATHIRAJAH, A. R. B. S. – OLÁH, J. (2025F). Paving the way of entrepreneurship for university students: the role of innovativeness, technological adaptability, and self-management, with risk-taking and family support as moderator. *Cogent Education*, 12(1), 2455230. <https://doi.org/10.1080/2331186X.2025.2455230>

List of publications related to the dissertation



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Articles, studies (5)

1. Habib, A., Khan, M. A., **Chuluunbaatar, E.**, Oláh, J.: Does Mandatory CSR Reporting Help Combat Climate Risk in the Presence of Green Finance and Green Innovation?
Amfiteatru Economic. 27 (68), 163-179, 2025. ISSN: 1582-9146.
DOI: <http://dx.doi.org/10.24818/EA/2025/68/163>
IF: 2 (2024)
2. Lyeonov, S., Moroz, A., Dudzik, I., **Chuluunbaatar, E.**: Green rules & grey markets: Do environmental policies influence the informal economy?
Economics & Sociology. 18 (1), 313-338, 2025. ISSN: 2071-789X.
DOI: <http://dx.doi.org/10.14254/2071-789X.2025/18-1/17>
IF: 1.8 (2024)
3. Oláh, J., Khan, K. A., Akhtar, M. A., **Chuluunbaatar, E.**: Take a ride on the green side: e-vehicle purchase intentions in the emerging economy context.
Economics and Sociology. 17 (3), 267-290, 2024. ISSN: 2071-789X.
DOI: <http://dx.doi.org/10.14254/2071-789X.2024/17-3/14>
IF: 1.8
4. Szabó, Z. T., **Chuluunbaatar, E.**, Alpek, L.: The shortening of sustainable supply chains in Hungary and Europe.
Journal of Central European Green Innovation. 11 (2), 93-110, 2023. EISSN: 2064-3004.
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Address: 1 Egyetem tér, Debrecen 4032, Hungary Postal address: Pf. 39. Debrecen 4010, Hungary
Tel.: +36 52 410 443 Fax: +36 52 512 900/63847 E-mail: publikaciok@lib.unideb.hu, Web: www.lib.unideb.hu



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