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Sustainability Management Control Systems and Sustainable Financial Performance: An Integrated Framework for Sustainability Management Practices.

Mohanad Mohammed Sufyan Ghaleb*, *College of Business, King Faisal University, Al-Ahsa, Saudi Arabia. 31982.* Email: mghaleb@kfu.edu.sa

*Corresponding Author (Mohanad Mohammed Sufyan Ghaleb. Email: mghaleb@kfu.edu.sa)

ABSTRACT

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Sustainability Management, Control Systems, Eco-Innovation, Digital Adaptability, Operational Performance, Economic Performance.

This study examines the influence of sustainability management control systems (SMCS) on sustainable economic performance in the petrochemical industry of Saudi Arabia by integrating the roles of eco-innovation, digital adaptability, and operational performance. Using a quantitative research design, data were collected from 291 employees of petrochemical companies through a structured questionnaire and analyzed using Structural Equation Modelling (SEM) with Smart-PLS. The findings reveal that SMCS significantly enhances eco-innovation and digital adaptability, which subsequently improves operational performance and sustainable economic performance. The study further demonstrates that digital adaptability positively influences both operational performance and sustainable economic performance, while operational performance has a strong effect on sustainable economic performance. Mediation analysis confirms that digital adaptability mediates the relationship between eco-innovation and operational performance, whereas operational performance mediates the relationship between digital adaptability and sustainable economic performance. The study contributes to sustainability management literature by offering an integrated framework that highlights the importance of sustainability-oriented managerial practices and digital transformation in achieving long-term economic sustainability in industrial sectors.

INTRODUCTION

The petrochemical industry in Saudi Arabia plays a central role in national economic diversification and industrial development. As one of the world's leading producers of petrochemical products (Al-Gobaisi et al., 2025), the sector significantly contributes to gross domestic product, exports, employment generation, and industrial competitiveness. However, the growing global demand for environmental

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sustainability, resource optimization and digital transformation has forced petrochemical companies to rethink their business operations and strategies (Elmaghraby et al., 2025). The definition of organizations is no longer limited to financial profitability but also what can be achieved with sustainable economic performance using environmentally responsible and technically adaptable business operation. In this regard, sustainability management control systems (SMCS) have been identified as a managerial device to involve sustainability goals in the operational decision-making of companies(Rehman et al., 2021). Similarly, eco-innovation and digital adaptability have emerged as organizational capacities that allow us to optimize the functioning of operations, minimize environmental waste, and consistently leverage economic sustainability in industrial sectors.

Even though sustainability standards are crucial for the strategies of petrochemical companies in Saudi Arabia (Abdel-Halim et al., 2025; Alshhadat, 2025), they are still facing significant practical problems in achieving sustainable economic performances. The industry is greatly reliant upon energy intensive production methods that not only lead to environmental damage but also to operational inefficiencies and rising compliance expenses with sustainability laws (Attia et al., 2026). Moreover, the fast-paced development of technologies and the international environmental expectations demand that organizations must embrace new green technologies and boost their digital skills on a regular basis. But many companies face challenges when it comes to implementing sustainable management systems effectively within an environment where sustainability (Attia et al., 2026), innovation, and digital adaptability are being adopted in practice, leading to poor operational coordination and lower long-term economic results. While previous studies have examined sustainability management practices and financial performance individually (Aziz & Cek, 2025; Citterio, 2025; Kaffash et al., 2026), very few empirical studies have examined the impact of sustainable management control systems on sustainable economic performance via eco-innovation, digital adaptability and operational performance in the petrochemical industry in Kingdom of Saudi Arabia. This gap points to the necessity of the need for a comprehensive framework to explain the interconnected relationships between these variables in a new industrial environment driven by sustainability.

The present study makes a significant contribution to existing literature in several important areas. First, an integrated framework is designed that integrates SMCS, eco-innovation, digital adaptability, operational performance and sustainable economic performance in one empirical model. Second, the research adds to the body of sustainability and management control literature, as it looks at the role that operational performance and digital adaptability play as mediators between sustainability-oriented practices and economic outcomes. Third, the study is limited to the petrochemical industry in Saudi Arabia, which has not been well-studied in previous sustainability management research, although it plays an important role in the global economy. The results offer empirical evidence of the significant influence of SMCS on eco-innovation and digital adaptability, which then enhances operational performance and sustainable economic performance. The research combines the technological ‘adaptability' and eco-innovation 'perspective' to provide a more comprehensive understanding of the relationship between how organizations can implement sustainability goals and how they can remain operationally competitive in a fast-changing industrial landscape.

The primary aim of the present study is to explore how SMCS affect sustainable economic performance, which is mediated by digital adaptability and operational performance in the petrochemical industry of Saudi Arabia. More specifically, this study examines direct relationships between constructs that were proposed in the study, as well as the indirect effects that lead to sustainable economic outcomes. This study has significant importance in the academic world and in industry. The results offer practical examples to policy and industrial managers on the potential to enhance the effectiveness of operations and sustainable use by implementing sustainability-oriented control mechanisms and digital transformation strategies. The study deepens the theoretical knowledge of sustainability management in the field by providing an overarching framework of empirical indicators for new industrial economies. Moreover, the research contributes to the wider sustainability agenda of the Kingdom of Saudi Arabia in the context of national development programs that emphasize eco-responsibility and sustainable development in industry and economy.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Sustainable Economic Performance

Sustainable economic performance is the capability of the organization to sustain economic growth in the long run, whilst maintaining environmental responsibility and efficient use of resources (Afsar & Umrani, 2020). Sustainable economic performance goes beyond just profitability, focusing on achieving a balance between profitability and sustainability goals like waste reduction, efficient use of energy, and responsible operations (Singh et al., 2023). Businesses with a focus on sustainable economic performance want to generate economic value without infringing on their environmental and social responsibilities. In industry, in general and especially in the petrochemical industry, sustainable economic performance is manifested in better management of resources, better profitability, lower operating costs and higher production efficiency. Sustainability-focused strategies enable businesses to better meet environmental laws, stakeholder demands, and market competition. Studies have previously pointed out the positive relationship between sustainable practices and organizational competitiveness and long-term survival. Hence, sustainable economic performance is an important measure for assessing the sustainability and economic stability of an organization as well as operational resilience in today's business.

Sustainability Management Control System

SMCS is a collection of managerial practices, policies and monitoring mechanisms that incorporate the objectives of sustainability into organization's business and strategy (Dharmayanti et al., 2023; Rehman et al., 2021). The system helps organizations manage environmental, social and economic activities and helps them align with sustainability targets. By using SMCS, companies can track resource usage, environmental standards and compliance, stakeholder interactions and ethical governance processes (Gerasimov et al., 2019). In recent years there has been a growing trend of implementing control systems with sustainability elements to enhance transparency, accountability in operations and organizational performance over the long term. In the petrochemical sector, SMCS can be vital for lowering environmental dangers and advancing effective working processes. The system also enables the adaptation of the organization towards a green innovation and digital transformation by offering support for sustainability-based decision making. The existing literature shows that companies that have good control systems on sustainability had better sustainability practices, more operational capability, and better financial results. As a result, SMCS has evolved into an indispensable means of securing sustainably competitive and sustainable organizations.

Eco-Innovation

Eco-innovation is the creation and adoption of environmentally responsible products, processes, technologies and management practices that have positive effects on organizational performance and that reduce negative environmental impacts (de Oliveira Brasil et al., 2016; Miao et al., 2023). The idea integrates innovation activities with sustainability goals to encourage cleaner production, resource reduction and environmental protection. Eco-innovation helps these organizations to lessen the amount of waste they produce, save on energy use, and use green technologies as part of sustainable industrial development (Xu et al., 2023). Eco-innovation is especially relevant in the petrochemical sector as production processes are energy-intensive and sensitive to the environment (Oduro, 2024). Incorporating eco-innovative practices can help organizations become more efficient in their operations, achieve better environmental compliance, and become more competitive in the market. It is also assisting companies to meet growing stakeholder expectations on sustainability and environmental responsibility (Almeida & Wasim, 2023). The existing studies indicate that eco-innovation has a positive impact on the adaptability, efficiency of operation and economic performance of the organization. Eco-innovation has become a key enabling tool for the management of industrial productivity and environmental sustainability and long-term business growth.

Digital Adaptability

Digital adaptability is the ability of an organization to adapt, integrate, and make effective use of digital technologies to tackle the evolving business landscape and operational needs (Dharmayanti et al., 2023). It is an indicator of the organization's agility toward adopting technological innovation, digital transformation and data-driven decision making processes. Technological integration, development of digital skills, use of data analytics, management of cyber security, and innovation-oriented organizational culture are part of digital adaptability. In today's industrial landscape, digital agility is crucial for optimizing operations, enriching customer experiences, and promoting sustainable business models (Atobishi et al., 2024). Digital adaptability allows companies in the petrochemical sector to optimize their production processes, enhance environmental management, and use digital systems and automation to better manage their resources. Having digital adaptability is a key advantage for organizations to take in the face of market uncertainty and sustainability issues. Empirical research showed the positive effect of digital adaptability on innovation, operational performance and organizational competitiveness. Therefore, digital adaptability is viewed as a key organizational capability in technology-based industrial environments for sustainable development and for improving business performance in the long term.

Operational Performance

Operational performance is the effectiveness of an organization in using its operational processes to ensure the delivery of productivity, quality improvement, flexibility and rapid response to the market (Basuki et al., 2020). It demonstrates how efficient internal business processes are at creating products and services at the lowest cost and with the least waste of resources. The high performance in operation helps companies enhance their production efficiency, customer satisfaction, and organizational competitiveness (Bushman & Smith, 2001). Operational performance is a key factor in the petrochemical industry since business firms are exposed to a high level of competition and the application of resources is high, and the efficiency of production can significantly influence the profitability and sustainability of the businesses. Process flexibility, fast product development, efficient use of resources and meeting customer demand are typically attributes of good operational performance. Businesses with high operational performance have greater potential to sustain their growth and competitive edge over time.

SMCS offer organizations a framework of systems to incorporate environmental and sustainability goals within the strategy and operations of the organization (Rehman et al., 2021). They facilitate tracking, assessment and coordination of sustainable practices and help companies invest in sustainable innovation initiatives (Teece, 2018). In the context of sustainability governance, stakeholder participation, and environmental certification, it becomes easier for organizations to create environmentally friendly products, production processes and green technologies. Past research found a positive association between effective sustainability management controls and the promotion of innovative environmental practices and sustainable technological development (Rehman et al., 2021; Vitezić & Vitezić, 2015). SMCS helps companies in the petrochemical sector increase environmental accountability and drive eco-innovation programs in a sector where environmental issues and regulation are high. Hence, it is expected that the organizations with robust SMCS would show their eco-innovation capability at a higher level and have an operation in an environmentally friendly manner.

H1: SMCS significantly enhance eco-innovation.

SMCS contribute significantly to building organizational adaptability towards technological and digital transformation (Rehman et al., 2021). It makes easier to implement strategic planning, performance management, and decision-making for sustainability, fostering businesses' use of more sophisticated digital tools and innovation-based approaches. Sustainability management controls tend to build up a flexible operation and a data-driven management that enhances the ability to respond to environmental and market shifts (Al-Qassab et al., 2019). Businesses that want to be digital-ready must embrace technological infrastructure, strengthen digital capabilities, and leverage data analytics to make better decisions, boost efficiency, and drive sustainability. The challenge to be digitally adaptable is particularly acute in industries that are sensitive to sustainability, like the petrochemicals sector, where tracking environmental performance, optimizing resource usage, and enhancing production efficiency are critical. According to the previous literature, organizations that have robust sustainability governance and control system are more likely to be able to undertake digital transformation projects (Verhoef et al., 2021). Hence, SMCS are expected to have a positive impact on the organizations' digital adaptability and technological responsiveness.

H2: SMCS significantly enhance digital adaptability.

Operational performance is enhanced through eco-innovation (Munodawafa & Johl, 2024), which allows an organization to implement environmentally friendly technologies, production processes, and operational practices. Firms can use eco-innovative activities to decrease waste production and the use of energy, resources and lower the costs of their operation (Gavrilescu et al., 2017). These enhancements directly support production efficiency, flexibility in operations and responsiveness to market demands. In industrial activities, like petrochemicals, eco-innovation is especially crucial since its activities are resource-intensive and sensitive to the environment. Organizations that employ eco-innovation practices can more easily meet process optimization goals alongside environmental compliance and sustainability goals. Few previous research indicated that eco-innovation can positively affect the organizational competitiveness (Lewandowska, 2020; Ziaei & Roshani, 2024) by increasing productivity, decreasing inefficiencies and boosting the capabilities of the organizations in operation. In addition, environmentally friendly innovations can help to ensure long-term operational stability and quality improvement. Thus, it is expected that eco-innovation will have a positive impact on the operational performance through the improvement of efficiency, flexibility and operational outcomes that will have an impact on sustainability.

H3: Eco-innovation significantly enhance operational performance.

Eco-innovation is a push to use modern technology and innovative operational systems which enhance the digital adaptability of the organizations (Dharmayanti et al., 2023). Firms frequently need to incorporate digital technologies like smart monitoring systems, data analytics, automation systems, and digital communication platforms into their environmentally sustainable innovations. Organizations that seek to be eco-innovative are more technologically aware and can adjust to the needs of digital transformation. Digital adaptability is defined as the organization's ability to use digital technologies effectively to enhance sustainability, performance, operational efficiency and competitive advantage (Florek-Paszkowska & Ujwary-Gil, 2025). Eco-innovation can help the industry implement cutting-edge digital technologies to promote environmental monitoring, resource efficiency, and sustainable production practices for the petrochemical sector. Hence, eco-innovation is expected to have a positive effect on digital adaptability through technological integration, organizational agility, and digital transformation capabilities.

H4: Eco-innovation significantly enhance digital adaptability.

Digital adaptability enhances operational performance by facilitating the incorporation of cutting-edge technologies, data-driven systems, and flexible digital processes into operations. Digital adaptability is a key trait of organizations that can thrive in response to market shifts, customer needs, and technological advancements (Goel & Garg, 2018). The use of digital technologies like automation systems, real-time monitoring, artificial intelligence, and data analytics improves the efficiency of production processes, minimizes delays in operations, and optimizes decision-making. Adaptability is especially significant in the petrochemical industry because companies must be in a highly competitive setting that is also technologically advanced. Other studies highlighted the advantages of digitally adaptive organizations in terms of their greater productivity, flexibility in operations and process optimization over those with lower tech capacity (Kawiana, 2023). In addition, digital adaptability fosters innovation and continuous improvement of operations (Nambisan et al., 2017), thereby consolidating the organizational competitiveness and sustainability. Hence, digital adaptability is likely to have a meaningful impact on operational efficiency, responsiveness and technology integration in the day-to-day operations of organizations, thereby propelling operational performance.

H5: Digital adaptability significantly enhance operational performance.

Furthermore, by integrating cutting-edge digital systems and fostering innovation-driven practices, digital adaptability empowers organizations to navigate technological shifts with ease and meet changing market needs. By leveraging data analytics and intelligent technologies, companies with robust digital adaptability can boost efficiency, optimize resource use and make better decisions. In sectors that prioritize sustainability, digital technologies enable environmental tracking (Khan et al., 2024), energy management, waste reduction and process automation, helping to ensure sustainability in the long term. In the petrochemical sector, digital adaptability can empower companies to enhance production productivity and implement sustainability goals (Elmaghraby et al., 2025), while also cutting down on operational expenses. Successfully implemented digital transformation will be more competitive, flexible and financially viable in a dynamic business environment. Moreover, the ability to adapt to digital also contributes to organizational resilience and innovation (Heinz et al., 2021), a positive factor in the medium to long-term economic results (Velyako & Musa, 2024). As a result, the adaptability to digital is anticipated to have a significant positive impact on sustainable economic performance in terms of efficiency, technological responsiveness and sustainable-oriented operational improvements.

H6: Digital adaptability significantly enhance sustainable economic performance.

Operational performance is seen as one of the most critical factors underpinning sustainable economic performance (Duong, 2022) as it will directly impact on profitability, productivity and organizational sustainability in terms of operational activities. Companies with high operational performance can streamline their production, minimize waste, enhance product quality, and be agile in meeting customer and market requirements. For industrial companies like petrochemicals, where production costs are high, activities are energy consuming and where the environment is becoming more of a concern, there is need for operational efficiency. Optimized operations enable better use of resources and cost savings, leading to increased profitability and sustainable business development (Veerasamy et al., 2025). Efficient operational systems have been reported to be better able to achieve environmental, economic and competitive advantages with economic sustainability. Additionally, operational agility and productivity boost the resilience of the organization in a dynamic business context. Hence, it is hoped that operational performance will positively impact sustainable economic performance, through improved efficiency, lowered operational inefficiencies and long-term organizational sustainability.

H7: Operational performance significantly enhance sustainable economic performance.

Eco-innovation allows organizations to integrate socially responsible technologies (Pan et al., 2021), production methods and resource efficient processes, which also help to enhance the competitiveness of the organization and its sustainability. However, the impact of eco-innovation to improve operational performance can be affected by an organization's capability to change with digital transformation. It enables the seamless implementation of cutting-edge technologies, automation solutions, and data analysis tools into eco-innovative practices, thus enhancing operational efficiency, flexibility, and process optimization. Therefore, the relationship between the concept of eco-innovation and operational performance (Munodawafa & Johl, 2024) is expected to be mediated by digital adaptability. Effective operational systems can help organizations optimize production activities, lower operational costs, maximize resource usage, and boost productivity, particularly when they are digital adaptable. These operational enhancements then help to drive long-term profitability and sustainable economic growth. Hence, digital adaptability is hypothesized to act as a mediating mechanism between digital competence and sustainable economic performance.

H8: The relationship between eco-innovation and operational performance is mediated by digital adaptability.

H9: The relationship between digital adaptability and sustainable economic performance is mediated by operational performance.

Figure 1 highlighted the relationship between SMCS, eco-innovation, digital adaptability, operational performance and sustainable economic performance. Digital adaptability and operational performance are considered a mediating variable. Furthermore, sustainable economic performance is considered as dependent variable which can be influenced by SMCS, eco-innovation, digital adaptability and operational performance.

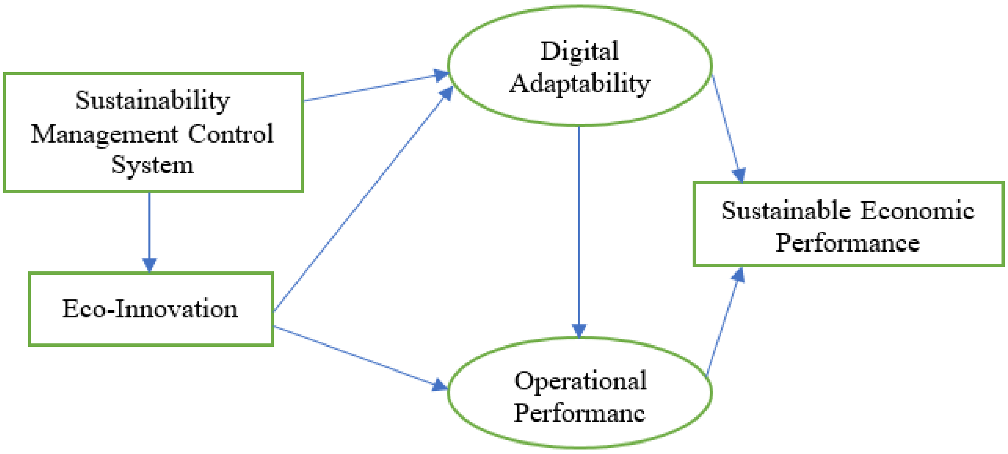

Figure 1: Conceptual Framework

METHOD

This study was carried out by using a quantitative research design and cross-sectional survey to investigate the relationship between SMCS, eco-innovation, digital adaptability, operational performance and sustainable economic performance in the petrochemical sector in Saudi Arabia. The quantitative approach is suitable for a study which involves testing hypothesized relationships, direct and indirect effects among proposed constructs through statistical analysis. This research used a deductive method that involved collecting structured data from industry respondents to test the hypotheses that were formed based on the literature.

The population of the study is based on employees of petrochemical companies in Saudi Arabia. The petrochemical sector was chosen because it is one of the most sustainability-sensitive and technologically advanced sectors, with environmental management, digital transformation and operational efficiency playing a significant role in the sustainability of the organization and economic performance. The population comprises people engaged in sustainability management, operational management, production processes, compliance with environmental regulations, digital transformation, and strategic decision-making processes. The respondents are deemed suitable since they have appropriate organizational knowledge on sustainability practices, eco-innovation projects, digital adaptability and operational performance in their companies.

The data is collected from petrochemical organizations by using simple random sampling. The list of respondents was obtained from petrochemical companies in Saudi Arabia and respondents were chosen randomly. The survey is sent out physically and electronically to employees in the petrochemical industry all over Saudi Arabia. A total of 305 respondents were chosen from the different petrochemical companies in Saudi Arabia, and 291 valid responses were received. This sample size is deemed sufficient for the structural equation modeling analysis as it meets the minimum sample size criteria for testing complex mediation relationships and multiple constructs at the same time.

The respondents comprise of employees including: managers, supervisors, sustainability officers, operational managers, production executives, IT staff and administrative employees across the petrochemical sector. These are people that are actively engaged in organizational sustainability efforts, operations management, digital transformation projects, and environmental compliance. The selection of respondents is based on departments related to sustainability management, operations, production, digital systems and strategic planning. They can provide reliable information on SMCS, eco-innovative practices, digital adaptability, operational performance and sustainable economic performance.

This study used survey method with a structured questionnaire. The questionnaire was prepared by adopting the measurement items from previous studies. The questionnaire is refined by academic experts and industry professionals prior to final distribution for clarity, relevance and comprehensibility. In addition, a pilot study is carried out by using 60 responses to make sure that the survey instrument is appropriate for the respondents. SMCS is measured by using four scale items and eco-innovation is measured by using seven scale items adapted from Dharmayanti et al. (2023). Seven scale items for digital adaptability are adapted from Kurniawan, Dzarfan Othman, et al. (2022). Furthermore, three scale items are adapted from Flynn et al. (2010) and three are adapted from Li et al. (2025) to measure operational performance and sustainable economic performance, respectively. All the measures are reported in the following section.

Sustainability Management Control System (Dharmayanti et al., 2023**)**
"SMCS1 =Compliance with Environmental Regulations.
SMCS2 =Resource Efficiency.
SMCS3 =Stakeholder Engagement.
SMCS4 =Governance and Ethics."

Eco-Innovation (Bahzar, 2019**;** Firman et al., 2023**)**
"EIN1 =Number of Eco-Innovative Products/Services.
EIN2 =Reduction in energy consumption and water usage.
EIN3 =Adoption of Green Technologies.
EIN4 =Collaborations and Partnerships.
EIN5 =Employee Engagement and Skills.
EIN6 =Conservation of biodiversity and natural resources.
EIN7 =Revenue attributed to eco-innovative products or services."

Digital Adaptability (Kurniawan, Dzarfan Othman, et al., 2022**)**
"DIA1 =Digital Skills and Competencies.
DIA2 =Technology Adoption and Integration.
DIA3 =Data Analytics and Insights.
DIA4 =Customer Engagement and Experience.
DIA5 =Innovation and Agility.
DIA6 =Cybersecurity and Data Privacy.
DIA7 =Digital Culture and Leadership."

Operational Performance (Flynn et al., 2010**)**
"OPER1 = Swiftly modify products to meet the needs of our primary customers.
OPER2 = Rapid introduction of new products to the market is within the capability of our firm.
OPER3 = Capacity to promptly respond to changes in market demands."

Sustainable Economic Performance (Li et al., 2025)
"SECO1 = Improvement in resource management efficiency within our firm.
SECO2 = Significantly enhances sales profitability.
SECO3 = Reduce the costs associated with purchasing raw materials."

Once the data has been collected, the responses are checked for missing values, incomplete responses and outliers before making a statistical analysis. The study then proceeds to test the measurement model, relationships between the constructs, and mediation effects between the constructs using SmartPLS and Structural Equation Modeling (SEM).

FINDINGS

The reliability of individual scale items for each construct is reported in Table 1 and Figure 2 using the standardized factor loading. This study followed the recommendation of previous studies to confirm the reliability and validity of constructs (Henseler et al., 2015; Nitzl et al., 2016; Sattler et al., 2010). The internal consistencies for digital adaptability are all satisfactory, from 0.835 to 0.874, and all items have strong loadings. The indicators of digital adaptability tend to be well aligned and able to capture the underlying concept. The loadings for the item on the eco-innovation scale range from 0.709 to 0.768. All values are in the acceptable range of 0.70 and showed satisfactory reliability. The loadings for the operational performance are high, ranging from 0.892 to 0.917, indicating high item reliability and strong consistency between the three items. Likewise, sustainable economic performance has high loadings between 0.859 to 0.908. Moreover, the loading values of the items in the SMCS are high ranging from 0.833 to 0.900, indicating good reliability for items.

Table 1: Reliability of Scale Items

Variables	Scale Items	Reliability Level (Loading)
Digital Adaptability	DIA1	0.838
	DIA2	0.835
	DIA3	0.854
	DIA4	0.846
	DIA5	0.874
	DIA6	0.853
	DIA7	0.865
Eco-Innovation	EIN1	0.739
	EIN2	0.759
	EIN3	0.738
	EIN4	0.741
	EIN5	0.727
	EIN6	0.768
	EIN7	0.709
Operational Performance	OPER1	0.911
	OPER2	0.917
	OPER3	0.892
Sustainable Economic Performance	SECP1	0.866
	SECP2	0.908
	SECP3	0.859
Sustainability Management Control System	SMCS1	0.833
	SMCS2	0.898
	SMCS3	0.897
	SMCS4	0.9

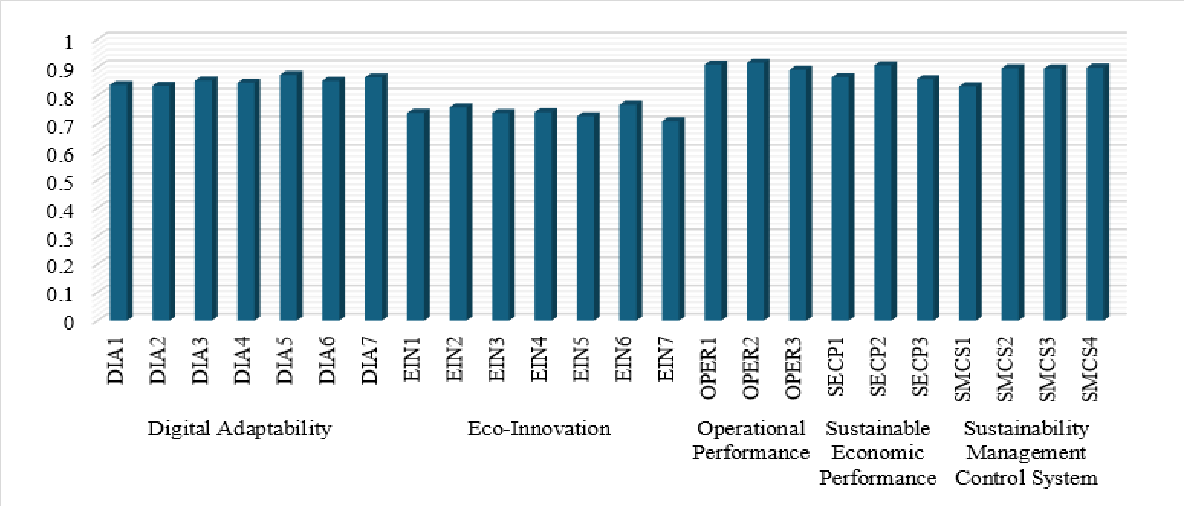

Figure 2: Reliability of Scale Items

The construct-level reliability and convergent validity are presented in Table 2 through Cronbach's alpha (α), composite reliability (CR) and average variance extracted (AVE) (Chin, 1998; Goodhue et al., 2012). The values of α = 0.937 and CR = 0.949 indicate excellent internal consistency, while AVE = 0.726 confirms strong convergent validity, which is above the recommended value of 0.50. The Cronbach alpha (0.863) and CR (0.895) show good reliability for the construct of eco-innovation, while the AVE value (0.548) is still relatively low compared to other constructs but acceptable. Operational performance is reliable and valid with α = 0.892 and CR = 0.933, AVE = 0.822 which is very high, and the construct has explained a high proportion of variance in the items, thereby having excellent convergent validity. Additionally, the reliability of SMCS is high (α = 0.905, CR = 0.934) and the convergent validity is also high (AVE = 0.779), thus the construct is well measured and conceptually strong. Sustainable economic performance also has a high Cronbach's Alpha (α = 0.851, CR = 0.910) and a high AVE (0.771), which means that the construct is internally consistent and convergent.

Table 2: Reliability of Constructs and Convergent Validity

Variable	α	CR	AVE
Digital Adaptability	0.937	0.949	0.726
Eco-Innovation	0.863	0.895	0.548
Operational Performance	0.892	0.933	0.822
SMCS	0.905	0.934	0.779
Sustainable Economic Performance	0.851	0.91	0.771

The Fornell-Larcker criterion results show good discriminant validity of the constructs because the square roots of the AVEs (diagonal elements) are greater than the inter-construct correlation (Hilkenmeier et al., 2020). Digital adaptability has good validity as its correlations are higher than inter-construct correlation. The operational performance and SMCS also have good discriminant validity. Eco-innovation demonstrates good but somewhat lower separation from SMCS. The constructs show good discriminant validity for sustainable economic performance. Table 3 highlighted the AVE Square Root.

Table 3: AVE Square Root

Variable	DIA	EIN	OPER	SMCS	SECP
Digital Adaptability	0.852				
Eco-Innovation	0.706	0.74			
Operational Performance	0.61	0.562	0.907		
Sustainability Management Control System	0.442	0.671	0.483	0.882	
Sustainable Economic Performance	0.639	0.634	0.761	0.504	0.878

This study considered t-value 1.96 to examine the significance of the relationship and beta value to check the direction of the relationship, which is recommended by several previous studies (Latan et al., 2017; Nitzl et al., 2016; Shmueli et al., 2016). The results that are presented in Table 4 and Figure 3 further confirm the statistical significance and support of the hypothesized direct relationships. The result shows that SMCS have a strong positive effect on eco-innovation and a moderate but significant impact on digital adaptability, highlighting the importance of structured sustainability governance in fostering environmental innovation and technological readiness. Eco-innovation has a strong relationship with digital adaptability and a positive relationship with operational performance, highlighting the importance of environmentally oriented innovation for the technological integration and efficiency of the processes of firms. Digital adaptability has a positive impact on operational performance and sustainable economic performance. Furthermore, the relationship between operational performance and sustainable economic performance is positively high, which means that efficiency-oriented operations are a key element in the advancement of economic sustainability in petrochemicals.

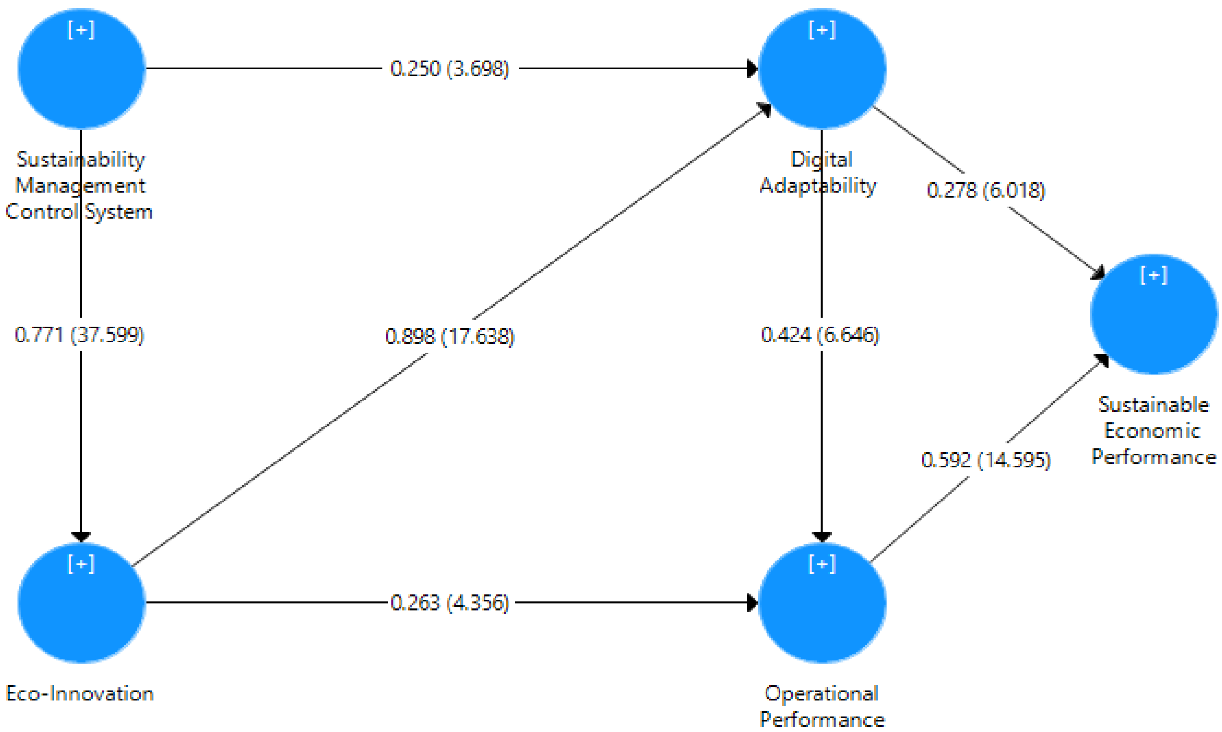

Figure 3: Path Coefficient Results (T-value and Beta Value)

Table 4: Results of Direct Relationships

Hypothesized Relationships	Beta	SD	T Statistics	P Values	Decision
Digital Adaptability -> Operational Performance	0.424	0.064	6.646	0	Supported
Digital Adaptability -> Sustainable Economic Performance	0.278	0.046	6.018	0	Supported
Eco-Innovation -> Digital Adaptability	0.898	0.051	17.638	0	Supported
Eco-Innovation -> Operational Performance	0.263	0.06	4.356	0	Supported
Operational Performance -> Sustainable Economic Performance	0.592	0.041	14.595	0	Supported
Sustainability Management Control System -> Digital Adaptability	0.25	0.068	3.698	0	Supported
Sustainability Management Control System -> Eco-Innovation	0.771	0.02	37.599	0	Supported

As shown in Table 5, the results of the mediation analysis show that both the proposed indirect effects are statistically significant and significantly supported. The effects of eco-innovation on operational performance are also influenced strongly by digital adaptability, indicating that the operational efficiency value added by eco-innovation is primarily through its digitalization and integration with digital tools. Likewise, the link between digital adaptability and sustainable economic performance is significantly mediated by operational performance, suggesting that digital technologies have no direct link to sustainable economic performance without having a positive impact on the operational performance and productivity. The findings underscore that sustainability-driven performance occurs in a way that is more multi-layered than simple direct impacts. Figure 4 highlighted the structural model results, direct and mediation relationships with scale items, beta value and t-values.

Table 5: Results of Mediation Relationships

Hypothesized Relationships	Beta	SD	T Statistics	P Values	Decision
Digital Adaptability -> Operational Performance -> Sustainable Economic Performance	0.251	0.036	7.057	0	Supported
Eco-Innovation -> Digital Adaptability -> Operational Performance	0.381	0.058	6.522	0	Supported

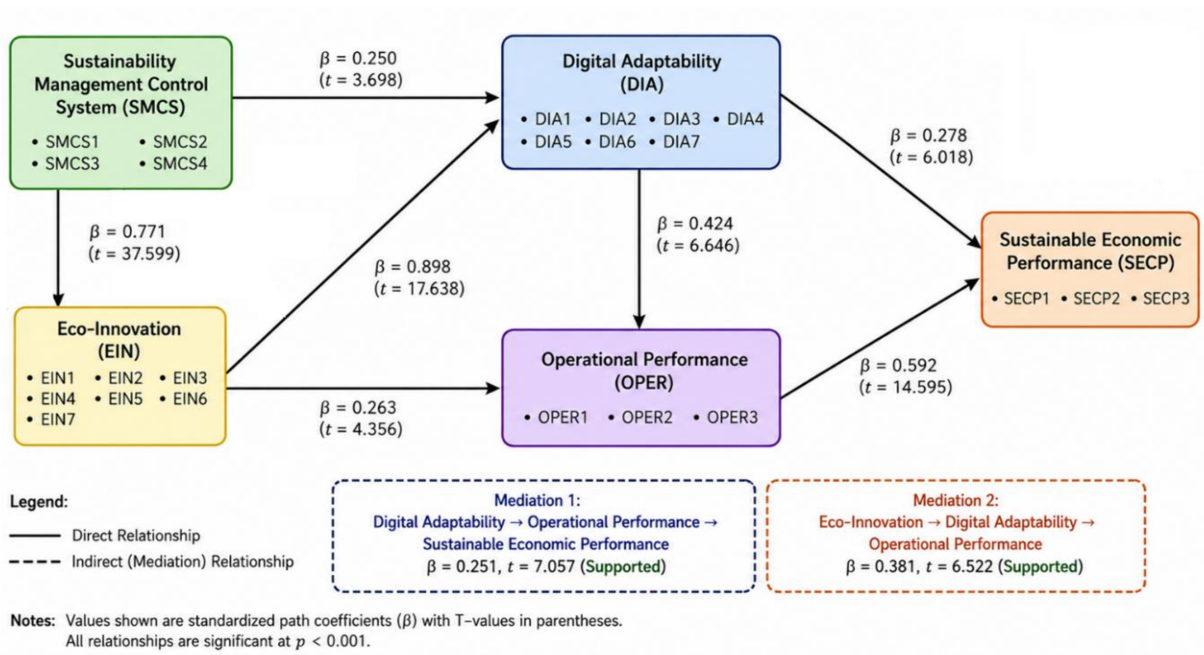

Figure 4: Structural Model Results: Direct and Mediation Relationships with Scale Items, Beta Value and T-Values

DISCUSSION AND CONCLUSION

The findings of this study provide substantial empirical evidence regarding the relationships among SMCS, eco-innovation, digital adaptability, operational performance, and sustainable economic performance in the petrochemical industry of Saudi Arabia. The results demonstrate that sustainability-oriented managerial practices and technological adaptability play a significant role in improving operational efficiency and long-term economic sustainability within industrial organizations.

SMCS had a significant impact on improving eco-innovation, supporting hypothesis 1. The results show that organizations with effective sustainability-oriented control mechanisms are more likely to be able to foster green innovation practices. The SMCS help companies to embed sustainability goals into their business processes, promote cleaner production techniques, resource conservation and green technological development (Einhorn et al., 2023; Rehman et al., 2021). The results of this study aligns with the study conducted by Dharmayanti et al. (2023) which states that sustainability management systems can increase the capability of organizational innovation and environmental sustainability. Likewise, the results are in line with Bahzar (2019), who indicated that managerial strategies that focus on sustainability positively impact eco-innovation initiatives. The present study, however, extends the previous literature by confirming this relationship in the petrochemical industry where the pressure of the environment and operational sustainability are of high importance.

Hypothesis 2 focused on the effect of SMCS on digital adaptability. The findings did demonstrate that there is a positive correlation between the presence of effective sustainability management systems and digital adaptability capabilities within the organizations. Environmentally conscious managerial practices promote the use of sophisticated digital technologies, digital systems and technological infrastructures, all of which increase the firms' capabilities to manage environmental and operational issues. This is in line with the research of Dharmayanti et al. (2023) which concluded that sustainability management mechanisms are supportive of digital adaptability and technology transformation. The findings also align with Kristoffersen, Blomsma, et al. (2020) who argued that organizations with a focus on sustainability are more likely to use digital technologies in their operations. In comparison with the previous studies, the current research offers more empirical evidence of the impacts of sustainability management systems on digital transformation in industrial sectors sensitive to sustainability issues.

Moreover, hypothesis 3 suggested that it is possible to increase the operational performance significantly by adopting eco-innovation. The results confirmed this relationship, indicating that innovations with an ecological profile positively affect the efficiency of the production process, operational flexibility, and responsiveness of the organization. Eco-innovation helps companies improve operational efficiency, minimize waste and make more efficient use of resources by using cleaner production technologies and more environmentally responsible practices (Xu et al., 2023). The outcome of the study is in line with the previous studies, which showed that the eco-innovation has a positive role in the success of the organization and sustainable operational activities (Almeida & Wasim, 2023; Oduro, 2024). Furthermore, hypothesis 4 studied the impact of eco-innovation on digital adaptability. The findings showed that eco-innovation has a positive effect on the digital adaptability of an organization, consistent with the previous studies (Hussain et al., 2026; Khan et al., 2026; Montresor & Vezzani, 2023). The result suggests that companies that are more likely to engage in innovations that are beneficial for the environment are more likely to implement digital technologies, automation systems, and technologically advanced processes of various operations.

Results of hypothesis 5 suggested that digital adaptability would have a significant impact on operational performance. The results validated the link between high levels of digital adaptability and high levels of operational efficiency and flexibility for organizations. Digital adaptability provides companies with the ability to leverage automation (Dharmayanti et al., 2023), data analytics, real-time monitoring, and technologically-enabled operational processes to boost productivity and decision-making quality. This result aligns with literature that has highlighted the need for digital transformation to improve operations (Dióssy et al., 2025; Yu et al., 2022). Additionally, hypothesis 6 explored the link between digital adaptability and sustainable economic performance. This relationship was supported by the results, showing that organizations with digital adaptiveness are more likely to be economically sustainable in the long run. The advantages of digital adaptability include enhanced operational efficiency, resource management, environmental monitoring, and organizational responsiveness, all supporting sustainable economic outcomes. Similarly, hypothesis 7 suggested that the operational performance has a significant impact on sustainable economic performance. The results indicate that the companies that have good operational systems are more capable of achieving sustainable economic growth and profit. These results are consistent with the studies highlighting the significant relationship between operational systems and sustainable economic growth (Duong, 2022; Yani et al., 2025). Improved operational performance helps to reduce costs, optimize processes, enhance quality, and efficiently manage resources, all of which improve sustainable economic results. The current research adds to previous studies within the framework of sustainability and environmental pressures, applied to the context of petrochemical companies.

Furthermore, hypothesis 8 tested the mediation effect of digital adaptability between eco-innovation and operational performance. The results confirmed the mediation effect, which showed that the positive effect of eco-innovation on operational performance is more pronounced with a high digital adaptability capability of organizations. This finding indicates that, while innovations with ecological footprints can have a positive effect on operational activities, however, it is not enough without simultaneously using modern digital technologies and adaptive technological systems. These results align with previous research that has pointed to a complementary nature of digital transformation to enhance innovation results. The present research builds on the existing literature by showing how digital adaptability is a crucial intermediary mechanism between eco-innovation and operational efficiency within industrial organizations. Additionally, hypothesis 9 examined the relationship between digital adaptability and sustainable economic performance which is mediated by operational performance. This mediation effect was confirmed, as digitization of organizations leads to sustainable economic effects mainly with the help of better operational efficiency and productivity. Digital adaptability increases technological responsiveness, optimizes processes, which in turn supports operational performance and supports economic sustainability. The current research adds to the literature by adding empirical evidence that the operational performance acts as an important intermediate explanation of how digital adaptability relates to sustainable economic performance in the petrochemical industry.

IMPLICATIONS OF THE STUDY

The findings of this study provide important theoretical and practical implications for sustainability management and industrial performance literature. The study contributes theoretically by developing an integrated framework that explains how SMCS influence sustainable economic performance through eco-innovation, digital adaptability, and operational performance. The research complements existing literature on sustainability and management control by empirically proving the connection of technological adaptability and environmental innovation in the petrochemical industry in the Kingdom of Saudi Arabia. The study also contributes to the knowledge of mediation mechanisms by showing how digital adaptability and operational performance are key mediators between sustainability-oriented practices and long-term economic sustainability.

Practically, the results are useful for industrial managers, policy makers and sustainability practitioners. The findings indicate that the SMCS of the petrochemical companies needs to be improved to foster innovation and technological change in an environmentally responsible manner. Digital technologies, automation systems, and eco-innovative practices are important activities for organizations to enhance operational efficiency and sustainable economic results. Moreover, policy makers can leverage these findings to create policies that foster a more sustainable industrial approach in sectors that are sensitive to sustainability, enabling digital transformation, environmental responsibility and long-term industrial competitiveness.

RECOMMENDATION FOR FUTURE STUDIES

Future studies should extend the current research by examining additional organizational and environmental factors that may influence sustainable economic performance in industrial sectors. Researchers may incorporate variables such as organizational culture, green human resource management, technological readiness, environmental uncertainty, and leadership support to provide a broader understanding of sustainability-driven organizational performance. Comparative analysis of various industries or countries could also be performed in future studies to assess the generalizability of the proposed framework over other industries or other countries other than the petrochemical industry in Saudi Arabia. For analyzing long-term effect of sustainability management practices and digital transformation on organizational sustainability outcomes, longitudinal research designs are also recommended. In addition, future researchers can benefit from using mixed method approaches to gain a better understanding of managerial issues in implementing control systems and eco-innovation strategies for sustainability.

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