https://doi.org/10.59865/abacj.2023.29

STUDYING THE RELATIONSHIP BETWEEN BLOCK CHAIN TECHNOLOGY AND CIRCULAR ECONOMY DIMENSIONS FROM PRODUCTION ASPECT AND ITS ASSOCIATION WITH ORGANIZATIONAL PERFORMANCE: A CASE STUDY OF PAKISTANI FIRMS

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Abstract

Blockchain technology and the circular economy are two distinct concepts, which together can serve the economy and businesses in a better way. This research focused on exploring the relationship between blockchain technology and circular economy components from the production aspect to increase organizational performance in Pakistan. The 302 observations were collected from Pakistani companies of different nature of work. A purposive sampling method and closed-question questionnaire were adopted for the collection of data. The PLS-SEM (4.0) method was utilized for analysis purposes. The results point toward blockchain technology's positive effects on circular economy practices. Overall, blockchain technology shows an affirmative impact on green design (GD), green manufacturing (GM), and recycling and remanufacturing (RR) in Pakistan. However, the association between recycling and remanufacturing, environmental performance, and economic performance was not supported. It can be concluded that adopting the practices of the circular economy can significantly improve business operations in terms of financial and environmental performance. It is recommended that businesses should incorporate blockchain technology along with the practices of circular economy in manufacturing systems for achieving long-term goals.

Keywords Blockchain technology, Circular economy, Economic performance, Environmental sustainability, Pakistan

1. INTRODUCTION

Blockchain technology originated and was initiated as a significant element of the fourth industrial revolution in 2011 in Germany by the federal government, as an immutable phenomenon (Kumar et al., 2019). Blockchain technology is a technology that first converts the industry's manual procedures into scientific procedures assisting in the implantation of technologically advanced machinery and equipment such as 3D printers, new technologies, artificial intelligence, and large data analytics (Calabrese et al., 2021; Szasz et al., 2020). Furthermore, the process refers to an optimized, incorporated, integrated, interoperable, and service-oriented manufacturing process with big data,

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high technologies, and algorithms included (Szasz et al., 2020). Papadopoulos et al. (2022) mentioned that blockchain can support the adoption of sensors, processors, and software within enterprises. Swarnakar et al. (2021) pointed out that all the technological signs of progress are managed and integrated with human beings. Moreover, blockchain technology is giving a huge boost to the circular economy (CE). Whereas the circular economy refers to the concept of reusing, recycling, repairing, remanufacturing, green purchasing, and eco-designing the product (Felice et al., 2021). Draghici and Ivascu (2022) elaborate on the relationship between blockchain technology with the circular economy through the manufacturing model shift. So, the collaboration of blockchain technology with the circular economy brings innovation and protects economic situations, and works on their sustainability (Tang et al., 2022). The focuses of the circular economy are on recycling, the reuse of things, and recovery techniques. By adopting these techniques, used and discarded goods are transformed into new and useful things (Taddei et al., 2022). The administrative and manufacturing structure for processing these things is also changed. Similarly, the efficiency, as well as effectiveness of these processes, becomes more crucial. The transformation of conventional models of businesses in an account of a circular economy is difficult but achievable (Stumpf et al., 2021; Pieroni et al., 2020). Hajoary and Akhilesh (2021) elaborate that the use of a circular economy becomes crucial to manufacturing a useful consumer product through strategic processes and a policy-driven approach. Research is lagging in the area of discovering the integration of block chain technology and the circular economy. By using block chain technology, a consumer product can be made effectively with the help of a circular economy that can be executed through strategic processes and a policy-driven approach (Hajoary & Akhilesh, 2021). Block chain technology is integrated along with the circular economy by using information-sharing strategies and supply chain operations. As a result, through effective operational techniques, organizations can achieve their long-term goals, production growth, and ultimately profit maximization. Side by side, the collaboration of producer, suppliers, and customers are also essential to achieve these targets. Kinra et al. (2022) discussed the integration of technology with a circular economy to build trust, visibility, reliability, and traceability, among all stakeholders. Furthermore, environmental management and protection can also be managed effectively and their use in the agricultural supply chain can enhance production via recovery and recycling processes, making processes effective and environmentally friendly (Tang et al., 2022).

The circular economy is incorporated with many technologies as well as with blockchain technology (Tang et al., 2022). Besides other technologies, blockchain technology is recieving fame for its effective and efficient information exchange arrangements and systems, its practicality, and its functional aspects, such as consistency, intelligent operation, and disclosure. Treiblmaier et al. (2021) explain that information saved in blockchain ledgers includes information about product details, materials, energy usage, edge cycle, and about processes, as explained. Taddei et al. (2022) concluded that blockchain technology also allows businesses to be familiar with the roots, prestige, and location, in the supply chain operation of any product or service in a concurrent situation. Kannan et al. (2022) argue that all the features of manufacturing companies help to create and maintain a green system that endorses recyclability, circularity outcomes management, and reuse. Blockchain technology also develops and maintains trust factors in the supply chain network. So, these targets can be achieved through blockchain technology. It also eliminates uncertainties within supply chain management. Stratopoulos, et al. (2022) further clarify about most of the studies, it is claimed that blockchain technology is an imminent revolution. However, most studies claim that blockchain technology is over-glorified (Haddara et al., 2021).

The adoption of blockchain technology and its consequences in terms of financial and environmental aid is a vital issue, and there is a shortage of research studies focusing on blockchain and its practices in business, especially at the company level. This aspect is very critical in the context of Pakistan. Pakistan is especially lagging in the race of global corporations adopting blockchain technologies in operational processes (Jawaad et al., 2022). The Pakistani industries are adopting these innovative techniques but at a slow pace; it is necessary to find out their adoption pace and their ultimate consequences. This situation also suffers from a shortage of evidence inspecting the collision of blockchain technology and its effects on organizational, environmental, and financial performance (Chaudhry & Amir, 2020). Furthermore, it is also necessary to scrutinize the effectiveness of the companies for making a benchmark for further research studies to examine any company's performance. In the Pakistani context, state-owned companies and enterprises enjoy benefits and special attention in terms of financing, having direct access to resources, and having a strong infrastructure. In this way, private firms are lagging in the adoption and incorporation of technology. Business enterprises face intense and difficult competition to adopt block chain technology and circular economy practices. However, technological transfer due to overseas investment can help home enterprises to increase their production. Blockchain technology has the potential for recovering circular economy practices. The aim of the current research is to organize a groundwork for researchers and companies to form economic and environmental objectives and purposes by adopting blockchain technology in their circular economy practices.

2. LITERATURE REVIEW

The ecological modernization theory (EMT) emphasizes that economic growth causes environmental issues (Calabrese et al., 2021). These environmental issues can be diminished by improving and using resources efficiently with the help of technological advancement. Such technological advancement includes green SC practices that improve organizational, economic, and environmental conditions, and performance (Ciliberto et al., 2021). In this specific issue, environmental conservation and its improvement are considered an opportunity. The protection of the environment is not considered a problem, but it is considered an opportunity (De Felice & Petrillo, 2021). This concept ultimately supports the "economizing ecology" and "decolonizing economy" concepts. Green SC practices encourage a practice-based view (PBV) for the improvement of the socio-economic form of organizations along with environmental outcomes (Haddara et al., 2021), as the most sophisticated version and accounts for the resource-based view theory. The PBV describes that with the help of unique business practices and procedures, organizational performance can be enhanced (Hettiarachchi et al., 2021). The PBV describes procedures as established and maintained practices or a set of practices or exercises within the enterprise that executes them. The practice-based view theory uses organizational recital as a dependent variable. Most of researchers from various fields integrate ecological issues with organizational substance. Environmental matters are incorporated with a triple-bottom-line, ecological footprint, ecological efficiency, ecology in industry, and life cycle management issues. The integration of these issues with environmental issues helps corporation executives to incorporate the financial, environmental, and business strategies, with the societal issues. The current research follows the practice-based view theory (PBV) and ecological modernization theory (EMT). According to the EMT theory, economic growth causes environmental issues and these issues can be solved with the help of technological innovation (Kumar et al., 2020). The conceptual framework in relation to variables of the present study explains that blockchain technology pushes the practices of a circular economy which include green manufacturing, recycling, re-engineering, and green design in the environment of industrial development. This results in the company's eco-environmental outcomes and these outcomes eventually improve organizational growth.

2.1 Blockchain Technology and the Circular Economy

Blockchain technology and the circular economy are following a rising trend in technological aspects used to improve firms' long-term production. In return, the firm's financial, operational, and ecological presentation improve production gradually and consistently with the supply chain (Rejeb et al., 2023). Sacco et al. (2021) found a strong association between blockchain technology and the circular economy. It is also argued that the help of organizational systems and structure enhances supply chain efficiency and growth. Blockchain technology and the circular economy can boost any company economically and environmentally. In response, companies can convert the production chain into digitized form. By adopting these advanced technologies, businesses can make greater revenue in the long term (Vrontis et al., 2022; Chaudhry & Amir, 2020). Furthermore, Masukuijaman et al. (2021) added that ecological and social sustainability have a direct link with financial growth and sustainability.

3. CONCEPTUAL FRAMEWORK

3.1 Blockchain Technology

Blockchain technology along with the circular economy is an innovative and rising phenomenon in the technical and organizational era, ensuring enhanced productivity. The integration and incorporation of blockchain technology along with the circular economy under the industrial revolution ensures the administration of the data information system and management. Blockchain technology relates to radio frequency and global positioning sensors that help to get reliable information. It also helps to resolve trace and true track issues (Jawaad et al., 2022). These features support the flow of information for stakeholders and supply chain operations. Blockchain technology encourages a circular economy through efficient information use regarding green manufacturing, green design, recycling, and manufacturing (Kannan et al., 2022). This information becomes beneficial for the companies to know about their competitors' supply chain systems, to assure and improve their own performance (Taddei et al., 2022). The combination of both helps to promote the circular model which is noted as a sustainable model (Stumpf et al., 2021). According to the above discussion, it is suggested that:

H1: Blockchain technology has a significant relationship with green design manufacturing as an element of the circular economy.
H2: Blockchain technology has a significant relationship with recycling and manufacturing (RR) as an element of the circular economy.
H3: There is a significant association between blockchain technology and green manufacturing as an element of the circular economy.

3.2. Environmental Performance

Environmental issues have become a greater concern in recent years, especially those caused by business activities. The integration of blockchain technology with the circular economy increases business growth with the help of recycling, regenerating, remanufacturing, and circular design, and further, directs to reduce environmental costs. Lim et al. (2021) indicated that the execution and practices of a circular economy can decrease the harmful impacts of businesses. By adopting this method, manufacturers recycle waste products in the entire manufacturing system by using and adopting green circular purchases (Dumitra et al., 2022; Sahoo & Vijayvargy., 2020). An exclusive relationship has been found between environmental performance and its impact on economic performance (Masukujjaman et al., 2021). Green manufacturing helps in green economic output and reuse of waste materials by creating employment, also requiring less land for dumping industrial waste, reducing production costs, reducing system waste, increasing efficiency, protecting the ecosystem, and improving economic growth with better environmental performance (Mukherjee et al., 2022). According to the above explanation, it is hypothesized that:

H4: Circular economy practices (including green design, recycling and manufacturing, and green manufacturing) have a significant relationship with environmental performance.

H5: Environmental performance has a significant association with economic performance.

3.3. Economic Performance

Economic performance is normally measured through the financial performance of businesses. It is the result of companies' performance and decisions the companies have taken over a long period of time. An increase in production efficiency in terms of the circular economy and the production of the firm can boost the financial position of the business, as circular economy uses recycling, circular design, re-manufacturing, and circular purchasing, which ultimately increases the financial performance of the business. If good practices are governed, then the target economic performance can be achieved and vice versa (Draghici & Ivascu, 2022). Circular economy practices help supply chain methods to link with an eco-friendly system, with two-fold results of profitability and significant environmental progress. A positive association has been found between circular economy practices and eco-friendly efficient supply chain systems due to improved economic performance in the form of profitability in both Pakistani and Chinese firms (Khanfar et al., 2021; Alobid et al., 2022).

H6: Circular economy practices (including green design, recycling and manufacturing, and green manufacturing) have a significant association with economic performance.

3.4. Organizational Performance

The success of any business is linked to the organization's performance through economic and environmental performance. The organizational achievements of the company are measured by sales volume, market shares, and operating costs, while securing environmental performance. Circular economy practices aid businesses by lessening operating costs and strengthening environmental performance which ultimately increases sales and the market share of the company (Ciliberto et al., 2021). Information technology and supply chain systems affect the operational, economic, and environmental performance of the company which directly impacts the company's profitability (Hajoary & Akhilesh, 2021). Circular economy and advanced technological stages generate productivity benefits in terms of profit (Kinra et al., 2022). The company's stock prices, share of the market, and the returns of the company are also increased (Kouhizadeh, 2021). These all contribute by boosting organizational performance.

H7: Environmental performance has a substantial impact on the operational performance of the firm.

H8: Economic performance has a significant impact on a firm's operational performance.

3.5. Conceptual Framework

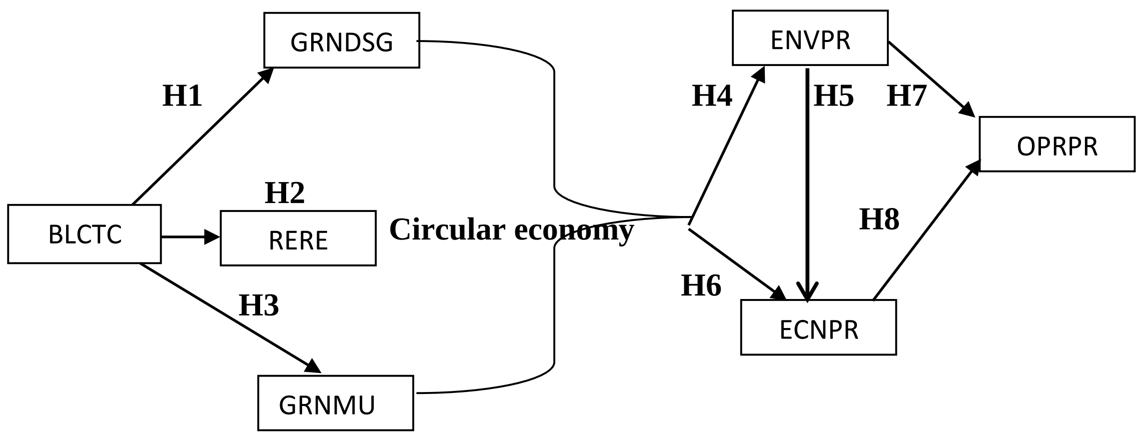

Figure 1 Conceptual Framework

Note: ECNPR = economic performance; ENVPR = environmental performance; OPRPR = operational performance; GRNDSG = green design; RERE = recycling and remanufacturing; GRNMU = green manufacturing; BLCTC = Blockchain technology

4. RESEARCH METHODOLOGY

The data for analysis purposes were collected through purposive sampling from Pakistani companies through their operating supply chain operations. Six different types of industries having different natures of work like chemical, electronic, textile, transportation, plastic, and paper industries were selected with 50 distributed questionnaires each except for the paper industry which requires 52 questionnaires. The combinations of public and private firms were selected for data collection. Companies' presidents and vice presidents were involved in getting information about blockchain technology, and economic, environmental, and organizational performance. For the circular economy dimensions plant, procurement, production, and operational managers were involved. A total no of 302 data observations was added for the data analysis. Our sample size supported the rule of thumb by PLS-SEM which can estimate a complex relationship with a minimum size of 10 (Sarstedt et al., 2014). The study used the power analysis method by G*power software that showed employing 0.15 effect size, 0.05 value of alpha, and 85 minimum sample size is required (Buja et al., 2019). So, the result shows that in this way our sample size is adequate. The detail on the total number of different managerial roles that participated from 6 targeted companies is given below in Table 1.

4.1. Demographic Characteristics

The demographic summary of the research is described in Table 1. The assortment of the companies was their activities, to find out the blockchain technology's result over the circular economy for betterment along with further enhancement of the supply chain performances of Pakistani business organizations.

5. RESULTS

The collected data and data collection method were assessed through reliability and validity criteria as reported below.

5.1 Testing of the Measurement Model

5.1.1 Convergent Validity

Convergent validity is usually measured via item loading, the AVE, and composite reliability. The standard values of the loadings and composite reliability should be more than

0.707 while the value of AVE must be greater than 0.5 to meet the convergent validity criterion (Sarstedt et al., 2014; Trafimow et al., 2022). Results of this study are shown in Table 2, including item loading, composite reliability, and AVE values, which all met the minimum standards.

5.1.2 Discriminant Validity

Table 3 confirms the discriminant validity of the data, as the diagonal values are significantly higher than the off-diagonal values of the matching rows and columns (Trafimow et al. 2022). The values reported in Table 3 show that each construct meets the required level of discriminant validity.

5.2 Structural Model Analysis

PLS-SEM is used in SmartPLS 4.0 for the evaluation of structural model analysis and validation of hypotheses**.** Bootstrapping was performed with a sub-sample of 5000. The findings show that the incorporation of blockchain technology with the circular economy ultimately results in enhanced organizational, environmental, and economic performance. In order to describe the explanatory power of the model, path coefficients (β-values), t-values, and coefficients of determination (R^2), were used to analyze the outcomes along with predictive relevance (Q^2). Further, the upshot of the hypothesis testing of the structural model is explained in Table 5 and Figure 2. For ensuring predictive accuracy, the coefficient of determination denoted by R^2 (Table 4) is used as a criterion for predictive accuracy. Ramayah H. (2018) declares the value of R^2 as 0.67; this value refers to an extensive predictive relationship, while a value of 0.33 refers to a moderate sensible predictive relationship, and a value of 0.19 is taken as a weak predictive association. Sarstedt et al., (2014) state that the R^2 value alone is insufficient to support the predictive

Table 1 Demographic Profile

Characteristics	*N*	%
Title		
President	54	16.36
Vice president	38	11.52
Plant manager	82	24.85
Procurement manager	49	14.85
Production manager	64.	19.39
Operational manager	9	2.73
Information system manager	6	1.23
Work experience		
<5	23	6.97
5-10	32	9.70
10-15	41	12.24
15-20	75	22.73
20-25	41	12.42
<25	60	18.18
Industry type		
Chemical industry	50	19.39
Electronic industry	50	28.48
Transportation industry	50	5.76
Textile industry	50	6.36
Plastic industry	50	5.76
Paper industry	52	6.36

Table 2 PLS Factor Loadings, AVE, and CR

Construct	Items	Loadings	CR	AVE
Blockchain technology	BLCTC1	0.927	0.933	0.78
	BLCTC2	0.936		
	BLCTC3	0.917		
	BLCTC4	0.737		
Economic performance	ECNPR1	0.965	0.971	0.895
	ECNPR2	0.944		
	ECNPR3	0.962		
	ECNPR4	0.912		
Environmental performance	ENVPR1	0.942	0.762	0.587
	ENVPR2	0.927		
	ENVPR3	0.723		
Green design	GRNDSG1	0.83	0.862	0.61
	GRNDSG2	0.76		
	GRNDSG3	0.685		
	GRNDSG4	0.839		
Green Manufacturing	GRNMU1	0.715	0.837	0.634
	GRNMU2	0.755		
	GRNMU3	0.905		
Organizational performance	OPRPR1	0.733	0.901	0.697
	OPRPR2	0.831		
	OPRPR3	0.887		
	OPRPR4	0.879		
Recycling and reengineering	RERE1	0.619	0.859	0.697
	RERE2	0.891		
	RERE3	0.777		
	RERE4	0.807		

Table 3 Discriminant Validity

	BLCTC	ECNPR	ENVPR	GRNDSG	GRNMU	OPRPR	RERE
BLCTC	**0.883**						
ECNPR	0.514	**0.946**					
ENVPR	0.342	0.609	**0.766**				
GRNDSG	0.774	0.645	0.461	**0.781**			
GRNMU	0.429	0.761	0.637	0.579	**0.796**		
OPRPR	0.426	0.54	0.574	0.618	0.566	**0.835**	
RERE	0.647	0.537	0.329	0.707	0.516	0.365	**0.78**

Table 4 Predictive Relevance

Variables	**R Square**	**Q Square**
ECNPR	0.659	0.5867
ENVPR	0.425	0.3565
GRNDSG	0.599	0.5334
GRNMU	0.184	0.4031
OPRPR	0.388	0.3126
RERE	0.418	0.4663

relevance of any model. Consequently, the value of Q^2 is also used as a criterion for predictive relevance (Buja et al., 2019). The value of Q^2 shows predictive relevance and should be greater than zero (Sarstedt et al., 2014). A value of 0.02 is referred to as a weak effect, while 0.15 refers to a medium effect, and 0.35 refers to a strong effect (Sarstedt et al., 2014). For the current study, economic performance was shown to have a strong effect with an R square value of 0.659 and Q square value of 0.5867. However, among the blockchain technology model, green design was shown to have a strong level of predictive relevance with R square and Q square values of 0.599 and 0.5334 respectively, while re-engineering held an R square value of 0.418 and Q square value of 0.4663. Lastly green manufacturing held a predictive relevance of 0.184 as indicated by its R square value, and 0.4031 by Q square value. The proposed model of economic and environmental performance relevance with operational or firm performance indicated a moderate predictive relevance with an R square value of 0.388 and Q square value of 0.4663.

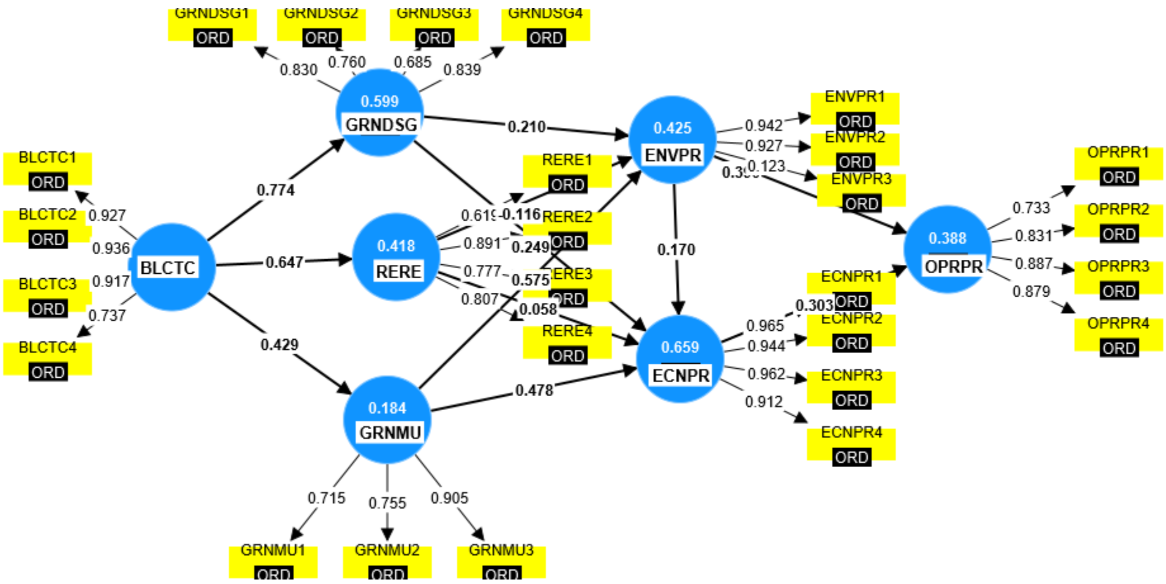

Figure 2 The Structural Model Results

Table 5 The Structural Model Analysis (Hypothesis Testing Results)

Paths	VIF	Beta	SD	*t-values*	*P values*	*f square*	Results
H1:BLCTC -> GRNDSG	1.69	0.774	0.026	9.079	0.000	0.005	A/C
H2:BLCTC -> GRNMU	1.55	0.429	0.055	7.846	0.000	0.13	A/C
H3:BLCTC -> RERE	1.53	0.647	0.031	8.794	0.000	0.138	A/C
H4a:GRNDSG -> ENVPR	1.67	0.210	0.073	2.863	0.002	0.312	A/C
H4b:RERE -> ENVPR	1.51	0.116	0.068	1.702	0.006	0.331	R/C
H4c:GRNMU -> ENVPR	1.66	0.575	0.064	8.921	0.000	0.380	A/C
H6a:GRNDSG -> ECNPR	1.71	0.249	0.054	4.611	0.000	0.329	A/C
H6b:GRNMU -> ECNPR	1.77	0.478	0.006	7.969	0.000	0.249	A/C
H6c:RERE -> ECNPR	1.61	0.058	0.044	1.309	0.008	0.231	R/C
H5:ENVPR -> ECNPR	1.38	0.170	0.045	3.755	0.000	0.367	A/C
H7:ENVPR -> OPRPR	1.69	0.390	0.064	6.094	0.000	0.414	A/C
H8:ECNPR -> OPRPR	1.42	0.303	0.053	5.717	0.000	0.001	A/C

By examining the beta values, all the proposed hypotheses in the current study were supported except for H4b (the relationship of recycling and re-engineering with environmental performance) and H6c (the relationship of recycling and re-engineering with economic performance), which were tested as elements of the circular economy, due to their insignificant t-values. With reference to Table 5, the association between blockchain technology and green design (β = 0.774; t-value=9.079; p-value = 0.000; f^2=0.005) demonstrates a statistically positive and significant relationship with a relatively small effect size as the f^2 value is >=0.02 following the work of Cohen (1988), therefore, H1 was accepted. The association between blockchain technology and green manufacturing (β = 0.429; t-value=7.846; p-value = 0.000; f^2=0.13) was also determined to be statistically significant with a relative medium effect size as the f^2 value is >= 0.15 (Cohen, 1988); H2 was also accepted. Similarly, the association between blockchain technology and recycling, and re-engineering (β = 0.647; t-value=8.794; f^2=0.138) was statistically significant, hence H3 was also accepted. Additionally, hypothesis H4 was tested to determine the relationship between a circular economy and environmental performance through the elements of circular economy as H4a, H4b, and H4c respectively (green design and environmental performance β = 0.210; t-value=2.863; f^2=0.312), (recycling, re-engineering, and environmental performance β = 0.116; t-value=1.702; f^2=0.331), (green manufacturing and environmental performance β = 0.575; t-value=8.921; f^2=0.380). Only two elements of the circular economy, H4a and H4c, showed a significant relationship with environmental performance. The results for hypothesis H5 showed that environmental performance does have a significant impact (β = 0.170; t-value=3.755) on economic performance with a large effect size of f^2=0.367. Just like hypothesis H4, H6 was tested through the elements of a circular economy in relation to economic growth as H6a, H6b, and H6c respectively (green design and economic performance β = 0.249; t-value=4.611; f^2=0.329), (green manufacturing and economic performance β = 0.478; t-value=7.969; f^2=0.249) (recycling, re-engineering, and economic performance β = 0.058; t-value=1.309; f^2=0.231). Only two elements of the circular economy, H6a and H6b, were shown to have a significant relationship with economic performance as indicated by their significant t-values. Lastly, H7 and H8 were determined to be statistically significant with t-values of 6.094 and 5.717 respectively. It is interesting to note that H7 showed a higher effect size of 0.414, which was highest among all other f^2 values.

5.3 The Conceptual Model Fit Analysis

The conceptual model fit analysis was conducted after specifying the paths and modifying the original model (Table 6). The value of RMSEA was 0.079 and as this value is less than 0.08 shows that the model average square error is acceptable (Ramayah et al., 2018). The value of NFI indicates more than the acceptable ideal criterion and a value above 0.9 shows an appropriate model fit (Sarstedt et al., 2014).

6. DISCUSSION

This research aimed to determine the effects of blockchain technology on the components of the circular economy. The proposed hypotheses were found to be acceptable with more or fewer values but surprisingly two hypotheses that were tested as components of circular economy (H4b,

Table 6 Specific Model Fit Statistics

Name	Amount/ Values	Acceptable fitness Cut-off
Standardized root mean square residual	0.079	0.05< RMSE<0.08
Normed fit index	0.91	0.9≤ NFI <0.95

H6c) were determined to be insignificant. The association between recycling and re-engineering and environmental performance, and the association between recycling and re-engineering and economic performance were not supported. The remaining findings show that blockchain technology and circular economy practices have a significant association. These results indicate that blockchain technology and green design have a noteworthy positive association, and indicate that a 1% change in the blockchain can bring about a change of 0.774% in green design. Blockchain technology and green manufacturing have a surprisingly significant relationship, with a raise of 1% in blockchain technology leading to a 0.429% increase in green manufacturing. Similarly, a 1% change in blockchain technology brings a 0.647% change in recycling and remanufacturing. The study shows a significant association between the circular economy and blockchain technology (Tavera et al., 2021). The outcomes of the research study align with the research findings of Tang (2022) and Min (2019). The results indicate that green manufacturing, green design, re-engineering, and recycling, have an affirmative impact on economic performance at 0.35% and on environmental performance at 0.36%. An eco-friendly system of product development can lead to financial benefits for a company (Huong et al., 2021), while green design and green purchasing improve ecological performance and improvement in environmental practices (Li, 2020). Regulatory agencies and governmental bodies also secure environmental issues by imposing harsh penalties on businesses to avoid environmental pollution. In this way businesses may maintain their track in the correct way. The current study results depict that blockchain technology exercised within circular economy practices is catching more attraction in Pakistan for ensuring environmental growth and financial aid for businesses.

7. CONCLUSION

This study explored the impact of blockchain technology on the circular economy considering its applications and their impacts on company performance, ultimately impacting operational performance. A combination of public and private business enterprises of Pakistan were selected for data collection. The PLS-SEM method was exercised to measure the effectiveness of blockchain on the circular economy and its components. The study outcomes describe the relationship between blockchain technology and green design, green manufacturing, recycling, and re-manufacturing as an affirmative significant association. Further, the results indicate blockchain technology's benefits for the circular economy and its ability to significantly improve and enhance the supply chain recital. It is also concluded that the best way to improve and change the financial and ecological conditions and recital of businesses is a circular economy along with its associated practices. This is helpful to achieve greater financial performance that leads to improved operational performance. The result of the study assists in improving understanding of blockchain technology's performance and its applications and coordination with the long-term management of the supply chain and circular economy, understanding waste management along with its positive impacts, green practices, and improving environmental sustainability.

8. POLICY IMPLICATIONS

Policy implications for businesses are a necessary contribution of any research, based on its results. This section provides some important policy implications of the current research for business managers and policymakers. Firstly, the findings of the research encourage business enterprises to use and apply blockchain technology in business operations to gain a financial advantage, as well as other benefits in social, environmental, and economic areas. Blockchain technology helps the regulator to maintain track of the company's initiatives in respect of positive environmental protection.

The research highlights that blockchain technology use with practices and applications of the circular economy help businesses to decrease carbon emissions. The government can make available tax exemptions, concessionary loans, and grants for the mechanism of blockchain technology practices within business activities. Overall, based on the results, private and public enterprises can adopt blockchain technology with circular economy practices to achieve monetary, financially viable, economic, and ecological benefits.

REFERENCES

Buja, A., Brown, L., Berk, R., George, E., Pitkin, E., Traskin, M., & Zhao, L. (2019). Models as approximations I: Consequences illustrated with linear regression. *Statistical Science*, *34*(4), 523-544.

Chaudhry, N. I., & Amir, M. (2020). From institutional pressure to the sustainable development of firm: Role of environmental management accounting implementation and environmental proactivity. *Business Strategy and the Environment*, *29*(8), 3542-3554.

Calabrese, A., Levialdi Ghiron, N., & Tiburzi, L. (2021). 'Evolutions' and 'revolutions' in manufacturers' implementation of industry 4.0: a literature review, a multiple case study, and a conceptual framework. *Production Planning & Control*, *32*(3), 213-227.

Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Łuniewska, M., Ruggieri, A., & Ioppolo, G. (2021). Enabling the Circular Economy transition: A sustainable lean manufacturing recipe for Industry 4.0. *Business Strategy and the Environment*, *30*(7), 3255-3272.

De Felice, F., & Petrillo, A. (2021). Green Transition: The Frontier of the Digicircular Economy Evidenced from a Systematic Literature Review. *Sustainability*, *13*(19), 11068.

Dirsehan, T., & Henseler, J. (2022). Modeling indices using partial least squares: How to determine the optimum weights? *Quality & Quantity*, 1-15.

Dumitra, C. M., Moiceanu, G., & Dumitrescu, C. I. (2022). The Circular Economy Approach. *FAIMA Business & Management Journal*, *10*(1), 43-59.

Draghici, A., & Ivascu, L. (2022). Green Manufacturing in the Context of Circular Economy. *In Sustainability and Innovation in Manufacturing Enterprises* (pp. 1-15). Springer, Singapore.

Haddara, M., Norveel, J., & Langseth, M. (2021). Enterprise systems and blockchain technology: The dormant potentials. *Procedia Computer Science*, *181*, 562-571.

Hajoary, P. K., & Akhilesh, K. B. (2021). Conceptual framework to assess the maturity and readiness towards Industry 4.0. *In Industry 4.0 and Advanced Manufacturing* (pp. 13-23). Springer, Singapore.

Hettiarachchi, B. D., Seuring, S., & Brandenburg, M. (2021, September). Industry 4.0 Driven Quantitative Methods for Circular Supply Chains: A Bibliometric Analysis. In *IFIP International Conference on Advances in Production Management Systems* (pp. 394-401). Springer, Cham.

Huong, P. T., Cherian, J., Hien, N. T., Sial, M. S., Samad, S., & Tuan, B. A. (2021). Environmental management, green innovation, and social–open innovation. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(1), 89.

Jawaad, M., Hasan, T., Amir, A., & Imam, H. (2022). Exploring the impact of green human resource management on firm sustainable performance: roles of green supply chain management and firm size. *Journal of Management & Organization*, 1-23.

Kannan, G., Pattnaik, M., Karthikeyan, G., Balamurugan, E., Augustine, P. J., & Lohith, J. J. (2022, March). Managing the Supply Chain for the Crops Directed from Agricultural Fields using

Blockchains. In 2022 International Conference on Electronics and Renewable Systems (ICEARS) (pp. 908-913). IEEE.

Kinra, A., Siekmann, F., & Kotzab, H. (2022). Social Media Analytics in Operations and Supply Chain Management: Opportunities, Challenges, and Paradoxes. *Diginomics Research Perspectives*, 185-212.

Kouhizadeh, M., Saberi, S., & Sarkis, J. (2021). Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International Journal of Production Economics*, *231*, 107831.

Kumar, R., Singh, R. K., & Dwivedi, Y. K. (2020). Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges. *Journal of cleaner production*, *275*, 124063.

Masukujjaman, M., Alam, S. S., Siwar, C., & Halim, S. A. (2021). Purchase intention of renewable energy technology in rural areas in Bangladesh: Empirical evidence. *Renewable Energy*, *170*, 639-651.

Mukherjee, A. A., Singh, R. K., Mishra, R., & Bag, S. (2022). Application of blockchain technology for sustainability development in agricultural supply chain: Justification framework. *Operations Management Research*, *15*(1), 46-61.

Mukherjee, S., Chittipaka, V., & Baral, M. M. (2022). Addressing and Modeling the Challenges Faced in the Implementation of Blockchain Technology in the Food and Agriculture Supply Chain: A Study Using TOE Framework. In *Blockchain Technologies and Applications for Digital Governance* (pp. 151-179). IGI Global.

Parhi, S., Joshi, K., Wuest, T., & Akarte, M. (2022). Factors affecting Industry 4.0 adoption–A hybrid SEM-ANN approach. *Computers & Industrial Engineering*, *168*, 108062.

Pieroni, M. P., McAloone, T. C., & Pigosso, D. C. (2020). From theory to practice: systematising and testing business model archetypes for circular economy. *Resources, conservation and recycling*, *162*, 105029.

Prewett, K. W., Prescott, G. L., & Phillips, K. (2020). Blockchain adoption is inevitable—Barriers and risks remain. *Journal of Corporate accounting & finance*, *31*(2), 21-28.

Papadopoulos, T., Singh, S. P., Spanaki, K., Gunasekaran, A., & Dubey, R. (2022). Towards the next generation of manufacturing: implications of big data and digitalization in the context of industry 4.0. *Production Planning & Control*, *33*(2-3), 101-104.

Ramayah, T. J. F. H., Cheah, J., Chuah, F., Ting, H., & Memon, M. A. (2018). Partial least squares structural equation modeling (PLS-SEM) using smartPLS 3.0. *An updated guide and practical guide to statistical analysis*.

Rejeb, A., Appolloni, A., Rejeb, K., Treiblmaier, H., Iranmanesh, M., & Keogh, J. G. (2022). The role of blockchain technology in the transition toward the circular economy: Findings from a systematic literature review. *Resources, Conservation & Recycling Advances*, 200126.

Sacco, P., Vinante, C., Borgianni, Y., & Orzes, G. (2021). Circular economy at the firm level: A new tool for assessing maturity and circularity. *Sustainability*, *13*(9), 5288.

Sahoo, S., & Vijayvargy, L. (2020). Green supply chain management practices and its impact on organizational performance: evidence from Indian manufacturers. *Journal of Manufacturing Technology Management*.

Sarstedt, M., Ringle, C. M., Smith, D., Reams, R., & Hair Jr, J. F. (2014). Partial least squares structural equation modeling (PLS-SEM): A useful tool for family business researchers. *Journal of family business strategy*, *5*(1), 105-115.

Stratopoulos, T. C., Wang, V. X., & Ye, H. J.

(2022). Use of Corporate Disclosures to Identify the Stage of Blockchain Adoption. *Accounting Horizons*, *36*(1), 197-220.

Stumpf, L., Schöggl, J. P., & Baumgartner, R. J. (2021). Climbing up the circularity ladder? –A mixed-methods analysis of circular economy in business practice. *Journal of Cleaner Production*, *316*, 128158.

Stumpf, L., Schöggl, J. P., & Baumgartner, R. J. (2021). Climbing up the circularity ladder? –A mixed-methods analysis of circular economy in business practice. *Journal of Cleaner Production*, *316*, 128158.

Swarnakar, V., Singh, A. R., Antony, J., Tiwari, A. K., & Cudney, E. (2021). Development of a conceptual method for sustainability assessment in manufacturing. *Computers & Industrial Engineering*, *158*, 107403.

Szász, L., Demeter, K., Rácz, B. G., & Losonci, D. (2020). Industry 4.0: a review and analysis of contingency and performance effects. *Journal of Manufacturing Technology Management*, *32*(3), 667-694.

Taddei, E., Sassanelli, C., Rosa, P., & Terzi, S. (2022). Circular supply chains in the era of Industry 4.0: A systematic literature review. *Computers & Industrial Engineering*, 108268.

Trafimow, D., Hyman, M. R., & Kostyk, A. (2022). Are structural equation models theories and does it matter? *Journal of Global Scholars of Marketing Science*, 1-16.

Tang, Y. M., Chau, K. Y., Fatima, A., & Waqas, M. (2022). Industry 4.0 technology and circular economy practices: business management strategies for environmental sustainability. *Environmental Science and Pollution Research*, 1-18.

Vrontis, D., Christofi, M., Pereira, V., Tarba, S., Makrides, A., & Trichina, E. (2022). Artificial intelligence, robotics, advanced technologies and human resource management: a systematic review. *The International Journal of Human Resource Management*, *33*(6), 1237-1266.