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The Role of Environmental Regulation, Digital Transformation, and CSR on Green Innovation and Firm Productivity in the Textile Industry in Pakistan

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ABSTRACT

This study investigated the impact of environmental regulation, digital transformation, and CSR on green innovation and firm productivity in the textile industry of Pakistan. Green innovation was the mediator, and CSR was the moderator. Data were collected from the senior managers of textile companies in Lahore, Faisalabad, Gujranwala and Sialkot. We distributed a total of 720 questionnaires and analyzed 385 valid responses using PLS-SEM (Smart PLS). CSR is the most significant predictor of green innovation. Green innovation positively and significantly affects firm productivity and fully mediates the relationship between CSR and productivity. In contrast, environmental regulation and digital transformation had no significant impact, which in this case contradicts the Porter Hypothesis. The results indicate that in the textile industry in Pakistan, where regulatory enforcement is weak and digital adoption is limited, internal value-driven motivations such as CSR are stronger drivers than external pressures. In theory, this research contributes to integrate CSR, regulation, digital transformation, green innovation and productivity in a multi-theoretical framework. Practically, the study suggests that managers take a strategic view of CSR, policymakers should strengthen regulation enforcement, and companies should focus on digital investments supporting green objectives (e.g., energy monitoring, sustainable supply chains).

Keywords: *Green Innovation; Environmental Regulation; Digital Transformation; Corporate Social Responsibility; Firm Productivity; Textile Industry*

INTRODUCTION

There is a great deal of awakening going on at this time. Industry practices (production, consumption and disposal) can no longer be assessed without considering the environmental impacts that they have. Governments are setting more stringent standards, consumers are calling for more eco-friendly products and business is being put to the test in a new sense of competitiveness in an ecological age. The global transformation is based on green innovation, the development of cleaner technologies, more environmentally friendly processes and more sustainable products, which have a lower impact on the environment, but also improve the economic performance. Green innovation has become a reality and green innovation approaches

have become a part of the socio-ecological goals of firms in today's competitive world with the increasing awareness of the environment.

Pakistan's textile and apparel industry provides an important empirical context for investigating the relationships among environmental regulation, digital transformation, CSR, green innovation, and firm productivity. The sector constitutes the country's largest manufacturing and employment-generating industry and maintains extensive backward and forward linkages with cotton cultivation, ginning, spinning, weaving, processing, apparel production, logistics, and international trade. During July–January FY2026, textile and apparel products contributed 59.7% of Pakistan's merchandise exports and 24.2% of industrial value addition (Mehar, 2022). The sector generated approximately US$13.58 billion in export earnings during this period. Government policy estimates also indicate that the industry accounts for approximately 40% of industrial employment and has traditionally contributed around 8.5% to national GDP. Its economic importance, resource-intensive production processes, dependence on international markets, and exposure to environmental and social compliance requirements make it particularly suitable for examining how regulatory, technological, and socially responsible business practices affect green innovation and productivity (Abbas & Bhutto, 2024).

Green regulation is among the key factors of green innovation. The Porter Hypothesis is that good regulation can stimulate innovation and efficiency improvements. The empirical evidence indicates that environmental regulation can improve productivity by means of green technological innovation as a mediator (Shan et al., 2025). However, in Pakistan, the effectiveness of environmental governance is limited due to institutional weaknesses. Moreover, the effectiveness of regulations depends on firms' internal sustainability capabilities (Z. Li et al., 2024). Sustainability is changing across all industries with digital transformation. It promotes innovation, cost reduction, and efficient use of resources, which can lead to increased productivity (Lei & Wang, 2023). It also enhances knowledge sharing and sustainability outcomes driven by leadership. One of the important facilitators of sustainability is now corporate social responsibility (CSR). CSR enhances the environmental and financial performance by adopting green innovation and sustainable development mechanisms (H. Li et al., 2023). Previous research also supports that CSR has a positive impact on environmental sustainability and green innovation in manufacturing companies of Pakistan (Shehzad et al., 2023). Recent studies have revealed that green leadership and dynamic capabilities have a positive relationship on CSR innovation relationships. But, the nature of these relations varies depending on the context and sector-specific studies are important.

While green innovation is a topic of discussion in sustainability debates, an important question is what does it imply for a firm's bottom line? It is not environmental ideals that are forcing businesses to be more productive, it is profit goals and competitive demands. Evidence of the non-conflict between green innovation and firm performance is increasing and they can help each other. The study of 632 organizations shows that green innovation strategies, such as product and process innovation, help to improve firm performance, through efficiency and competitiveness, and that the nature of the benefits varies based on the regulatory pressures (Winanda, 2026). Green innovation can not only be a compliance cost, but also a benefit to the day to day operational performance. This linkage is particularly important for the textile industry of Pakistan which has thin margins and rising costs. This is also supported by the natural resource-based view that posits that green innovation can yield a competitive advantage and economic returns through enhancing product, process and organizational performance (Al-Hanakta et al., 2023). In this context, green innovation is not a compromise between profit and sustainability, but a way to long-term competitiveness.

As with any empirical research, there are a number of theoretical assumptions about the nature of the world and this research is no different. Theories used in the current study are based on three theories that have been proven to be effective in the sustainability literature and have been combined to be more effective than any of them alone. The institutional theory can be used to explain why firms do not make environmental decisions in a vacuum, but are rather influenced by regulatory, normative and cognitive pressures that not only influence what firms do, but also what they deem legitimate and strategically necessary. The Porter Hypothesis is a key

economic factor and implies that good environmental regulation can stimulate innovation and competitiveness by turning environmental constraints into opportunities (Porter & Linde, 1995). Then, the Resource-Based View shifts the attention to the inside and green innovation capabilities, digital assets and CSR-based social capital are regarded as strategic resources that can be built and leveraged to create a long-term competitive advantage. Empirical studies on the Resource-Based View have revealed that green innovation positively influences the performance of digital transformation in companies and that there is a positive interaction between green innovation and digital capability (She & Zhang, 2024). These three theoretical lenses are not only side by side, but also interact with each other in this study. Institutional pressures shape the regulatory and normative context in which firms decide on investing in green innovation; digital transformation enhances the effect of green innovation investments; and CSR enhances the legitimacy of green innovation investments to create stakeholder value. By combining RBV, institutional theory, stakeholder theory, and the triple bottom line (Javed et al., 2026). A multi-theoretical framework can offer a comprehensive framework for understanding how companies can build strategic environmental capabilities to attain actual sustainability results. This is the type of integrated and theory-based approach that this study offers to the textile industry in Pakistan where the need for green transition is as critical as the institutional, technological and strategic challenges to its implementation.

Environmental regulation, digital transformation and CSR each have an impact on green innovation. But, their synergistic effect in the textile industry of Pakistan is not explored. It is evident that there is a positive correlation between R&D investment, capital formation and green subsidies with innovation and performance (Masood & Fatima, 2025). But whether these effects will be observed in the textile industry is unknown. This study is an attempt to bridge this gap by exploring the effect of environmental regulation, digital transformation and CSR on green innovation and firm productivity in textile industry of Pakistan. The theories that are applied in this study are the theories of Porter Hypothesis, Resource-Based View and institutional theory.

LITERATURE REVIEW

Green innovation has gone from the margins of the academic debate to the mainstream of strategic management research in the past 20 years. Green innovation is about doing things smarter and cleaner redesigning products to minimize packaging, investing in an energy efficient production line, rethinking raw material sourcing and processing. It can be broadly classified as green product innovation and green process innovation, which is both to reduce environmental harm and improve the competitiveness of the firm (Y. Chen et al., 2015). The interesting aspect of green innovation is that it does not need to be a cost to profitability, but rather that the two can and often should go hand in hand. This dialogue is especially pertinent in the context of the textile sector in Pakistan. The textile manufacturing industry is one of the biggest and most resource-intensive industries in the country, and is facing more and more pressures such as tougher environmental legislation, energy prices and international buyers' demands for sustainability proof. It's the companies that do not just follow the rules that will likely be the winners, those that will think outside the box and innovate. They reduce the input costs, prevent regulatory fines and open export markets that value environmental integrity. It is proven that green innovation integrated in business strategy is not a cost but an investment which will pay off in financial, operational and reputational aspects.

Governments increase the standards for the environment, companies are the ones who have to abide by it, but they also find a way around it. This is the main idea behind the Porter Hypothesis, which suggests that good environmental laws and policies will cause firms to find efficiencies and invent technologies they may not have considered, and ultimately become more competitive (Porter & Linde, 1995). This has been generally confirmed by the empirical record. The findings from the different studies performed in the industrial environment reveal that companies that have more stringent environmental regulations are more inclined to be green product and process innovators since they must comply with the regulations and stay profitable (Ambec et al., 2013).

It is more complex in the developing economies but more or less similar. The Chinese and Pakistani studies reveal that green innovation investments occur not only when the regulation is implemented but also when the regulation is enforced (Zhang, 2022). Regulatory bodies like the Punjab Environmental Protection Department have introduced more stringent regulations regarding industrial pollution and waste management in the textile sector in Pakistan. Firms that see these requirements as an opportunity for innovation, redesign, environmental management systems or eco-friendly packaging are more likely to be successful than those that see compliance as a burden (Baloch et al., 2021). Regulation has an impact on the leadership attitude in addition to the technical answer. Once environmental requirements are no longer negotiable, top managers start to consider sustainability as part of the strategic planning process, instead of an add-on. This regulatory induced organisational change is a step towards green innovation to be sustained over time (Y.-S. Chen et al., 2006).

H1: Environmental Regulation has positive and significant effect on Green Innovation.

Consider digital transformation as providing companies with a new pair of eyes. AI, big data analytics, IOT sensors and block chain and cloud computing technologies not only streamline existing operations, but also reveal patterns, inefficiencies and opportunities that were previously unknown (Vial, 2021). This visibility can make all the difference for textile manufacturers. A sensor network can be put in place on a production floor to alert in real time if too much energy is being used. Using a data analytics platform, it's possible to identify the exact areas of raw material waste in the supply chain. The environmental attributes of each ingredient from farm to shelf can be recorded using a blockchain-based traceability system. All of these capabilities provide a basis for green innovation, which would be much more difficult to establish without digital tools (F. Chen et al., 2026). Such an enabling relationship is now acknowledged in the research literature. The digital transformation has a significant positive impact on green innovation performance in manufacturing companies, as it helps to mitigate information gaps and enhance dynamic environmental management capabilities (Lian et al., 2022). IOT in smart manufacturing can help to minimize energy waste and material loss, which can directly contribute to the green innovation of the manufacturing process. What is fascinating is that digitalization also decreases the risk of green innovation investment: digital tools allow for quick simulation and data-driven prototyping, which reduces the cost of experimentation with new environmental technologies, and thus makes it easier for firms to try, learn and improve their green innovations. Digital transformation is accelerating in the textile manufacturing industry in Pakistan, especially for export markets where there is a growing demand for increased transparency along the textile chain and buyers are demanding it (Phoumin et al., 2024). The use of digital technology and innovation performance of SMEs in Pakistan is positive and skilled human resources and committed leadership are one of the key factors (Lin et al., 2024). The companies that are digitally mature are more likely to be able to use regulatory pressure and market demand to drive green innovation, as they have the analytical tools to understand what to change and the agility to make the change. Digital transformation is a catalyst of green innovation capacity in this context.

H2: Digital Transformation has positive and significant impact on Green Innovation.

The urban markets in Pakistan are more attracted towards products which are less harmful to the environment, less harmful to the consumer and responsibly packaged. International buyers from Europe and the Gulf Cooperation Council countries are even more forthright: they establish environmental procurement standards and will not buy from suppliers who do not have sustainability credentials (Dangelico & Pujari, 2010). This market pressure is not a theoretical one, it is one that is seen in order books and contract negotiations of textile manufacturers. Those businesses that can make a credible claim to being an environmental leader win business, those that can't risk it. This demand side dynamic gives strong pull incentives for green innovation (Chang, 2011). The consumer environmental preference will result in the investment of the companies in green product development, reformulation of ingredients, redesign of packaging and restructure of supply chain to meet the consumer preference (Chanda et al., 2024). The consumer environmental awareness is one of the significant factors to predict green innovation adoption. The mechanism is simple: If there is a business opportunity in "going green" if it can lead to sales, if it can help to keep customers, if it can open new markets then companies

have an incentive to go green beyond the regulatory requirements. For the Pakistani textile companies, which are looking to export, it is not a luxury, but a prerequisite to access international market or to comply with EU sustainability import requirements or to meet international environmental standards like ISO 14001. This establishes a direct connection between CSR and green innovation investment, as companies need to continuously improve their environmental practices to stay competitive in premium markets (Afzal et al., 2023). CSR and regulatory pressure are found to complement each other in driving green innovation, with firms facing both CSR and regulatory pressure more likely to be green innovators than firms facing either CSR or regulatory pressure (Zhang, 2022). Green Innovation is positively and significantly influenced by CSR.

H3: CSR has a positive and significant effect on green innovation.

It is easy to say that green innovation is the right thing to do, but it's more of a call to action to say that it's profitable. One theory to explain this is the resource-based view of the firm (RBV) which posits that green innovation creates valuable, rare and hard-to-imitate resources, including resource efficiency, eco-brand equity and regulatory goodwill. The green product and process innovation is an important element to gain competitive advantage (Y. Chen et al., 2015). In addition, the green process innovation, in particular, can provide significant financial performance improvements, through reduced operating costs and increased production efficiency. In the textile processing industry, where profit margins are often very low, and raw material costs can be a major concern, the savings from reduced energy use, waste disposal and raw material use can be significant (Xie et al., 2019). Moreover, the green innovation enhances the quality of the product, the brand image and consequently leads to customer loyalty and recurring revenues (Dangelico & Pujari, 2010). Green innovation now correlates with improved export performance, improved buyer relationship and improved regulatory change resilience in the context of the textile industry in Pakistan (Shahzad et al., 2020). The environmental innovations in manufacturing firms in Pakistan have positive impact on financial and environmental performance measures (Shahzad et al., 2020).

H4: Green Innovation positively and significantly affects Firm Performance.

Only demonstrating the relationship between environmental regulation, digital transformation and CSR and firm performance is not enough. It must be comprehended how the “how” of the “what.” This study proposes that green innovation is that mechanism the critical pathway that converts external pressures to internal capabilities that results in performance. In this sense, mediation analysis is not just a statistical method, but a causal story of the way that companies create value from their environmental contexts. The mediated logic of environmental regulation has been first stated by Porter & Linde (1995) regulation leads to innovation and innovation leads to competitiveness. This pathway has been confirmed in subsequent empirical studies many times. The impact of environmental regulation on performance is primarily via the green innovations that are induced by regulation. In the context of emerging industrial economy in Pakistan (Zhang, 2022). In the textile industry, regulatory pressure incentivizes firms to innovate, change production processes and develop new product formulations, which reduces costs and improves quality, and hence performance, due to regulatory pressure.

H5: Green Innovation is a mediator between Environmental Regulation and Firm Performance.

It's the same for the mediation argument for digital transformation. Digital technologies have very good analytical and operational capabilities, but these need to be provided in a vehicle to provide performance outcomes. This is the car of Green Innovation. The performance gains of digital transformation in manufacturing companies are mainly driven by the green innovation, which is the action taken based on the digitalisation insights of where to improve (H. Li et al., 2023). The companies that are not able to transform their digital capabilities into environmental innovations realize much less of the potential performance gains from their digital investments. In the context of Pakistan's textile industry, this implies that the worth of

investing in AI or IOT systems hinges on their application to achieve tangible green process and product enhancements.

H6: Green Innovation is a connection between Digital Transformation and Firm Performance.

The most basic mediation logic is for the CSR. Consumer preference for green products is the basis for the commercial opportunity, but the firms need to innovate green products to be able to capture the opportunity (Chang, 2011). The CSR and market performance is green innovation: green innovators have better market performance than green labellers who do nothing. Such mediated pathway was found in textile manufacturers in developing economies, where CSR was found to induce green innovation, which in turn resulted in measurable profitability gains (Shahzad et al., 2020). The textile companies in Pakistan should be innovative with their products and processes and not just re-branding as there is a growing demand for green products but also focusing of CSR.

H7: Green Innovation is a mediator between CSR and Firm Performance.

Based on the above literature regarding the understudy variables and mediating associations, the present study has developed the model given below in Figure 1.

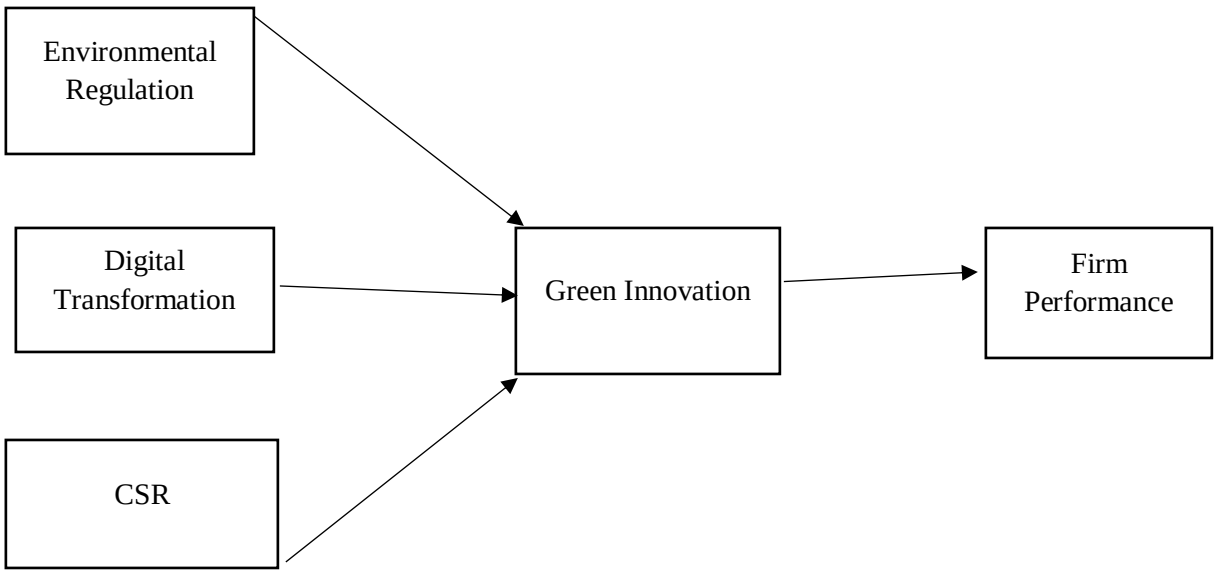

Figure 1: Theoretical model

RESEARCH METHODOLOGY

This paper focuses on the effect of environmental regulation and digital transformation on textile companies' performance in Pakistan. The study will focus on the mediating effect of green innovation, that is, whether the performance of the firms that adopt green innovation is improved due to regulatory and digital pressures. CSR is added as a moderating variable to see if the relationship between these variables is affected by a firm's social and environmental responsibility. The study is carried out on the textile manufacturing and processing companies of Punjab, Pakistan including Lahore, Faisalabad, Gujranwala and Sialkot. The cities were selected

as they are the key textile industry centres in the country. The individuals who will be surveyed are senior managers, who are the decision makers for sustainability, technology adoption and business strategy. The firm is the unit of analysis and the voice of the firm is the senior manager, as this study is about firm level issues. Textile companies from various sub-sectors (processing, packaging and distribution) are represented as digital and environmental trends are relevant for all.

The senior employees of the textile companies of Lahore, Faisalabad, Gujranwala and Sialkot were asked to fill a questionnaire to get a general idea of the textile industry in the major industrial zones of Punjab. This study was not random sampling but was a purposive sampling. This was a good idea, as the study required the views of those who are required to work on environmental compliance, digital systems, CSR programs and innovation strategies on a daily basis. Only those companies where there was a senior manager working in these areas were included. So, the answers are not guesses, but are based on real-life experiences in the organization. The Cochran's formula was used to calculate the number of responses that were needed, which is a formula used for large populations. A 95% confidence level and 5% margin of error were used to calculate the minimum number of respondents needed, which was 384. Because not all of those who receive a questionnaire will return it and not all who return it will answer all the questions, 720 questionnaires were sent out to accommodate for non-responses and incomplete responses. This was also considered adequate to conduct structural equation modelling, mediation and moderation analysis and get reliable results. Lastly, only those responses that were fully completed and that met the inclusion criteria were kept for analysis, which yielded a final sample of 385 and a response rate of about 53 percent.

A five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree) was used for all the variables in this study. The items in the questionnaire were not created from scratch but rather adapted from scales which have been used in other studies. This helps to ensure that the concepts being studied are what is being measured. Environmental regulation (ER) is considered as an independent variable and four items are adopted from Zhu, Sarkis and Lai (2013). They are given in Table 1 below.

Table 1: Environmental Regulation Scale

Items	Questions	Sources
ER1	"Environmental regulations in Pakistan's textile industry are becoming increasingly strict".	(Zhu et al., 2013)
ER2	"Our textile firm faces strong pressure from Pakistani environmental regulatory authorities (e.g., PEPA, EPA)".	
ER3	"Compliance with Pakistan's environmental laws pushes our firm to adopt greener textile production practices".	
ER4	"Government environmental policies in Pakistan directly influence our textile business operations".	

In this study, the second independent variable is Digital transformation (DT). It shows the degree of digitalisation a company has implemented in its day-to-day operations. Four items were adapted from Li, Su, Zhang and Mao (2018) and were used to measure this construct, as shown in Table 2.

Table 2: Digital Transformation Scale

Items	Questions	Sources
DT1	"Our textile firm extensively uses digital technologies (e.g., ERP, automation) in production and operations".	(L. Li et al., 2018)
DT2	"Digital systems are integrated across our textile production and supply chain departments".	

DT3	"Our textile company invests heavily in digital infrastructure to improve efficiency and sustainability".	
DT4	"Digital transformation has improved our textile firm's overall productivity and green practices".	

The mediator of this study is green innovation (GI). It is an indicator of the degree of environmental friendliness of a company's products, processes and materials. Four items from Chen, Lai, and Wen (2006) were used to measure this construct (see Table 3).

Table 3: Green Innovation Scale

Items	Questions	Sources
GI1	"Our textile firm develops products that reduce environmental impact (e.g., eco-friendly packaging, organic ingredients)".	(Y.-S. Chen et al., 2006)
GI2	"Our textile firm adopts eco-friendly production processes such as energy-efficient cooking and processing".	
GI3	"Our textile firm reduces waste and emissions through continuous innovation in textile processing".	
GI4	"Our textile firm uses environmentally friendly and locally sourced materials in textile products".	

Moderating variable is Corporate social responsibility (CSR). It's a testament to a company's commitment to social responsibility towards its community, stakeholders and the environment. Four items from Turker (2009) were used to capture this and these are shown in Table 4.

Table 4: Corporate Social Responsibility (CSR) Scale

Items	Questions	Sources
CSR1	"Our textile company actively participates in activities that protect the environment (e.g., reducing textile waste, clean production)".	(Turker, 2009)
CSR2	"Our textile company supports social welfare activities in local Pakistani communities".	
CSR3	"Our textile company emphasizes ethical behavior toward all stakeholders including suppliers, consumers, and regulators".	
CSR4	"Our textile company invests in sustainable practices to ensure textile security for future generations in Pakistan".	

Firm performance (FP) is the dependent variable. It indicates the growth of a company's sales, its profitability and market position. Four items as shown in Table 5 were used to measure this variable, which was adapted from Venkatraman and Ramanujam (1986).

Table 5: Firm Performance Scale

Items	Questions	Sources
FP1	"Our textile firm's sales growth has improved over the past few years".	((Venkatraman & Ramanujam, 1986)
FP2	"Our textile firm's profitability is better than our competitors in the Pakistani textile industry".	
FP3	"Our textile firm has achieved strong market performance within Pakistan's textile sector".	
FP4	"Overall, our textile firm's productivity and performance have improved over time due to green and digital practices".	

This study is quantitative in nature, and is used to test the relationships presented in the research model. All questionnaires were returned (100%) and data was carefully checked for missing data, outliers and data entry errors and only clean and complete data was forwarded. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to analyze the data using SmartPLS. This method was chosen because it can handle complex models, such as multiple latent variables, mediation paths and a moderation effect at the same time. It can be used in research, as in this case, where the research is directed towards prediction and theory building. The analysis was performed in two stages: (1) checking the soundness of the measurement model; and (2) testing the structural relationships and hypotheses.

Several tests were conducted to assess the measurement model to see if the scales were working properly. To test the reliability of the indicators, the outer loadings were used, and if it is 0.70 or more, it is reliable (J. Hair & Alamer, 2022)Items not meeting this criterion were only deleted if it was judged that the overall quality of the scale would be improved by their deletion. Cronbach's alpha and composite reliability were checked for internal consistency, where a value of more than 0.70 was considered acceptable (Hair Jr et al., 2020)The Average Variance Extracted (AVE) (J. F. Hair et al., 2017) was used to test the convergent validity, which was acceptable if it was 0.50 or higher. Lastly, the Fornell–Larcker criterion, cross-loadings, and the Heterotrait–Monotrait (HTMT) ratio were used to assess the discriminant validity. Constructs with HTMT values of less than 0.85 or 0.90 show that they are sufficiently different from each other (J. F. Hair et al., 2014)

The reliability and validity of the measurement model were confirmed and then hypotheses were tested using the structural model. This comprised direct effects of environmental regulation and digital transformation on firm performance, indirect effects of green innovation as a mediator and CSR as a moderator. The bootstrapping function in SmartPLS was used to analyze path coefficients, t-statistics and p-values. 5,000 resamples were used to bootstrap, a good estimate of statistical significance. Any hypothesis with a p value of < 0.05 was considered to support the hypothesis (Hair Jr et al., 2020)

Research Findings

The overall measurement model of all 5 constructs was adequate. Almost all the factor loadings exceeded the criterion value of 0.70 (0.659 – 0.844). Three items (DT1 (0.667), FP2 (0.681) and FP4 (0.659)) were slightly lower but not dropped as they were still above the more liberal criterion of 0.60 and reliability of the constructs was not affected. Cronbach's alpha ranged from acceptable to good (0.681 to 0.810) and composite reliability (CR) ranged from acceptable (0.690 to 0.821) except that the value of Firm Productivity was just at the threshold (CR = 0.690). All constructs' average variance extracted (AVE) values exceeded the recommended threshold of 0.50, ranging from 0.807 to 0.880, which means that a large proportion of the variance of each indicator is captured by its construct. Corporate Social Responsibility had the highest value ($\alpha = 0.810$, CR = 0.821, AVE = 0.875), and Firm Productivity had the lowest value among the five, but still acceptable ($\alpha = 0.681$, CR = 0.690, AVE = 0.807). The numbers indicate acceptable convergent validity and the measurement model is ready for structural testing. See Table 6.

Table 6: Results of convergent validity

Construct	Items	Factor Loadings	Alpha	CR	AVE
Environmental Regulation	ER1	0.736	0.756	0.771	0.844
	ER2	0.735			
	ER3	0.806			
	ER4	0.754			
Digital Transformation	DT1	0.667	0.729	0.739	0.831
	DT2	0.729			
	DT3	0.743			
	DT4	0.825			
Corporate Social Responsibility	CSR1	0.735	0.810	0.821	0.875
	CSR2	0.778			
	CSR3	0.830			
	CSR4	0.844			
Green Innovation	GI1	0.796	0.818	0.819	0.880
	GI2	0.821			
	GI3	0.815			
	GI4	0.786			
Firm Productivity	FP1	0.729	0.681	0.690	0.807
	FP2	0.681			
	FP3	0.788			
	FP4	0.659			

Fornell–Larcker criterion was also used to assess the discriminant validity by comparing the square root of the AVE of each construct with the correlation between the constructs. The diagonal values came out to CSR = 0.798, DT = 0.743, ER = 0.758, FP = 0.716, and GI = 0.805, and in every case the diagonal sat above the inter-construct correlations. The highest of these correlations were between CSR and GI (r = 0.736), FP and GI (r = 0.677), and CSR and DT (r = 0.588) — all of which are below the diagonal, indicating that each construct accounts for more variance in each of its indicators than in the other constructs. The closest was Firm Productivity and Green Innovation with a correlation of 0.677, which was close to the FP diagonal (0.716), but not quite. Overall, this validates the uniqueness of the constructs Environmental Regulation, Digital Transformation, Corporate Social Responsibility and Green Innovation and Firm Productivity. See Table 7.

Table 7: Fornell–Larcker Criterion

	CSR	DT	ER	FP	GI
CSR	**0.798**				

DT	0.588	**0.743**			
ER	0.375	0.537	**0.758**		
FP	0.559	0.494	0.414	**0.716**	
GI	0.736	0.520	0.350	0.677	**0.805**

Another measure of discriminant validity is to look at the cross-loadings and see if each item loads higher on its own construct than on any other. It does: CSR items loaded strongest on CSR (0.735–0.844), DT items on DT (0.667–0.825), ER items on ER (0.735–0.806), FP items on FP (0.659–0.788), and GI items on GI (0.786–0.821). A couple of cross-loadings were a little bit higher than the rest, CSR4 with GI (0.648) and GI3 with CSR (0.616), but even these were below each item's own-construct loading. Overall, the pattern is confirmed: the discriminant validity seems to be acceptable and the measurement model is ready for structural analysis. See Table 8.

Table 8: Cross-Loadings

	CSR	DT	ER	FP	GI
CSR1	0.735	0.447	0.344	0.331	0.514
CSR2	0.778	0.488	0.337	0.463	0.523
CSR3	0.830	0.393	0.227	0.442	0.646
CSR4	0.844	0.554	0.310	0.534	0.648
DT1	0.334	0.667	0.492	0.369	0.302
DT2	0.395	0.729	0.301	0.402	0.419
DT3	0.443	0.743	0.489	0.288	0.392
DT4	0.554	0.825	0.353	0.411	0.415
ER1	0.227	0.404	0.736	0.204	0.219
ER2	0.214	0.375	0.735	0.251	0.300
ER3	0.400	0.442	0.806	0.371	0.312
ER4	0.276	0.411	0.754	0.448	0.194
FP1	0.384	0.438	0.362	0.729	0.501
FP2	0.361	0.311	0.238	0.681	0.457
FP3	0.429	0.325	0.256	0.788	0.543
FP4	0.432	0.342	0.337	0.659	0.428
GI1	0.573	0.425	0.304	0.549	0.796
GI2	0.592	0.428	0.251	0.557	0.821
GI3	0.616	0.356	0.206	0.538	0.815
GI4	0.587	0.465	0.366	0.535	0.786

The Heterotrait–Monotrait (HTMT) ratio was also explored and the range of the model was between 0.429 and 0.904. All pairs were below the conservative threshold of 0.85, such as Environmental Regulation and Green Innovation (0.429), and Corporate Social Responsibility and Environmental Regulation (0.478), and thus evidence of discriminant validity for these pairs. But two pairs did not make it over that bar: Corporate Social Responsibility with Green Innovation (0.897) and Firm Productivity with Green Innovation (0.904), the latter even surpassing the more lax 0.90 mark. This implies that there are some similarities between Green Innovation and CSR and Firm Productivity which should be taken into consideration for future improvements and the model fails to explain. All the other pairs, however, did well. See Table 9.

Table 9: Heterotrait-Monotrait Ratio (HTMT)

	CSR	DT	ER	FP	GI
CSR					
DT	0.638				
ER	0.478	0.621			
FP	0.652	0.552	0.429		
GI	0.897	0.570	0.429	0.904	

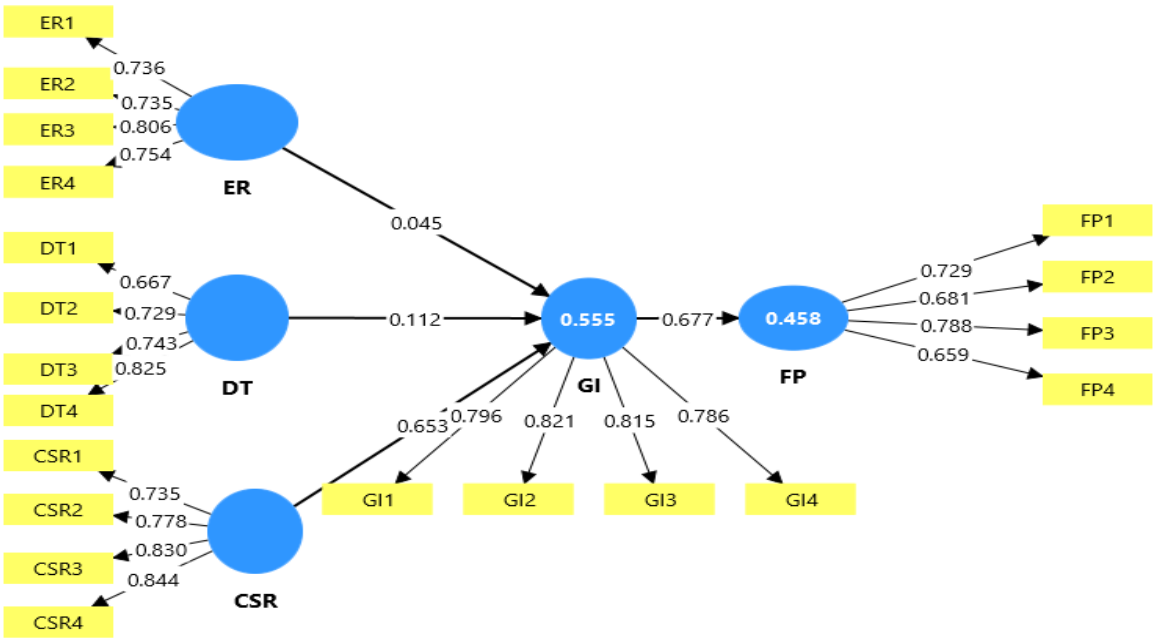

Figure 2: Measurement model

The bootstrapping method was used to test the hypothesized paths with 5,000 subsamples. Corporate Social Responsibility proved to be a good positive predictor of Green Innovation ($\beta = 0.653$, $t = 9.182$, $p < .001$) and Green Innovation was a good positive predictor of Firm Productivity ($\beta = 0.677$, $t = 10.825$, $p < .001$). Digital Transformation, on the other hand, didn't show a significant link to Green Innovation ($\beta = 0.112$, $t = 1.197$, $p = .231$), and neither did Environmental Regulation ($\beta = 0.045$, $t = 0.691$, $p = .490$). To sum up, CSR and Green

Innovation are drivers in this sample in terms of Firm Productivity and Digital Transformation and Environmental regulation do not seem to be drivers in terms of Green Innovation. See Table 10.

Table 10: Path Analysis (Structural Model Results)

Relationships	Beta Value	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
CSR -> GI	0.653	0.071	9.182	0.000
DT -> GI	0.112	0.093	1.197	0.231
ER -> GI	0.045	0.065	0.691	0.490
GI -> FP	0.677	0.063	10.825	0.000
ER -> GI -> FP	0.031	0.045	0.678	0.498
CSR -> GI -> FP	0.442	0.071	6.238	0.000
DT -> GI -> FP	0.076	0.063	1.199	0.231

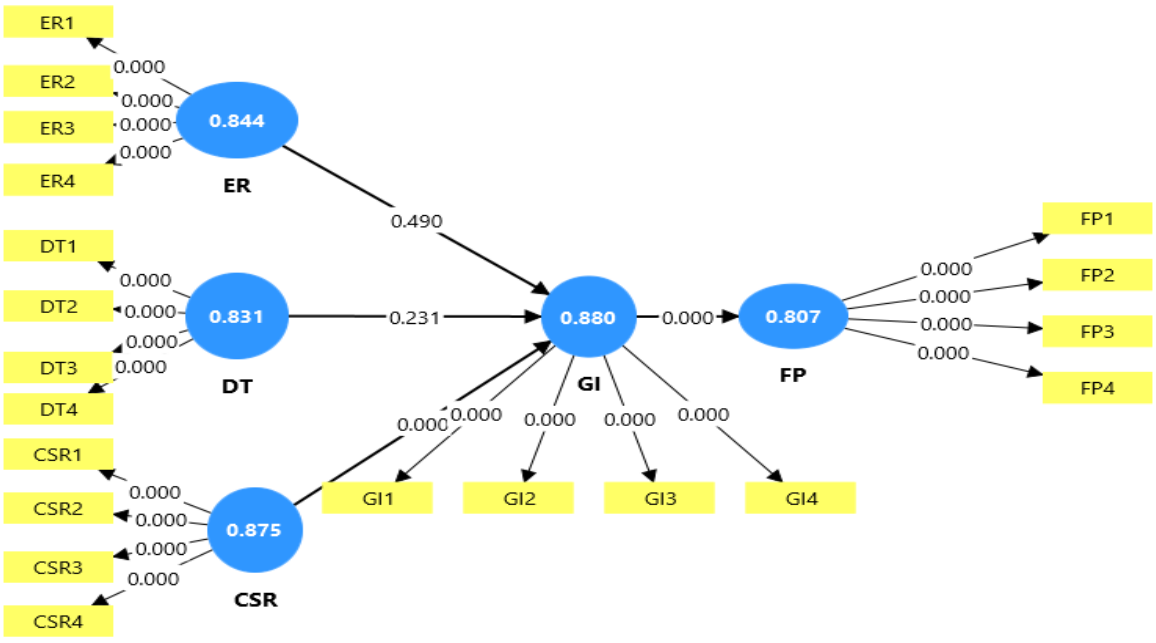

Figure 3: Structural model

DISCUSSION

The structural model results provide a full set of direct, indirect and mediation effects for the important relationships that are being examined. The following discussion relates each of the paths to existing theories in environmental management, corporate sustainability and organizational behaviour and implications for research and managerial practice in the textile industry in Pakistan are drawn. Corporate Social Responsibility

(CSR) with a beta coefficient of 0.653 ($t = 9.182$, $p < .001$) was the most powerful and significant direct predictor of Green Innovation (GI). This result is in line with the stakeholder theory (Freeman, 1984) which suggests that firms that react to the expectations of environmental and social stakeholders are more likely to invest in innovative green practices. In the context of Pakistan's textile industry, the companies that incorporate CSR in their business operations show their commitment towards sustainability which is directly reflected in green product development, cleaner production process and eco-friendly supply chain practices. This is consistent with earlier empirical research, which has revealed a positive relationship between CSR orientation and the outcomes of green innovation in companies in emerging markets (Saman et al., 2025; Junejo et al., 2025), highlighting the importance of responsible corporate behaviour as a basic driver of green innovation in this sector.

The coefficient of Green Innovation (GI) was 0.677 ($t = 10.825$, $p < .001$) which had a significant positive effect on Firm Productivity (FP). This is in line with the Natural Resource-Based View (Hart, 1995) which suggests that companies that invest in environmental capabilities (pollution prevention and clean technology development) will be able to enhance their resource efficiency and reduce their costs and hence increase their productivity. Adopting green innovations such as energy-efficient processing, waste reduction technologies, and sustainable packaging can benefit textile industry businesses in Pakistan, not just in terms of cost savings, but also by enhancing their competitiveness in the market due to the growing demand for environmentally responsible products. This result aligns with the literature, which has shown that there is a positive relationship between green innovation and performance in manufacturing and textile sector contexts (Lin et al., 2010; Correia et al., 2023). The mediation path from CSR to FP through green innovation was also significant ($\beta = 0.442$, $t = 6.238$, $p < .001$), which means that green innovation is a full mediation between CSR and FP. This helps to explain chain mediation logic: CSR commitments drive firms to make green innovations, and productivity gains are achieved via green innovations. Theoretically, this is significant as it can be used to explain the relationship between socially responsible behaviour and economic performance. Hence, in the textile industry in Pakistan, it is impractical to expect that CSR activities will directly result in productivity improvement but rather productivity improvement will be the result of investment in green innovation, which is CSR oriented.

Environmental Regulation (ER) had no direct effect ($\beta = 0.045$, $t = 0.691$, $p = .490$) and the indirect effect of ER on FP via GI was not significant ($\beta = 0.031$, $t = 0.678$, $p = .498$). This is an important finding that contradicts the theory of Porter's Hypothesis (Porter & van der Linde, 1995) that good environmental regulation will result in environmentally and economically beneficial innovation by companies. The non-significant result could be due to the regulatory environment in Pakistan's textile industry, where the enforcement of environmental policies is inconsistent, and firms may not feel the pressure of the regulations is strong enough to invest in green innovation (Ali, 2018; Government of Pakistan, 2021). This finding indicates that in a low regulatory enforcement environment, the need to comply with regulations to green is not as great and other motives like CSR orientation and stakeholder pressure might be more pertinent. Likewise, Digital Transformation (DT) had no direct significant effect on FP ($\beta = 0.112$, $t = 1.197$, $p = .231$) and the indirect effect of DT on FP via GI was also not significant ($\beta = 0.076$, $t = 1.199$, $p = .231$). Although digital transformation is known to facilitate green practices by improving efficiency, enabling smart monitoring, and providing supply chain transparency (Irshad, 2025), the impact of digital transformation in this sample might be limited due to the relatively nascent level of digital adoption in the textile sector in Pakistan. A number of small and medium textile companies in Pakistan are resource constrained and are unable to combine advanced digital technologies with their green innovation strategies (Ali, 2018; Oduro, 2020). There was also some overlap between CSR and GI (0.897) and FP and GI (0.904) that may suggest that more sophisticated digital and regulatory environments might yield more distinct effects of DT and ER with more nuanced measurement.

Theoretical Contribution

The theoretical importance of this study is that it is the first study to integrate the concepts of corporate social responsibility, environmental regulation, digital transformation, green innovation and firm productivity in one framework to test it in the context of Pakistan's textile industry. Models for each of these variables have been developed in the past, as well as in a bivariate context. This study contributes to theory by showing that CSR is the predominant motivational force behind green innovation, and that green innovation is the key mediating link between CSR and productivity improvements for the firm. This multi-layer mediation framework is based on the Natural Resource-Based View (Hart, 1995) and shows that there is no direct connection between responsible corporate action and economic performance, but a path that goes through the environmental innovation capability. The non-significant results of environmental regulation and digital transformation also provide some theory-based insights: In textile sectors in emerging economies, where enforcement regimes are weak and digitalisation is still in its infancy, the green innovation–productivity pathway might be more strongly stimulated by internal value-driven motives (CSR) than by external regulatory or technological pressures.

Practical Implications

The findings have obvious and implementable implications for the managers, policy makers and textile industry stakeholders in Pakistan. Firstly, CSR is the best predictor of green innovation and textile companies need to take environmental and social responsibility as a strategic decision and not as an activity on the fringe. Specific actions include the creation of codes of conduct for sustainability, discussions with suppliers on environmental issues and communicating green commitments to consumers and investors. Second, in this model, the key factor influencing firm productivity is green innovation, and managers in the textile industry should consider green production technologies, eco-design and waste minimization systems as productivity measures, rather than environmental responsibilities. Thirdly, the negligible impact of environmental regulation suggests that the design and implementation of environmental laws in textile sector in Pakistan needs to be improved. Regulation needs to be credible and must have real compliance costs to induce the Porter Hypothesis effect and to encourage green innovation through compliance. Fourth, while digital transformation did not directly contribute to green innovation in this sample, companies shouldn't give up on digital investments. Instead, they should use digital tools specifically to support green innovation goals, such as data analytics to find energy inefficiencies, IOT sensors to monitor environmental compliance and digital supply chain platforms to ensure sustainable sourcing.

LIMITATIONS AND FUTURE DIRECTIONS

There are a number of limitations to this study. First, cross sectional design does not allow for any causal inferences, data is only collected at one point in time and no indication of the direction of relationship over time. Longitudinal research designs would enhance causal claims and enable the monitoring of the evolution of green innovation strategies over time, as a function of shifting regulatory and market conditions. Second, the study is based on self-reported survey data, which may lead to common method bias and social desirability in the answers to the CSR and environmental practices questions. Future research should be combined with perceptual data with objective data on firm-level performance, such as patent counts, energy consumption records, or audited sustainability reports. Thirdly, the sample is taken from a specific population of textile industry in Pakistan and it may not be applicable to other industries and countries. Multi-sector and cross-country comparisons would enable testing of the stability of the models in different institutional settings. Fourth, the impact of digital transformation and environmental regulation is negligible and more research is required. Further research is needed to examine the circumstances (e.g. firm size, ownership, and the effectiveness of regulatory enforcement) that may give rise to such relationships. Qualitative and mixed-methods research might also yield more in-depth understanding of the reasons behind the lack of digital transformation in this sector to green innovation and what organizational and infrastructural challenges are yet to be overcome.

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