

Research Article

**GREEN TECHNOLOGY, GREEN PRODUCTS, CONSUMER
BEHAVIOR AND FIRM PERFORMANCE: A MICRO
ANALYSIS**

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Abstract

A large number of scholars explored this relationship but this area is still unexplored due to complexity and non-linearity between main theoretical streams and empirical findings, providing a research gap for further research. This study aims at investigating the influence of green technology, green products innovation, R&D expenditures and consumer behavior on firm performance, using primary data collected 425 employees of 10 selected textile firms located in Multan, Faisalabad, Karachi, and Lahore districts of Pakistan through questionnaire survey during October-December 2023. Using firm performance metrics, particularly annual profit as a proxy, the study employs Correlation matrix and ARDL approach to analyze the relationships between independent variables: green technology, green product innovation, research and development expenditures, consumer behavior, and dependent variable, firm performance. According to the findings, green technology, green product innovation, and customer preferences have positive and significant impact on firm performance, while the impact of R&D on firm performance was found insignificant.

Keywords: Green Technology; Green Products; Consumer Behavior; Research and Development; Firm Performance.

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1. Introduction

Nowadays the world is nowadays very much concerned about sustainability and environmental protection (Zhao & Chen, (2019). This emerging concept has generated the idea of green technology and the manufacturing of green products (Ghosh, Shah, & Swami, (2018). The impact of green technology on business firms and consumers' behavior. Firms wants to learn whether adopting green technology would be fruitful to them and how their customers respond to green products by making their purchase decisions (Xu et al.2023). Therefore, there is a link between green technology, green products, consumer behavior and firm performance. Due to growing concern about sustainability, businesses are adopting green technology much faster to attract more customers, boost sales volumes, and ultimately boost performance. Go green would enhance a company's reputation in front of customers and in society. Balaceanu,et al. (2020).In addition, adoption of green technology would reap tax exemptions and subsidies granted by governments in different countries and save them from legal action and penalties (Arthur, et al, (2022).

Like western countries, Pakistan has huge potential for adopting green technology, but still, it lags behind. Many companies are shifting their conventional energy sources to energy efficient modes like solar energy, while others are replacing their traditional machinery, producing non-green products by an eco-friendly production process to increase efficiency, decrease energy use and reduce waste. An innovative method of green product development is emerging in the textile sector, and Pakistan is a leading destination for imported second-hand textile items that are recycled and sold in posh areas and lucrative markets. In Europe, there is a tradition of discarding shirts and

cloth items after they are used for a brief period, and according to an estimate, 12.6 million tons of textile waste is produced every year in the European union. Pakistan is among the top importers of second-hand textile items because it recycles these items and sell them in domestic and international markets. Pakistan exports 68% of its textiles to the European Union, and circularity can expand the life cycle of a product in a situation of climate crisis and depletion of resources. In such a situation the recycling of used textile items can be important for the poor masses, and small-and medium-enterprises, and the value chains. The climate crisis has forced the textile industry to rethink its traditional business model of consumption and production by opting for green product innovation ([Daily Dawan, August 01, 2024](#)). In this way, firms take advantage of the dual benefits of cost minimization and production optimization ([Vermeir, 2021](#); [Nielsen, 2018](#); [Chen & Chang, 2012](#)). Thus, profits and performance would be enhanced in the end. In Pakistan, even though adoption is very low, its trend is increasing rapidly. There are many potential gaps to be evaluated regarding how Pakistani firms are responding to the wave of going green, how their customers are taking this good at what level, and how performance affects. Therefore, this study examines the impact of green technology and green product innovation on Pakistani firms and their consumers.

Green Products refer to the products may may use less packaging, organic and recyclable materials, and are more energy efficient ([Rizwan et al.,2021](#)). Green textile products and green textile industries/ firms are energy-efficient firms that use organic and recycled materials to produce textile goods. In order to explore the impacts of green products on a firm's performance, it may useful

to investigate the volume of expenses being spent on R&D) for the production of green technology and green products (Wissal, et al. (2018).. If the use of energy increases, it increases the carbon dioxide emissions (CO₂ emissions) because we cannot separate the energy use and the carbon dioxide gas emissions. Additionally, expenses on science and technology are necessary in the growth of green products as research and development (R&D) may prove helpful to ease the way in which green products and green technology are used in Pakistan. Consumer behavior is vital to firm's performance. The consumer behavior toward green products and green technology indicates a firm's performance (Raza, Chen & Tang. (2022)). Therefore, it is imperative to explore the impacts of consumer behavior on firm performance empirically. Thus, the main research question of this study is to explore how green technology, green product innovation, and consumer behavior impact firm's performance. In light of this research question, the objectives of this study are to examine the impact of green technology, green product innovation, R&D and specially consumer behavior on firm performance. By exploring these objectives, we can understand individual impacts of these variables and the crucial role of consumer behavior in green product innovation. Variables, such as green technology, green product innovation, and R&D are closely linked to consumer behavior, and firm performance also depends on consumer behavior. Positive consumer behavior toward green products motivates the firm to invest in R&D to develop green innovative products and expand their business. This also prompts the firms to improve their production functions by inducting cutting-edge technologies into firm. Thus, the current study is intended to examine the relationship between green technologies, green

product innovation, R&D, consumer behavior, and firm performance in Pakistan given the scarcity of literature on this relationship.

2. Literature Review and Hypothesis Development

2.1 Link between green technology and firm performance

This literature review encompasses several studies that provide valuable insights into the dynamic green technology, green products, consumer behavior, research and development and their impact on firm performance within the context of Pakistan. [Shen, et al. \(2020\)](#) examined the impacts of green products on firm's behavior and the performance of firm. The study examined the data of 140 Turkish manufacturing firms from various sectors of the economy. Variables such as green products innovation, firm's performance and competitive advantages of firms were used for analysis, employing Structural Equation Model. The results revealed that there was a positive relationship between green products innovation and the firm's performance in the different regions of Turkey. This study recommended that there should be enhancement in innovation process of the green technology to improve firms' performance. [Ghosh, Shah., & Swami, \(2018\)](#) estimated the impacts of green products innovation on motorcycle industry firm's performance for Vietnam. The study generated 208 questionnaires to estimate the effects of market demand for green products and how the green products innovation affected firm's performance. The study used primary data collected from four leading foreign firms. The results showed that market demand of green products was positively and significantly correlated with firms' performance and green technology was also positively related to the market demand for the green products in Vietnam. Adoption of green technology enhances firms' financial performance, market share, brand reputation, and

innovation capabilities, making them more competitive and sustainable in the long term (Aghion, (2023). Daniele, et al. (2017) analyzed the impacts of green technology, ecological actions a firm's performance in Italy. The data of 122 Italian companies was collected through electronic survey method and the core variable used for the analysis were ecological forces, market performance, environment quality and energy use etc. The results indicated that as the energy use increased in order to increase production in manufacturing sector of Italy this increased environmental degradation as emissions level rose rapidly. But after the adoption of green technology firm's performance enhance sharply. Carsten, (2018) examined the relationship among green supply chain, green communication, green technology and firm's performance. The variables such as green purchasing, green manufacturing, green innovation, green packing, air pollution, green supply chain and performance of the firms were selected. The data was collected from 429 workers of the firms, and the Structural Equation Model was used for analysis. The results noted that in the presence of air pollution the green productivity was very low. The study also recommended that there should be reduction in the air pollution in order to increase the green production. Junsong, et al. (2020) studied the relationship between eco-innovation, technology and manufacturing firms' performance in Pakistan. The study emphasized that Pakistan has potential for green manufacturing but lacks attention. There is significant market space and growth potential in Pakistan's green energy sector. The study suggested inclusion of other sectors in future studies. Balaceanu, et al. (2020) evaluated green technology strategies for sustainable development of solar power projects in Pakistan. He examined the moderating role of cost and risks, using capital budgeting techniques. Data collected from

44 respondents (Chief Financial Officers (CFOs) and Chief Executive Officers (CEOs) through a questionnaire survey. The findings show that green technology strategies positively impacted the sustainable development of solar power projects. Profitability index was a good source of higher financial performance. Cost and risk methods significantly moderate the nexus of capital budgeting techniques. Findings provide a valuable manual for policymakers and government institutions. [He, Chen, & Feng, \(2023\)](#) scrutinized the effects of green intellectual capital on green innovation adoption, using data sample of 235 manufacturing SMEs in Pakistan. The findings noted that Green human capital and green structural capital increase green innovation adoption, Green relational capital has positive but insignificant impact on green innovation adoption. [Ana & Mendonça, \(2018\)](#) identified factors influencing adoption and diffusion of solar energy technology (SET) by SMEs in Pakistan. They analyzed the factors driving adoption: enterprise size, perceived ease of use, and perceived reliability. They also probed the factors hindering adoption: perceived price, competition pressure, and energy cost intensity. They found that lack of technical knowledge about SET is a neutral factor while important factors noted were: price, energy cost intensity, enterprise size. The study recommends that price of SET should be reduced to encourage adoption by Pakistani SMEs. [Guo, Y. \(2023\)](#) estimated the impact of green intellectual capital (GIC) on firms' green performance (GP) and found that exploitative and exploratory green innovation (GI) mediates between GIC and GP. Technological turbulence (TT) moderates the effects of GIC on GI. It offers insights for manufacturing firms and policymakers to achieve sustainable green performance. [Jawad & Sağsan, \(2019\)](#) noted that adoption rate of green

innovation technology was low in manufacturing industry. They used green innovation adoption (GIA) model based on unified theory of acceptance and use of technology (UTAUT) predicts green behavioral intention. They found that green behavioral intention (GBI) has a strong direct and mediating effect on GIA. Organizational size moderates the relationship between constructs. Green working conditions have the highest relative importance for green innovation adoption (GIA). [Laun et al. \(2016\)](#) studied the importance of green technology adoption in the Taiwan. The study used primary data, which was collected through a questionnaire from different firms of Taiwan. The study used variables such as expenses on research and development, green products and green technology, employing Simple regression technique for data analysis. The results demonstrated that as the firms invested in research and development on measuring the importance of green products, the research may prove helpful in decision making behavior and performance of firms. [Shen, et al. \(2020\)](#) examined the impacts of green technology adoption and its consequences on the sustainable performance in the circular economy in the Pakistani small and medium scale enterprises. Green technology adoption, circular economy principle, sustainable supply chain practices and the sustainable performance were the variables used for analysis. The study examined 435 small and medium scale enterprises data, which were collected from the government database.

As the link between green technology and firm performance in Pakistan has not been fully explored; current study discovers the need of delving into the nexus between green technology and firm performance. Therefore, we conclude that green technology is positively related to firm performance,

which is consonant with past study in textile sector. Hence, we propose first hypothesis:

H1: Green technology is positively associated to firm performance.

2.2 Link between Green product innovation and firm performance

[Adjengdia, et al. \(2020\)](#) estimated the association among green product innovation, managerial concerns and firm's performance in China, using the data of 180 manufacturing firms. Variables such as inflation, green innovation, green agri-business and firm performance and the managerial concerns were used for analysis. The results showed that there is positive relationship among managerial concerns and the uplift of green products and green innovation and firm's performance in China. Managerial concerns were most important decisions in bolstering green products. [Md. Et al., \(2024\)](#) identified that green product innovation is crucial for modern firms' success. Green innovation can be enhanced by integrating green business strategies and green competencies. Green value co-creation mediates the relationship between integrated competencies and green innovation. Data collected from managers of manufacturing firms in Pakistan. Green competencies and green business strategies have positive impact on green value co-creation and green innovation. Green value co-creation improves firms' green performance and helps achieve green innovation. These studies established close link between green product innovation and firm performance in different countries. Hence, there is a dearth of research on this relationship. Therefore, we propose second hypothesis:

H2: Green products innovation is positively associated with firm performance.

2.3 Link between R&D policies and sustainable development

Ma, Li, & Wu, G. (2018) examined the relationship between ecological regulation, government R&D funding, and green technology innovation. The study divided green technology innovation into green product and green process innovation, focused on energy saving and emission reduction. The study provided practical implications for policymakers and firms, emphasizing the need for aligned ecological regulation and government R&D funding policies to promote green technology innovation. The paper used panel data from 30 Chinese provinces and applied a fixed effect model to analyze the effects of ecological regulation and government subsidy. The findings revealed an "inflection point" in the role of ecological regulation and highlighted the positive impact of direct government funding on green technology innovation. The study proposed that future research should explore the broader implications of green technology innovation beyond energy and emissions. Jiang, et al. (2019) analyzed the impacts of green product innovation and its impacts on firm's performance in China. The study examined the role of government policies in promotion of green products innovation. The data of 231 traditional manufacturing firms was gathered through survey method and the variables such as green innovation, firm's performance, research and development were adopted for analysis. The outcomes of the study documented that innovation in green products manufacturing significantly improved firm's performance. Aindrila & Roy, (2015) studied the relationship between environment stability and green product, using primary data collected from 282 respondents of Pakistani firms from January to April 2019 and estimated the relationship among ecological degradation, environment sustainable development techniques and green

products. This study used partial least square, structural equation model. The study concluded that ecologically sustainable techniques were positively and significantly related to the enhancement of green technology. [Zhang et al. \(2020\)](#) examined the government policy (tax or subsidy) to induce firms to adopt green technology from a supply chain perspective. The study aimed to maximize social welfare by considering the decisions of the government policy-maker and the manufacturer in a two-tier supply chain. The findings noted crucial role of government policies and suggested that appropriate policy framework should be adopted to incentivize firms to adopt green technology, which contributes to a reduction in carbon emissions and ecological protection. [Rizwan et al. \(2021\)](#) analyzed the role of government incentives in the relationship between green innovation and sustainable development goals (SDGs). They found green innovation has a significant influence on SDGs, community development, and ecological activities. Government support strengthens the relationship between green innovation and ecological practices. Government support does not moderate the path between green innovation and community development. SMEs should focus on adopting green innovation and technology. Government should assist SMEs financially and non-financially to achieve SDGs. Thus, we can assume that there is a significant relationship between R&D and firm sustainability. We also noted that there is scarcity of literature on this relationship particularly in the context of textile industry in Pakistan, which call for in depth research on this topic, therefore, we propose third:

H₃: Research and development (R&D) are positively associated with firm performance.

2.4 Link between consumer behavior and firm's performance

Consumers' perceptions are varied about the attributes of products because they purchase them for consumption and this perception mainly depends upon their income, utility and environmental safety. At the stage of use, consumers also give importance to environmentally sustainable attributes keeping in view their sustainable values. They are also focus on technologies to reduce their level of consumption. The Findings of previous studies about the impact of product attributes on consumer behavior (such as purchase intention or willingness to pay a premium price) are widely discussed. Mostly these studies are related to the consumer behavior about the use of green products. A future research agenda is proposed to advance knowledge on the role of consumer behavior and firm performance. Consumer prefers green products which proves health standard and affordability. Generally Green products attributes are environmentally friendly characteristics which reflect holistic design and engineering efforts to make it sustainable [Mingfeng et al, \(2018\)](#); [Guo, \(2023\)](#). The studies relating to marketing and consumer behavior identified that the perception of consumer's intention is difficult and its is known when he purchases a product. The consumer also assesses the purchase alternatives but he gives value to sustainable products if he is conscious of environmental concern ([Kaplan, et al. \(2018\)](#)). [Zhang et.al. \(2020\)](#) examined the causes that drive consumers to purchase green products. They also identified the impact of product attributes (such as, eco-labels, product personality, price, performance, country of origin, health attributes) on consumers' purchase intention. They concluded that the visible attributes, product quality, packaging, and originality are the most common aspects considered by consumers. One of the most important aspects is the attribute

of innovative green product which attract the consumer to purchase and use it due to its suitability (Balaceanu, et al. (2020). Therefore, the firms should focus on the green product innovation and approach environmentally aware consumers. There are some studies which emphasized that consumer-orientation for the success of green innovations is crucial and the firms must focus on this aspect. The proximity with consumer and identification of his preferences enables the organization to develop environmentally sustainable products Junsong, et al. (2020). Thus, the studies conducted in different regions indicate that consumer behavior has strong association with firm performance and suitability. We also noted that there are very few studies on this relationship particularly in textile industry of Pakistan. It calls for deeper investigation into the relationship between consumer behavior and firm sustainability in Pakistan. Thus, we propose forth hypothesis:

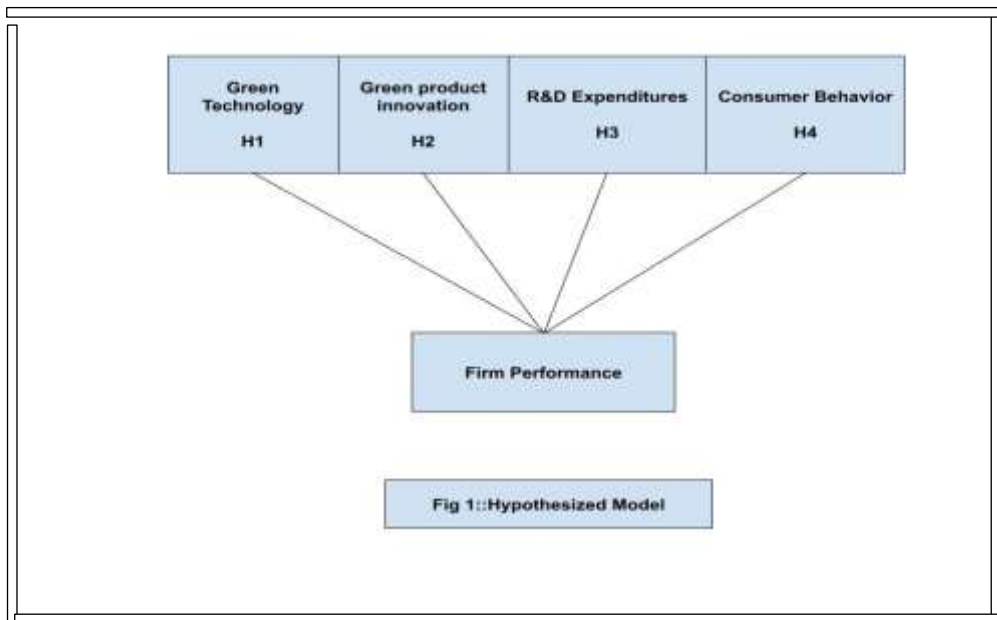
H4: Consumer behavior is positively associated with firm performance.

2.7. Research gap and novelty of the study

Despite the availability of extensive studies on the relationship between green product innovation and firm performance, there are very few studies that explore relationship between green product innovation and firm performance in Pakistan, therefore, a notable gap exists in the literature. The studies on Italy, Taiwan, China, Vietnam, Turkey and Iraq mostly demonstrated the positive impacts of green products innovation on firm performance, but there is a lack of research focusing on Pakistani firms. This gap provides an opportunity add fresh insight by examining how green product innovation affects firm performance in Pakistan's unique economic and environmental landscape. Previous studies mostly focus on developed and emerging economies, leaving a research gap for understanding the dynamics of

Pakistan's economy. The investigation into green product innovation in Pakistani context is the novelty of this study. Using a sample of Pakistani firms, this study aims to offer localized insights into the effect of green innovation on firm performance and in this way, this study contributes to the broader discourse on sustainable business practices in the developing countries. Another unique aspect of this study is that it will examine the interaction between government policies, ecological sustainability, and green technology adoption, offering practical implications for policymakers and business managers aiming to uplift firm performance through green product innovations in Pakistan.

In the light of hypotheses and reviewed literature, the hypothetical model for this study is developed. This model consists of 4 independent variables and 1 dependent variable, displaying their hypothesized linear relationships in [Figure 1](#)



3. Material and methods

3.1 Sampling procedure and selection of variables

First phase of the research involved examination of the current state of green technology and green product in Pakistan. For this purpose, primary data has been collected using interviews and survey methods during October 2023 and December 2023. Total 10 Textile firms: four from Multan, three from Faisalabad, one from Karachi and two from Lahore were selected and primary data was collected from 425 employees of these textile units through a structured questionnaire. About 30 visits were made to collect filled questionnaires. The consent of participants was taken before collection of data. All the participants were fully explained the objective of data collection. They were also assured that the information provided by them will be kept secret and only be used for research purpose. In order to calculate sample of study we used Cochran's formula, suggested by (Uakarn *et al.*, 2021). This formula is widely used where population is infinite. The formula is given below: -

$$n = z^2 * p * (1 - p) / e^2$$

where:

n = Size of sample (number of participants needed)

z = Z-score relating to desired confidence level (e.g., 1.96 for 95% confidence)

p = Estimated proportion of the population with the characteristic of interest (between 0 and 1)

(1-p) = 1 minus the estimated proportion (ensures we consider both possibilities)

e = Desired level of precision (margin of error).

For example, if we want to estimate the proportion of people in a large city who prefer to work in urban areas for higher wages (p). We want a 95%

confidence level and a margin of error of 5% ($e = 0.05$). We also have no prior knowledge about the proportion, so we can estimate $p = 0.5$ (assuming an even split between those who prefer the working in urban areas and those who don't). Including these values into the formula:

$$n = (1.96)^2 * 0.5 * (1 - 0.5) / (0.05)^2 \quad n \approx 385.$$

The calculation of formula suggests that a sample size of around 385 people would be sufficient to achieve your desired level of precision and confidence in this scenario. As the sample size of current study is 425 it meets the criteria of Cochran's formula.

Four cities, Karachi, Lahore, Faisalabad and Multan are big business centers of Pakistan and most of large Textile units are situated there. All selected mills are ISO certified and are large in size, volume of production and sales. The names of selected textile units are: Colony Textile Mills, Multan, Reliance Weaving Mills, Multan, Mehmood Textile Mills, Multan, Fazal Cloth Mills, Multan, Crescent Textile Mills, Faisalabad, Nishat Mills Faisalabad, Interloop Ltd, Faisalabad, Nishat Chunia, Lahore, Shah Taj Textile Mills, Lahore and Gul Ahmad Textile Mills, Karachi. The questionnaire was developed on the basis of 5-points Likert scale, which is very flexible and easy to record response of participants and computation of results. The firm's performance (FIRP) is dependent variable whereas green products (GRPRO), Green technology (GRTEC), Research & Development (R&D) and consumer behavior towards green products (CONB). The firm performance variable was adopted from the study of [Raza, Chen & Tang. \(2022\)](#). The variable, green product innovation, was adopted from the study of [Ghosh, et al. \(2018\)](#), while the variable green technology was adopted from the study of [Adebiyi, et al. \(2020\)](#). The variable, research and development

(R&D) was adopted from the study of [Zhang et al. \(2020\)](#); [Rizwan et al. \(2021\)](#). The variable, consumer behavior, was adopted from the study of [Arthur, \(2022\)](#); [Jacopo, et al. \(2018\)](#).

3.2 Description of variables

3.2.1 Firm's Performance (FIRP):

A firm's performance refers to the firm's overall efficiency in attaining its objectives and goals. It is the comprehensive measure that evaluates how well an organization or a business is doing in numerous parts of its procedures. Firm's performance can be estimated using the combination of non-financial as well as financial indicators, and it frequently includes considerations such as the profitability, productivity, market share, efficiency, customer satisfaction, overall competitiveness and innovation. Here firm's annual profit has been taking as proxy for firm performance.

3.2.2 Green Technology (GRTEC):

Green technology, which is also known as the eco-friendly technology or the sustainable technology, refers to the growth and application of the products, processes, and the systems that aim to minimize their ecological influence and promote the sustainability. Primary goals of the green technology are to decrease the use of non-renewable resources, to promote the well-being of both environment and the human society and to minimize the waste and the pollution. Here Likert scale method is used to evaluate that to what extent a firm is adopting green technology by introducing new machinery to go green.

3.2.3 Green Products (GRPRO):

Green products usually refer to the goods or services that have been produced, designed and distributed in an ecologically friendly and

maintainable manner. These products or goods aim to minimize their influence on the environment through their whole life cycle, from raw material withdrawal and manufacture to use and disposal. Here green product is evaluated by assessing through questioner that is any firm manufacturing green products in their production.

3.2.4 Research and Development (R&D):

Ratio of expenses on science and technology is the measure of the amount of money which is spent by any firm or organization on research and development in order to increase its revenue and maximize its sales. Each and every firm wants to maximize its revenue through sales maximization or to price reduction. So, spending on Research and development may ensure their goal achievement though different strategies. Here R&D is analyzed by how much a firm spends on R&D annually.

3.2.5 Consumer Behavior (CONB):

Consumer behavior refers to study of the individuals, organizations or the groups and the procedures they use to secure, select, use, and disposal of the products, experiences, ideas or services to satisfy their wants and needs. It includes understanding how consumers make choices, including factors that affect their purchasing selections and the psychological procedures that drive their actions. Here consumer behavior is analyzed by assessing consumer attitude towards green products by making purchases of green products.

3.3 Specification of model

The general functional form of the model is given below:

$$\text{FIRP} = \beta_0 + \beta_1 (\text{GRTEC}) + \beta_2 (\text{GRPRO}) + \beta_3 (\text{R\&D}) + \beta_4 (\text{CONB}) + \varepsilon$$

This model is transformed into a mathematical equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + e$$

Where:

Y: Dependent variable (firm performance)

Bo: Constant

X₁ = Green technology

X₂ = Green products

X₃ = R&D

X₄ = Consumer behavior

e, = error term

In order to estimate results, we used different statistical tools, such as descriptive statistics, Correlation matrix, ADF unit root test, ARDL model and diagnostic tests.

4. Results

4.1 Descriptive Statistics

Descriptive statistics refer to the set of techniques used to summarize and describe the basic features of a dataset. These statistics provide simple summaries about the sample or population under study, typically focusing on measures of central tendency (such as mean, median, and mode) and measures of variability or dispersion (such as range, variance, and standard deviation). Descriptive statistics aim to condense large amounts of data into manageable summaries that allow researchers to gain insights into the characteristics of the data, identify patterns, and make initial interpretations. They are crucial in providing an overview of data distributions, helping researchers and analysts to understand the typical values, spread, and shape of the dataset without delving into complex inferential or predictive analyses. The estimated results of descriptive statistics are presented in [Table 1](#).

Table 1

Descriptive Statistics of variables

Descriptive statistics	FIRP	GRTEC	GRPRO	R&D	CONB
Mean	4.6815	3946.141	2869.517	227.1483	199.9583
Median	4.6997	3930.000	3421.419	323.3830	230.9811
Maximum	4.8037	5288.000	3744.625	387.3800	595.2107
Minimum	4.5260	0.00000	0.00000	0.0000	-433.9791
Std. Dev.	0.0780	1013.055	1305.769	159.9485	241.9001
Skewness	-0.4495	-1.69248	-1.691607	-0.73366	-0.75781
Kurtosis	1.9466	8.43867	4.078789	1.57718	3.00120
Jarque-Bera	2.4772	53.00629	16.2878	5.3958	2.96715
Probability	0.2897	0.00000	0.000291	0.06734	0.22682
Sum	145.1268	12330.4	88955.03	7041.59	6198.70
Sum Sq. Dev.	0.1829	3078843	51151015	767505.9	1755470

Source: Authors Calculations using e-views software

Table 1 demonstrates the descriptive analysis of variables, in this research, data is being estimated to calculate the impact of green products, green technology, research and development and consumer behavior on firm performance.

The mean value of firm performance is 84.6815, the value of median is 4.699, the maximum value is 4.8037, the minimum value is 4.5260, the value of standard deviation is 0.0780, and skewness is the test for normality.

Generally, if skewness value is equal to zero then distribution will be symmetric while, on the other hand, if the value of skewness is less than or more than zero then distribution will be negatively or positively skewed respectively, the negative skewness of FIRP is -0.4495, the value of kurtosis is 1.9466 which shows the distribution of kurtosis coefficient is platykurtic, value of Jarque-Bera is 2.4772, probability is 0.2897, sum is 145.1268 and sum of sq. dev is 0.1829.

The mean value of GRTEC is 3946.141, the value of median is 3930.000, the maximum value is 5288.00, the minimum value is 0.0000, the value of standard deviation is 1013.055, skewness is the test for normality the negative skewness of GRTEC is -1.6924, the value of kurtosis is 8.4386 which shows the distribution of kurtosis coefficient is platykurtic, the value of Jarque-Bera is 53.0062, probability is 0.0000, sum is 122330.4, sum of sq. dev Is 30788433.

The mean value of GRPRO is 2869.517, the value of median is 3421.419, the maximum value is 3744.625, the minimum value is 0.0000, the value of standard deviation is 1305.769, skewness is the test for normality the negative skewness of GRPRO is -1.6916, the value of kurtosis is 4.0787, which shows the distribution of kurtosis coefficient is platykurtic, the value of Jarque-Bera is 16.2878, probability is 0.000291, sum is 88955.03, sum of sq. dev is 51151015.

The mean value of R&D is 227.1483, the value of median is 323.38, the maximum value is 387.3800, the minimum value is 0.0000, the value of standard deviation is 159.948, skewness is the test for normality the negative value of skewness of R&D is -0.7336, the value of kurtosis is 1.5771, which shows the distribution of kurtosis coefficient is platykurtic, the value of

Jarque-Bera is 5.3958, probability is 0.067344, sum is 7041.597, sum of sq. dev is 767505.9.

The mean value of CONB is 399.95,83 the value of median is 230.9811, the maximum value is 595.210, the minimum value is -433.979, the value of standard deviation is 241.9001, skewness is the test for normality the negative value of skewness of CONB is -0.7578, the value of kurtosis is 3.0012 which shows the distribution of kurtosis is platykurtic, the value of Jarque-Bera is 2.9671, the probability is 0.2268, the sum is 6198.706, sum of sq. dev is 1755470. The results of that data are normally distributed.

4.2 Correlation Matrix

This tool is used to determine linear relationship between pairs of variables. The correlation may be positive or negative or zero. The correlation estimated results are presented in [Table 2](#)

Table 2

Correlation Matrix results

Variables	FIRP	GRTEC	GRPRO	R&D	CONB
FIRP	1				
GRTEC	0.699591	1			
GRPRO	0.054398	0.01897	1		
R&E	0.037856	0.51010	-0.9809	1	
CONB	0.89600	0.03761	0.00764	0.11590	1

Source: Author's calculation using e-views software

[Table 2](#) describe that the firm performance (FIRP) has a positive relation between green technology (GRTEC), green products (GRPRO), research and

development (R&D), consumer behavior (CONB) and coefficient values are 0.699, 0.054, 0.0378 and 0.8960, respectively. GRTEC has positive association with GRPRO, R&D and CONB as the correlation coefficient values are 0.0189, 0.5101 and 0.0376, respectively. GRPRO has negative association with R&D as its correlation coefficient value is -0.9809 and it has positive relation with CONB and its value is 0.0076. The R&D has positive correlation with CONB as its value is 0.1159. In short, the results of correlation are mixed.

4.3 ADFs Unit Root test:

This test is used to check stationarity among variables. For this purpose, first we check stationary of variables whether they stay stationary at the level or at the first difference. If all the variables are stationary at the same level than we can use Ordinary Least Square method. If variables stay stationary at first difference, we apply co-integration analysis and if variables are mixed i.e. they stay stationary equally at level and first difference then we can use Auto-Regressive Distributed Lag ARDL Model. The estimated results of ADF test are shown in [Table 3](#).

Table 3

Results of ADF Test

Variables	Level		1 st Difference		Conclusion
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	
FIRP	-1.0369 (0.1493)	-8.7230* (0.0000)	-4.8602* (0.0000)	-6.9944* (0.000)	Stationary at level's intercept and trend
GRTEC	3.5385* (0.0198)	-4.0903* (0.0040)	5.2385* (0.0000)	5.3158* (0.0000)	Stationary at level's intercept

GRPRO	-15.5700* (0.0000)	-14.3216* (0.0000)	-14.6628* (0.0000)	-7.0716* (0.0000)	Stationary at level's intercept
R&D	-6.5725* (0.0000)	-14.0324* (0.0000)	-11.6097* (0.0000)	-11.5287* (0.0000)	Stationary at level's intercept
CONB	- 1.2738656 (0.1014)	-8.4994* (0.1000)	-9.3344* (0.0000)	-30.2367* (0.0000)	Stationary at 1 ST difference intercept

Source: Author's calculations using e-views software

The results in Table 3 show that some variables are stationary at level whereas some are at the first difference, so we can use the Auto-Regressive Distributed Lag (ARDL) model for further analysis. According to estimates, our first variable, FIRP is stationary at level trend and intercept with probability value 0.0000. Second variable, which is GRTEC, is stationary at level intercept with probability value 0.0198. GRPRO is stationary at level intercept with probability value 0.0000. R&D is stationary at level intercept with probability value 0.0000. CONB is stationary at 1st difference intercept with probability value 0.0000. Our results showed that variables are stationary at different levels, so we can employ ARDL model for analysis of data.

4.4 ARDL Analysis:

The model of this study is:

$$\text{FIRP}_{it} = \beta_0 + \beta_1 \text{GRTEC}_{it} + \beta_2 \text{GRPRO}_{it} + \beta_3 \text{R\&D}_{it} + \beta_4 \text{CONB}_{it} + \hat{u}_{it}$$

Dependent variable: FIRP (Firm's Performance). The estimated results of ARDL model are presented in Table 4.

Table 4

ARDL Model estimated results

Variables	Coefficient value	Std. error value	t-statistics value	Probability value
GRTEC	1.42005	7.3506	1.9393	0.0634
GRPRO	3.73005	5.8306	6.4019	0.0000
R&D	0.00015	4.8805	3.1479	0.0041
CONB	5.9200	2.9505	2.0085	0.0551
C	4.6537	0.0355	130.841	0.0000

Source: calculated by author using software

In the ARDL model, the firm's performance was dependent variable whereas all other variables are independent variables. As per estimated results depicted in Table 4, the green technology (GRTEC) has a positive and significant relationship with firm performance (FIRP). The probability value of GRTEC is 0.0632 which shows a statistically significant relationship with FIRP. It means one unit increase in GRTEC is associated with an increase in the FIRP by 14.2 %, if all other factors remain constant. As the adoption of green technology increases, it in turn enhances the firm's performance. These findings confirm the results of Ae (2012), Geng et al. (2013), Daniele et al. (2017); Zhang et al. (2018), who found positive association between green technology and firm performance. These studies generally suggest that the adoption of green technology positively influences the firm performance.

Green product (GRPRO) has a positive and significant impact on firm performance (FIRP) as the probability value is 0.0000 so; this variable has also significant statistical relationship with FIRP. It means one unit increase in GRPRO is associated with an increase of firm performance (FIRP) by 37.3%.

As the use of green products increases it, in turn, will increase firm's performance. These results are consistent with the findings of [Aykut, et al. \(2015\)](#); [Balaceanu, \(2020\)](#) who identified the impact of green product innovation on firm performance. Firms manufacturing green products may experience increased consumer demand, market share, and revenue, contributing to improve overall performance of firm.

R&D has a positive and significant relationship with FIRP as the probability value of R&D is 0.0041. It means one unit increase in R&D is associated with an increase in firm performance by 0.015%. As the expenses on research and development increases the firm performance will likely to be increased. These results support to the findings of [Shen, Zhu, & Wang. \(2020\)](#).; [Raza, Chen, Tang, \(2022\)](#), who examined the role of R&D expenditure in promoting green innovation and improving firm performance. They also noted that R&D expenditure directed towards green innovation is expected to positively influence firm performance. Increased investment in R&D for green technology adoption and product development may lead to improved competitiveness, market presence, and innovation capabilities, ultimately enhancing firm performance.

Consumer behavior (CONB) has a positive and significant relationship with firm performance (FIRP) as probability value of FIRP is 0.0551. It suggests that one unit increase in consumer behavior (CONB) is associated with an increase in firm performance by 59.2%. Consumer behavior is the key component that may affect the firm's performance. As the consumer shows interest in firm's products the sales of firm will increase significantly. The relationship between consumer behavior towards green products and firm performance is statistically significant. These results are in line with the

findings of [Jacopo, \(2018\)](#); [Carsten et.al, \(2018\)](#), who also studied consumer behavior towards green products. They concluded that consumer behavior towards green products can significantly impact firm performance, particularly in industries like textiles. Positive consumer perceptions and preferences for green products may lead to increased sales, market share, and brand reputation, thereby improving overall firm performance.

4.5 Robustness checks

In order to make robustness checks we used diagnostic test suggested by Breusch-Pagan-Godfrey LM test for autocorrelation and heteroscedasticity among variables in the model. These tests are used to identify the problems of Auto-correlation and Heteroscedasticity and robustness of the model. The estimated results of diagnostic tests are presented in [Table 5](#).

Table 5

Results of Auto-Correlation and Heteroscedasticity test

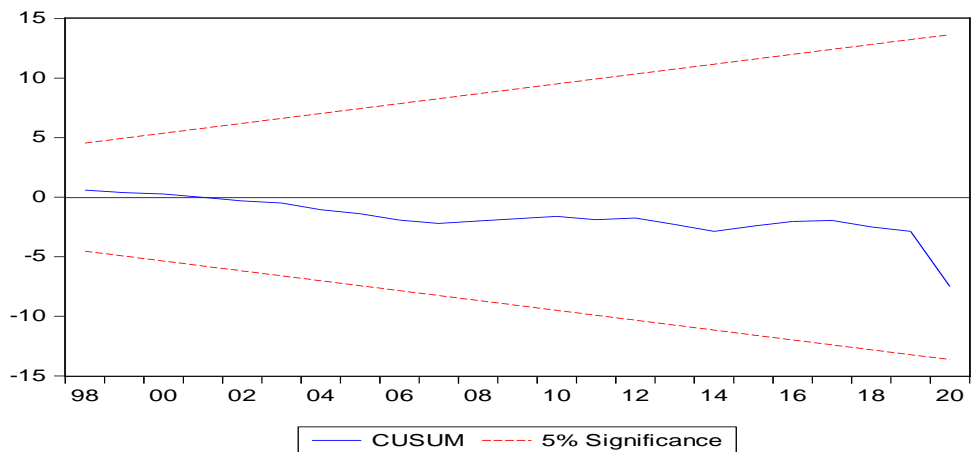
Name of tests	F-statistics value	Probability
Auto-correlation LM test Breusch-Pagan-Godfrey	2.016504	0.1551
Heteroscedasticity (Breusch-Pagan-Godfrey)	1.37900	0.2685
Harvey test	1.388138	0.2655
Glejser test	1.403951	0.2604
White test	1.684488	0.158004

Source: Estimated by author using software.

In table 5, the F-statistics value of serial correlation is 2.0165 and its probability is 0.1551 which is greater than 0.05 so it is statistically insignificant. We accept null hypothesis, which states that there is no serial correlation and reject alternative hypothesis, which says that there is serial correlation issue in the model. The F-statistics values of heteroscedasticity, according to Breusch Pagan Godfrey, Harvey, Glejser and white test, are 1.3790, 1.38813, 1.4039 and 1.6844, respectively and their probability values are 0.2685, 0.2655, 0.2604 and 0.1580, respectively, which are greater than 0.05. We accept null hypothesis that there is no heteroscedasticity in the model.

4.6. Stability Test

The CUSUM and Sq. CUSUM test, is used to check stability of the data during the study period. The data are plotted in the Figure 2 and 3, which shows the blue lines lies between the red critical lines so we can say that our model is stable at 5 percent significant level.



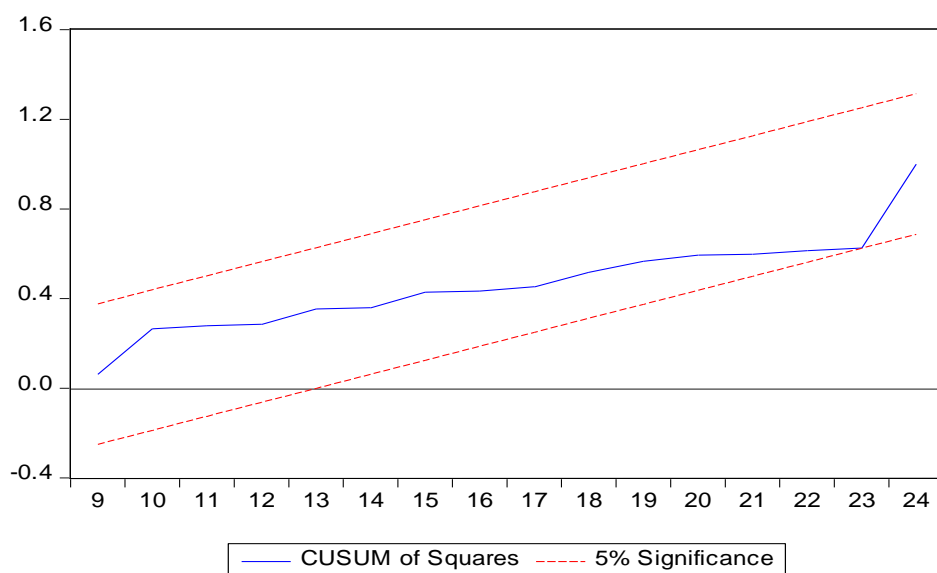


Fig 3 & 4: CUSUM & CUSUM of Square

5. Discussion

5.1 Main Findings

Although green technology is widely used in emerging economies and in developed nations, there is still a dearth of study on this topic in Pakistan. Therefore, the author decided to investigate the impact of green technology, green products innovation, consumer behavior on firms' performances in Pakistan. Primary data was used in this study and this data was collected from 425 employees of 10 large textile units operating in four big cities, Karachi, Lahore, Faisalabad and Multan through a structure questionnaire surveys. The firm performance was a dependent variable while green technology adoption, green product innovation, Research and Development (R&D) and consumer behavior were independent variables. The statistics techniques such as Correlation matrix and ARDL mode were used to examine relationship between selected variables. The results of correlation matrix demonstrate positive correlation between firm performance, green technology, green

product innovation, research and development (R&D) and consumer behavior. Green technology has also positive correlation with green product, R&D and consumer behavior. However, Green product innovation has negative association with R&D but positive relationship with consumer behavior. The R&D has positive correlation with consumer behavior. In a net shell, except green product, all other variables have positive correlation with each other.

According to ARDL model results predict that, green technology has positive impact on firm performance in the long run, if all other factors remain constant. This relationship is statistically significant. These results are in line with findings of [Zhang et al. \(2018\)](#); [Jiang, et al. \(2019\)](#). [Adebiyi, \(2020\)](#), [Aghion., Angrist, & Griffith, \(2023\)](#). who found positive association between green technology and firm performance, confirming that green technology boosts firm performance.

The empirical results also product that green product innovation (GRPRO) has a positive and significant impact on firm performance (FIRP) and the relationship between these two variables is statistically significant, suggesting that textile firms must focus on green product innovation to gain sustainability. These results are consistent with the findings of [Ma et al. \(2018\)](#); [Ghosh., Shah, & Swami, S. \(2018\)](#), who also identified positive impact of green product innovation on firm performance.

The ARDL Model results relating to Research and Development (R&D) predict that R&D also has a positive but insignificant impact on firm performance in Pakistan. However, the positive relationship indicates if R&D expenditures increase the firm performance will definitely move up. These results support to the findings of [Tang et al. \(2018\)](#), [Ma et al. \(2018\)](#); [Raza, Chen & Tang. \(2022\)](#), who found that R&D expenditure directed towards

green products innovation is expected to positively influence firm performance. Increased investment in R&D for green technology adoption and green product innovation may lead to improve competitiveness, market penetration, and innovation capabilities, ultimately fostering firm performance.

The ARDL results predict that consumer behavior (CONB) toward green product innovation has a positive and significant impact on firm performance (FIRP). The relationship between consumer behavior toward green products innovation and firm performance is statistically significant. It suggests that textile firms in Pakistan should expand their marketing network and launch campaign to introduce their green products in domestic and global markets to attract consumers. It will definitely have a positive impact on their sales and profitability as well as sustainability in the long term. These results are in line with the findings of [Jacopo, \(2018\)](#); [Jawad & Sağsan, \(2019\)](#); and [Adjengdia, \(2020\)](#), who identified significant impact of consumer behavior towards green products on firm performance. Thus, it can be concluded from the above results that positive consumer perceptions and preferences for green products may lead to increased sales, market share, and brand reputation, thereby improving overall performance of textile firms in Pakistan. The diagnostic tests were used to check problems of autocorrelation and Heteroscedasticity in the model, and the finding show that there is no such problem in the model. The distribution of data and model stability was checked through CUSUM and Sq. CUSUM tests and data distribution and model were found stable in the study period.

5.2 Forecasting technological and green product innovation impacts

Technology is considered as a vehicle of change and only those companies survive which adopt cutting technology and adapt its business model accordingly. The empirical results of ARDL dynamic model demonstrate that green technology has statistically significant positive relationship with firm performance and numerically if one-unit changes in green technology there will likely be increased in firm performance by 14.2%. In this way, we can forecast that any textile unit using green technology is likely to improve its output by 14.2% if all other factors remain constant. This forecast is good news for Pakistan's textile industry to make itself competitive in world market by opting green technology. As it has been noted that Pakistan's textile industry has already started green product innovation by recycling used imported clothes and making variety of textile items and selling them in the posh domestic and foreign markets. This green product innovation method does not only reduce the need of raw cotton and yarn but also significantly cut production costs and result in high profitability.

Data Statement

The data that used in this study and that supports its findings will be made available on strong request.

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Declaration of competing interests

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