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FINANCING SUSTAINABLE ENERGY MANAGEMENT: EVIDENCE FROM MANUFACTURING FIRMS IN PAKISTAN

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Green finance, sustainable energy management, energy efficiency, energy performance, environmental performance, PLS-SEM, manufacturing firms and Pakistan.

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ABSTRACT

Green financing is increasingly seen as a useful instrument for directing funding toward low-carbon development and energy-efficient and renewable energy projects. One of the main impediments to the development of sustainable energy management in high-energy-intensive businesses in developing nations is the availability of affordable and easily accessible financing. The influence of green finance on sustainable practices on the energy and environmental performance of manufacturing initiatives in Faisalabad, Pakistan's largest textile city, was thoroughly examined in this study. This study also looked at the moderating effect of regulatory pressure and the impact of senior management commitment. A cross-sectional, qualitative survey design was employed. By selecting key informants who are typical of the companies' owners, plant managers, energy managers, and finance managers structured questionnaires were utilized to gather data from 312 manufacturing companies. The computer application known as Smart-PLS 4 was used to examine the data using partial least squares structural equation modeling (PLS-SEM). Both the measurement model's convergent and discriminant validity were strong. Sustainable energy management strategies, which have strong beneficial benefits on energy performance and environmental performance, were further enhanced by access to green finance. The effects of green finance on both outcomes were partially mediated by sustainable energy management practices. The most significant elements influencing sustainable energy management were top management commitment and fortifying the connection between green financing and energy management techniques, with regulatory pressure acting as a reinforcer. It accounted for 36% of the variation in environmental performance, 41% of the variation in energy performance, and 52% of the variation in sustainable energy management techniques. Companies' gains from green finance are mostly due to sustainable energy management, the study says. It advocates for easier and simpler concretional green finance that is linked with energy audits and energy management system certification to ISO 50001, and tougher requirements.

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Introduction

Unprecedented reserves will be required to make the energy transition to a low-carbon system. Global investment in clean energy has grown dramatically, according to the International Energy Agency (IEA), although it is still mostly concentrated in China and established economies, with very little going to emerging and underdeveloped nations (International Energy Agency IEA, 2024). IRENA, the International Renewable Energy Agency further estimated that the investment needed in energy transition technologies will need to significantly ramp up, particularly in developing countries, to ensure global warming remains within 1.5 °C (International Renewable Energy Agency IRENA, 2023). This can only happen if there is promotion of private and public investments in energy efficiency and renewable.

A crucial answer to this is green finance. Any financial product or service that provides financing for environmentally friendly projects, like green credit and concessional loans. Green finance can stimulate private investment in clean energy and improve investments returns, and reduce investment risk (Taghizadeh-Hesary & Yoshino, 2019). Policy measures like tax spillovers and credit guarantees (Taghizadeh-Hesary & Yoshino, 2020) can make renewable investments a more attractive prospect for investors. The national climate commitments resulting from the Paris Agreement have led to a rapid growth in the market for green bonds, according to the studies carried out (Tolliver et al., 2020). A study about green bond literature found that green bonds are emerging as an increasing source of financing sustainable development (Bhutta et al., 2022).

There has been an explosive growth of research on green finance. According to the bibliometric analysis, the research on green finance has gradually been enhanced, and more attention is now being paid to the energy and climate policy implications of green finance (Zhang et al., 2019). A world overview revealed a broad spectrum of tools and results for green finance research and evidence is still rather scarce in developing countries (Ozili, 2022). Renewable energy finance studies demonstrate that policy design has a large impact on private reserves (Polzin et al., 2019), and that the cost of resources for renewable energy declines significantly in well-established countries, increasing the cost of the energy transition (Steffen, 2020).

This is especially the case at the firm level as there are several cost-effective implementation opportunities to increase energy efficiency that are not realized. This is recognized as the energy-efficiency gap and has been blamed on social problems, market fiascoes and financing problems (Gerarden et al., 2017). Energy management (energy monitoring, control, and improvement) is seen as a way to meet this need at an organization and involves systematic monitoring, control and improvement of energy use (Schulze et al., 2016). The International Standard for the execution of energy management systems (EMS) to achieve continuous improvement of energy performance (International Organization for Standardization ISO, 2018) is named International Organization for Standardization (ISO) 50001.

These issues are relevant in this context of Pakistan. A high energy cost, frequent shortage of energy supplies and dependence on imported fossil fuels is severe constraint on the manufacturing industry of the country. The State Bank of Pakistan (SBP) has also launched a Sponsoring Scheme for

Renewable Energy (SBP, 2016) to be responsible for concessional financing for renewable energy schemes and Green Banking Guidelines (SBP, 2017) for banks to include environmental risk management and green finance. The government of Pakistan had targeted growing the contribution of Renewable Energy in the national power mix as per the Alternative and Renewable Energy Policy 2019. However, little is known about how access to green finance can really help Pakistani manufacturers to implement sustainable energy plug-ins and expand their energy and environmental performance.

The city of Faisalabad, the hub of textile industry in Pakistan is a proper place for conducting this investigation. Energy use is a problem in the textile process of spinning, weaving, dyeing and finishing, and the high cost of electricity and gas has impacted the competitiveness of these businesses. The present study was thus aimed at (a) investigating the connection between access to green finance and the implementation of sustainable energy management practices, (b) exploring the impact of sustainable energy management practices on energy performance and environmental performance, (c) testing if sustainable energy management practices mediates the association between green finance and firm performance, and (d) examining the role of top management commitment and regulatory pressure.

Literature Review

Empirical evidence has shown that green finance not only has a positive impression on environmental and energy outcomes, but also on their efficiency. The results on the analysis of corporate green bonds showed that the ecological performance of the issuer will get better after the issuance of the green bond, and the green bond will attract long-term and environmental investors (Flammer, 2021). The study conducted in China revealed that green finance was found to have a progressive effect on green TFP, primarily through technological advancements (Lee & Lee, 2022). In China, the research at the province level revealed that green finance contributed to the progression of the budget and enhancement of the environment (Zhou et al., 2020). A research that merged green finance and fintech revealed that these tools facilitated environmental protection, which led to a reduction in pollution (Muganyi et al., 2021). The green finance results of analysis using the vector error correction model also showed that the green finance considerably affects the increase in non-fossil energy usage and the reduction of carbon intensity (Ren et al., 2020).

The results are reinforced by trans-national findings. To identify developed and developing countries with a noticeable gap in their capacity to finance low-carbon development, a Low-Carbon Finance index for such countries was developed (Mohsin et al., 2021). An analysis of N-11 and BRICS showed that green finance helped to address climate change and was very important for emerging economies (Nawaz et al., 2021). Furthermore, green finance has been identified as one of the important components that can help achieve the SDGs and enhance energy security, given that conventional finance is not investing enough in long-term investments, particularly in clean energy investments (Sachs et al., 2019).

The market mechanism and policy instruments play an essential role in the green finance mechanism. The study suggests that the companies with better environmental scores receive better

and shorter credit periods, and the companies with worse environmental scores receive tight credit terms (Xu & Li, 2020). Green finance may also be an answer to the financing problem of green growth (Yu et al., 2021). Green finance and policies based on markets are viewed as synergizing means to protect the environment (Wang & Zhi, 2016). That's not always the case, however, with financing. Green financial regulation has led to evidence of greenwashing and monitoring and verification are needed to ensure the actual improvement in the environment (Zhang, 2022). The results for financial barriers, which were also confirmed by the evidence from European manufacturing enterprises, agree with what was discovered previously.

Energy managing the process of converting finance to energy saving. Studies on energy intensive industries in Sweden identified that energy supervision practices such as monitoring of energy use, energy policies and employee engagement contribute to the application of the potential for energy efficiency (Thollander & Ottosson, 2010). In a study of Swedish industry, Johansson & Thollander (2018) discovered three main elements to be successful in in-house energy management: top management support, dedicated staff and long-term strategies based upon a barrier and driver review done by the research team. For manufacturing companies, the level of capital investment, information and management commitment played an important role in determining their energy efficiency decisions (Trianni et al., 2016). A methodical analysis of drivers for energy efficiency in manufacturing companies found that the economic, organizational and management drivers like financial incentives were important in explaining the energy efficiency gap (Solnørdal & Foss, 2018). Building on the concept of the energy efficiency gap, it has been found that savings can be significant over and above investment in energy efficiency technology, through energy supervision practices (Backlund et al., 2012).

The outcomes show that green finance is basic tools to enhance energy and environmental performance, as it is likely to stimulate the manufacturing companies to implement sustainable practices in energy management. The research also reveals that green financing is a substantial driver of the use of energy-efficient practices when it is available at good prices, with backing from senior management and regulatory pressure. The advantages of green finance, however, are to be enjoyed through effective implementation of the strategy on sustainable energy management.

The research suggests the need to streamline green financing and to tie in financing with energy audits and ISO 50001 certification. It also highlights the importance of the role of regulation and management in increasing sustainable industrial production. The study is, however, confined to manufacturing industries in Faisalabad only and the study should be extended to other industrial sectors and other regions of Pakistan.

The relationship between these can be theoretically described by the natural-resource-based view of the firm. It states that there are three ways a company can gain economical advantage: pollution prevention (PP), sustainable growth, and product stewardship (Hart & Dowell, 2011). In this view, green finance is the means, sustainable energy management is the ability and better energy and environmental performance is the result. The key to transform the resources into capabilities is top

management commitment and the incentives for effective use of green finance are regulatory pressure.

Based on the literature, implementation of energy management practices can be linked to positive effects of green finance on energy and environmental results. Most indication though is derived from China and developed economies and based on macro-level, or listed-firm data. Only a handful of studies have looked at, at the enterprise level, the connection between access to green finance and sustainable energy management and firm performance in Pakistan; or the impact of management commitment and regulations on this process. This literature led to the following hypotheses being tested:

H1: It has a positive relationship between access to sustainable energy and green finance management practices (businesses).

H2: Top management commitment has positive impacts on sustainable energy management practices.

H3: Good energy management practices have a positive impact on energy performance.

H4: Sustainable energy management practices have a positive impact on environmental performance.

H5: Access to green finance has a positive effect on Energiewende.

H6: Green finance positively impacts on environmental performance.

H7: Sustainable energy management practices mediate the connections between access to green finance and (a) energy performance and (b) environmental performance.

The "access to green finance" positively moderates between the pressures of regulatory and sustainable energy management practices (H8).

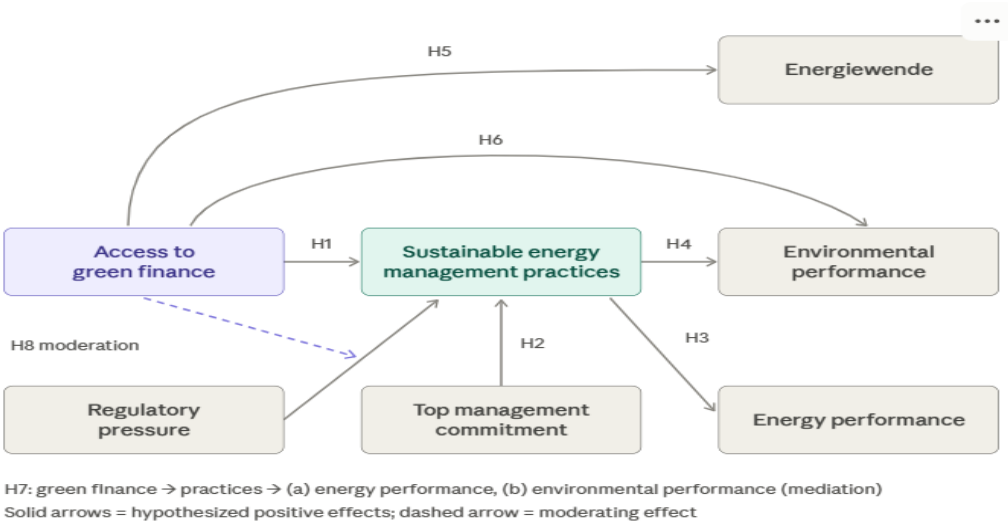


Figure 1: Conceptual framework of the study.

Methodology

Research Design

In this study, the research was conducted using the quantitative research method with a positivist research philosophy and a cross-sectional type of research. The deductive approach was used; hypotheses were inductively derived from theory and existing research was tested with primary data. This study used the method of partial least squares structural equation modeling (PLS-SEM), because in this study the research model contained mediating and moderating relationships, and the research was a predictive study.

Study Population

The population comprised manufacturing firms in Faisalabad which were involved in textile spinning, weaving, dyeing and processing, garments and allied manufacturing. The membership list of Faisalabad Chamber of Commerce and Industry was the sampling frame and then manufacturing companies with 20 or more employees were selected as these are likely to have formal energy and financial management functions.

The sample size

G-Power 3.1 was used to calculate the required number of sample items (Faul et al., 2009). For a seven predictor model with a power of.95 and a significance level of.05, the minimal sample size for this medium effect size (f^{*2} = 0.15) was 153. Industry sub-sector was used as the stratification variable for the sample selection of the 450 firms, using the proportionate stratified random sampling technique, due to non-response and return with incomplete data. Thirty-three-fourths

(334) questionnaires were received, and 312 were complete and usable (69.3% response rate). This sample was deemed satisfactory and above the minimum requirement.

The unit of analysis for this unit was the firm. Interviews were conducted with one key informant in each firm who was knowledgeable about both the energy use and financing decisions. These informants were owners, plant or general managers, energy or utility managers, and finance managers.

Measurement Instrument

A structured questionnaire was designed having two parts. The first section collected data on respondent characteristics, firm characteristics, etc. The second was measured by six constructs, each of which was measured by multiple items each measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The research on green finance focused on availability, affordability and ease of accessing green financing and concessional financing of energy projects, following the framework of green financing by SBP (2016, 2017) and previous research. The sustainable energy management practices (six items) were related to energy policies, monitoring and metering, energy audits, the implementation of efficiency technology, the use of renewable energy and training staff based on the energy management framework of Schulze et al. (2016) and the requirements of ISO 50001. Top management commitment (four items) and regulatory pressure (four items) have been taken from the energy efficiency barriers and drivers literature (Johansson & Thollander, 2018; Trianni et al., 2016). Energy performance (four items) quantified perceived decrease in energy intensity and energy costs in the last three years. Environmental performance (four items) was measured as decrease in emissions, effluents and resource waste. The questionnaire was content validated by 3 academic experts and 2 industry practitioners and a pilot test was conducted with 25 firms (not used in the main sample).

Data Collection

This information was gathered during four month periods of in-person visits and online forms. All respondents were guaranteed of confidentiality and secrecy, and participated on a voluntary basis.

Common Method Bias

One informational source was used and statistical and procedural remedies were employed to report common method bias. The respondent's anonymity was guaranteed; predictor items and outcome items were differentiated on the questionnaire; and the language of the items was neutral (Podsakoff et al., 2003). Statistically, a complete collinearity analysis was carried out. The common method bias was not a main problem as all the variance inflation factors were below 3.3 (Kock, 2015).

Data Analysis

SPSS version 27 was used to evaluate the data for missing values, outliers, and normalcy before Smart-PLS 4 was used for analysis (Ringle et al., 2022). There were two phases to the analysis (Hair

et al., 2022). The first phase examined the indicator's reliability (outer loading ≥.70), internal consistency reliability (Cronbach's α ≥.70 and composite reliability ≥.70), convergent validity (AVE ≥.50), and discriminant validity (HTMT <.85; Henseler et al., 2015). For the second step, the predictive relevance (Q^2predict) in the structural model with 10,000 subsamples was assessed together with the collinearity, path coefficients, bootstrapped path significance, coefficient of determination (R^2), and effect sizes (f^2). The two-stage interaction term was used to test the moderation, while the significance of the indirect paths (obtained using the bias-correct bootstrap confidence intervals) was used to test the indirect effects. Firm age and firm size were added as control variables.

Analysis

Profile of Firms and Respondents

The characteristics of the 312 firms are précised in table 1. Most of the sample was composed of textile spinning, weaving and processing companies. The majority of the firms was of medium size and majority of the respondents occupied senior managerial position. 38.5% of companies had secured any type of green and concessional energy funding.

Table 1: Profile of Sample Firms and Respondents

Characteristic	Category	n	%
Sub-sector	Spinning	74	23.7
	Weaving	81	26.0
	Dyeing and processing	63	20.2
	Garments	52	16.7
	Other manufacturing	42	13.5
Firm size (employees)	20–99	118	37.8
	100–499	141	45.2
	500 or more	53	17.0
Firm age (years)	Less than 10	64	20.5
	10–25	152	48.7
	More than 25	96	30.8
Respondent position	Owner / director	71	22.8
	Plant / general manager	104	33.3
	Energy / utility manager	69	22.1
	Finance manager	68	21.8
Obtained green or concessional energy finance	Yes	120	38.5
	No	192	61.5

Note. N = 312. Percentages may not total 100 because of rounding.

Measurement Model

Table 2 shows the outcomes of the measurement model. All the outer loadings were higher than .70 and Cronbach's α and composite reliability were higher than .80, while all AVE values were higher than .50. The results show that the indicators in this study are reliable, reliable internally and have convergent validity.

Table 2: Reliability and Convergent Validity of the Measurement Model

Construct	Items	Loadings range	Cronbach's α	Composite reliability (ρc)	AVE
Access to green finance (GFA)	4	.81–.89	.87	.91	.72
Top management commitment (TMC)	4	.78–.87	.85	.90	.69
Regulatory pressure (RP)	4	.76–.86	.83	.89	.66
Sustainable energy management practices (SEMP)	6	.77–.86	.90	.92	.67
Energy performance (EP)	4	.80–.88	.86	.91	.71
Environmental performance (ENV)	4	.82–.90	.88	.92	.74

Note. N = 312. AVE = average variance extracted.

Discriminant validity was assessed using the HTMT criterion (Table 3). All HTMT values were below .85, and bootstrap confidence intervals did not include 1, confirming discriminant validity.

Table 3: Discriminant Validity: Heterotrait–Monotrait Ratio (HTMT)

Construct	GFA	TMC	RP	SEMP	EP
TMC	.42				
RP	.38	.35			
SEMP	.61	.64	.47		
EP	.49	.44	.33	.72	
ENV	.46	.41	.39	.69	.67

Note. All values are below the .85 threshold (Henseler et al., 2015). GFA = access to green finance; TMC = top management commitment; RP = regulatory pressure; SEMP = sustainable energy management practices; EP = energy performance; ENV = environmental performance.

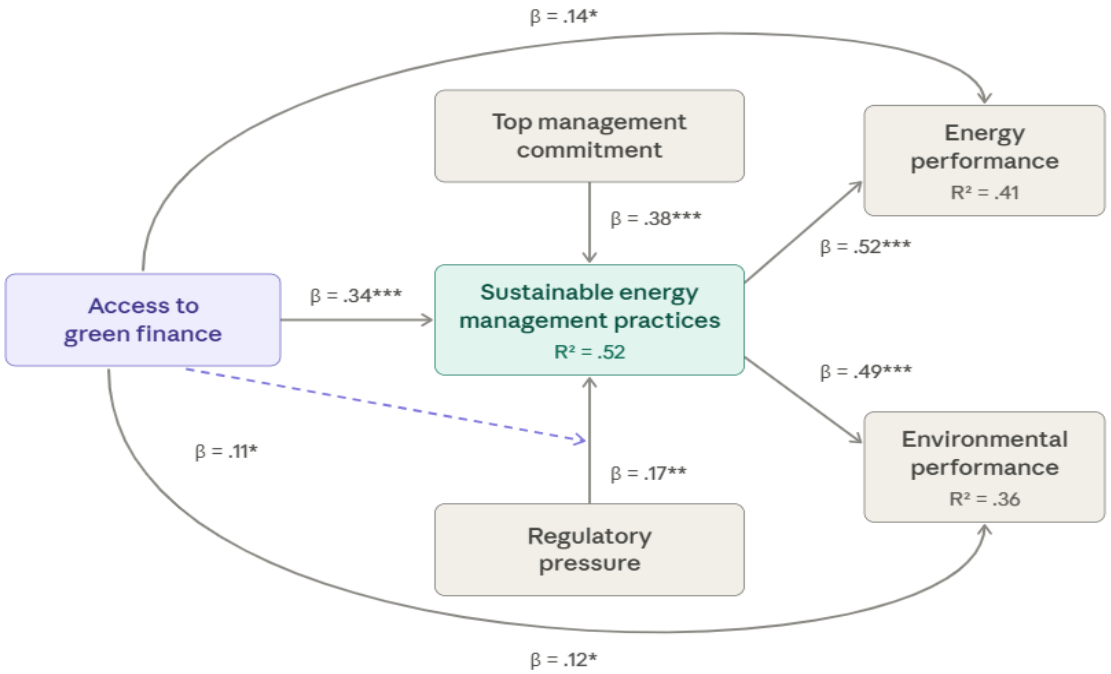
Structural Model

The variance inflation factors for inner models were in the range 1.21 to 2.14, which means there were no collinearity issues. The resulting path coefficients are given in table 4. In this regard, access to green finance positively influenced the sustainable energy management practices ($\beta = .34$, $p < .001$) which validated H1. Top management commitment had the most positive impact on sustainable energy management practices ($\beta = .38$, $p < .001$), which is consistent with H2. Sustainable energy management practices had a positive impact on energy performance ($\beta = .52$; $p < .001$) and environmental performance ($\beta = .49$; $p < .001$) in support of H3 and H4. There were also smaller, though still noteworthy, direct impacts of access to green finance on energy performance and environmental performance, respectively, in support of H5 and H6. The collaboration between green finance and regulatory pressure was positive and significant ($\beta = .11$, $p = .014$), thus supporting H8. The effects of control variables were not significant.

Table 4: Structural Model Results and Hypothesis Testing

Hypothesis	Path	β	t	p	f^2	Decision
H1	GFA → SEMP	.34	6.42	< .001	.17	Supported
H2	TMC → SEMP	.38	7.15	< .001	.21	Supported
H3	SEMP → EP	.52	9.84	< .001	.34	Supported
H4	SEMP → ENV	.49	9.02	< .001	.29	Supported
H5	GFA → EP	.14	2.58	.010	.03	Supported
H6	GFA → ENV	.12	2.21	.027	.02	Supported
H8	GFA × RP → SEMP	.11	2.46	.014	.03	Supported
—	RP → SEMP	.17	3.21	.001	.05	—
Control	Firm size → EP	.07	1.48	.139	.01	—
Control	Firm age → ENV	.04	0.86	.390	.00	—

Note. N = 312. Significance was evaluated by bootstrapping with 10,000 subsamples (two-tailed). f^2 values of .02, .15, and .35 indicate small, medium, and large effects. GFA = access to green finance; TMC = top management commitment; RP = regulatory pressure; SEMP = sustainable energy management practices; EP = energy performance; ENV = environmental performance.



*** p < .001, ** p < .01, * p < .05. Dashed arrow = moderating effect of green finance (GFA × RP).

Figure 2

Mediation Analysis

The outcomes of the mediation analysis are listed in Table 5. However, both of the indirect effects of access to green finance on energy performance and on environmental performance via the sustainable energy management practices were significant and the bias-corrected confidence intervals were not equal to zero. The direct effects also were important, and partially mediated both relationships, supporting H7a and H7b. Results from the variance accounted for (VAF) revealed that over half of the overall effect of green finance on each outcome mediated through energy management practices.

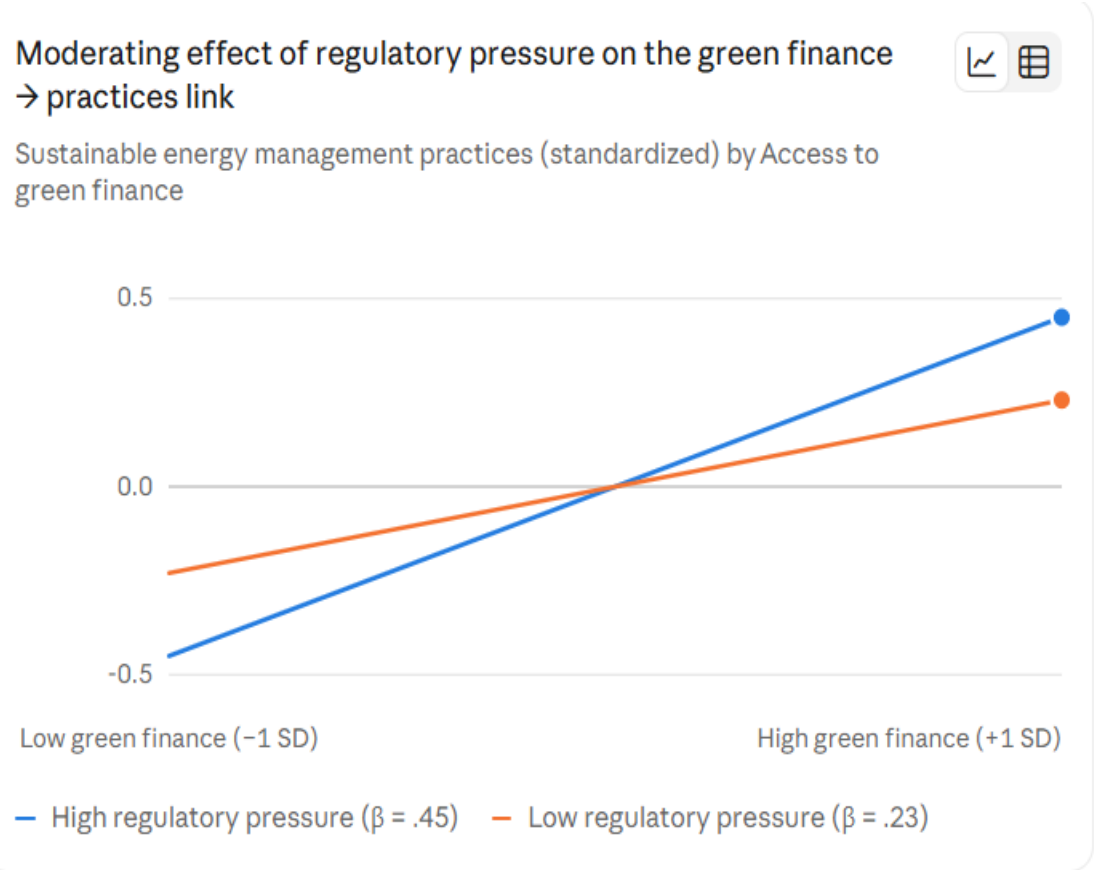


Figure 3

Table 5: Mediation Analysis: Indirect Effects Through Sustainable Energy Management Practices

Hypothesis	Indirect path	Indirect effect	t	95% BCa CI	Direct effect	VAF (%)	Mediation
H7a	GFA → SEMP → EP	.177	5.62	[.118, .241]	.14*	55.8	Partial
H7b	GFA → SEMP → ENV	.167	5.31	[.110, .229]	.12*	58.2	Partial

Note. N = 312. BCa CI = bias-corrected and accelerated bootstrap confidence interval (10,000 subsamples). VAF = indirect effect ÷ total effect.

* $p < .05$.

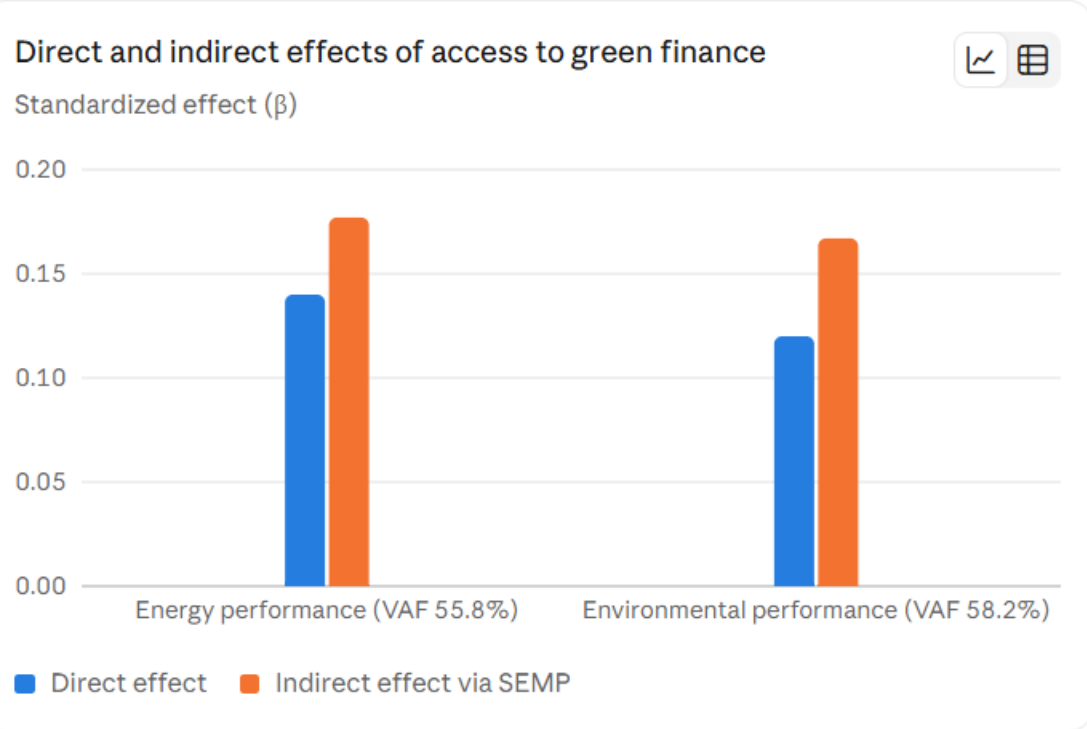


Figure 4: Direct vs indirect effects

Explanatory and Predictive Power

The explanatory and predictive power of the model is shown in Table 6. The model accounted for moderate explanatory power (52%, 41% and 36% of the variance in external variables sustainable energy management practices, energy performance and environmental performance, respectively). The Q^2predict values were all greater than zero, thus having predictive relevance. The standardized root mean square residual (SRMR) was .061, which is below .08, reflecting good model fit.

Table 6: Explanatory and Predictive Power of the Structural Model

Endogenous construct	R^2	Adjusted R^2	Q^2predict
Sustainable energy management practices	.52	.51	.47
Energy performance	.41	.40	.37
Environmental performance	.36	.35	.32

Note. N = 312. SRMR = .061.

Simple slope analysis revealed a significant increase in sustainable energy management practices with greater access to green finance at higher levels of regulatory pressure (β = .45) compared to

lower levels of regulatory pressure (β = .23). This means that when firms have credible regulatory expectations, this is when green finance works best.

Discussion

The research reveals that the availability of green finance has a positive influence on the energy and environmental performance of manufacturing companies in Faisalabad primarily through sustainable energy management practices. The results are in line with the evidence showing that green finance can enhance environmental outcomes and productivity (Flammer, 2021; Lee & Lee, 2022; Zhou et al., 2020). They also extrapolate that evidence to the firm-level manufacturing sector in Pakistan where there is less research.

The positive impact of green finance on energy management practices reinforces the notion that financing is a major reason for the energy-efficiency gap (Gerarden et al., 2017). Companies that had concessional green credits were more likely to perform energy audits, use energy-efficient equipment, invest in renewable energy (rooftop solar), and measure energy consumption. This discovery aligns with the evidence that financial issues can obstruct environmental innovation (Ghisetti et al., 2017), and that green finance can alleviate the constellated financing constraints affecting green investments (Yu et al., 2021). Overall, 38.5% of the manufacturers had received green finance, indicating that SBP's renewable energy financing scheme and green banking guidelines (SBP 2016 & 2017) are not yet reaching many manufacturers. This is indicative of the overall financing gap of clean energy in developing economies (IEA, 2024; Mohsin et al., 2021). Systematic energy management (Schulze et al., 2016; Thollander & Ottosson, 2010) has proved to be valuable as the strong influence of the energy management practices on the energy and environmental performance has been confirmed. The results are aligned with the argument made by Backlund et al. (2012) that efficiency gains are brought about by the energy management practices themselves, as well as the investment in energy technologies. The mediation result is of significant importance, especially in part, which one was. Two-thirds of the impact of green finance on performance happened through energy management practices, implying that finance can deliver its best results where firms have the organizational means to make good use of it. This discovery reinforces the natural-resource-based view, whereby resources need to be transformed into capabilities to provide environmental and competitive advantages (Hart & Dowell, 2011).

The most important influence on the sustainable energy management practices was top management commitment, coinciding with the findings of Solnørdal & Foss (2018), Trianni et al. (2016), and Johansson & Thollander (2018) that identified management support as a key factor for in house energy management. Owners of many of the Faisalabad companies, including some family-owned, make energy investment choices. If there's finance available, their awareness and commitment is the deciding factor as to whether it's used to make their energy improvements.

The moderating effect of regulatory pressure indicates that green finance works best if regulators, buyers and banks have credible expectations of firms to provide green finance. This is in line with the belief that the combination of market mechanisms and policies is effective for environmental protection (Wang & Zhi, 2016). It also emphasizes the importance of verification, as the lack of

evidence of greenwashing actually indicates that unmonitored finance does not lead to genuine improvements (Zhang, 2022). Green finance policies that bring together green finance with measurable outcomes like verified energy savings, can therefore be more effective.

Conclusion and Recommendations

This research revealed that green finance has a significant encouraging effect on sustainable energy management practices of manufacturing companies in Faisalabad and that sustainable energy management practices positively affect the energy and environmental performance of manufacturing companies has significant positive effect. Sustainable energy management practices partially mediated the association between green finance and both outcomes, suggesting that finance can make a difference when companies are able to manage their energy in a systematic way. The most important enabler for energy management was the top management commitment and the effect of green finance was strengthened by regulatory pressure. At the same time, less than 20% of companies had adopted any type of green or concessional financing of energy, in order to highlight the gap between policy intentions and the access to green financing in the companies.

SBP and commercial banks should streamline and improve the green credit facility for the manufacturers particularly SMEs by minimizing paperwork and facilitating credit guarantees and also educate the manufacturers about green business finance schemes. Green finance should be specific to energy audit and real energy savings; ensure that it is being spent on the highest return savings of energy and no greenwashing. Industry association like FC&I should promote energy management system, training should be provided to energy managers, awareness program should be carried out by energy manager's association and energy owners top management's association on energy management system ISO 50001. Regulators should reinforce and enforce environmental and energy efficiency norms and regulations more effectively and consistently as regulatory pressure is a main factor in strengthening the effect of green finance.

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