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Operational Efficiency in Pakistan's Textile Industry: A Panel Data Analysis from 2018 to 2023

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Abstract
This study examines the operational efficiency of Pakistan's textile industry from 2018 to 2023 using panel data analysis. The findings provide a comprehensive view of the industry's overall technical efficiency (OTE), pure technical efficiency (PTE), and scale efficiency (SE) over time. Efficiency levels fluctuated across the years, influenced by internal managerial practices, resource allocation, and broader economic factors. The textile sector in Pakistan plays a pivotal role in the national economy, significantly contributing to exports and employment. To ensure continued growth and efficiency, it is essential to evaluate the operational performance of textile firms within the country. The input-oriented Banker-Charnes-Cooper (BCC) model of Data Envelopment Analysis (DEA) is employed to assess the efficiency of textile firms. The results show varying efficiency patterns, with the highest efficiency observed in 2021 and significant challenges in 2019 and 2023. Analysis of returns to scale revealed that many textile firms operated under constant returns to scale, while firm size positively impacted efficiency. These findings align with Sustainable Development Goal 9 by emphasizing the need for technological advancement, resilient infrastructure, and sustainable industrial practices. Furthermore, Policymakers would implement targeted incentives for small and medium-sized businesses to easily access financial support and a regulatory framework that promotes sustainability in order to further improve operational efficiency in the textile industry. In order to build a more competitive and sustainable textile industry in Pakistan, it would also involve collaborations between the public and private sectors on infrastructure development, research and innovation, and skill development.

Keywords: Operational efficiency, Data Envelopment Analysis, textile industry, Pakistan, panel data, technical efficiency, returns to scale

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1. Introduction

The textile industry has long been a central pillar of Pakistan's economy, playing a significant role in driving economic growth and creating employment. According to the "Textile Division" (2018), this sector accounts for 57% of Pakistan's total exports, reflecting its importance in generating foreign exchange and sustaining national trade (Ghafoor & Iqbal, 2023). The industry also constitutes 8.5% of the country's Gross Domestic Product (GDP) as of 2018, making it one of the largest contributors to Pakistan's economic landscape. With its position as the second-largest employment generator in the country, the textile sector supports around 40% of the national workforce, making it a vital source of livelihood for millions of families.

In terms of global competitiveness, however, Pakistan's textile sector has underperformed. Despite its substantial domestic contribution, Pakistani textiles make up less than 5% of the global textile exports, lagging behind major textile-exporting countries such as China, India, and Bangladesh (Aneel & Gyarmati, 2022). Javed (2019) noted that the industry has yet to deliver its full potential, and there is much room for improvement in both output and the quality of goods. This underperformance is attributed to several factors, including outdated infrastructure, high production costs, and limited technological advancement.

Despite these challenges, the textile sector continues to show pockets of growth. In 2018, the sector experienced a 12.8% surge in textile goods on an annual basis, contributing USD 7.72 billion in semiannual revenues, which represented a 7.18% increase from the previous year (Memon et al., 2020). These numbers, while promising, also underscore the need for more robust policies and strategic initiatives to further elevate Pakistan's position in the global textile market. The industry's contribution to job creation and export earnings positions it as a crucial player in the nation's bid to stabilize its economy.

While the textile industry remains a major economic driver, it faces significant challenges that hinder its growth and potential. The industry struggles with a frail logistics network, which limits its ability to meet international demand and efficiently transport goods. This logistical weakness, coupled with rising production costs, has made it difficult for Pakistani textile firms to maintain competitiveness on a global scale. As the market becomes increasingly demanding and competitive, there is a pressing need for Pakistan's textile sector to improve its output and develop unique selling propositions (USP) to distinguish itself from competitors (Ali, 2022).

The devaluation of the Pakistani rupee against the US dollar has further exacerbated these issues. The weakened currency has increased the cost of imported raw materials, while failing to boost export competitiveness. As a result, textile exports plummeted by over 6% in November 2018, a trend highlighted by Azam (2022). This decline has been compounded by external factors, such as the US-China trade war, which disrupted Pakistan's wool exports to China, a key market.

Moreover, internal policy decisions have negatively impacted the industry's performance. The government's termination of tax exemptions on finished goods and the discontinuation of credit facilities on Value Added Tax (VAT) have raised production costs, further burdening textile manufacturers. This has led to a static growth rate, with textile exports remaining flat at $12.3 billion for the fiscal year 2019 (Memon, 2022). The closure of 125 textile companies serves as a stark

reminder of the sector's ongoing struggles. Despite these setbacks, certain segments of the industry have shown resilience. For instance, the export of off-the-shelf wearables increased by 33%, while clothing exports rose by 18%, and pillow sheets by 2%, reflecting some positive movement within the broader industry.
The study in the northern state of India using the DEA technique, provides the specific insights into the efficiency levels of textile operations, focusing on measurement of operational efficiency in the textile industry (Darji and Dahiya, 2023). Hence, this particular study sought to fill this gap by applying DEA to analyze the operational efficiency of the textile industry in Pakistan, pinpoint factors affecting efficiency, and thus provide insights into performance enhancement. The primary objective of this study is to assess the efficiency trends within Pakistan's textile sector from 2018 to 2023 by using Data Envelopment Analysis technique and to identify strategies for enhancing the operational efficiency of textile firms in Pakistan.

2. Literature Review

The textile sector holds a pivotal role in Pakistan's economy, serving as the backbone of its export earnings and a significant contributor to employment generation (Javed & Suleri, 2019). As the 8th largest exporter of textile products in Asia, the industry accounts for 8.5% of the national GDP (Board of Investment, 2025) and provides livelihoods to approximately 15 million people, equating to 38% of the country's workforce (Khan & Ahmad, 2018; Iqbal et al., 2010). Despite these contributions, Pakistan's share in the global textile trade remains less than 1%, highlighting a considerable potential for growth and enhanced operational efficiency (Wadho & Chaudhry, 2018).
Given Pakistan's position as the world's 4th largest producer and 3rd largest consumer of cotton, the textile industry (Tanveer & Zafar, 2012) has historically been a key driver of industrialization and economic development. With over 1,221 ginning units, 442 spinning units, and numerous processing and garment manufacturing facilities (Iqbal et al., 2010), the industry represents a complex value chain spanning large-scale organized sectors to fragmented cottage industries. However, the industry's fragmented nature and reliance on small and medium-sized units present challenges to operational efficiency and global competitiveness.
The global textile and clothing trade has experienced significant growth over the past few decades, evolving from $212 billion in 1990 to $612.1 billion in 2008 (Gereffi et al., 2010). This growth underscores the increasing global demand for textile and clothing products, with clothing trade expanding at a faster rate. However, the industry has also faced periods of economic turbulence. The global financial crisis of 2007–2008, for instance, drastically impacted trade volumes, resulting in a 12% drop in world trade in 2009, which exceeded economists' expectations (Cheung & Guichard, 2009). This decline led to reduced demand for textile and clothing products in developed economies, limiting expansion opportunities for exporters like Pakistan.
The textile industry, a cornerstone of Pakistan's economy, is facing numerous challenges that hinder its ability to compete globally and sustain its role as a major employment generator. These challenges include:
One of the most pressing challenges faced by Pakistan's textile sector is the energy crisis. Electricity shortages, with 8-10 hours of load-shedding daily and gas

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shortages for 2-4 days per week, have significantly disrupted production (Shah, 2011). The situation in Punjab has been particularly dire, with industrialists forced to shut down operations due to extended outages, leading to the loss of $1 billion in exports in the first half of 2012 alone. The textile industry loses approximately $305 million per month due to energy deficits (Shah et al., 2014).
The cost of raw materials, particularly cotton, has risen significantly, primarily due to inefficiencies in supply chains and the exploitation of growers by middlemen (Shah et al., 2014). Farmers often protest unfair pricing by burning crops, while some have switched to growing alternatives like sugarcane, further reducing cotton availability. This volatility in raw material prices increases production costs, making Pakistani textiles less competitive internationally.
Pakistan's textile sector is facing intense competition from countries like China, India, and Bangladesh (Ali et al., 2020). While China dominates with $55 billion in textile exports, Pakistan lags far behind at $13.8 billion. Bangladesh benefits from the European Union's *Everything But Arms* (EBA) scheme, granting it duty-free access to EU markets, a privilege not extended to Pakistan. These competitive disadvantages further erode Pakistan's market share globally (Sarwar, 2012).
The five-year textile policy (2009-2014) aimed to boost exports from $13.8 billion to $25 billion by introducing funds for technological upgrades and infrastructure improvement. However, the policy was largely unsuccessful due to inadequate funding and implementation failures. Only Rs. 24.75 billion was allocated against a planned Rs. 123 billion, with Rs. 6 billion worth of projects stuck in bureaucratic delays (Government of Pakistan, 2015).
The absence of robust research and development (R&D) institutions is another critical shortfall. Improved cotton quality and innovative product designs are necessary to compete globally. Unfortunately, Pakistan lacks the institutional support to drive these advancements (Nazeer, 2019).
Outdated machinery and technology further diminish productivity and product quality. Modernizing equipment is essential for the sector to enhance efficiency and produce value-added goods. However, the lack of new investments in this area exacerbates the problem (Shabalov et al., 2021).
High inflation, rising interest rates, and the devaluation of the Pakistani rupee have led to increased production costs. These factors make it difficult for the textile sector to compete on price in international markets (Bhatti et al., 2024).

3. Methodology
3.1. Data Envelopment Analysis (DEA)
Data Envelopment Analysis (DEA) is a quantitative method used to evaluate the relative efficiency of decision-making units (DMUs) that convert multiple inputs into multiple outputs. Developed by Farrell in 1957 and refined by Charnes, Cooper, and Rhodes in 1978, DEA has become a widely used tool for assessing performance in various sectors, including healthcare, education, banking, and manufacturing. Unlike traditional parametric methods, DEA is a non-parametric technique that employs linear programming to construct an efficiency frontier, against which the relative performance of each DMU is assessed. This method is particularly useful for identifying best practices and benchmarking performance (Chen & Chen, 2024).
In the textile industry, DEA can be employed to measure operational efficiency by considering inputs such as total assets, wages, operational expenses, and raw

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materials, and output such as sales revenue. By identifying efficient and inefficient firms, DEA provides insights into resource utilization and areas for improvement.

Mathematical Representation

Objective Function

$$Maximize \frac{\sum_{r=1}^{s} U_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \quad ....1$$

Subject to Constraint

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \forall j = 1, \dots, n \quad ....2$$

$$u_r > 0, v_i > 0, \forall r = 1, \dots., s; i = 1, \dots, m \quad ....3$$

Where:

- y_{rk} and x_{ik}: Represent the outputs and inputs of DMU k, respectively.
- ur and vi: Are the weights for outputs and inputs, respectively.
- s: Number of outputs.
- m: Number of inputs.
- n: Total number of DMUs.

Mathematical formulation determines the overall technical efficiency of a DMU. Equation (2) imposes a restriction in that the weights for all outputs and inputs of DMU k do not allow for an efficiency score greater than one when applied to any other DMU in the dataset. This applies pretty and justly, thereby allowing all DMUs to be compared. Equation (3) demands that all weights must not be less than zero for outputs (ur) and inputs (vi). This is because the weights point to trivial solutions if they aren't. This solution involves solving an optimization problem. Every distinct unit can be analyzed for its technical efficiency through the formulation of a linear programming problem.

3.2. Models in Data Envelopment Analysis (DEA)

DEA primarily consists of two basic models: The Charnes-Cooper-Rhodes (CCR) model and the Banker-Charnes-Cooper (BCC) model. Each model serves a unique purpose and operates under different assumptions (Fatehian, 2022).

3.2.1. The Charnes-Cooper-Rhodes (CCR) Model

The Charnes-Cooper-Rhodes (CCR) model assumes constant returns to scale (CRS), implying that changes in inputs lead to proportional changes in outputs. The model evaluates the overall technical efficiency of Decision-Making Units (DMUs) through a mathematical formulation which is transformed into a linear programming.

Mathematical Representation

Objective Function

$$Minimize \quad \theta_k - \varepsilon \sum_{r=1}^{s} s_r - \varepsilon \sum_{i=1}^{m} s_i \quad ....4$$

Subject to Constraints

$$y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} + S_r = 0 \qquad r = 1, \dots \dots, s$$

.......5

$$\theta_k x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} - s_i = 0 \qquad i = 1, \dots \dots, m$$

.......6

$$\lambda_j s_r s_i \geq 0 \qquad \forall j = 1, \dots \dots, n; \quad r = 1, \dots \dots, s; \quad i = 1, \dots \dots, m \quad ....7$$

where, λ_j represent the associated weighting of outputs and inputs of firm j, θ_k represent the technical efficiency of firm k, y_{rk} and x_{ik} shows the outputs and inputs

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of DMU k, "ε" is non-archimedean, meaning smaller than any positive actual number: ε>0 and s_r *and* s_i are the slack variables.

3.2.2. The Banker-Charnes-Cooper (BCC) Model

The Banker-Charnes-Cooper (BCC) model extends the CCR model by incorporating variable returns to scale (VRS). This model recognizes that DMUs may operate under increasing or decreasing returns to scale and decomposes efficiency into pure technical efficiency and scale efficiency (Zarrin & Brunner, 2023). The BCC model introduces a convexity constraint and provides a more nuanced view of efficiency, distinguishing between increasing, constant, and decreasing returns to scale.

The input-oriented BCC model transformed into linear programming can be described as:

<u>Mathematical Representation</u>

Objective Function

$$Minimize\ \ \theta_k - \varepsilon \sum_{r=1}^{s} s_r - \varepsilon \sum_{i=1}^{m} S_i \qquad ....8$$

Subject to Constraints

$$y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} + S_r = 0 \quad r = 1, \dots\dots, s \qquad ....9$$

$$\theta_k x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} - s_i = 0 \quad i = 1, \dots\dots, m \qquad ....10$$

$$\sum_{j=1}^{n} \lambda_j = 1 \qquad ....11$$

$$\lambda_j s_r s_i \geq 0 \quad \forall j = 1, \dots\dots, n; r = 1, \dots\dots, s; i = 1, \dots\dots, m \qquad ....12$$

where, "ε" is non-archimedean, meaning smaller than any positive actual number ε>0 , s_r *and* s_i represents the slack variables. λ_j is the associated weight of inputs and outputs firm j, θ_k shows the technical efficiency of firm k, x_{ik} and y_{rk} represent the inputs and output of DMU k and $\sum_{j=1}^{n} \lambda_j = 1$ is the variable return to scale constraint.

Denote the optimal solution of problem a DMU's performance is deemed fully (100%) efficient if and only if $\theta^* = 1$ *and all slacks* $s_i^{-*} = s_r^{+*} = 0$ and weakly efficient DMUs are those that meet both of these criteria. $\theta^* = 1$ *and all slacks* $s_i^{-*} \neq s_r^{+*} \neq 0$.

3.3. Data Collection

Secondary data for the research was obtained from the year 2018 to 2023 from the SBP website (financial statement of non-financial firm). Key data points include:

- **Inputs**: Raw material costs, operational expenses, total assets, and wages.
- **Output**: Sales revenue

3.4. Application of DEA to Textile Firms in Pakistan

The textile sector in Pakistan plays a pivotal role in the national economy, significantly contributing to exports and employment. To ensure continued growth and efficiency, it is essential to evaluate the operational performance of textile firms within the country (Aneel et al., 2022).

The input-oriented BCC model was employed to assess the efficiency of the Decision-Making Units (DMUs), i.e., textile firms. In this study, the inputs include:

- Total assets

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- Wages
- Operational expenses
- Raw materials

The output is represented by:

- Sales revenue

This analysis benchmarks firms against the efficiency frontier, identifying those that optimize their resources and those that lag behind. The results provide actionable insights for improving resource allocation, reducing wastage, and enhancing productivity.

4. Empirical Findings

4.1. Efficiency Analysis of Pakistan's Textile Industry (2018-2023)

The panel data analysis of Pakistan's textile sector reveals notable fluctuations in operational efficiency across the six-year period. Table 1 presents the comprehensive efficiency scores for the 69 textile manufacturing units analyzed.

Table 1: Efficiency Scores of Textile Manufacturing Units in Pakistan (2018-2023)

Year	Efficiency Type	Min	1st Quartile	Mean	Median	3rd Quartile	Max	SD
2018	OTE	0.05	0.30	0.59	0.64	0.94	1.00	0.32
	PTE	0.06	0.37	0.65	0.70	1.00	1.00	0.31
	SE	0.14	0.90	0.90	0.97	1.00	1.00	0.18
2019	OTE	0.03	0.20	0.44	0.38	0.70	1.00	0.32
	PTE	0.29	0.46	0.70	0.70	1.00	1.00	0.26
	SE	0.03	0.35	0.62	0.68	0.91	1.00	0.32
2020	OTE	0.02	0.19	0.46	0.40	0.72	1.00	0.33
	PTE	0.29	0.43	0.69	0.61	1.00	1.00	0.26
	SE	0.02	0.39	0.66	0.75	0.96	1.00	0.32
2021	OTE	0.02	0.28	0.59	0.67	1.00	1.00	0.34
	PTE	0.32	0.57	0.79	0.84	1.00	1.00	0.22
	SE	0.02	0.47	0.73	0.90	1.00	1.00	0.33
2022	OTE	0.01	0.25	0.51	0.48	0.77	1.00	0.32
	PTE	0.26	0.52	0.72	0.69	1.00	1.00	0.25

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	SE	**0.04**	**0.44**	**0.68**	**0.74**	**0.97**	**1.00**	**0.31**
2023	**OTE**	**0.02**	**0.18**	**0.46**	**0.42**	**0.70**	**1.00**	**0.32**
	PTE	**0.29**	**0.46**	**0.72**	**0.72**	**1.00**	**1.00**	**0.26**
	SE	**0.02**	**0.28**	**0.63**	**0.68**	**0.96**	**1.00**	**0.33**

Note: OTE = Overall Technical Efficiency; PTE = Pure Technical Efficiency; SE = Scale Efficiency

In 2018, the mean OTE was 0.59, indicating moderate technical efficiency, while PTE (0.65) suggested better managerial efficiency. The high SE (0.90) reflected strong scale efficiency across textile units. The industry experienced a significant decline in overall efficiency in 2019, with OTE dropping to 0.44, though managerial efficiency remained relatively stable (PTE = 0.70). Scale efficiency also decreased substantially (SE = 0.62).
A marginal recovery was observed in 2020 (OTE = 0.46), which strengthened considerably in 2021 when both managerial efficiency (PTE = 0.79) and scale efficiency (SE = 0.73) showed marked improvements. However, 2022 and 2023 saw a gradual decline in overall technical efficiency, with OTE returning to 0.46 by 2023, despite relatively stable managerial performance (PTE = 0.72).

4.2. Returns to Scale Analysis

The distribution of Decision-Making Units (DMUs) by returns to scale category provides further insights into operational efficiency patterns. Table 2 presents the number of firms operating at different returns to scale over the study period.

Table 2: Returns to Scale Distribution of Textile Manufacturing Units (2018-2023)

Returns to Scale	2018	2019	2020	2021	2022	2023
CRS	50	47	45	50	49	53
IRS	12	9	12	17	10	7
DRS	7	13	12	2	10	9
Total	69	69	69	69	69	69

Note: CRS = Constant Returns to Scale; IRS = Increasing Returns to Scale; DRS = Decreasing Returns to Scale

Throughout the study period, the majority of textile units operated at Constant Returns to Scale (CRS), indicating optimal operational efficiency. In 2018, 72.46% of the DMUs (50 units) operated at CRS, while 17.39% (12 units) functioned under Increasing Returns to Scale (IRS) and 10.15% (7 units) under Decreasing Returns to Scale (DRS).
By 2023, the proportion of CRS units increased to 76.81% (53 units), representing the highest level of the study period. Simultaneously, the number of IRS units decreased to its lowest level (7 units, 10.14%), suggesting fewer firms needed additional inputs to achieve full efficiency. The number of DRS units remained relatively stable at 13.04% (9 units), indicating modest scale inefficiencies.
Notably, 2021 showed a distinctive pattern with an unusually high number of IRS units (17, 24.64%) and very few DRS units (2, 2.90%), coinciding with the period

of improved overall efficiency observed in Table 1.

5. Discussion

The panel data analysis of Pakistan's textile industry from 2018 to 2023 reveals significant fluctuations in operational efficiency. The findings demonstrate that overall technical efficiency (OTE) exhibited considerable variability, with mean values ranging from 0.44 to 0.59 across the six-year period. This inconsistency in efficiency scores suggests that the textile sector in Pakistan has been subject to various internal and external pressures affecting its operational performance. Notably, 2019 marked a substantial decline in OTE (0.44) compared to 2018 (0.59), indicating challenges in resource utilization and technical operations during this period. While there was a marginal recovery in 2020 (0.46), performance improved significantly in 2021 (0.59) before declining again in 2022 (0.51) and 2023 (0.46).

Pure technical efficiency (PTE), which reflects managerial efficiency, demonstrated greater stability with means ranging from 0.65 to 0.79, suggesting that managerial practices remained relatively consistent despite fluctuations in overall performance. This aligns with findings from Darji and Dahiya (2023), who observed similar patterns in their assessment of textile firms in India. The highest PTE was recorded in 2021 (0.79), corresponding with the post-pandemic recovery period, indicating improved management practices possibly in response to the unprecedented challenges posed by COVID-19.

Scale efficiency (SE) also fluctuated considerably, ranging from 0.62 to 0.90, with the highest value observed in 2018 (0.90) and the lowest in 2019 (0.62). This pattern suggests that firms were operating at optimal scale in 2018 but struggled to maintain this efficiency in subsequent years. These findings reinforce Abbas and Halog's (2021) assertion that operational efficiency in textile industries is significantly influenced by scale factors and resource allocation strategies.

The returns to scale analysis provides valuable insights into the operational dynamics of Pakistan's textile industry. Throughout the study period, a majority of firms (65.22% to 76.81%) operated at Constant Returns to Scale (CRS), indicating that these units achieved optimal operational efficiency where changes in inputs resulted in proportional changes in outputs. This finding is consistent with research by Fatehian (2022), who emphasized the importance of achieving scale optimization in manufacturing industries.

Interestingly, 2021 exhibited a unique pattern with a high proportion of firms operating under Increasing Returns to Scale (IRS) (24.64%) and very few under Decreasing Returns to Scale (DRS) (2.90%). This coincided with improved overall efficiency metrics, suggesting that during this period, many firms were positioned to benefit from scaling up their operations. By 2023, the industry showed signs of improved scale optimization with 76.81% of firms operating at CRS, the highest proportion during the study period.

The fluctuation in IRS and DRS categories across years indicates that textile firms in Pakistan faced challenges in determining their optimal operational scale. Firms operating under IRS could potentially improve efficiency by increasing their scale of operations, while those under DRS needed to streamline or downsize to achieve better efficiency. These findings align with Yang et al. (2023), who highlighted the dynamic nature of operational efficiency and the importance of appropriate scaling decisions.

The operational efficiency challenges identified in this study have significant implications for the textile industry's alignment with Sustainable Development Goal 9 (SDG 9), which focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. As Singh (2023) emphasizes, Pakistan's textile sector must prioritize technological advancement, infrastructure development, and sustainable production practices to enhance its global competitiveness and environmental sustainability.

Our findings highlight several areas that require attention to better align with SDG 9. First, the fluctuating technical efficiency scores indicate inconsistent resource utilization, which contradicts sustainable industrialization principles. Second, the presence of firms operating under suboptimal returns to scale suggests inefficiencies in resource allocation, which can lead to waste and environmental degradation. Third, the positive relationship between firm size and performance underscores the importance of scale economies in achieving sustainable operations, as noted by Latif (2022).

The textile industry in Pakistan faces particular challenges related to infrastructure limitations, including energy shortages and outdated machinery, which hinder its ability to operate efficiently and sustainably. Addressing these challenges requires a multi-faceted approach that encompasses technological upgrades, enhanced infrastructure, and innovative production methods. By improving operational efficiency, the textile sector can reduce resource consumption, minimize waste, and lower its environmental footprint, thereby contributing to the sustainable industrialization goals outlined in SDG 9.

6. Policy Recommendation

Policymakers should concentrate on establishing industry-wide standardization to guarantee consistent operational benchmarks, facilitating access to technology by offering incentives for the adoption of cutting-edge equipment and digital tools, and assisting small and medium-sized businesses (SMEs) by offering financial assistance and training initiatives in order to address the identified inefficiencies and enhance operational performance. Furthermore, it is critical to increase research and development (R&D) funding to foster innovation in textile production, promote sustainable practices through resource-efficient production methods, and strengthen infrastructure investment by creating industrial zones with trustworthy utilities and supply chain networks. Programs for workforce training should also be extended in order to enhance skill development and flexibility in response to changing industry demands. Pakistan's textile industry can greatly improve its sustainability, efficiency, and worldwide competitiveness by incorporating these policy initiatives, guaranteeing resilience and long-term economic growth.

7. Conclusion

This study provides comprehensive insights into the operational efficiency of Pakistan's textile industry from 2018 to 2023, employing a panel data approach to analyze technical, managerial, and scale efficiencies. The findings reveal significant fluctuations in efficiency over the study period, with notable improvements in 2021 and challenges in 2019 and 2023. The majority of textile firms operated at Constant Returns to Scale, indicating optimal operational efficiency, while those under Increasing or Decreasing Returns to Scale faced various inefficiencies requiring strategic interventions.

From a policy perspective, addressing the identified inefficiencies requires a multi-pronged approach. Enhancing technical efficiency necessitates investments in modern machinery, technology upgrades, and workforce training. Improving managerial efficiency calls for capacity-building programs, lean manufacturing principles, and better resource allocation strategies. Scale efficiency can be optimized through appropriate sizing decisions, strategic collaborations, and access to financing for optimal capacity utilization.

The textile industry's alignment with Sustainable Development Goal 9 requires prioritizing technological innovation, sustainable production practices, and resilient infrastructure development. By fostering a conducive environment for efficiency improvements, policymakers can enhance the sector's competitiveness while promoting environmentally responsible operations. Additionally, strengthening industry-academia linkages can drive innovation and knowledge transfer, addressing the productivity challenges identified in this study.

Policymakers should aim to enhance the textile industry's efficiency by providing financial support and implementing sustainability-focused regulations for small and medium-sized businesses, while the collaboration between the public and the private sector is the key for infrastructure development, research, innovation and skill building. These measures strive to create a competitive and sustainable textile industry in Pakistan.

In conclusion, while Pakistan's textile industry demonstrates potential for growth and efficiency improvement, consistent operational strategies and supportive policy interventions are essential to address the volatility observed in efficiency metrics. By focusing on technological advancement, managerial capabilities, and sustainable practices, the sector can achieve long-term resilience and competitive advantage in global markets, contributing significantly to national economic development and environmental sustainability.

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