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Digital and Legacy Telecommunications Efficiency in Indonesia: Evidence from a Two-Stage DEA

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Abstract: This study examines operational efficiency of Indonesian telecommunications firms by distinguishing digital and legacy services within a two-stage framework, addressing whether efficiency differences arise from managerial performance rather than firm size amid digital transformation. Audited annual reports of three major operators from 2014 to 2024 are analysed. The first stage applies output-oriented Data Envelopment Analysis under Variable Returns to Scale to measure technical efficiency in converting operational inputs into heterogeneous revenue outputs. The second stage employs panel regression estimated using weighted EGLS with Cross Section SUR to explain efficiency variations through firm-level profitability indicators. Results reveal pronounced heterogeneity across firms. PT Telkomsel consistently achieves the highest VRS efficiency, reflecting superior managerial control independent of scale advantages. Input slack analysis identifies operational expenditure as the primary source of inefficiency, whereas labour input remains near optimal utilization and total assets show structural rigidity. Second-stage estimation indicates that Return on Equity positively and significantly affects efficiency, while Net Profit Margin lacks a significant individual effect, though profitability indicators are jointly meaningful. Sustainable efficiency improvement depends on strategic resource allocation, effective equity utilization, and disciplined cost management rather than scale expansion. This study contributes by integrating digital and legacy outputs within a two-stage DEA framework and linking operational efficiency to financial performance, offering actionable insights for managers seeking to enhance firm-level performance during digital transformation.

Keyword: Data Envelopment Analysis, Financial Performance, Operational Efficiency, Telecommunications Industry, Two-stage DEA.

INTRODUCTION

The Indonesian telecommunication industry is undergoing a profound structural shift, driven by the rapid growth of digital services reshaping revenue composition and operational priorities. Telkomsel's transformation into a digitally oriented operator exemplifies how data-

driven services coexist with legacy offerings, which, despite slower growth, continue to generate significant revenue (Telkomsel, 2024). At the group level, Telkom has accelerated digital initiatives to strengthen the national digital ecosystem while maintaining the sustainability of core telecommunications operations, highlighting the growing importance of operational efficiency in resource allocation (Telkomsel, 2023). Similarly, Indosat Ooredoo Hutchison has pursued network modernization and digital integration to enhance long-term competitiveness, emphasizing that revenue growth alone does not fully reflect operational performance (Indosat Ooredoo Hutchison, 2025). XL Axiata's adoption of cloud-based capabilities and artificial intelligence further illustrates industry-wide efforts to enhance service efficiency amid rising operational complexity (XL Axiata 2024a; 2025b).

The broader industry landscape is shaped by strategic consolidation, including the merger between XL Axiata, Smartfren, and Smart Telecom, which aims to strengthen national digital infrastructure and expand network-based services (KOMDIGI, 2025a). Government policies emphasize equitable and secure digital transformation, positioning operational efficiency as a key prerequisite for sustainable industry growth (KOMDIGI, 2025b). Revenue trajectories across operators reveal heterogeneous patterns: Telkomsel's digital revenue increased from approximately Rp 62.3 trillion in 2020 to Rp 78.4 trillion in 2023, while legacy revenue declined modestly, reflecting steady but slower traditional service growth. XL Axiata's digital revenue remains limited, with legacy services dominating, whereas Indosat demonstrates gradual digital revenue growth alongside significant legacy revenue, indicating transitional revenue mixes. These patterns underscore the heterogeneity of digital transformation and highlight the necessity of evaluating operational efficiency separately for legacy and digital outputs.

Despite these transformations, prior studies in Indonesia have predominantly focused on inter-period financial comparisons and responses to macroeconomic or regulatory changes. Studies by Kloko and Bayunitri (2020), Jauzaa and Hirawati (2021) and Dharma et al. (2025) provide valuable insights into profitability, financial stability, and sectoral performance, particularly during the COVID-19 period. However, these studies generally treat firm output as a single aggregated revenue measure, thereby overlooking the structural shift in revenue composition driven by digital transformation. Similarly, Daryanto et al. (2020) highlighted competitiveness dynamics associated with emerging technologies such as the Internet of Things, yet did not explicitly evaluate operational efficiency within an input-output analytical framework.

This reveals a critical research gap. Existing literature has not explicitly distinguished between digital and legacy revenue streams when assessing operational efficiency, despite their fundamentally different growth trajectories, cost structures, and strategic roles. As a result, current evidence may obscure how efficiently firms allocate resources between traditional and digital services during the transition process. The absence of this disaggregated perspective limits the ability to capture the true nature of efficiency in digitally transforming firms.

This study contributes by extending DEA applications through the separation of digital and legacy revenue streams and by linking operational efficiency to financial performance. The findings provide insights for strategic resource allocation and efficiency optimization in the context of digital transformation.

Accordingly, this study examines the operational efficiency of Indonesian telecommunication firms during 2014–2024 by distinguishing between digital and legacy revenues using a two-stage Data Envelopment Analysis (DEA) framework. Specifically, it aims to (1) compare efficiency levels across major operators and (2) assess the influence of firm-level financial performance, particularly return on equity (ROE) and net profit margin (NPM), on efficiency variation.

Efficiency in the Telecommunications Industry

Efficiency reflects a firm's ability to convert available resources into outputs in an optimal manner. From a theoretical perspective, efficiency is grounded in the framework proposed by Farrell, (1957), who distinguishes between technical efficiency (maximizing output from given inputs) and allocative efficiency (optimal input allocation based on costs). Building on this foundation, Charnes et al. (1978) introduced Data Envelopment Analysis (DEA) as a non-parametric method to measure relative efficiency, which was later extended to Variable Returns to Scale by R. D. Banker et al. (1984). These models enable the decomposition of efficiency into technical and scale components and are widely applied in telecommunications and ICT (Information and Communication Technology) sectors (Ajibesin & Vajjhala, 2024; Fotova Čiković & Lozić, 2022; Rody et al., 2023).

In the capital-intensive telecommunications sector, efficiency becomes a strategic necessity due to high fixed costs, continuous infrastructure investments, and rapid technological change (Asiedu, 2020). The transition from voice-based to data-driven and digital services further increases operational complexity, requiring firms to manage both legacy and scalable digital platforms simultaneously (Sithamparam & Kumar, 2024). Differences in managerial capability, adaptability, and cost control contribute significantly to variations in efficiency across operators (Isma et al., 2022), reinforcing the view that efficiency is not solely determined by scale but also by managerial effectiveness (R. Banker et al., 2022).

Building on DEA, the two-stage DEA approach extends efficiency analysis by linking efficiency scores to external determinants. In the first stage, DEA evaluates relative efficiency based on input–output relationships, while the second stage examines how firm-specific factors, such as financial performance, influence efficiency variation. This integrated approach enhances explanatory power and is widely used in efficiency and performance studies (Ajibesin & Vajjhala, 2024; Horváthová & Mokrišová, 2024; Simar & Wilson, 2007).

From a digital transformation perspective, firms reconfigure resources to adapt to platform-based and data-driven business models. Digital services are generally more scalable and cost-efficient, whereas legacy services remain infrastructure-intensive and less flexible (Bharadwaj et al., 2013; Vial, 2021). This structural distinction implies that aggregating revenues may obscure differences in operational performance, particularly in industries undergoing rapid technological change.

Accordingly, integrating two-stage DEA with digital transformation logic enables a more nuanced assessment of efficiency. By separating digital and legacy outputs in the first stage and linking efficiency to financial indicators in the second stage, the framework captures both heterogeneous production structures and managerial drivers of performance. This approach aligns with recent efficiency research emphasizing the role of technological change and firm-level capabilities in shaping operational outcomes (Albassam, 2020; Thu & Xuan, 2023).

Structural advantages such as network coverage, subscriber base, and operational scale enhance resource utilization (Sithamparam & Kumar, 2024). From an efficiency perspective, firms operating at larger scales tend to achieve higher technical and scale efficiency, enabling more effective input–output conversion (R. D. Banker et al., 1984; Farrell, 1957). Empirically, operators with broader market reach and established infrastructure are better positioned to sustain revenue generation during technological transitions, particularly when managing both legacy and digital services (Sithamparam & Kumar, 2024).

Beyond structural factors, managerial efficiency plays a critical role in financial performance. Efficient resource allocation, cost control, and output optimization are expected to improve profitability indicators such as return on equity (ROE) and net profit margin (NPM). In a two-stage DEA framework, this relationship is captured in the second stage,

where efficiency scores are linked to financial variables, indicating that superior managerial practices lead to higher profitability (Simar & Wilson, 2007).

In the Indonesian telecommunications industry, firms with stronger market positions and managerial capabilities, such as PT Telkomsel, are more likely to leverage scale and efficiency to generate both digital and legacy revenues (Isma et al., 2022). This indicates that efficiency is driven not only by scale but also by managerial effectiveness in utilizing resources during digital transformation. Based on this reasoning, the study proposes:

H1: PT Telkomsel achieves the highest operational efficiency in converting inputs into digital and legacy revenues compared to PT XL Axiata and PT Indosat Ooredoo Hutchison between 2014 and 2024

Decision-Making Units, Inputs, and Outputs

Telecommunication firms are treated as decision-making units (DMUs) that utilize multiple inputs to generate outputs. In DEA theory, DMUs are evaluated based on their ability to transform inputs into outputs efficiently (R. D. Banker et al., 1984; Charnes et al., 1978). In this study, inputs include operating expenditure, total assets, and labour, while outputs are represented by digital and legacy revenues, capturing both resource utilization and heterogeneous production structures during digital transformation (Isma et al., 2022).

Operating Expenditure as an Input Variable

Operating expenditure (OPEX) represents controllable costs that reflect managerial efficiency in resource allocation (Harahap & Kamilah, 2023). In efficiency theory, inefficient use of such inputs reduces a firm's ability to maximize outputs, indicating lower technical efficiency (Farrell, 1957). Within the DEA framework under Variable Returns to Scale, deviations from the efficiency frontier are primarily attributed to managerial inefficiency rather than scale effects (R. D. Banker et al., 1984; Sharma, 2025).

In digitally transforming industries, ineffective OPEX management can offset technological gains, weakening both efficiency and financial performance. Accordingly, in a two-stage DEA framework, better cost control is expected to improve efficiency and enhance profitability indicators such as return on equity (ROE) and net profit margin (NPM) (Simar & Wilson, 2007). Based on this reasoning, the study proposes:

H2: Operating expenditure exhibits the largest inefficiency slack under the VRS-based DEA model, indicating that operational cost management represents the primary source of inefficiency among Indonesian telecommunication firms.

Total Assets as a Proxy for Infrastructure Capacity

In DEA-based efficiency studies, input variables should represent productive resources used to generate outputs. When physical measures are limited, aggregated financial indicators such as total assets serve as proxies for infrastructure capacity (Wong, 2021). Within the DEA framework, inputs are evaluated based on their contribution to output generation efficiency (R. D. Banker et al., 1984; Charnes et al., 1978).

In the telecommunications sector, total assets reflect accumulated network infrastructure essential for service delivery. However, large asset bases do not necessarily ensure higher efficiency, as they may reduce short-term flexibility and reflect scale rather than managerial effectiveness (Cui et al., 2025). Accordingly, total assets capture structural capacity, complementing operating expenditure in distinguishing scale-related effects from managerial efficiency.

Digital and Legacy Revenues as Outputs

Digital revenue represents data-driven and internet-based services, while legacy revenue reflects traditional voice and messaging services. These outputs differ in scalability, growth potential, and cost structure (Asiedu, 2020; Masson et al., 2016). Within the DEA framework, multiple outputs are incorporated to capture heterogeneous production processes and assess how efficiently firms transform inputs into diverse revenue streams (R. D. Banker et al., 1984; Charnes et al., 1978).

In the context of digital transformation, digital services are more scalable but operationally complex, whereas legacy services provide relatively stable cash flows. Distinguishing these outputs enables a more accurate assessment of efficiency by capturing structural differences and transformation dynamics within firms (Sithamparam & Kumar, 2024).

Variable Returns to Scale Assumption

The study adopts the Variable Returns to Scale (VRS) assumption to isolate pure technical efficiency by separating managerial performance from scale effects (Hosen, 2013). In DEA theory, the VRS model allows efficiency measurement independent of firm size, unlike the CRS model which may confound managerial inefficiency with scale advantages (R. D. Banker et al., 1984; Hasanatina et al., 2020).

This approach is particularly relevant in industries with heterogeneous firm sizes, such as telecommunications, where differences in scale can bias efficiency comparisons. By focusing on resource utilization under managerial control, VRS provides more accurate and actionable insights for improving operational efficiency (Hadini & Wibowo, 2021).

Financial Indicators in the Second-Stage DEA: ROE and NPM

While DEA efficiency scores capture relative operational performance, they do not explain the financial factors underlying efficiency differences. The second stage of DEA addresses this limitation by linking efficiency scores to firm-specific determinants, such as profitability indicators (O'Loughlin et al., 2023).

Return on Equity (ROE) reflects a firm's ability to generate returns from shareholders' capital and indicates the effectiveness of strategic financial management (Kloko & Bayunitri, 2020). Net Profit Margin (NPM) measures the firm's capacity to control costs and convert revenue into net profit in a capital-intensive environment (Sahoo & Sahoo, 2022). Although both indicators capture financial performance, they represent distinct managerial dimensions influencing efficiency. Based on this reasoning, the study proposes:

H3: Net Profit Margin has a significant effect on VRS efficiency scores of Indonesian telecommunication firms from 2014 to 2024.

H4: Return on Equity has a significant effect on VRS efficiency scores of Indonesian telecommunication firms from 2014 to 2024.

H5: Net Profit Margin and Return on Equity jointly have a significant effect on VRS efficiency scores of Indonesian telecommunication firms from 2014 to 2024.

METHOD

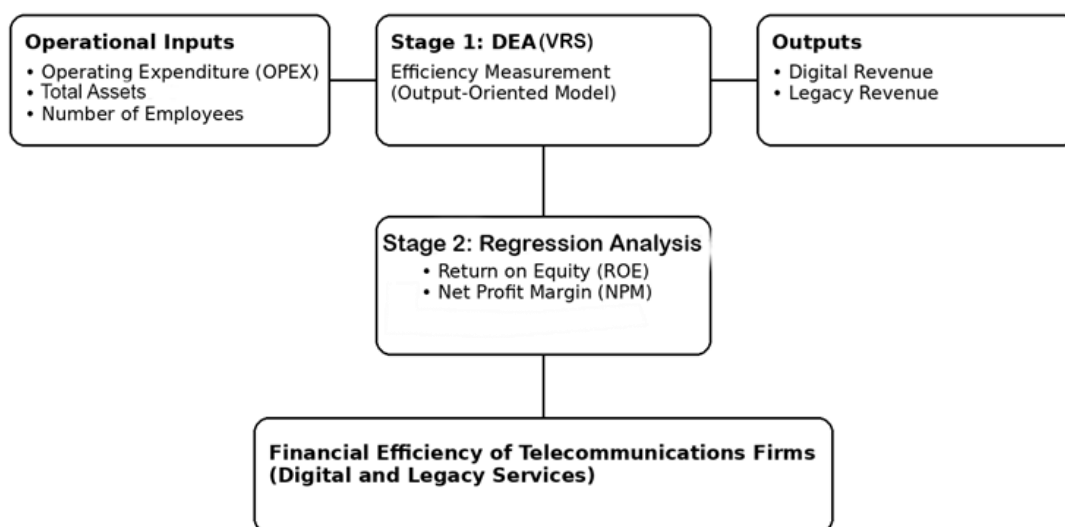


Figure 1. Research Framework

Source: Authors, 2025

Figure 1 presents the conceptual framework linking inputs, outputs, and financial performance in Indonesian telecommunication firms during 2014–2024. Data are obtained from audited annual reports, with each firm-year treated as a decision-making unit (DMU). Inputs include operating expenditure, total assets, and labor, while outputs consist of digital and legacy revenues, capturing heterogeneous production structures during digital transformation. Monetary values are standardized to ensure comparability across time. Within DEA theory, efficiency is evaluated based on the ability of DMUs to transform multiple inputs into outputs (R. D. Banker et al., 1984; Charnes et al., 1978).

In the first stage, technical efficiency is measured using output-oriented DEA under Variable Returns to Scale (VRS), enabling the isolation of managerial performance from scale effects (R. D. Banker et al., 1984). Efficiency scores equal to 1 indicate frontier performance, reflecting optimal resource utilization. In the second stage, efficiency scores are regressed on financial indicators to examine their influence on efficiency variation, following the two-stage DEA framework (O’Loughlin et al., 2023).

Return on assets (ROA) reflects asset utilization efficiency, return on equity (ROE) captures strategic capital management, and net profit margin (NPM) indicates cost efficiency under managerial control. Integrating DEA with financial performance analysis provides a coherent framework to assess how managerial decisions and financial conditions jointly shape operational efficiency in the telecommunications sector.

RESULT AND DISCUSSION

Table 1 summarizes the input and output trends of Telkomsel, XL Axiata, and Indosat Ooredoo Hutchison between 2014 and 2024. Over this period, Telkomsel increased its total assets by nearly 28% and workforce by 29%, which corresponded with a remarkable rise in digital revenue of roughly 238%, while legacy revenue gradually declined by around 83% as the firm shifted toward digital services. Indosat Ooredoo Hutchison expanded its assets by approximately 104% and workforce by 37%, with digital revenue growing by nearly 17% and legacy revenue remaining relatively stable, indicating a balanced reliance on both service streams. XL Axiata recorded more modest growth, with assets rising by 48% and employees by 35%, while digital and legacy revenues grew by 140% and 88%, respectively, consistently trailing the other two operators.

Table 1. Operational Input–Output Structure of Telecommunications Firms

Company	Year	OPEX	Total Asset	Total Employee	Revenue Digital	Revenue Legacy
Telkomsel	2014	26,140	91,907	4,900	23,180	48,720
Telkomsel	2015	27,320	94,650	5,050	27,460	45,980
Telkomsel	2016	28,890	96,820	5,120	31,740	42,110
Telkomsel	2017	30,240	98,550	5,200	36,980	38,240
Telkomsel	2018	32,110	100,730	5,280	42,560	33,870
Telkomsel	2019	34,780	102,910	5,320	49,210	29,540
Telkomsel	2020	36,010	103,652	5,371	62,328	24,775
Telkomsel	2021	37,485	101,302	5,535	68,231	19,275
Telkomsel	2022	38,551	100,991	5,658	72,930	16,109
Telkomsel	2023	50,293	112,966	6,455	78,473	10,671
Telkomsel	2024	62,003	117,403	6,343	78,286	8,447
XL Axiata	2014	19,870	51,430	2,600	11,420	15,890
XL Axiata	2015	20,960	54,210	2,720	13,980	14,120
XL Axiata	2016	21,740	56,880	2,850	15,630	12,740
XL Axiata	2017	22,910	59,940	2,910	17,890	10,930
XL Axiata	2018	23,780	61,120	2,950	19,980	9,120
XL Axiata	2019	24,540	62,030	2,980	21,140	6,980
XL Axiata	2020	25,118	62,369	2,987	21,732	4,215
XL Axiata	2021	25,812	64,710	3,004	23,119	3,486
XL Axiata	2022	27,915	67,543	3,219	24,512	2,931
XL Axiata	2023	32,004	72,489	3,483	26,881	2,104
XL Axiata	2024	34,228	75,611	3,512	27,394	1,873
IOH	2014	23,410	55,820	2,980	9,740	30,560
IOH	2015	24,190	58,130	3,020	11,230	29,140
IOH	2016	24,980	60,220	3,050	13,180	28,740
IOH	2017	25,470	61,540	3,080	15,640	27,330
IOH	2018	25,810	62,210	3,090	17,980	26,120
IOH	2019	26,240	62,610	3,100	19,860	25,040
IOH	2020	25,526	62,814	3,104	4,283	23,643
IOH	2021	21,034	63,397	2,891	5,415	25,973
IOH	2022	36,162	113,880	3,815	5,726	41,026
IOH	2023	40,801	114,722	4,041	6,473	44,756
IOH	2024	45,049	114,387	4,097	7,987	47,900

Notes: IOH = Indosat Ooredoo Hutchison. OPEX, Total Assets, Revenue Digital, and Revenue Legacy are measured in IDR billion. Employees are measured in number of persons.

Source: Annual reports of IOH, Telkomsel, and XL Axiata (2014–2024); authors’ analysis

Table 2 reports the mean DEA efficiency scores for the three firms, highlighting differences in operational effectiveness. Under the Variable Returns to Scale (VRS) assumption, Telkomsel achieved the highest efficiency (0.98 on average), followed by Indosat Ooredoo Hutchison (0.88) and XL Axiata (0.73). This indicates that Telkomsel was the most capable of converting operational inputs into digital and legacy revenues relative to its peers. These results provide empirical support for Hypothesis 1, confirming that Telkomsel’s advantages in resource scale and allocation translate into superior operational efficiency.

Table 2. Mean DEA Efficiency Scores by Firm

DEA Efficiency Scores by Firm	Mean CRS	Mean VRS	Mean SE
PT Telkomsel	0.91	0.98	0.92
PT XL Axiata	0.41	0.73	0.64
PT Indosat Ooredoo Hutchison	0.84	0.88	0.90

Source: Authors’ analysis using MAXDEA

Building on the assessment of mean efficiency scores, Table 3 presents the yearly DEA efficiency scores of Telkomsel, XL Axiata, and Indosat Ooredoo Hutchison from 2014 to 2024. PT Telkomsel consistently achieved very high VRS efficiency, often reaching 100%, although CRS efficiency dipped to 69% in 2023 and 54% in 2024, reflecting scaling challenges during late-stage digital transformation. XL Axiata experienced persistent efficiency challenges, with VRS scores fluctuating and remaining below 1.0 in many years, while Indosat Ooredoo Hutchison showed steady improvement, reaching full efficiency in 2024. These trajectories illustrate diverse adaptation paths to digitalization in the Indonesian telecom sector, highlighting Telkomsel’s robust operational performance, XL Axiata’s slower adjustment, and Indosat’s progressive alignment of resources

Table 3. Yearly DEA Efficiency Scores by Firm (2014–2024)

Firm Year - DMU	CRS Efficiency	VRS Efficiency	Scale Efficiency
2014-Telkomsel	1.00	1.00	1.00
2015-Telkomsel	0.99	1.00	1.00
2016-Telkomsel	0.96	0.97	1.00
2017-Telkomsel	0.95	0.96	0.99
2018-Telkomsel	0.93	0.95	0.98
2019-Telkomsel	0.93	0.95	0.98
2020-Telkomsel	1.00	1.00	1.00
2021-Telkomsel	0.99	0.99	1.00
2022-Telkomsel	1.00	1.00	1.00
2023-Telkomsel	0.69	1.00	0.69
2024-Telkomsel	0.54	1.00	0.54
2014-XL Axiata	0.62	1.00	0.62
2015-XL Axiata	0.64	0.95	0.67
2016-XL Axiata	0.64	0.83	0.77
2017-XL Axiata	0.60	0.82	0.73
2018-XL Axiata	0.54	0.91	0.59
2019-XL Axiata	0.45	0.88	0.51
2020-XL Axiata	0.30	1.00	0.30
2021-XL Axiata	0.26	1.00	0.26
2022-XL Axiata	0.21	0.32	0.67
2023-XL Axiata	0.15	0.15	0.95
2024-XL Axiata	0.13	0.14	0.95
2014-Indosat	1.00	1.00	1.00
2015-Indosat	0.84	0.95	0.89
2016-Indosat	0.89	0.98	0.91
2017-Indosat	0.91	0.98	0.93
2018-Indosat	0.93	1.00	0.94
2019-Indosat	0.95	1.00	0.95
2020-Indosat	0.30	0.35	0.86
2021-Indosat	0.48	1.00	0.48
2022-Indosat	0.61	0.65	0.94
2023-Indosat	0.71	0.73	0.97
2024-Indosat	1.00	1.00	1.00

Source: Authors’ analysis using MAXDEA

To investigate the sources of inefficiency under the VRS framework, input slack movements were analyzed and summarized in Table 4. The results indicate the extent to which each input could be reduced without affecting digital or legacy revenues. Operational expenditure (OPEX) showed the largest negative mean slack (−667.94), implying that, on average, excess costs of roughly IDR 667.94 billion could be trimmed without reducing output. Total assets displayed a larger absolute slack (−2,163.38) but represent a secondary

inefficiency due to limited short-run flexibility. Labour input exhibited a minimal slack (-14.92), suggesting near-efficient utilization. These findings highlight that operational expenditure constitutes the primary source of inefficiency among Indonesian telecommunication firms, providing empirical support for Hypothesis 2 under the VRS-based DEA model.

Table 4. Mean Input Slack under VRS-Based DEA Model

Input Variable	Mean Slack Movement	Status
Operational Expenditure (OPEX)	-667.94	Primary source of inefficiency
Total Assets	-2,163.38	Secondary source of inefficiency
Number of Employees	-14.92	Near-efficient / negligible inefficiency

Source: Authors' analysis using MAXDEA

Following the assessment of operational efficiency, firm-level financial performance is examined as a potential determinant of technical efficiency. Table 5 presents the return on equity (ROE) and net profit margin (NPM) for Telkomsel, XL Axiata, and Indosat Ooredoo Hutchison over the 2014–2024 period. The results reveal substantial variation in profitability across firms and years, reflecting differences in capital structure, operational strategies, and competitive positioning in the Indonesian telecommunications market.

Return on equity exhibits greater volatility than net profit margin, suggesting wider dispersion in equity returns across firms and periods. Episodes of negative profitability are observed in several years, indicating periods of weaker financial performance. Telkomsel consistently maintained positive profitability, with NPM ranging from 19% to 33% and ROE fluctuating between 39% and 72%, highlighting its ability to generate strong returns from operational resources. XL Axiata experienced several years of negative NPM and ROE, though gradual improvements are visible in the later years. Indosat Ooredoo Hutchison showed mixed performance, with early losses followed by significant recovery, particularly in ROE, which peaked at 73.5% in 2021.

This variation in financial indicators provides sufficient dispersion for the second-stage DEA analysis, enabling a meaningful examination of how financial performance relates to efficiency differences across firms

Table 5. Financial Ratios of the Three Telecommunication Firms

Company	Ratio	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Telkomsel	NPM	29.00	29.00	33.00	33.00	29.00	28.00	27.00	26.00	18.00	20.00	19.00
	ROE	39.00	43.00	51.00	54.00	49.00	51.00	50.00	58.00	53.00	72.00	72.00
XLAxiata	NPM	-14.30	-0.10	1.80	1.60	-14.00	2.80	1.40	4.80	3.80	3.90	5.40
	ROE	-5.70	-0.20	1.80	1.70	-18.00	3.80	1.90	6.60	4.90	4.90	7.00
IOH	NPM	-8.30	-4.90	3.80	3.80	-10.40	6.00	-2.60	21.50	10.10	8.80	8.80
	ROE	-14.80	-10.40	8.60	8.30	-6.00	12.30	-6.00	73.50	16.70	14.70	14.70

Source: Annual reports of IOH, Telkomsel, and XL Axiata (2014–2024)

The financial ratios reported in Table 5 highlight notable variation in profitability across firms and years, providing a foundation to examine how these differences relate to operational efficiency. Table 6 further summarizes this information by presenting descriptive statistics for the VRS efficiency scores alongside ROE and NPM, capturing the overall distribution, variability, and extremes in both financial performance and efficiency.

Table 6. Descriptive Statistics

	ROE	NPM	SCORE_VRS
Mean	21.58485	9.839394	86.20602
Median	8.600000	5.400000	98.04740
Maximum	73.50000	33.00000	100.0000
Minimum	-18.00000	-14.30000	13.87450
Std. Dev.	27.88540	13.99770	25.04871
Skewness	0.516387	0.162043	-2.000666
Kurtosis	1.871370	1.952913	5.626679
Jarque-Bera	3.218089	1.651958	31.50139
Probability	0.200079	0.437806	0.000000
Sum	712.3000	324.7000	2844.799
Sum Sq. Dev.	24883.06	6269.939	20078.02
Observations	33	33	33

Source: Data analysis was conducted using EViews 13

The descriptive statistics of the VRS efficiency score, return on equity (ROE), and net profit margin (NPM) are presented in Table 6. On average, the telecommunication firms operate relatively close to the efficiency frontier, with a mean VRS efficiency of 86.21. However, the minimum efficiency score of 13.87 highlights that certain firm-year observations still face substantial inefficiency, revealing opportunities for performance improvement. Both ROE and NPM display considerable variability across firms and periods, with ROE ranging from -18.00 to 73.50 and NPM from -14.30 to 33.00. This wide dispersion underscores the heterogeneous financial conditions among Indonesian telecommunication operators and provides a robust basis for examining how profitability indicators relate to observed efficiency differences in the second-stage DEA analysis. The observed variation ensures that the panel regression can meaningfully capture the influence of both long-term equity performance and short-term profitability on operational efficiency.

Table 7. Second-Stage Panel Regression Results (EGLS–SUR)

Dependent Variable: SCORE_VRS				
Method: Panel EGLS (Cross-section SUR)				
Date: 12/26/25 Time: 23:22				
Sample: 2014 2024				
Periods included: 11				
Cross-sections included: 3				
Total panel (balanced) observations: 33				
Linear estimation after one-step weighting matrix				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	83.97996	5.617105	14.95075	0.0000
ROE	0.441797	0.114137	3.870772	0.0005
NPM	-0.320588	0.213537	-1.501328	0.1437
Weighted Statistics				
R-squared	0.390211	Mean dependent var		2.607133
Adjusted R-squared	0.349559	S.D. dependent var		7.791713
S.E. of regression	0.937157	Sum squared resid		26.34792
F-statistic	9.598682	Durbin-Watson stat		1.073066
Prob(F-statistic)	0.000599			
Unweighted Statistics				
R-squared	0.083584	Mean dependent var		86.20602
Sum squared resid	18399.80	Durbin-Watson stat		0.667435

Source: Data analysis was conducted using EViews 13

Table 7 summarizes the explanatory power of the weighted EGLS–SUR regression linking financial performance to DEA efficiency scores. The weighted R² of 0.3902 indicates that roughly 39% of the variation in VRS efficiency is associated with differences in Return on Equity and Net Profit Margin, while the adjusted R² of 0.3496 accounts for model complexity, showing that about 35% of efficiency variation remains systematically explained. These results suggest that financial performance provides meaningful insight into operational efficiency, while also highlighting that other firm-specific or contextual factors may contribute to the remaining variation. Based on this model fit, the second-stage regression is specified using Panel EGLS with Cross-Section SUR weighting to reliably estimate the relationship between profitability indicators and efficiency outcomes.

$$VRS_{it} = 83,9799 + 0,4418 ROE_{it} - 0,3206 NPM_{it} + e_{it}$$

where SCORE_VRS_{it} represents the DEA efficiency score of firm i in year t. The positive and statistically significant coefficient for ROE indicates that firms achieving higher equity returns tend to operate closer to the efficiency frontier, reflecting more disciplined and effective resource management. In contrast, the coefficient for NPM is negative and not statistically significant, implying that short-term fluctuations in profit margins do not consistently translate into improved operational efficiency. The constant term captures the baseline efficiency level when both profitability indicators are held at their reference values.

Table 8. Results of Partial Hypothesis Testing

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	83.97996	5.617105	14.95075	0.0000
ROE	0.441797	0.114137	3.870772	0.0005
NPM	-0.320588	0.213537	-1.501328	0.1437

Source: Data analysis was conducted using EViews 13

The partial t-test is used to assess the individual contributions of the explanatory variables to DEA efficiency. Results from the EGLS SUR estimation, presented in Table 8, show that ROE has a positive and statistically significant coefficient ($\beta = 0.4418$; $p < 0.01$), indicating that firms with higher equity returns tend to manage resources more effectively and operate closer to the efficiency frontier. In contrast, NPM displays a negative and statistically insignificant coefficient ($p > 0.05$), suggesting that short-term fluctuations in profit margins do not consistently translate into enhanced operational efficiency. Based on these findings, H3 is not supported, whereas H4 receives empirical confirmation.

Table 9. Simultaneous Test Results

Weighted Statistics			
R-squared	0.390211	Mean dependent var	2.607133
Adjusted R-squared	0.349559	S.D. dependent var	7.791713
S.E. of regression	0.937157	Sum squared resid	26.34792
F-statistic	9.598682	Durbin-Watson stat	1.073066
Prob(F-statistic)	0.000599		

Source: Data analysis was conducted using EViews 13

The F-test is applied to assess the combined influence of ROE and NPM on DEA efficiency (SCORE_VRS). As shown in Table 9, the Prob (F statistic) equals 0.000599, well below the 5% significance threshold, indicating that the two profitability indicators jointly exert a meaningful and statistically significant effect on efficiency scores. These results support H5, highlighting that financial performance, when considered collectively, plays an important role in explaining efficiency variations across Indonesian telecommunication firms.

The VRS-based DEA results reveal significant differences in operational efficiency among Indonesian telecommunication firms. PT Telkom consistently operates near the efficiency frontier, outperforming PT Indosat Ooredoo Hutchison and PT XL Axiata. This finding aligns with international evidence suggesting that efficiency in telecommunications is primarily driven by managerial capability rather than scale advantages alone (Asiedu, 2020; Gökgöz & Demir, 2014; Oredgebe & Zhang, 2020). Theoretically, this is consistent with the Variable Returns to Scale framework, which isolates pure technical efficiency and highlights managerial effectiveness in transforming inputs into outputs (R. D. Banker et al., 1984).

Using financial proxies such as operating expenditure, total assets, and labour is consistent with DEA applications in ICT sectors where technical indicators are limited (Fotova Čiković & Lozić, 2022). Slack analysis indicates that operating expenditure is the primary source of inefficiency, reinforcing efficiency theory that controllable inputs are central to managerial performance (Farrell, 1957). This supports prior findings that cost management is a critical determinant of efficiency in capital-intensive industries (Masson et al., 2016). In contrast, inefficiencies in total assets are structural due to long-term investment rigidity, while labour utilization is already close to optimal.

The separation of digital and legacy revenues captures heterogeneous production structures during digital transformation. The findings show that efficiency trajectories vary across firms, confirming that technological transitions do not produce uniform outcomes. This supports digital transformation theory, which emphasizes resource reconfiguration and managerial adaptability as key drivers of performance (Kim & Yoo, 2024; Sithamparam & Kumar, 2024).

The second stage results further strengthen the theoretical interpretation. Return on Equity (ROE) has a strong and significant positive effect on efficiency, indicating that firms with effective capital management operate closer to the efficiency frontier. This finding is consistent with prior studies linking financial discipline and resource allocation to improved operational performance (Kloko & Bayunitri, 2020; Yangden & Pradhan, 2023).

In contrast, Net Profit Margin (NPM) does not show a significant effect. Conceptually, this can be explained by its sensitivity to short-term market dynamics, pricing strategies, and regulatory conditions. Unlike ROE, which reflects structural financial performance, NPM captures temporary profitability and does not necessarily represent underlying operational efficiency. This supports prior evidence that profitability alone may not adequately explain efficiency in dynamic and technology-driven industries (Sahoo & Sahoo, 2022; Yuniastuti & Nasyaroeka, 2022).

The findings suggest that operational efficiency in telecommunications is more strongly influenced by strategic financial management and cost control than by firm size or short-term profitability. This study contributes to the literature by extending the DEA–finance linkage framework, demonstrating that efficiency in telecommunications is primarily shaped by structural financial performance (ROE) rather than short-term profitability (NPM). It also reinforces digital transformation theory by showing that managerial capability in resource reconfiguration, rather than scale or technology adoption alone, is the key determinant of sustained operational efficiency. These insights reinforce that sustainable operational efficiency in digitally transforming telecommunications firms relies more on strategic management and disciplined resource allocation than on scale expansion alone.

The findings provide several practical insights for managers in the telecommunications sector. First, operating expenditure emerges as the most critical and controllable driver of efficiency. Managers should prioritize cost discipline, improve budgeting accuracy, and optimize operational processes to reduce inefficiencies. Second, while total assets remain essential for maintaining network infrastructure, their structural rigidity limits short-term

adjustments. Therefore, investment decisions should be carefully aligned with long-term strategic objectives, particularly in supporting digital service expansion.

Third, labour utilization appears close to optimal, indicating that efficiency improvements are less likely to come from workforce reduction and more from enhancing productivity and skill alignment, especially in digital capabilities. Fourth, the distinction between digital and legacy revenues highlights the need for balanced resource allocation. Managers must ensure that investments in digital services do not compromise the stability of legacy revenue streams, particularly during transitional periods.

Finally, the strong role of ROE suggests that efficiency improvements are closely linked to effective capital management. Firms should focus on optimizing equity utilization and maintaining financial discipline, as these factors contribute more consistently to efficiency than short-term profitability measures such as NPM. Taken together, these implications indicate that sustainable efficiency in digitally transforming telecommunications firms depends primarily on managerial capability, strategic alignment, and disciplined resource allocation rather than scale expansion alone.

CONCLUSION

This study sheds light on how Indonesian telecommunications firms convert operational resources into digital and legacy revenues, revealing pronounced differences in efficiency across major operators. PT Telkomsel consistently stands out, demonstrating a remarkable ability to translate expenditure, assets, and labor into revenues effectively, while XL Axiata experiences slower progress and Indosat Ooredoo Hutchison show gradual improvement over time. These patterns suggest that operational excellence is driven more by managerial skill and strategic resource allocation than by scale alone.

Examining input slack further clarifies where inefficiencies lie. Operational expenditure emerges as the main area for potential improvement, with firms carrying excess costs that could be reduced without affecting outputs. Labour utilization is already near optimal, and total assets remain largely rigid, highlighting that cost management and not workforce or infrastructure remains the key lever for efficiency gains.

The second stage analysis adds another layer of insight, showing that financial performance influences efficiency in nuanced ways. Stronger equity returns are associated with better operational efficiency, while short term profitability fluctuations measured by net profit margin do not consistently translate into improved resource management. When considered together, these indicators provide a meaningful explanation for the variations observed across firms.

This study contributes theoretically by extending the DEA–finance linkage framework within the context of digital transformation, demonstrating that operational efficiency is primarily driven by structural financial performance (ROE) rather than short-term profitability (NPM). It also advances digital transformation theory by showing that managerial capability in resource reconfiguration, rather than scale expansion or technology adoption alone, is the key determinant of sustained efficiency. This contribution provides a more integrated perspective on efficiency by linking operational, financial, and digital transformation dimensions within ICT sectors.

Several limitations should be noted. The analysis relies on accounting-based data, which may not fully capture technical or network level performance, and the sample focuses on major Indonesian operators, which could limit generalizability. Future research could extend this analysis through cross-country DEA comparisons, integration of network-level and service quality indicators, and dynamic efficiency approaches to better capture technological evolution in the telecommunications sector.

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