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BENCHMARKING FRAMEWORK FOR PRODUCTIVITY FRONTIER FIRMS IN THE MALAYSIAN ELECTRICAL AND ELECTRONICS INDUSTRY

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ABSTRACT

The objective of this study is to develop a benchmarking framework using Data Envelopment Analysis (DEA) to measure and identify frontier firms in Malaysia's Electrical and Electronics (E&E) industry. This framework equips policymakers and business leaders with a decision-making tool to allocate resources efficiently and promote productivity improvements. The study assesses the relative efficiency of 21 Bursa Malaysia-listed E&E firms using firm-level productivity data from 2017 to 2019, identifies frontier firms as benchmarks, and quantifies inefficiencies for non-frontier firms. The Malmquist Productivity Index is then applied to analyse productivity growth, decomposing technical change, pure efficiency change, and scale efficiency change. Findings reveal fluctuating frontier firm compositions, with few consistently efficient firms and significant sectoral productivity contributions from frontier firms. Non-frontier firms can improve by aligning with benchmarks, although productivity trends vary across the subsector. The analysis combines quantitative DEA with a qualitative case study to provide a holistic assessment of productivity, capturing organizational and managerial factors beyond numerical data. This comprehensive approach supports targeted productivity-enhancement policies and strategic resource allocation at the enterprise level, providing valuable insights into firm-level performance dynamics in the Malaysian Electrical and Electronics industry.

Keywords: Benchmarking; Productivity; Electrical and Electronics; Data Envelopment Analysis (DEA); Malmquist Productivity Index.

INTRODUCTION

The Electrical and Electronics (E&E) sector is one of the major drivers of Malaysia's industrial development. It plays a pivotal role in Malaysia's economy, contributing significantly to exports and gross domestic product (GDP). The sector accounts for about 40 percent of Malaysia's total exports, contributing 3.7 percent to global E&E exports. It is also a vital source of employment, supporting approximately 600,000 jobs, with an average monthly wage of RM4,019, which is far above the manufacturing sector's average of RM3,448 in 2024. As the world's ninth-largest E&E exporter, Malaysia is positioning itself as a critical hub in the global electronics value chain (BNM, 2024). E&E industry's strong performance underpins Malaysia's competitiveness. Given E&E's strategic importance, measuring and enhancing productivity in the sector are essential to Malaysia's economic resilience. Productivity assessment enables policymakers and industry players to identify efficiency gaps, foster innovation, and design targeted interventions that strengthen the sector's value creation and global integration.

An examination of the E&E industry will generate viable and implementable knowledge to foster sustainable economic growth through initiatives in workforce development, digital readiness, responsible business practices, regulatory frameworks, and governance. The Malaysia Productivity Blueprint (MPB) also emphasizes a comprehensive approach to productivity enhancement at national, sectoral, and enterprise levels. It identifies nine priority sectors, including the E&E industry, that are supported by dedicated Productivity Nexus platforms designed to coordinate, monitor, and accelerate productivity initiatives within each sector. At the firm level, targeted programs such as the Enterprise Productivity Program conducted by the Malaysia Productivity Corporation (MPC) have focused on boosting firm productivity by promoting collaboration and benchmarking performance. These initiatives identify leading firms as role models and enable the diffusion of best practices, positioning the E&E sector as a key driver of innovation and economic progress. Recent policies, such as Malaysia's 2025 Budget, 12th Malaysian Plan Mid-term review, and NIMP, reinforce the importance of advancing digital and Industry 4.0 technologies within the E&E sector to enhance productivity, address the talent gap, and strengthen supply chain resilience amid global uncertainties.

The importance of the E&E sector to Malaysia's economy and Malaysia's emphasis on sustainable, inclusive, and innovation-driven growth underscore the importance of firm-level productivity studies in understanding E&E sector productivity. Employing the rigorous Data Envelopment Analysis (DEA) method to benchmark E&E firms' performance offers valuable insights, supporting evidence-based industrial strategies and policy-making. This approach, additionally, closely aligns with the MADANI agenda's goals, making DEA a highly appropriate tool for developing robust benchmarking frameworks. Existing research recognizes the E&E sector's critical role in driving global technological advancement and economic development (Zhao & Huang, 2023). Productivity challenges in this sector arise from rapidly changing technology, supply chain volatility, and the need for skilled labor (Kumar & Tan, 2025). Benchmarking efforts specific to the E&E sector have emphasized the importance of digital transformation, innovation management, and operational agility (Fernandez et al., 2024). However, there remains a gap in research that integrates these dimensions through a rigorous benchmarking framework that quantitatively evaluates firm productivity while incorporating a country's sectoral context. This study aims to fill that gap by employing the DEA, complemented by a case study of the E&E firms in Malaysia, which provides actionable insights for key stakeholders.

LITERATURE REVIEW

Benchmarking is a pivotal strategic tool for organizations aiming to enhance operational efficiency by comparing themselves against leading industry standards. It serves as a means of identifying productivity gaps and adopting best practices that drive continuous improvement (Smith & Brown, 2023). By establishing clear performance targets, benchmarking enables firms not only to gauge their competitive standing but also to implement focused strategies for advancement (Lee et al., 2024). This approach has particular relevance in industries where rapid innovation and efficiency gains are critical for sustainability and growth. Within the benchmarking framework, the concept of frontier firms represents companies that operate at the highest levels of productivity within their sector. Frontier firms are essential drivers of economic and technological progress, often setting innovation and efficiency benchmarks that others aspire to emulate and grasp (Garcia & Thompson, 2022). Empirical research highlights significant disparities in productivity among firms, underscoring the importance of these leading entities in diffusing knowledge and elevating industry-wide performance (Chen et al., 2023). The identification of frontier firms highlights those that have achieved exceptional performance, and this achievement serves as the fundamental basis for setting benchmarks, enabling policymakers and business leaders to develop targeted initiatives grounded in the proven success of these leading firms (Wang & Li, 2024).

Data Envelopment Analysis (DEA) is widely recognized as a robust methodology for benchmarking, especially well-suited to evaluating multi-input and multi-output production processes characteristic of manufacturing and high-technology industries (O'Donnell & Coelli, 2023). DEA's nonparametric nature allows for flexible and comprehensive efficiency measurement without needing an explicit functional form, which is valuable when assessing diverse firm operations in the E&E sector (Podinovski & Wan Husain, 2017; Singh & Kumar, 2024). Previous studies have successfully applied DEA to benchmark productivity in various industrial clusters, demonstrating its capability to identify best-practice firms and suggest realistic targets for underperformers (Podinovski & Wan Husain, 2017; Nguyen et al., 2022; Patel & Shah, 2023). The essence of the DEA relative performance approach makes it an ideal choice for constructing benchmarking frameworks tailored to the complex nature of frontier firms in evolving sectors such as the E&E sector.

In the Malaysian context, national policies such as the MPB and the MADANI agenda underscore productivity enhancement and digital readiness as key economic priorities (Malaysia Productivity Corporation, 2024; Ministry of Economic Affairs, 2025). Prior studies on productivity frontier firms in Malaysia have begun mapping firm-level performance patterns but have yet to fully exploit DEA's potential for benchmarking within the E&E sector (Rahman et al., 2024). Aligning benchmarking efforts with these strategic goals ensures relevance and practical utility, enabling policymakers to devise targeted support programs and firms to adopt efficiency-enhancing innovations consistent with the country's development agenda (Ismail & Abdullah, 2025). Studies on productivity of firms in the E&E sector at the micro level in Malaysia using DEA and Malmquist decomposition point to substantial heterogeneity in different types of efficiency and pockets of underperformance requiring targeted upgrading (MPC, 2022; Ismail et al., 2007). Across sectors in Malaysia, Mahadevan (2002) found that technical change (frontier shift) and efficiency improvements contributed differently across subsectors, highlighting that policy to raise productivity should target both technological upgrading and firm-level efficiency. The heterogeneity in terms of productivity is similar across industries. For example, Sulaiman and Ismail (2021) for palm oil, while Rusli et al. (2022) for logistics firms.

METHODOLOGY

The analysis is undertaken in two complementary phases. The first phase applies a nonparametric approach, DEA, to quantitatively evaluate firm-level microdata and measure productivity based on the reported financial statements. This phase provides an objective, data-driven assessment of firm productivity using published statistics. However, understanding the context behind the quantitative results requires a qualitative approach, which forms the second phase of the analysis. This phase involves conducting a case study to capture broader dimensions of productivity, including organizational factors, innovation processes, and management practices that are not fully reflected in numerical data alone. Combining quantitative benchmarking via DEA with qualitative inquiry ensures a holistic assessment of firm performance, yielding richer insights for policy and strategic decision-making.

Data Envelopment Analysis (DEA)

DEA serves as an excellent benchmarking framework for studying the best practices of firms through the lens of productivity and economic efficiency. Unlike traditional methods, which often rely on single-factor efficiency ratios, financial metrics, or predefined functional forms that assess performance based on limited criteria, DEA evaluates the relative efficiency of decision-making units by simultaneously considering multiple inputs and outputs without requiring a predefined functional form (Charnes, Cooper, & Rhodes, 1978; Podinovski & Wan Husain, 2017; O'Donnell & Coelli, 2023). This capability allows DEA to effectively handle the complexities and multidimensional nature of firm performance. By comparing firms against the "best practice" frontier, DEA identifies which firms are operating efficiently and highlights specific areas where less efficient firms can improve. It not only quantifies efficiency but also provides actionable target benchmarks, showing companies the necessary adjustments to emulate top performers. Additionally, the flexibility of DEA allows it to be adapted to different industries and perspectives, making it a robust tool for continuous performance improvement. Its comprehensive approach offers deep insights into productivity, resource utilization, and operational strategies, making it highly valuable for economic and productivity analyses in the contemporary competitive landscape.

Malmquist Productivity Index (MPI)

In addition to providing a performance evaluation for a specific period, such as annually, DEA can also assess performance over multiple periods through the computation of the Malmquist Productivity Index (MPI). The MPI, or DEA-based Malmquist productivity index, measures total factor productivity (TFP) change between two periods. Productivity change over time can be decomposed into two components (Figure 1): (i) *Technical change* is the movement or shift of the production frontier, representing changes in the firm's potential capabilities. It encompasses broad improvements such as advancements in knowledge stock, new technologies, and smart infrastructure; and (ii) *Efficiency change* is the movement of the firm toward or away from the best-practice frontier. It reflects changes in operational efficiency (also called pure efficiency change) and/or changes in efficiency caused by scale effects (scale efficiency change).

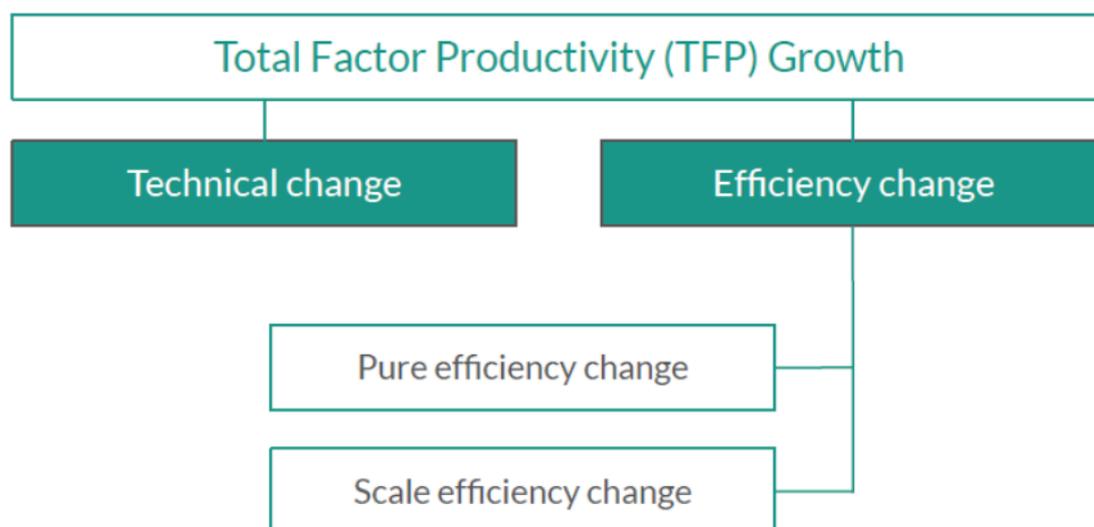


Figure 1
Decomposition of Total Factor Productivity (TFP) Growth

The MPI values quantify the rate of productivity growth or contraction between adjacent periods. Index values greater than one indicate positive growth, while index values less than one reflect productivity decline. This interpretation also applies to the technical change, pure efficiency change, and scale efficiency change components of TFP growth. For this study, MPI computations adopt the model developed by Ray and Desli (1997).

The data for this analysis consists of all publicly listed companies in the E&E sector for the period of 2017-2019. Importantly, this framework is designed to remain equally applicable and meaningful when applied to more recent data, thereby maintaining its relevance amid changing economic conditions. This two-phase approach demonstrates how DEA can serve as a comprehensive and practical benchmarking framework. It quantifies the optimality of resource use and identifies benchmark firms tailored to each company's scale and operational characteristics. Consequently, it guides the formulation of targeted, evidence-based productivity improvement strategies specific to the complexities of the E&E industry.

ANALYSIS AND RESULTS

Data Description

The reported analysis focuses on 21 publicly listed Electrical & Electronics (E&E) companies comprising 10 semiconductor and 11 technology equipment companies. The six largest by market capitalization within the E&E sector are Frontken Corporation, Inari Amertron Bhd, Malaysian Resources Corporation, Mi Technovation Bhd, Pentamaster Corporation, and Vitrox Corporation. Additionally, Turiya Bhd, Unisem Bhd, JCY International Bhd, and Pentamaster Bhd are companies with holding entities incorporated abroad. The Malaysian semiconductor sector remains robust in 2025, boosted by increased investment in chip design and advanced manufacturing as government incentives fuel over RM1 trillion in committed expenditure by 2024, alongside global demand growth driven by emerging technologies such as 5G, electric vehicles, and AI (Mordor Intelligence, 2025; MATRADE, 2025). Penang continues to be a key hub for semiconductor production, supported by expansions in outsourced assembly and testing facilities. This dynamic ecosystem underscores the significance of these 21 firms as focal points for industry productivity and innovation studies.



Figure 2
Profile of the Shortlisted Electrical & Electronics Firms

The primary data source comprises annual financial reports of publicly listed companies in Bursa Malaysia's main market. The focus is on E&E as a priority sector within the Productivity Nexus, and on key domains for assessing firm productivity from 2017 to 2019. As illustrated in Figure 3, the analytical sample consists of 21 firms. The analysis of frontier firms within this sample reveals that seven were classified as frontier firms in 2017, five in 2018, and seven in 2019. Since companies listed on the main market fully comply with rules imposed by the Securities Commission and Bursa Malaysia, the dataset is robust and reliable. Additionally, being market-driven, the primary market listing reflects strong alignment with market benchmarks, ensuring the selected sample fairly represents top performance standards within the industry.



Figure 3
Number of Leading Firms for the Electrical & Electronics Industry Between 2017-2019

This study adopts the general output and input specifications established by the OECD MultiProd project to measure and examine firm efficiency and productivity (Berlingieri et al, 2017). Specifically, value added (calculated as revenue minus the cost of sales) is used as the output measure, while the inputs include capital, investment, and labor. Aligned with disclosure and reporting standards, this study selects three specific input variables: total assets, total equity, and labor input proxied by staff costs.

These input measures were chosen to ensure comparability across firms and to maximize coverage. Figure 4 illustrates the input-output specifications adapted from the OECD MultiProd framework (Berlingieri et al., 2017).

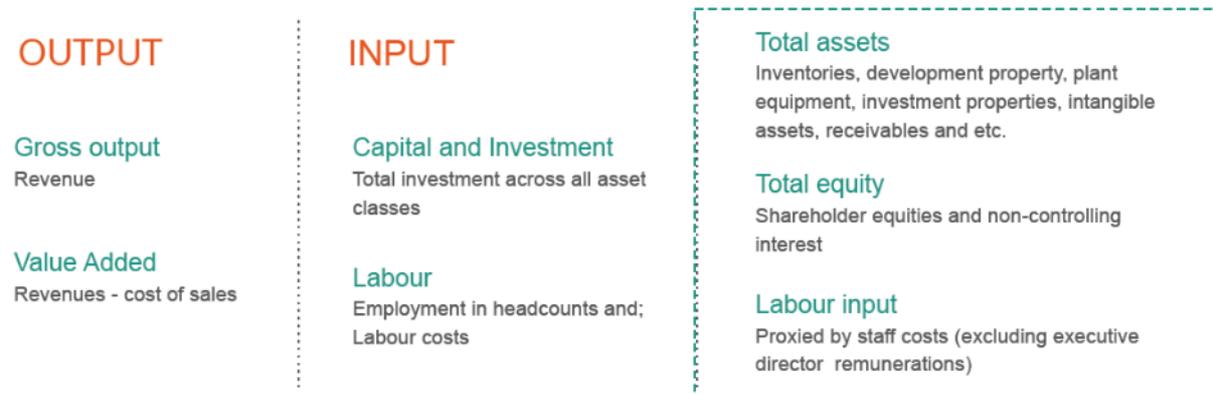


Figure 4
Output and Input Specifications

The Frontier Firms

Figure 5 reports the frontier firms and technical efficiency scores for the three consecutive years, 2017 to 2019. The annual performance analysis reveals that seven firms were identified as frontier firms in 2017 and again in 2019. However, in 2018, only five firms were identified as frontier firms.



Figure 5(a)
Frontier Firms of Electrical & Electronics (E&E) Industry for 2017-2019

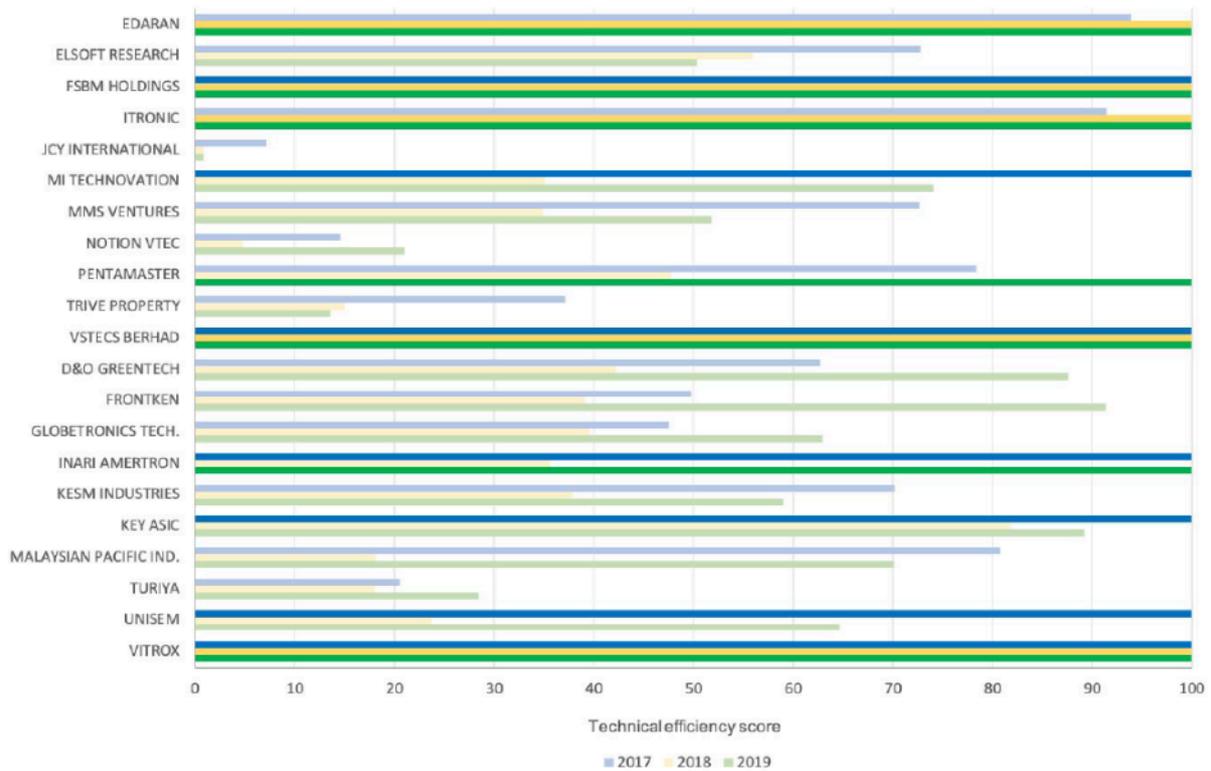


Figure 5(b)
 Technical Efficiency Score of Electrical & Electronics (E&E) Firms for 2017-2019

Overall, frontier firms struggled to maintain consistent efficient performance throughout the period, with the number of efficient firms fluctuating between five and seven from 2017 to 2019. Among those consistently efficient over the period were three companies: FSBM Holdings Berhad, VSTECs Berhad, and VITROX Berhad. FSBM Holdings and VSTECs Berhad alternated the first and second positions based on their technical efficiency scores for the E&E sector in 2017, 2018, and 2019, while VITROX Berhad maintained a steady third place over these years (see Figure 6).



Figure 6
 Ranking of Electrical & Electronics (E&E) Frontier Firms for 2017-2019

The Non-Frontier Firms

Regarding non-frontier firms, Figure 7 summarizes the overall technical efficiency scores, averaging 57.10% in 2017, 33.13% in 2018, and 54.64% in 2019. These scores imply that, on average, non-frontier firms used more than twice the inputs required to produce comparable output levels. For instance, Pentamaster International Limited Bhd (PENTA) scored 78.32% efficiency in 2018, indicating room for input usage optimization by 21.68% compared to its peers. Despite a decline to 47.77% in 2018, PENTA bounced back to become a frontier firm in 2019.

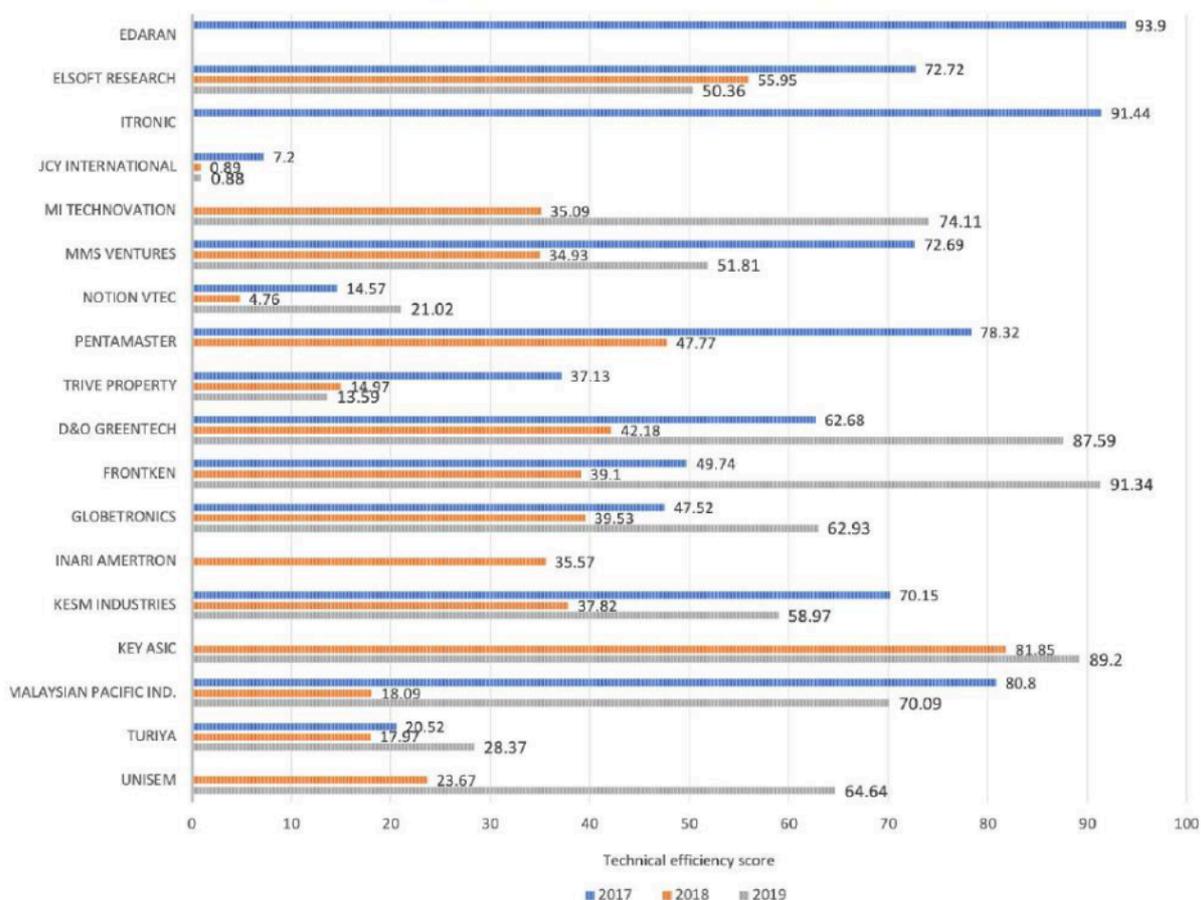


Figure 7
Technical Inefficiency of Non-frontier Electrical & Electronics (E&E) Firms

The Benchmark Peers

DEA attributes the relative significance of peers as a benchmark and role model for non-frontier firms by generating lambda values, as illustrated in Figure 8. To substantiate, for JCY International Bhd, its recommended ideal benchmark is entirely FSBM Holdings, with a lambda of 1 (100 % as significance). Key Asic Bhd, meanwhile, has multiple recommended benchmarks, but predominantly FSBM Holdings with a lambda of 0.78 (78 % as significance), compared to only 1% as significance for VSTECS and 3% as significance for ViTrox.

	Non-frontier firms	 FSBM	 VSTECs	 VITrox ⁺
1.	Elsoft Research	(0.80)	(0.04)	(0.07)
2.	JCY International	(1.00)	(0.00)	(0.00)
3.	MI Technovation	(0.00)	(0.27)	(0.34)
4.	MMS Ventures	(0.64)	(0.00)	(0.04)
5.	Notion VTEC	(0.00)	(0.02)	(0.09)
6.	Trive Property	(0.99)	(0.00)	(0.00)
7.	D&O Greentech	(0.00)	(0.00)	(0.00)
8.	FRONTKEN	(0.00)	(0.00)	(0.04)
9.	Globetronics	(0.00)	(0.00)	(0.16)
10.	KESM Industries	(0.00)	(0.00)	(0.08)
11.	Key Asic	(0.78)	(0.01)	(0.03)
12.	Malaysia Pacific Industries	(0.00)	(0.00)	(0.00)
13.	Turiya	(0.92)	(0.06)	(0.02)
14.	UNISEM	(0.00)	(0.00)	(0.00)

Figure 8

Efficient Peers for Non-frontier Electrical & Electronics (E&E) Firms (2019)

The Laggards

Figure 9 illustrates the laggards or non-frontier firms which consistently ranked among the bottom four in efficiency scores within the Electrical and Electronic sector. Among the laggards shown in Figure 9, Turiya Bhd and Notion Vtec Bhd improved their standings after 2017, whereas Trive Property Bhd did not. JCY Bhd persistently ranked lowest in efficiency throughout the study period.

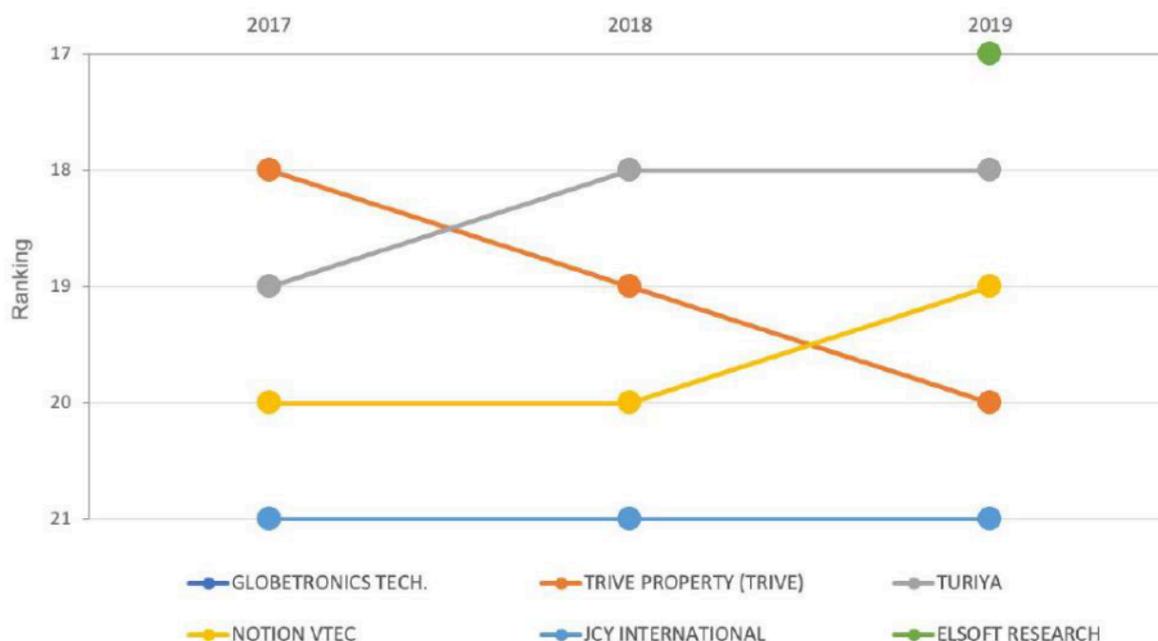


Figure 9
The Laggard Firms in the Electrical & Electronics (E&E) Industry

The subsequent Figure 10 demonstrates efficiency improvement targets for inefficient E&E firms, generated by the DEA by replicating the best practices of the identified frontier firms. Using Elsoft Bhd as an example, the firm must reduce total input usage by approximately 50% to be fully efficient, based on the practice of its suggested benchmarks. Precisely, a 49.64% reduction in total assets, equity, and wages/salaries, to align with benchmarks set by FSBM Bhd, Vitrox Bhd, and VSTECs Bhd. The proposed and personalized improvement targets are argued to be practical and feasible as they are derived specifically for Elsoft Bhd based on the observed performance of its benchmark peers.



Figure 10
Improvement Targets for Inefficient Electrical & Electronics (E&E) Firms (2019)

Productivity Trends

The Malmquist productivity index is applied to measure changes in firm-level productivity patterns over time. It captures the total factor productivity (TFP) change from one period to another by

decomposing this change into specific components, including technical change and efficiency change. The index is calculated using a distance-function approach that compares production technologies and efficiency levels across different time periods, providing a robust framework to analyze productivity dynamics. This method effectively reveals insights into technological progress and operational improvements within firms (Färe et al., 1994; Johnes, 2006). Figure 11 (left) shows the overall total factor productivity (TFP) trend for the E&E sector, with index values greater than 1 for 2017-2018 and 2018-2019 indicating positive productivity growth, or 11.8% and 7.7%, respectively. Since the index values for both periods (2017–2018 and 2018–2019) exceed 1, this indicates that the sector, on average, experienced positive productivity growth throughout 2017 to 2019. Specifically, total factor productivity (TFP) increased by 11.8% during 2017–2018 and grew at a slower rate of 7.7% in 2018–2019.

The sources of total factor productivity (TFP) growth for the E&E firms are illustrated in Figure 11 (right). The figure highlights that significant technological change is the primary driver of sector growth. Specifically, technological change advanced at a rate of 67.3% during 2018–2019, despite experiencing a 31.9% decline in 2017–2018. Conversely, pure efficiency exhibited the opposite trend, registering a sharp decline with a negative growth rate of 36.5% in 2018–2019. These trends align with findings in the literature that emphasize the predominant role of technological progress in productivity growth, often counterbalanced by variations in operational efficiency (Färe et al., 1994; Johnes, 2006).

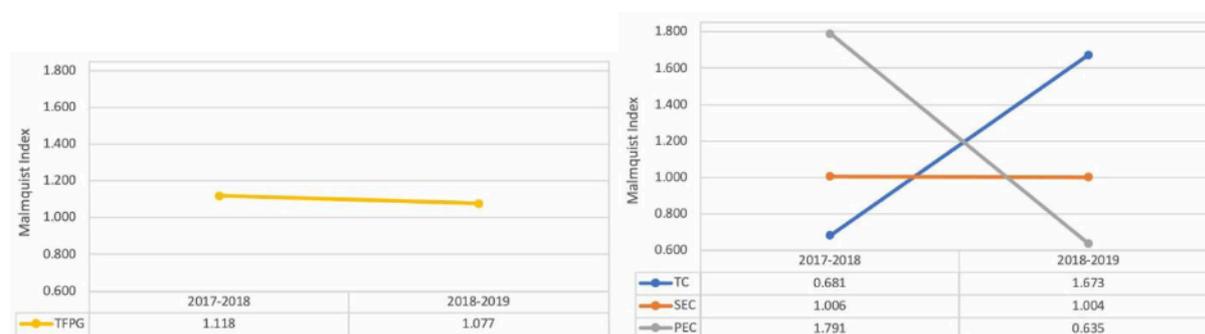


Figure 11
Productivity Trends and their Decompositions for Electrical & Electronics Firms

Figure 12(a) and Figure 12(b) illustrate the breakdown of productivity trends for both frontier and non-frontier firms. On average, total factor productivity (TFP) showed positive growth for both groups between 2017 and 2018. Non-frontier firms experienced slightly higher productivity growth compared to frontier firms during this period, outperforming by approximately 1.4%. However, this momentum did not continue in 2018–2019 among frontier firms, which experienced a TFP decline of about 1.4%. In contrast, non-frontier firms maintained positive TFP growth, albeit at a slower rate compared to 2017–2018. Such divergence in productivity patterns reflects broader evidence that frontier firms typically grow productivity more rapidly but can also face fluctuations. In contrast, non-frontier firms tend to have steadier but slower growth trajectories.

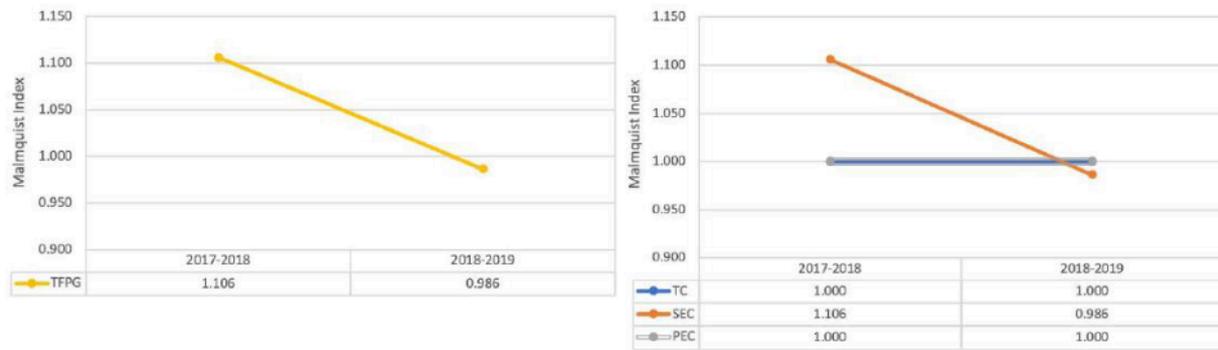


Figure 12(a)

Productivity Trends and their Decompositions for Frontier Electrical & Electronics Firms

The primary source of negative growth for frontier firms in the recent period was largely due to an average decline in scale efficiency. In contrast, for non-frontier firms, the decrease in total factor productivity (TFP) during 2018–2019 was mainly driven by a significant decline in pure efficiency, which experienced a negative growth rate of 41.2%. This distinction underscores differing productivity challenges faced by frontier versus non-frontier firms, with scale inefficiencies primarily impacting the former and operational inefficiencies affecting the latter.

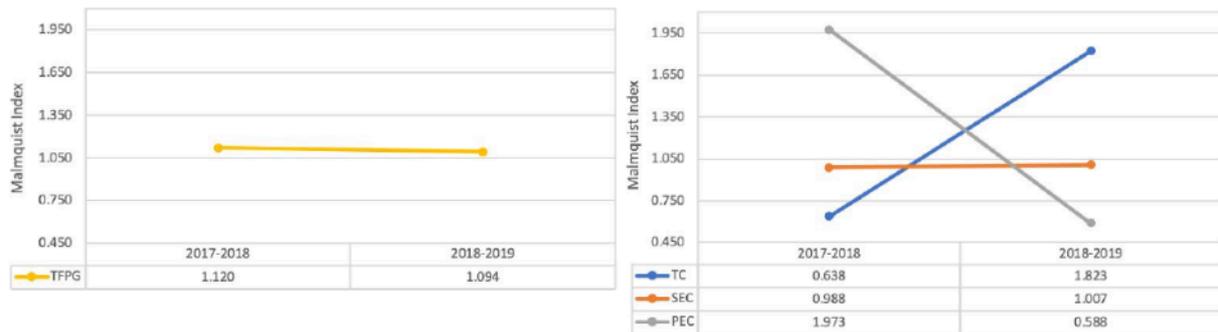


Figure 12(b)

Productivity Trends and their Decompositions for Electrical & Electronics Non-frontier Firms

Among non-frontier firms, 69% of the companies showed improvements in overall productivity during 2018–2019, whereas the remaining experienced declines. Elsoft Research Berhad recorded the most significant improvement relative to others, while Notion Vtech Berhad was among the least performers in this period.

In summary, the DEA analysis reveals a dynamic efficiency landscape in Malaysia's E&E sector from 2017 to 2019, characterized by fluctuating frontier firms, led consistently by FSBM Holdings Berhad, VSTECs Berhad, and VITROX Berhad, and persistently inefficient laggards like JCY International Bhd, underscoring the need for targeted input optimization and peer benchmarking. Non-frontier firms, averaging below 60% efficiency, demonstrate potential for substantial gains by emulating best practices from dominant benchmarks, as evidenced by personalized improvement targets. Complementing this, Malmquist productivity index results highlight positive sector-wide TFP growth (11.8% in 2017–2018 and 7.7% in 2018–2019), primarily driven by technological advancements despite efficiency setbacks, with non-frontier firms exhibiting more stable progress than their frontier counterparts. These insights collectively affirm the sector's resilience amid volatility, offering actionable pathways for enhancing operational performance and competitiveness.

BENCHMARK FIRM

Building on the quantitative identification in Phase 1 of leading firms between 2017 and 2019 using DEA, the second phase of the study focuses on frontier firms consistently ranked as top performers according to the MPC Productivity Nexus. This qualitative phase aims to explore and understand the operational strategies and best practices that underpin their superior productivity. Data collected from multiple sources, including annual reports and relevant articles, was then analyzed using ATLAS.ti Version 8 software to systematically code, categorize, and interpret qualitative information. The analysis primarily focuses on productivity drivers and operational practices that contribute to these firms' benchmark status, providing rich insights for other E&E companies to emulate. This case study approach involves three stages of data analysis and is limited to Bursa Malaysia mainboard-listed companies identified in Phase 1. By combining quantitative benchmarking with qualitative inquiry, the study seeks to develop a comprehensive understanding of how leading firms achieve and sustain high productivity performance.

ViTrox Berhad is selected as the benchmark firm among the consistently efficient frontier companies from 2017-2019 due to its superior scale, innovation focus and sustained growth. Its pioneering machine vision solutions for high-growth areas like semiconductors, AI and electric vehicles, coupled with Deloitte's 2025 Gold Best Managed Companies recognition, make it a source of deeper, contextually relevant insights for benchmarking analysis of manufacturing frontiers in Malaysia's E&E landscape.

Case Study on Benchmark Firm: ViTrox Corporation Berhad (ViTrox)

The most frequently cited leading firm as a benchmark for the Electrical & Electronics (E&E) industry is ViTrox Corporation Berhad (ViTrox). ViTrox is a leading company in the E&E industry as of 2025. It continues to operate as an investment holding company and as a developer of advanced 3D and machine-vision inspection systems. Beyond the six wholly-owned subsidiaries and one associate company that ViTrox had as of April 2020, it now operates additional subsidiaries to expand its technology and service offerings. ViTrox's strategic vision to be a One-Stop solution center remains central, aiming to help manufacturing customers achieve zero defects by integrating cutting-edge machine vision, artificial intelligence (AI), embedded electronics, and robotics into its comprehensive, technology-driven product portfolio. This differentiation strategy focuses on delivering innovative, advanced, cost-effective solutions, reinforcing ViTrox's dominance in the Surface Mount Technology (SMT) inspection market. The company's reputation was notably cemented when it was named to the Forbes Asia 200 Best Under a Billion list in 2019, signaling its excellence and growth potential within Asia's dynamic technology sector. In recent years, ViTrox has expanded its collaborations and penetrated rapidly growing markets, including China's outsourced assembly and testing sector, effectively diversifying its revenue streams to offset fluctuations in mature markets such as Taiwan and Southeast Asia.

Vitrox Corporation Berhad showcases exemplary strategic leadership and a prudent growth strategy that allows it to navigate market volatility and advance industry leadership. The company prioritizes innovation underpinned by strong financial fundamentals and robust cash flow management, enabling sustained growth even in uncertain global environments. With a significant commitment to research and development, Vitrox dedicates approximately 12% of its revenue to R&D, reflecting a deep investment in advancing AI-based vision inspection equipment and related technologies. This focus on innovation is complemented by an aggressive approach to talent acquisition and development, which

brings in skilled engineers and fosters a culture of continuous improvement to maintain a competitive advantage. In terms of market penetration, Vitrox actively diversifies its global customer base to minimize dependence on any single market. The company has strategically tapped into the rapidly expanding Chinese outsourced assembly and testing sector to offset slowing demand in more mature markets such as Taiwan and Southeast Asia. This geographical and sector diversification is supported by strong alliances with sales channel partners, distributors, and original equipment manufacturers worldwide, enabling Vitrox to broaden its footprint while mitigating regional market risks.

Vitrox's approach to risk management is comprehensive and enterprise-wide. It features continuous review systems and dedicated committees that ensure adherence to regulatory requirements and sustainability standards. The company's risk management framework is integral to daily operations, driving proactive identification and mitigation of risks aligned with global best practices and internal objectives.

Operational excellence is a cornerstone of Vitrox's success, achieved by integrating sophisticated Enterprise Resource Planning (ERP) systems and real-time manufacturing monitoring tools, such as its proprietary V-ONE® platform. These technological deployments optimize process efficiency, lead-time management, and defect reduction, recording a greater than 30% decrease in manufacturing defects while ensuring timely product delivery to customers.

Innovation at Vitrox is an ongoing priority; the company consistently launches multiple enhanced or new products yearly. Among these are AI-powered vision inspection systems designed to adapt to multi-dimensional variables, reflecting Vitrox's commitment to staying at the forefront of technological advancement in manufacturing inspection. Complementing innovation is Vitrox's dedication to technology diffusion. The company actively fosters knowledge sharing and adoption of machine vision technologies among Malaysian SMEs, catalyzing growth within the local semiconductor and automation ecosystems. This outreach not only supports industry-wide advancement but also positions Vitrox as a key enabler of national technological progress.

Corporate social responsibility is prominently featured in Vitrox's operational ethos. It supports STEM education through various outreach programs, philanthropic donations amounting to approximately RM300,000 in 2019, and by hosting educational events at universities. Additionally, Vitrox leads in environmental sustainability initiatives, adhering to the 5Rs (Rethink, Reduce, Reuse, Repair, Recycle) and 5S+ methodologies to reduce waste and maintain environmentally friendly facilities.

Besides, talent management at Vitrox is robust, emphasizing ongoing employee development and wellness. In 2019 alone, employees completed over 41,000 hours of learning, supported by HR excellence awards, whistleblowing policies, and an organizational culture grounded in integrity, accountability, courage, trust, respect, gratitude, and care.

Integrating strategic foresight, innovation, operational discipline, and community engagement, Vitrox exemplifies best practices for Malaysian technology firms. Its resilience in the face of external challenges, coupled with effective risk mitigation and sustainability commitments, underpins its continued industry leadership in an increasingly data-centric global landscape. In summary, the case of Vitrox Corporation Bhd illustrates how high-tech Malaysian SMEs can achieve frontier performance by aligning strategic leadership, operational excellence, innovation, and technology diffusion with social responsibility. This integrated management approach is essential to thrive amid global market uncertainties and fast-paced technological change.

CONCLUSIONS

The integrated two-phase benchmarking framework presented in this study combines the rigor of Data Envelopment Analysis (DEA) with in-depth qualitative case studies to create a robust tool for measuring and improving productivity in the electrical and electronics (E&E) industry. DEA offers precise, replicable measurement of productivity frontiers by analyzing firm-level data, while case studies contextualize these results by exploring real-world operational strategies of leading firms. This dual approach provides actionable benchmarks that guide firms in the E&E sector toward sustainable productivity improvements and competitiveness. The E&E industry is a vital driver of Malaysia's economic growth, accounting for nearly 45% of manufacturing exports and around 23% of GDP, positioning the country as a crucial player in the global electronics supply chain. Despite its strong foundation since the 1970s and its status as a high-technology manufacturing hub, the sector faces challenges, including limited R&D, skills shortages, and gaps in digital infrastructure, that constrain productivity growth. Government policies, such as the Malaysia Productivity Blueprint and initiatives through the Electrical & Electronics Productivity Nexus (EEN), aim to address these issues by fostering innovation and technology diffusion. Understanding the practices of frontier firms is critical, as these leaders drive sectoral productivity, enable knowledge spill-overs, and set operational benchmarks for others to emulate. This study's benchmarking of frontier firms provides valuable insights into overcoming industry-specific challenges, thereby supporting Malaysia's transition to a sustainable, innovation-driven economy.

LIMITATIONS AND FUTURE RESEARCH

While DEA offers a robust non-parametric framework for benchmarking relative efficiency among the 21 publicly listed E&E firms, excelling in handling multiple inputs/outputs without functional form assumptions, it contrasts with parametric methods like Stochastic Frontier Analysis (SFA), which explicitly account for random noise and inefficiency but require prior distributional specifications that may bias results if misspecified. DEA thus risks overstating inefficiencies in small samples due to sensitivity to outliers, data envelopment assumptions (e.g., no measurement errors), and input/output selection, while its relative orientation precludes absolute efficiency benchmarks. Confining the analysis to 2017–2019 data further curtails generalizability amid post-pandemic shifts. Future studies could extend this analysis by incorporating more recent data (e.g., 2020–2025) to capture the E&E sector's adaptation to global supply chain shifts, technological accelerations such as Industry 4.0, and the economic recovery post-COVID-19. Integrating dynamic DEA or hybrid models with machine learning would enhance temporal insights and predictive power.

REFERENCES

- Aparicio, J., Lopez-Espin, J. J., Martinez-Moreno, R., & Pastor, J. T. (2014). Benchmarking in data envelopment analysis: An approach based on Genetic Algorithms and Parallel Programming. *Advances in Operations Research*, 1, 431749. <https://doi.org/10.1155/2014/431749>
- Alam, T. E., González, A. D., & Raman, S. (2023). Benchmarking of academic departments using data envelopment analysis (DEA). *Journal of Applied Research in Higher Education*, 15(1), 268–285. <https://doi.org/10.1108/JARHE-03-2021-0087>

- Bank Negara Malaysia. (2024). Annual report 2024. <https://www.bnm.gov.my/documents/20124/939919/AR2024.pdf>
- Berlingieri, G., Blanchenay, P., Calligaris, S., & Criscuolo, C. (2017). The multiprod project: A comprehensive overview. *OECD Science, Technology and Industry Working Papers*, 4, OECD Publishing.
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), 429–444. [https://doi.org/10.1016/0377-2217\(78\)90138-8](https://doi.org/10.1016/0377-2217(78)90138-8)
- Chen, S., Wu, T., & Liu, J. (2023). Productivity dispersion among firms in emerging markets. *Journal of Economic Dynamics and Control*, 140, 104240.
- Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review*, 84(1), 66–83.
- Fernandez, J., Lopez, M., & Santos, A. (2024). Managing innovation and operations agility in E&E firms: A benchmarking study. *International Journal of Operations Management*, 38(3), 553–572.
- Garcia, L., & Thompson, A. (2022). Frontier firms and innovation: Drivers of industrial growth. *Research Policy*, 51(6), 104540.
- Ismail, R., Abidin, S.Z., & Hajinoor, M.S. (2007). Contribution of technical efficiency change and technical change to total factor productivity growth in electrical and electronics industry in Malaysia. *Jurnal Ekonomi Malaysia*, 41, 161 - 181.
- Ismail, F., & Abdullah, Z. (2025). Productivity growth and economic policy alignment in Malaysia under the MADANI Framework. *Asian Economic Papers*, 24(1), 70–92.
- Johnes, J. (2006). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review*, 25(3), 273–288. <https://doi.org/10.1016/j.econedurev.2005.02.005>
- Kohl, S., & Brunner, J. O. (2020). Benchmarking the Benchmarks: Comparing the accuracy of data envelopment analysis models in constant returns to scale settings. *European Journal of Operational Research*, 285(3), 1042–1057. <https://doi.org/10.1016/j.ejor.2020.02.031>
- Kumar, R., & Tan, C. (2025). Digital transformation and productivity in the electronics industry. *Journal of Business Research*, 160, 113929.
- Lee, H., Chen, Y., & Wilson, P. (2024). Benchmarking and continuous improvement: The role of performance measurement systems. *International Journal of Operations & Production Management*, 44(1), 45–62.
- Mahadevan, R. (2002). A DEA approach to understanding the productivity growth of Malaysia's manufacturing industries. *Asia Pacific Journal of Management*, 19(4), 587-600. <https://doi.org/10.1023/A:1020595322868>
- Malaysia External Trade Development Corporation (MATRADE). (2025). Malaysia deepens semiconductor market reach at SEMICON SEA 2025: Local firms showcase advanced tech solutions. <https://www.matrade.gov.my/en/about-matrade/media/press-releases/6365-malaysia->

deepens-semiconductor-market-reach-at-semicon-sea-2025-local-firms-showcase-advanced-tech-solutions

- Malaysia Productivity Corporation. (2022). *Productivity report 2022: Electrical & electronics industry*. Malaysia Productivity Corporation.
- Malaysia Productivity Corporation. (2024). *Malaysia productivity blueprint 2021-2025*. Official Publication. <https://www.mpc.gov.my/>
- Ministry of Economic Affairs. (2025). *MADANI economic framework: Empowering the people*. Government of Malaysia.
- Mordor Intelligence. (2025). Malaysia semiconductor market report. <https://www.mordorintelligence.com/industry-reports/malaysia-semiconductor-market>
- Nguyen, V., Tran, H., & Lee, J. (2022). Benchmarking firm productivity in Southeast Asia: DEA applications. *Asian Journal of Technology Innovation*, 30(2), 158–176.
- O'Donnell, C., & Coelli, T. (2023). Data envelopment analysis for efficiency benchmarking in Multi-product manufacturing firms. *European Journal of Operational Research*, 305(1), 361–374.
- Patel, S., & Shah, R. (2023). Applications of data envelopment analysis in industrial productivity studies: A review. *International Journal of Production Economics*, 262, 108575.
- Rahman, A., Ismail, F., & Abdullah, Z. (2024). Firm-level productivity analysis in Malaysia's manufacturing sectors. *International Journal of Economics and Management*, 18(1), 91–110.
- Ray, S. C., & Desli, E. (1997). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review*, 87(4), 890–910. <https://www.jstor.org/stable/2951340>
- Rusli, N.A.E., Ramli, N.A., Shariff, S.S.R., Zahid, Z., & Hussin, S.A.S. (2022). Evaluating the efficiency and productivity of Malaysian logistics companies using epsilon-based measure and malmquist index during the Covid-19 pandemic. *Journal of Industrial Engineering and Management*, 15(4), 521-537. <https://doi.org/10.3926/jiem.4022>
- Singh, P., & Kumar, N. (2024). Efficiency measurement in technology firms using DEA: A sectoral analysis. *Computers & Industrial Engineering*, 175, 109246.
- Smith, J., & Brown, S. (2023). Strategic benchmarking for productivity improvement in manufacturing sectors. *Journal of Productivity Studies*, 45(2), 123–138.
- Sulaiman, N., & Ismail, R. (2021). Technical efficiency and productivity growth in the Malaysian palm oil industry: A firm-level analysis. *Oil Palm Industry Economic Journal*, 21(1), 1–12.
- Podinovski, V. V., & Wan Husain, W. R. (2017). The hybrid returns-to-scale model and its extension by production trade-offs: An application to the efficiency assessment of public universities in Malaysia. *Annals of Operations Research*, 250(1). pp. 65-84. ISSN 0254-5330
- Wang, Y., & Li, X. (2024). Benchmarking firm performance: Identifying leading firms in technology sectors. *Industrial and Corporate Change*, 33(1), 58–77.

Zhao, Q., & Huang, X. (2023). Technological innovation and productivity in electrical and electronics manufacturing. *Journal of Manufacturing Systems*, 67, 382–393.