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# THE IMPACT OF TECHNOLOGY ON LOGISTICS SERVICES IN SAUDI ARABIA

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SUMMARY

This research strives to explore the impact of technological advancements which have transformed logistics services in Saudi Arabia in line with Vision 2030 goals. It examines key technologies viz. Big Data, Internet of Things (IoT), Blockchain, autonomous vehicles and drones etc. which have enhanced operational efficiency, reduced costs and improved service quality, thereby significant operational improvements to the logistics companies in Saudi Arabia. Case studies have been taken from local companies which demonstrate successful implementation of these technologies. Given the inherent challenges like regulatory requirements, infrastructure developments etc., the research also highlights the potential of autonomous vehicles and drones to further revolutionize transportation and last-mile delivery services. Overall, this study concludes that technological integration is critical for driving efficiency, competitiveness, and sustainability in the logistics sector, aligning with Saudi Arabia's broader economic transformation goals.

Key words: *technology, logistics services, IOT, blockchain, saudi arabian vision 2030.*

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## INTRODUCTION

As the Kingdom of Saudi Arabia continues to experience rapid technological evolution, questions about the potential benefits and negative consequences of technology in the logistics sector have become increasingly relevant [29]. Integration of supply chain management (SCM) has become imperative for companies operating in agile manufacturing industries in Saudi Arabia, as it can significantly enhance operational efficiency and effectiveness. Organizations are re-organizing and streamlining to adapt with growing significance of SCM.

### Background of the Study

In Saudi Arabia, government initiatives have played a crucial role in promoting the diffusion of online retailing, leading to a major expansion in the retail sector and increased e-commerce adoption by retailers and customers [3]. Manufacturing industry in Saudi Arabia has recognized the importance of SCM, which has led to a focus on partnership and strategic alliances to optimize resources, performance and gains in SCM.

These developments have laid the groundwork for understanding the current state of logistics services in Saudi Arabia and impact of technology on this sector [15].

**Research Objectives**

This research envisages exploring the application of IT in logistics, highlighting its benefits and future trends, defining research questions and specifying objectives, in context of Saudi Arabia [21, 22, 23].

Advancement in information and communication technology (ICT) has brought added advantages to logistics and supply chain globally and Saudi Arabia is also integrating various logistics technologies in order to become a regional logistics hub and diversify its economy.

Given the importance of significant logistics, Saudi Arabian firms are identifying ways to enhance competitiveness throughout effective SCM.

**Scope and Significance**

This research aims to study the impact of technology on different aspects of logistics services, viz. transportation, warehousing, inventory management etc., in context of Saudi Arabia. Additionally, the significance of this topic lies in its potential to enhance efficiency, effectiveness and competitiveness of logistics operations in Saudi Arabia, aligning with the growing importance of SCM.

LITERATURE REVIEW

Logistics services in Saudi Arabia have been witnessing significant transformation with technological advancements. This literature review attempts to assess the impact of modern technological feats such as Big Data and Analytics, Internet of Things (IoT) and Blockchain on logistics efficiency, service quality, and competitiveness under the aegis of Saudi Vision 2030. Vikaliana [43] have observed that data-driven capabilities provided by Big Data and Analytics integrate e-commerce and new data sources which streamline logistics processes and improve financial performance in context of Saudi Arabia. Al-Otaibi and Al-Zahrani [8] observed that impact of Big Data extends to inventory management as well in order to reduce stockouts and improve customer satisfaction with the help of analytics within logistics companies. It is noteworthy to mention that Saudi Post has reaped tangible benefits from Big Data systems, including reductions in delivery times and fuel consumption, demonstrating its potential in optimizing logistics services [30].

Internet of Things (IoT) has changed the dimensions of real-time tracking and operational visibility, which signifies its role in transforming logistics sector in Saudi Arabia. Jarašūnienė et al., [17] illustrated the significance of IoT on warehouse management and outbound logistics [16]. A report of Saudi E-Commerce signified that IoT innovations such as smart lockers have shown significant improvements in delivery success rates [37]. However, there remains challenges, including infrastructure requirements and cybersecurity threats, which necessitates stringent guidelines for IoT deployments [25] [2].

While working with Blockchain Technology, it becomes important to improve transparency and security in supply chains. Kromes et al., [20] conceptualized that Blockchain deployment in logistics is heralded as a game-changer for its ability to ensure trustworthy records and reduce fraud. The study by [7] [36] reflected that blockchain adoption in Saudi Arabia faces regulatory hurdles indeed, but certain initiatives by Saudi Customs Authority and private banks like SABB have shown early successes in transaction efficiency and fraud reduction.

Though, the benefits ensured by technological advancements are evident, this literature strives to highlight certain barriers which come in line while adopting new technologies. Al Ghamdi et al., observed that regulatory environment remains a challenge which requires transparent frameworks to support technological integration. Alenezi, [4] highlighted that infrastructure limitations, including underdeveloped technological framework, remain sizeable obstacle. Alongside [9] emphasized notable

skill gaps which requires investment in training and education to facilitate effective technology deployment in logistics.

**Key Technologies Transforming Logistics**

New technologies such as Big Data and Analytics, Internet of Things (IoT) and Blockchain Technology have emerged as key drivers of transformation of logistics industry in Saudi Arabia. Vikaliana [43] has observed that in the instant digital era, data availability is multiplying by every passing year and the same has benefitted logistics sector by way of continuous flow of varied and unstructured data which are managed and analyzed to enhance the value of information in business decision-making. In addition to this [1] observed that engagement of ICT facilities, such as Enterprise Resource Planning (ERP) and software for transport optimization, has significantly transformed various business transactions, including logistics, stock management, warehousing, and trucking which has ultimately improved the quality of services in the logistics industry [24].

**Benefits of Technological Integration in Logistics**

Integration of technology into logistics enhances efficiency and reduces costs by streamlining communication channels, reducing intermediaries, and establishing direct connections with customers [1]. Additionally, the use of ERP and MRP software led to improved productivity, quality services, operational efficiency, and cost reduction. Technological integration and electronic data interchange have significantly improved SCM operations. Overall, adapting ICT facilities in logistics services brings about significant improvements in operational processes, customer service, and supply chain relationships in the context of Saudi Arabia [26]. Vision 2030 initiatives of Saudi Arabia aim to diversify the economy and reduce dependence on oil revenues, with logistics playing a crucial role in this transformation [43]. Adapting advanced technologies in logistics has become necessary for Saudi Arabia to position itself as a global logistics hub.

**Challenges and Barriers to Technology Adoption**

Though, technology integration has brought evident benefits, but its adoption in logistics sector in Saudi Arabia is not free from challenges. Al Ghamdi et al., [3] and Alenezi, [4] have observed that technology deployment is significantly impacted by regulatory constrains and they both pressed for the need for clear regulations and supportive legislation. Additionally, due to compelling need towards expanding network of technological application, infrastructure limitations are required to be addressed. Skills gap have been identified by [9] as a hurdle towards effective technology adoption and it requires a robust training program to enhance the skill set of workforce to bridge that gap.

**Case Studies of Technology Implementation**

In order to understand the practical benefits of adopting key technologies, this research work has examined two case studies. Company A has leveraged IoT sensors to enhance supply chain traceability, whereas Company B has implemented Blockchain technology for tracking. As evident from the work of [12], implementation of IoT sensors has positive bearing on stakeholder communication and information sharing, which optimizes the yields of forecasting models. On the other hand, Verhoeven et al., 2018 have arrived at a conclusion that integration of blockchain technology has drastically reduced tracking times, showcasing its capability to address logistics challenges effectively [27].

**Future Trends and Innovations in Logistics Technology**

Kostrzewski [19] have postulated that logistics industry shows trends of further integration of Artificial Intelligence (AI) and Machine Learning (ML) for demand forecasting and inventory management. Whereas [19] have observed that use of Autonomous Vehicles and Drones are bound to revolutionize SCM as they offer improved navigation and cost efficiencies.

Notwithstanding regulatory and infrastructural hurdles, the Kingdom's commitment to digitalization and smart cities bodes well for their integration of innovative technologies into logistics.

## RESEARCH METHODOLOGY

A mixed-method approach has been employed in this study in order to investigate the impact of technology on logistics services in Saudi Arabia, which is designed to provide a comprehensive analysis of both quantitative and qualitative data and it offers significant insights into the layered interplay between technological adoption and logistics performance in context of the Kingdom.

### Data Collection

In order to ensure comprehensive and accurate representation of logistics sector in Saudi Arabia, this study has employed meticulous method of date collection from multiple sources. Secondary data have been collected from the Saudi General Authority for Statistics and the Ministry of Transport and Logistics Services along with financial statements of logistics companies listed on Tadawul and annual reports and investor presentations of major logistics firms. The primary data have been gathered from surveys and interviews, which provide firsthand insights into logistics sector, and also complement the aforesaid secondary data. The study period covers a span of nine years, from 2015 to 2023, and this timeline is carefully chosen to capture the rapid technological advancements and their impacts on the logistics sector following the announcement of Saudi Vision 2030.

### Sample Selection

The study sample has been drawn from a diverse and representative selection of participants for Saudi Arabian logistics industry. Stratified random sampling has been employed to arrive at a set of 150 logistics companies which operates across various sub-sectors, in order to ensure comprehensive representation. Also, insights from 50 interviews conducted with industry experts and government officials have also been incorporated, which provide depth and expert perspectives on the logistics landscape of Saudi Arabia. These are complemented by survey responses collected from 300 logistics professionals which offers a broad viewpoint on industry practices and technological integration.

### Variables

An array of variables has been examined through this study in order to assess the impact of technology on logistics performance in Saudi Arabia. Return on Assets (ROA), Operating Profit Margin, and Total Factor Productivity (TFP) have been treated as dependent variables as they serve as key indicators for measuring financial and operational efficiency. At the same time, this study relies of independent variables which focus on various aspects of technological integration, highlighted by the Technology Adoption Index. This index is a composite measure which incorporates the ratio of IT spending to revenue, the number of smart warehouses relative to total warehouses, the percentage of shipments with electronic tracking and the number of autonomous vehicles as a proportion of the total fleet size [5]. Additionally, other factors such as Digital Transformation Score, IoT Implementation Level and Blockchain Adoption have also been incorporated as independent variables, as each of them provides insights into the degree and efficacy of technological adoption [6]. Several other factors such as Company Size, Market Share, Age of Company, and GDP Growth Rate have been taken as control variables to ensure robust analysis, as these factors are capable of influencing relationships between technology adoption and logistics performance.

### Quantitative and Qualitative Analysis

A host of statistical techniques have been employed in this study in order to ensure a comprehensive analysis of the data which has been collected on enhanced performance of logistics industry due to technological advancements in Saudi Arabia [8]. These techniques include Descriptive Statistics, which provide a basic overview of the data, and Correlation Analysis, which examines relationships between variables [10, 11]. Also, Multiple Linear Regression has been used to assess the influence of

independent variables on dependent variables, while Panel Data Analysis has been employed to ascertain insights over the period studied [13]. Ordinary Least Squares (OLS) and Generalized Method of Moments (GMM) have been applied for accurate estimation of parameters of interest. Appropriate model for analysis has been arrived with the use of Hausman Test, while Variance Inflation Factor (VIF) Analysis has been utilized to check issues pertaining to multicollinearity. Thematic analysis has been performed on interview transcripts and open-ended survey responses to extract key themes and patterns in addition to the quantitative analysis, which offers qualitative perspective that complements the quantitative findings.

**Ethical Considerations**

Ethical guidelines have been adhered in the study to ensure participant confidentiality, informed consent and data protection. Approval from the relevant ethics committee has also been obtained.

**Methodological Limitations**

Several potential limitations have been acknowledged in the study with underlying impression that these could impact the findings and interpretations. There is reliance on self-reported data to begin with in order to measure technology adoption; however, this may reflect biases or inaccuracies while representing the true extent of technological integration within firms. Thereafter, omitted variable bias can be observed due to the presence of unobservable firm characteristics which has potential to influence the results but are not accounted for in the analysis. Lastly, while the study aims to provide valuable insights of logistics sector in Saudi Arabia, but there can be limitations of its applicability in other countries due to the unique economic and cultural context of Saudi Arabia which is significantly distinct from different countries [14].

RESULTS

A comprehensive analysis of the data collected on the impact of technology adoption on logistics services in Saudi Arabia for a span on nine years from 2015 to 2023 has been discussed in this section. A blend of quantitative statistical methods with qualitative insights has been utilized in order to arrive at a holistic understanding of the relationships between technological integration and logistics performance [31-35].

**Descriptive Statistics**

Insight into the logistical landscape over the period from 2015 to 2023 has been observed by using descriptive statistics for this study. Key variables, relevant to the performance and technological adoption within the logistics sector, have been identified and a total of 1,350 observations per variable have been considered for detailed analysis [28].

The Return on Assets (ROA) is a generally accepted measure of profitability. The study reflects an average value of ROA as 7.23%, with a median of 6.95%, which indicates a generally consistent performance across logistics companies. The standard deviation of 2.84% points to some variability in profitability among firms, as values range from a low of 1.12% to a high of 15.37%.

Operating Profit Margin is another profitability indicator, with an average of 11.56% and a median of 10.89%, displaying a greater degree of variability (standard deviation of 3.72%) than ROA. Values stretch from 2.35% to 22.41%, indicating diverse financial health within the sector.

The Technology Adoption Index, averaging 0.58, reveals a moderate level of overall technological integration across the industry, with a median of 0.55 and a standard deviation of 0.21. This measure reflects the extent of IT spending relative to revenue, the prevalence of smart warehouses, electronic tracking, and the use of autonomous vehicles, demonstrating the sector's gradual embrace of technological advancements within specified limits of 0.15 and 0.97.

Electronic Tracking stands out as a well-established technological practice, with a high mean of 68.92% and a median of 72.50%, suggesting widespread implementation across companies. Despite a wider standard deviation of 22.17%, indicating some disparity, almost full adoption is evident as the maximum reaches 100%.

Conversely, Smart Warehouses have a mean usage of 32.45%, indicating they are less common, with a median significantly lower at 28.00%, and variability shown by an 18.63% standard deviation. However, the maximum recorded is 85%, reflecting that some companies have significantly invested in this technology.

Autonomous Vehicles are still emerging in the logistics landscape of Saudi Arabia, reflected by a low average usage of 5.37%, and a median of just 2.00%. We have observed the standard deviation of 7.84%, which highlights variability and reflects that some companies have adopted this technology more extensively than others, as evident by the maximum value as 35% [38].

Collectively, these statistics shows functioning of the logistics sector which is passing through different stages of technological adoption, with areas of strong uptake like electronic tracking and more nascent technologies like autonomous vehicles are still under prominence. Key variables' descriptive statistics from 2015 to 2023 shown in Table 1.

Table 1. Descriptive statistics of key variables (2015-2023)

| Variable | Mean | Median | Std Dev | Min | Max | N |
|---|---|---|---|---|---|---|
| ROA (%) | 7.23 | 6.95 | 2.84 | 1.12 | 15.37 | 1,350 |
| Operating Profit Margin (%) | 11.56 | 10.89 | 3.72 | 2.35 | 22.41 | 1,350 |
| Tech Adoption Index | 0.58 | 0.55 | 0.21 | 0.15 | 0.97 | 1,350 |
| Smart Warehouses (%) | 32.45 | 28.00 | 18.63 | 0.00 | 85.00 | 1,350 |
| Electronic Tracking (%) | 68.92 | 72.50 | 22.17 | 10.00 | 100.00 | 1,350 |
| Autonomous Vehicles (%) | 5.37 | 2.00 | 7.84 | 0.00 | 35.00 | 1,350 |

**Correlation Analysis**

Valuable insights into the relationships between profitability, technology adoption, and specific technological implementations within the logistics sector have been examined by correlation matrix for the key variables in this study.

Return on Assets (ROA) and Operating Profit Margin (OPM) reflect a strong positive correlation of 0.82. This indicates that companies with higher profitability margins also tend to have a higher return on their assets, which highlights close relationship between these two financial performance metrics in the logistics industry.

Substantial positive correlations have been shown by the Technology Adoption Index which reflects ROA (0.65) and OPM (0.71). These findings are indicative of the fact that the firms investing more in technology tend to perform better financially. The Technology Adoption Index also has high correlation values with specific technological components, which reflects a comprehensive integration approach among companies.

Smart Warehouses shows a moderate positive correlation with ROA (0.54), OPM (0.62), and the Technology Adoption Index (0.78). This is indicative of the fact that firms adopting smart warehouse technologies frequently also invest in broader technological advancements, which collectively contribute to improved financial outcomes.

While considering Electronic Tracking, it appears to be a significant component of technological integration with correlations of 0.58, 0.66 and 0.85 respectively with ROA, OPM and Technology Adoption Index. Its strong correlation with Smart Warehouses (0.70) and Autonomous Vehicles (0.57), implies that it is often implemented alongside other tech strategies, which has potential to enhance operational transparency and efficiency in firms.

Notwithstanding its early stage of adoption, Autonomous Vehicles show a positive correlation with ROA (0.41) and OPM (0.45). Also, the strong correlation with the Technology Adoption Index (0.69) is indicative of the fact that firms utilizing autonomous vehicles are generally more committed to overall technological integration. Additionally, the correlation with Smart Warehouses (0.53) and Electronic Tracking (0.57) highlights the mutual connection of these technologies in shaping a modern logistics approach.

Overall, the correlation matrix indicates that technology adoption, especially in electronic tracking and warehouse modernization, yields significant contributions for better financial performance in the logistics sector. This interdependence highlights the importance of integrated technological strategies for enhancing operational effectiveness and profitability. Correlation analysis of key variables. Shown in Table 2.

Table 2. Correlation Matrix of Key Variables

| Variable | ROA | OPM | Tech Index | Smart WH | E-Track | Auto Veh |
|---|---|---|---|---|---|---|
| ROA | 1.00 | | | | | |
| OPM | 0.82* | 1.00 | | | | |
| Tech Index | 0.65* | 0.71* | 1.00 | | | |
| Smart WH | 0.54* | 0.62* | 0.78* | 1.00 | | |
| E-Track | 0.58* | 0.66* | 0.85* | 0.70* | 1.00 | |
| Auto Veh | 0.41* | 0.45* | 0.69* | 0.53* | 0.57* | 1.00 |

Note: * $p<0.001$

**Regression Analysis**

Objective of multiple regression analysis is to provide insights into the impact of various technological and operational factors on Return on Assets (ROA) of logistics companies. In line with this objective, this analysis has strived specifically to examine the contributions of The Technology Adoption Index, use of smart warehouses, electronic tracking and autonomous vehicles alongside firm size on ROA.

Intercept of 1.853 has been revealed by the regression model, which is substantial and indicates the baseline level of ROA when all independent variables are held at zero. The t-value of 4.498 and the p-value of less than 0.001 confirms the statistical significance of this intercept.

Technology Adoption Index reflects a highly significant positive coefficient of 5.721, which is indicative of the fact that greater adoption of technology correlates with notable increase in ROA. This is reinforced by a t-value of 6.531 and a p-value below 0.001, which signifies the critical role that comprehensive technological integration plays in enhancing financial performance.

Smart Warehouses factor exhibits a positive coefficient of 0.028, in addition to a significant t-value of 3.111 and a p-value of 0.002. This shows that the percentage use of smart warehouse technologies is indicative of improved ROA, however to a lesser extent compared to broader technological adoption.

Electronic Tracking demonstrates a significant positive influence on ROA, with a coefficient of 0.035, a t-value of 4.375, and a p-value below 0.001. This suggests a strong relationship between the implementation of electronic tracking systems and enhanced financial returns, emphasizing the value of real-time operational visibility.

Autonomous Vehicles have a positive coefficient of 0.052 and are statistically significant with a t-value of 2.476 and a p-value of 0.014, suggesting that even at an early adoption stage, the use of autonomous vehicles contributes positively to ROA.

The Firm Size (log assets) is also positively associated with ROA, reflected by a coefficient of 0.387, a t-value of 3.757, and a highly significant p-value of less than 0.001. Larger firms presumably benefit more from economies of scale when implementing technological advancements.

Overall, the model is reasonably strong with an R-squared of 0.583 and an adjusted R-squared of 0.571, indicating that approximately 58.3% of the variability in ROA is explained by the independent variables included in the model. The F-statistic of 47.26 with a p-value below 0.001 confirms the overall statistical significance of the regression model. The crucial role of technology adoption and firm size in driving financial performance within the Saudi logistics sector is highlighted by this analysis. Results of multiple regression (Dependent Variable: ROA) Shown in Table 3.

Table 3. Multiple Regression Results (Dependent Variable: ROA)

| Variable | Coefficient | Std Error | t-value | p-value |
|---|---|---|---|---|
| Intercept | 1.853 | 0.412 | 4.498 | <0.001 |
| Tech Adoption Index | 5.721 | 0.876 | 6.531 | <0.001 |
| Smart Warehouses (%) | 0.028 | 0.009 | 3.111 | 0.002 |
| Electronic Tracking (%) | 0.035 | 0.008 | 4.375 | <0.001 |
| Autonomous Vehicles (%) | 0.052 | 0.021 | 2.476 | 0.014 |
| Firm Size (log assets) | 0.387 | 0.103 | 3.757 | <0.001 |

R-squared: 0.583, Adjusted R-squared: 0.571 F-statistic: 47.26, p-value: <0.001

**Panel Data Analysis**

With an objective to garner improved Return on Assets (ROA), the panel data analysis using a fixed effects model has been used in this study, which offers detailed insights into the influence of technological factors on firm performance. Both time-variant and invariant characteristics across logistics firms for a span of 9 years, i.e. from 2015 to 2023, have been considered in this analysis.

The Technology Adoption Index reflecting a coefficient of 4.876 shows a significant positive impact on ROA. This indicates that the increased adoption of technology contributes significantly towards enhancing financial performance. A high t-value of 6.562 and a p-value of less than 0.001 reinforce the statistical significance of this relationship, which reflects the robust evidence of technology adoption as a key profitability determinant within the logistics sector.

Smart Warehouses show a positive coefficient of 0.023, with a t-value of 2.875 and a p-value of 0.004. This demonstrates a significant but relatively smaller contribution to ROA compared to the overall technology adoption index. It can be deduced by these findings that investments in smart warehouse technologies has potential to improve firm’s performance, although the effect is less proclaimed than the broader technological initiatives.

Electronic Tracking is another significant factor positively affecting ROA, with a coefficient of 0.029. The t-value of 4.143 and a p-value below 0.001 highlight the substantial impact of electronic tracking systems on financial outcomes, underscoring the importance of operational transparency facilitated by such technologies.

Autonomous Vehicles have a positive coefficient of 0.041, indicating a beneficial impact on ROA. The significance of this effect is confirmed by a t-value of 2.278 and a p-value of 0.023, reflecting the potential of autonomous vehicles to contribute positively to firm performance, even at initial stages of adoption.

The Within R-squared value of 0.412 implies that 41.2% of the variability in ROA within individual firms over time is explained by the model, while the Between R-squared of 0.597 suggests that 59.7% of the variance between different firms' average ROA is captured by the independent variables. The Hausman Test result, with a chi-square value of 28.34 and a p-value less than 0.001, indicates that the fixed effects model is appropriate for this analysis, effectively accounting for time-invariant characteristics of the firms.

Overall, the panel data analysis robustly confirms a positive relationship between technology adoption and enhanced firm performance in the Saudi logistics sector, highlighting the importance of technological investments for achieving operational and financial efficiencies, even when accounting for firm-specific characteristics. Panel data analysis using the fixed effects model shown in Table 4.

Table 4. Panel Data Analysis (Fixed Effects Model)

| Variable | Coefficient | Std Error | t-value | p-value |
|---|---|---|---|---|
| Tech Adoption Index | 4.876 | 0.743 | 6.562 | <0.001 |
| Smart Warehouses (%) | 0.023 | 0.008 | 2.875 | 0.004 |
| Electronic Tracking (%) | 0.029 | 0.007 | 4.143 | <0.001 |
| Autonomous Vehicles (%) | 0.041 | 0.018 | 2.278 | 0.023 |

Within R-squared: 0.412, Between R-squared: 0.597 Hausman Test: $\chi 2 = 28.34$, p-value < 0.001

**GMM Estimation**

This study has undertaken shape while using panel data analysis with fixed effects model. This underlying method provides deeper insights into the influence of technological factors on firm performance, specifically signifying the Return on Assets (ROA). Both time-variant and invariant characteristics across logistics firms for a span of 9 years, i.e. from 2015 to 2023, have been considered in the analysis.

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Electronic Tracking, depicting a coefficient of 0.029, is yet another significant factor which affects ROA positively. A t-value of 4.143 and a p-value below 0.001 highlight the substantial impact of electronic tracking systems on financial outcomes, which highlights the importance of operational transparency facilitated by such technologies.

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Overall, the panel data analysis robustly confirms a positive relationship between technology adoption and enhanced firm performance in the Saudi logistics sector, highlighting the importance of technological investments for achieving operational and financial efficiencies, even when accounting for firm-specific characteristics [40]. Results of the System GMM estimation shown in Table 5.

Table 5. System GMM Results

| Variable | Coefficient | Std Error | z-value | p-value |
|---|---|---|---|---|
| Lagged ROA | 0.284 | 0.062 | 4.581 | <0.001 |
| Tech Adoption Index | 3.987 | 0.689 | 5.786 | <0.001 |
| Smart Warehouses (%) | 0.019 | 0.007 | 2.714 | 0.007 |
| Electronic Tracking (%) | 0.025 | 0.006 | 4.167 | <0.001 |
| Autonomous Vehicles (%) | 0.037 | 0.016 | 2.313 | 0.021 |

Sargan Test: $\chi 2 = 42.18$, p-value = 0.328 AR(2) Test: z = 0.843, p-value = 0.399

**Qualitative Insights**

The thematic analysis of interview data for this study uncovers several crucial insights into the dynamics of technological implementation within the sector.

Challenges in technology implementation have emerged as crucial factor that has emerged out of this study. Significant obstacles, particularly concerning workforce skills and infrastructure limitations, have been highlighted by the interviewees. Many logistics companies encounter problems in securing skilled personnel who are well versed in managing and operating new technologies, which throws challenges in effective implementation. Existing infrastructural constraints, such as inadequate digital connectivity and need for substantial upgrades, also play obstacle in adopting advanced logistics technologies due to which potential efficiencies and benefits are not fully realized.

Support of government in facilitating technology adoption is another critical which requires attentions. Government initiatives and policies have been identified by the participants as attributes that can play a pivotal role in promoting and enabling technological advancements within the logistics sector. They have identified factors vis. provision of incentives, regulatory frameworks and strategic investments by the government as essential enablers for logistics companies in order to overcome initial implementation costs and risks that could foster a conducive environment for innovation and digital transformation in line with Saudi Vision 2030.

The transformative potential of blockchain and IoT has also emerged as yet another key theme out of this study. Interviewees recognized the significant impact blockchain and IoT on enhancing supply chain transparency. Blockchain technology is seen as a game-changer, which provides secure and tamper-proof records fostering trust and traceability across supply chain operations. Similarly, IoT technologies are highly praised for their ability to offer real-time data and insights, which enhances operational visibility and decision-making accuracy. Both these technologies have been discussed as stellar tools for modernizing logistics processes, streamlining operations and ultimately strengthening competitive advantage in the sector.

These qualitative findings highlight different nuances of Saudi Arabian logistics industry throwing light on reciprocity between technological potential and challenges in practical implementation, thereby accentuating the complex contours of logistics which is undergoing a facelift. Critical areas, where targeted efforts particularly in workforce development, infrastructure enhancement and government policy are required, have also been highlighted and it is expected that these can significantly accelerate the digital transformation journey of logistics sector [39-42].

DISCUSSION

This study throws light on significant positive impact of technology adoption on the performance of logistics firms in Saudi Arabia. Strong positive coefficients associated with the Technology Adoption Index in both the Ordinary Least Squares (OLS) and fixed effects models ($\beta = 5.721$ and $\beta = 4.876$, respectively) indicate that the firms which tend to invest more in technological integration, reap notably higher ROAs. These results indicate a clear sync between broad technological adoptions and enhanced

financial outcomes, which is an outcome of strategic digital transformation in logistics sector driving growth therein.

Upon examining various technologies, the study arrived at finding that electronic tracking factor has shown the biggest impact on firm's performance, closely followed by autonomous vehicles and smart warehouses. The rampant use of electronic tracking systems has yielded enhanced operational transparency and efficiency, which ultimately leads to better financial metrics. Notwithstanding its nascent stages, adoption of autonomous vehicles has yielded promising positive relationship with returns, which is indicative of high potential of such technologies. Smart warehouses also contribute significantly, which promotes improved resource management and operational workflows within logistics firms.

It has come as an outcome that larger firms tend to garner more benefits from technology adoption, probably due to their capacity to leverage economies of scale and also their tendency to absorb initial technology investment costs effectively. This signifies that though, all firms are likely to gain from technological advancements, the larger entities are better placed to extract more potential benefits due to their market positioning and resource capacity.

These findings were further corroborated by the System Generalized Method of Moments (GMM) model which reveals a significant coefficient for the lagged ROA (0.284), which suggests consistency in performance trends over time and emphasizes the sustained benefits of technology adoption. While examining different sectors, the transportation sub-sector exhibited the strongest correlation with technological advancements, which was followed by warehousing and freight forwarding. This finding reflects the critical role of technology in enhancing the efficiency and responsiveness specifically within transportation logistics.

In line with the strategic goals outlined under Vision 2030 document, results of this study outline significant implications for logistics firms and policymakers within Saudi Arabia [18]. These have outlined the reinforced need for continued investment in digital infrastructure and workforce skill development in order to completely harness the benefits of technology. Further, it is estimated that the targeted government support could bridge current gaps, which could foster an environment that encourages innovation and also ensures competitive edge on a global scale. Given the evolving nature of logistics sector, embracing technological advancements deems to be essential for achieving sustainable growth and operational excellence.

## CONCLUSION

This comprehensive study has strived to examine the impact of technological advancements on logistics services in Saudi Arabia. As a result thereof, the transformative role of technological advancements in aligning the logistics sector with the ambitious Vision 2030 goals has come prominently to the fore. Over the time horizon of nine year, i.e. the study period, spanning from 2015 to 2023, various key technologies such as Big Data, the Internet of Things (IoT), Blockchain, autonomous vehicles and drones have displayed significant potential in enhancing operational efficiency, reducing costs and improving service quality within the industry.

First and foremost, integration of Big Data and Analytics in logistics has played a pivotal role in streamlining operations, which has led to enhanced financial performance and customer satisfaction. Also, the use of data-driven strategies has facilitated companies with optimized inventory management, to minimize stockouts and to reduce delivery times, which has been evidenced by the case study on organizations like Saudi Posts. Additionally, deployment of IoT technologies has also revolutionized logistics by way of providing real-time tracking and operational visibility, which significantly fosters productivity and logistics process efficiency.

Blockchain technology, which offers enhanced transparency and security in supply chain operations, has emerged as another game-changer for logistics industry in Saudi Arabia. It has demonstrated utility for

fostering trust and reducing instances of fraud. Even though, the adoption technological advancements have numerous advantages for logistics sector, the study acknowledges that the ongoing regulatory challenges and infrastructural limitations play hindering role in achieving full-scale adoption. Thus, it is imperative to underline that the full potential of these advancements can be realized by way of addressing these obstacles while bridging the skills gap through workforce training and education alongside.

Results of this study stresses significantly on the considerable impact of these technologies, particularly in the domains of electronic tracking, autonomous vehicles and smart warehouses. It has been apparent that the larger firms are better positioned to garner more potential benefits from technology adoption, as they are adept in leveraging economies of scale. Meanwhile, improved financial outcomes, viz. Return on Assets (ROA) and profitability margins for logistics firms, have been affirmed to have positive relationship with technology adoption, as evidenced by empirical analyses which have been carried out through regression and panel data models.

As far the policy perspectives are concerned, it has been keenly observed that the government initiatives are integral in promoting digital transformation within the logistics sector in Saudi Arabia. In order to maintain competitive edge, it will be crucial to have continued investment in digital infrastructure; so as to foster an environment conducive to innovation. It is also evident that more targeted support can bridge the existing gaps, which could enable the firms of varying sizes to adapt the evolving technological trends effectively.

As Saudi Arabia embarked on its journey towards economic diversification, it is expected that technology will remain key driving force for growth of logistics sector. With the advent of new technologies, viz. AI, Machine Learning, autonomous vehicles and drone integration, logistics sector is bound to experience supply chain efficiency and service quality. The position of Saudi Arabia as the leading logistics hub will be further cemented by embracing these innovations, which will ultimately contribute towards its realization of Vision 2030 objectives.

This study concludes by affirming that strategic technology adoption has significant potential of enhancing operational capabilities and it can also accelerate the alignment Saudi logistics sector with global industry standards, which will prepare grounds for a sustainable and technologically adept logistics ecosystem in the Kingdom.

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