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The impact of big data analytics on financial market integration and efficiency in Saudi Arabia

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ABSTRACT

This study investigates the impact of Big Data Analytics (BDA) on market integration and efficiency in Saudi Arabia's financial sector. Using data from 182 participants in financial institutions, it examines key BDA dimensions—data volume, variety, velocity, accuracy, and analytical tools—and their effects on market performance. A structured survey and structural equation modeling (SEM) were used for data analysis. Findings highlight that data accuracy and advanced analytical tools significantly enhance market efficiency, while data volume and variety have a limited impact. The results emphasize prioritizing data quality and effective interpretation over quantity and diversity, with artificial intelligence (AI) playing a key role in decision-making and market efficiency. Despite regional and cross-sectional limitations, the study provides valuable insights for practitioners and policymakers. Future research should expand the scope and explore the long-term effects of BDA on financial markets.

1. Introduction

The emergence of Big Data Analytics (BDA) has fundamentally transformed numerous sectors, with the financial markets notably experiencing substantial progress attributable to its application. In Saudi Arabia, the BDA is now viewed as a vital instrument that enhances how financial entities tackle large-scale structured and unstructured data. This evolution facilitates more precise forecasting, comprehensive risk assessment, and informed decision-making, all of which are vital for sustaining the competitiveness and stability of the financial sector. As Alaskar et al. (2021) articulated, BDA empowers financial institutions to swiftly adapt to market fluctuations, thereby serving as a potent enabler of tailored services and strategic planning. Even with these advancements, a significant research void persists regarding the direct influence of BDA on market integration and efficiency, particularly within the financial milieu of Saudi Arabia.

Although the incorporation of BDA into the financial sector is extensively documented, more exhaustive studies are still needed to investigate the specific effects of BDA on the integration and efficiency of financial markets within Saudi Arabia. Most existing literature has concentrated on BDA's operational advantages, including enhancing decision-making processes and optimizing regulatory frameworks (Niu, et al., 2021). Nonetheless, the broader effects of BDA on the general market landscape have received comparatively less scrutiny, particularly in how it promotes collaboration among crucial stakeholders, including regulators, financial entities, and market actors. The current body of literature indicates that BDA mitigates information asymmetries and promotes competitive practices; however, how this translates into concrete improvements in market integration and efficiency still needs to be more adequately elucidated (Martin and Nagel, 2022).

The dynamic landscape of the financial sector necessitates a more profound examination of how BDA can assist in rectifying market inefficiencies. This research aims to bridge the knowledge gap by investigating how the fundamental components of BDA—namely, data volume, variety, velocity, and quality—contribute to the integration and efficiency of the financial market in Saudi Arabia. In particular, it will analyze how BDA enhances regulatory frameworks, stimulates innovation, and bolsters market resilience—elements that have previously been insufficiently explored within the Saudi context. This investigation is of considerable

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significance as it delves into a pivotal domain of financial market evolution—namely, market integration and efficiency—by examining the ramifications of advanced data analytics. Comprehending this interplay is particularly crucial for Saudi Arabia, a nation striving to establish itself as a preeminent global financial hub through strategic initiatives such as Vision 2030. By scrutinizing the function of Big Data Analytics (BDA) in augmenting the operations of financial markets, this inquiry is poised to furnish insights beneficial to financial institutions and policymakers endeavoring to cultivate a robust and competitive financial ecosystem.

Furthermore, the research adds to the expansive discourse surrounding technology deployment in financial markets, which has gained substantial traction in recent years (Javaid, 2024). Beyond facilitating innovation, BDA promotes transparency and mitigates market inefficiencies, rendering it an indispensable instrument for guaranteeing that Saudi Arabia's financial market retains its competitive edge internationally. This investigation also builds upon the contributions of Kumar et al. (2022), who underscored the significance of BDA in sustainable finance by probing into how it can enhance market dynamics and regulatory frameworks within the Saudi financial landscape.

This research aims to investigate the ramifications of Big Data Analytics (BDA) on the integration and efficiency of the financial market in Saudi Arabia. In pursuit of this objective, the study will initially explore how BDA fosters improved collaboration among principal market stakeholders, encompassing regulators, financial institutions, and market participants, thereby enhancing overall market integration. Moreover, it will assess how BDA influences operational efficiency in the financial sector, specifically highlighting its contribution to reducing information asymmetry and fostering a more open and competitive market landscape. This research intends to investigate the distinct aspects of BDA—including data quantity, types, pace, correctness, and standard—and their roles in the overall dynamics and success of the financial markets in Saudi Arabia.

By fulfilling these objectives, this study will yield a thorough comprehension of BDA's role in shaping the trajectory of Saudi Arabia's financial market.

While a substantial corpus of scholarly work continues to investigate the advantages of Big Data Analytics (BDA) for financial institutions, notable deficiencies persist in comprehending the implications of BDA on market integration and efficiency, particularly within the Saudi context. Previous research endeavors (Ren, 2022) have predominantly concentrated on the technical dimensions of BDA, including its potential to enhance operational processes or identify fraudulent activities. Nonetheless, the comprehensive ramifications of BDA on market structure, interrelations among financial stakeholders, and the regulatory landscape still need to be more adequately examined. Specifically, there exists a scarcity of empirical data that correlates the application of BDA with enhancements in market efficiency and the mitigation of information asymmetries (Li et al., 2022).

This study examines how Big Data Analytics (BDA) can improve market integration and efficiency in Saudi Arabia's financial sector. The study supports Saudi Arabia's Vision 2030, a transformational plan to diversify the economy and make it a regional financial and technological hub. Here, BDA offers unique opportunities to improve market transparency, streamline operations, and improve financial institution decision-making. This study helps financial institutions, policymakers, and regulators use advanced analytics to build a more robust and interconnected financial marketplace by examining how BDA affects market integration and efficiency. It also stresses the importance of BDA dimensions like data accuracy and advanced analytical tools over data volume or variety. This nuanced approach sheds new light on data-driven financial advancements, especially in emerging economies like Saudi Arabia, where rapid modernization presents unique challenges and opportunities. The findings show how region-specific factors affect BDA's use in finance, contributing to the global discourse on its role and meeting the growing demand for financial technology and market integration innovation.

2. Literature review and hypothesis development

Big Data Analytics (BDA) has transformed the financial sector by facilitating enhanced decision-making processes and augmenting market efficiency and integration. This section critically examines the significance of BDA within financial markets, particularly emphasizing essential components such as data volume, variety, velocity, accuracy, and analytical methodologies. In light of this examination, hypotheses are formulated to investigate the extent to which these facets of BDA exert influence over financial market integration and efficiency.

2.1. Big data analytics and the financial market

Big Data Analytics has revolutionized several aspects of the financial sector, significantly influencing market trends, investment strategies, risk management, and regulatory compliance. By taking advantage of large data sets, investors and financial companies have obtained unprecedented information about market behaviors and patterns, leading to greater predictive capacities (Adesina et al., 2024; Almawishir and Benlaria, 2024). Predictive analysis not only improves decision-making but also reinforces the business's general performance by enabling data-based ideas (Htun et al., 2023; Zabat et al., 2024).

Integrating deep learning and Big Data in risk management has been fundamental to predicting financial risk behavior (Xu et al., 2024). This technological advance allows interested parties to effectively anticipate potential risks and devise strategies, facilitating a proactive approach instead of reagent (Javaid, 2024). However, the dependence on sophisticated algorithms introduces challenges, particularly about algorithmic biases and their repercussions on investment results (Nguyen et al., 2023; Hussien et al., 2024; Benlaria et al., 2024).

In addition, the large volume of data requires strict regulatory compliance measures to protect confidential information. Financial institutions must balance innovation with fulfilling regulations, a task often complicated by the rapid rhythm of technological progress (Bose et al., 2023). Ultimately, although Big Data Analytics presents substantial opportunities for financial stakeholders, it also imposes significant challenges that require vigilant management (Kumar et al., 2022; Nnaji et al., 2024).

2.2. Big data analytics and financial market integration (MI)

Big Data Analytics has significantly transformed financial market integration, facilitating data-oriented enhanced insights that influence negotiation strategies, regulatory compliance, and market efficiency. The vast amounts of data generated in today's financial environments allow traders to develop more sophisticated algorithms, increasing their decision-making processes (Kumar et al., 2022). By leveraging big data, market participants can obtain information about market trends, volatility, and price movements, leading to more efficient commercial strategies that quickly adapt to market conditions.

In addition, integrating Big Data Analytics promotes compliance with regulatory requirements. The need for transparency and responsibility has grown as financial markets become more complex. Big data tools help organizations monitor transactions and identify possible irregularities, thus facilitating adherence to regulatory standards (Inamdar et al., 2021). This enhanced monitoring capacity is vital to maintaining market integrity and protecting investors.

In addition to influencing strategy and compliance, Big Data Analytics contributes to the overall market efficiency. By optimizing orders and improving liquidity through more informed negotiations, financial markets can operate more smoothly, benefiting all stakeholders (Bello, 2024). As such, the role of Big Data analysis in the integration of the financial market cannot be underestimated, with its implications that extend to commercial practices, regulatory structures, and general market functionality (Maheshwari et al., 2021; Aljumah et al., 2021; Lutfi et al., 2022).

Based on this understanding, the following hypotheses are proposed:

H1: Big Data Analytics (BDA) positively influences financial MI:

H1a: Data Volume (DV) positively influences MI.
H1b: Data Variety (DVar) positively affects MI.
H1c: Data Accuracy and Quality (DAQ) positively influences MI.
H1d: Data Velocity (DVel) positively impacts MI.
H1e: The use of Analytical Tools and Technologies (ATT) positively influences MI.

2.3. Big data analytics and market efficiency

Big Data Analytics has significantly improved market efficiency in various industries by optimizing decision-making, reducing information asymmetry, and improving predictive capabilities. One of the main benefits of Big Data Analytics is its ability to refine decision-making within organizations. Li et al. (2022) emphasized that using Big Data analysis leads to better decision-making quality, which is critical for a competitive advantage. Ren (2022) supported this optimization, emphasizing that companies can optimize their financial management and decision-making systems through extensive data, resulting in more informed strategic choices.

In addition to decision-making, Big Data Analytics is vital in reducing information asymmetry among market participants. Martin and Nagel (2022) pointed out that greater access to vast data sets allows companies to align more closely with market demands, thus mitigating discrepancies in information typically present in traditional markets. This reduction in information asymmetry encourages a more equitable market environment.

In addition, Big Data Analytics improves predictive capacities, allowing organizations to forecast consumer trends and behaviors effectively. According to Niu et al. (2021), the integration of business intelligence and analytical tools facilitates improved decision-making through better predictions. In addition, Nisar et al. (2021) argued that strong decision-making capacities derived from Big Data management contribute to better environmental performance in companies, demonstrating the wide implications of Big Data analysis. Collectively, these advances underline the transformative impact of Big Data analysis on market efficiency.

The following hypotheses are proposed based on these insights:

H2: Big Data Analytics (BDA) positively influences financial market efficiency (ME):

H2a: DV positively impacts ME.
H2b: DVar positively influences ME.
H2c: DAQ positively affects ME.
H2d: DVel positively influences ME.
H2e: The use of ATT positively impacts ME.

The literature shows that Big Data Analytics (BDA) improves financial market integration and efficiency through data volume, variety, accuracy, velocity, and analytical tools. Fig. 1 shows how these insights inform our research framework, which hypothesizes BDA dimension-market outcome relationships. This framework emphasizes the need for a robust empirical approach to study interdependent relationships. This study uses SEM to analyze multiple pathways simultaneously, validating our hypotheses and providing a complete picture of BDA's effects.

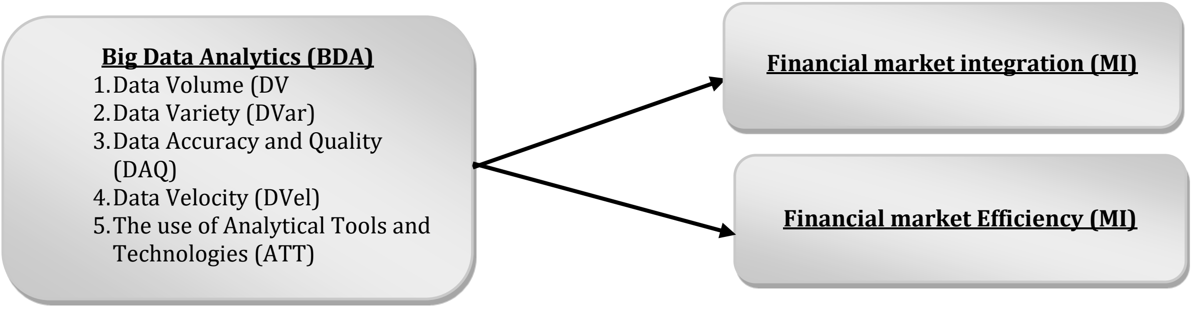

Fig. 1: Research framework

3. Methodology

3.1. Subjects

The study was conducted using a sample of 182 respondents drawn from professionals working in the financial sector in some parts of Saudi Arabia. These subjects were selected based on their involvement in using Big Data Analytics (BDA) in financial decision-making processes within their respective institutions. Respondents included a diverse group of professionals, such as financial analysts, data scientists, IT specialists, and managers. All had experience handling large datasets, employing analytical tools, and engaging with data-driven decision-making systems in the financial market.

Inclusion criteria required respondents to have at least two years of experience using or overseeing Big Data Analytics processes within their organization. Additionally, participants were required to be involved in or knowledgeable about the organization's financial market operations, ensuring that their responses accurately reflected the role of BDA in market integration and efficiency. Respondents were primarily drawn from commercial banks, investment firms, fintech companies, and other financial institutions where BDA is integral to decision-making. Participants were invited through direct outreach and recommendations from industry associations.

3.2. Methodological justification for SEM

Structural Equation Modeling (SEM) is used in this study to analyze complex, interdependent relationships, which supports our hypotheses about BDA's multidimensional effects on market integration and efficiency. Unlike simple regression or factor analysis, SEM can simultaneously examine multiple relationships, comprehensively assessing each BDA dimension's impact on financial market outcomes (Sarstedt et al., 2021; Almawishir and Benlaria, 2024). SEM's ability to handle latent constructs and multiple pathways makes it ideal for this study, which examines BDA's financial sector role through direct and indirect effects. This method improves methodological rigor and ensures nuanced analysis by better capturing BDA dimension interactions than other models, offering enhanced insights into data-driven decision-making in the financial domain (Sarstedt and Liu, 2024; Hussien et al., 2024).

3.3. Survey

A structured survey was developed to assess the role of Big Data Analytics in market integration and efficiency. The survey was distributed electronically using an online platform, allowing participants to complete the questionnaire at their convenience. The survey instrument was carefully designed to measure participants' perceptions of the impact of BDA on financial market performance, with a particular focus on MI and ME.

The questionnaire employed in this study consisted of Likert-type scales, where respondents were asked to indicate their level of agreement with various statements related to the study variables. The Likert scale ranged from 1 (Strongly Disagree) to 5 (Strongly Agree), providing a standardized method for measuring subjective perceptions. The statements within the questionnaire were derived from validated scales in previous studies on Big Data Analytics, with modifications to fit the specific context of this research.

The survey instrument was divided into sections. The first section focused on demographic information, including the respondent's role in their organization, years of experience, and the institution they represented. The subsequent sections explored the independent variables related to BDA, including data volume, data variety, data accuracy and quality, data velocity, and analytical tools and technologies. Respondents were asked to evaluate how these aspects of BDA influenced market integration and efficiency within their organization. Additionally, the survey contained questions to assess the mediating role of regulatory frameworks in implementing BDA in the financial sector.

To ensure content validity, the questionnaire was reviewed by subject matter experts in finance and data analytics. A pilot test was conducted with a small subset of respondents (n=30) to refine the survey questions and ensure clarity. Following the pilot, minor revisions were made to the wording of specific questions to enhance comprehension. Data collection occurred over four weeks, with weekly reminders sent to participants who still needed to complete the survey. A total of 182 valid responses were received, which formed the basis for the subsequent analysis. As illustrated in Table 1, the predominant age group of respondents is 35-44 years old, comprising 39%, with a similar percentage of individuals boasting 6-10 years of experience (39%). Regarding the classification of institutions, 41.8% are employed in commercial banks, closely followed by 28.6% in investment firms. This heterogeneous sample guarantees a comprehensive representation of financial practitioners, yielding critical insights pertinent to the study's examination of Big Data Analytics within the financial sector.

Table 1: Likert-type questionnaire respondent sample characteristics (N=182)

Characteristic	Frequency (N)	Percentage (%)
Gender		
Male	134	73.6
Female	48	26.4
Age group		
25-34 years	78	42.9
35-44 years	71	39.0
45-54 years	25	13.7
55+ years	8	4.4
Years of experience		
2-5 years	62	34.1
6-10 years	71	39.0
11-15 years	29	15.9
More than 15 years	20	11.0
Institution type		
Commercial bank	76	41.8
Investment firm	52	28.6
Fintech company	30	16.5
Other financial institutions	24	13.2

4. Results

Fig. 2 presents the measurement model assessment, evaluating the validity and reliability of the study's constructs. Key indicators such as data volume, variety, velocity, accuracy, and analytical tools are tested for reliability, while strong R-square values for MI and ME indicate a high level of model accuracy and explanatory power.

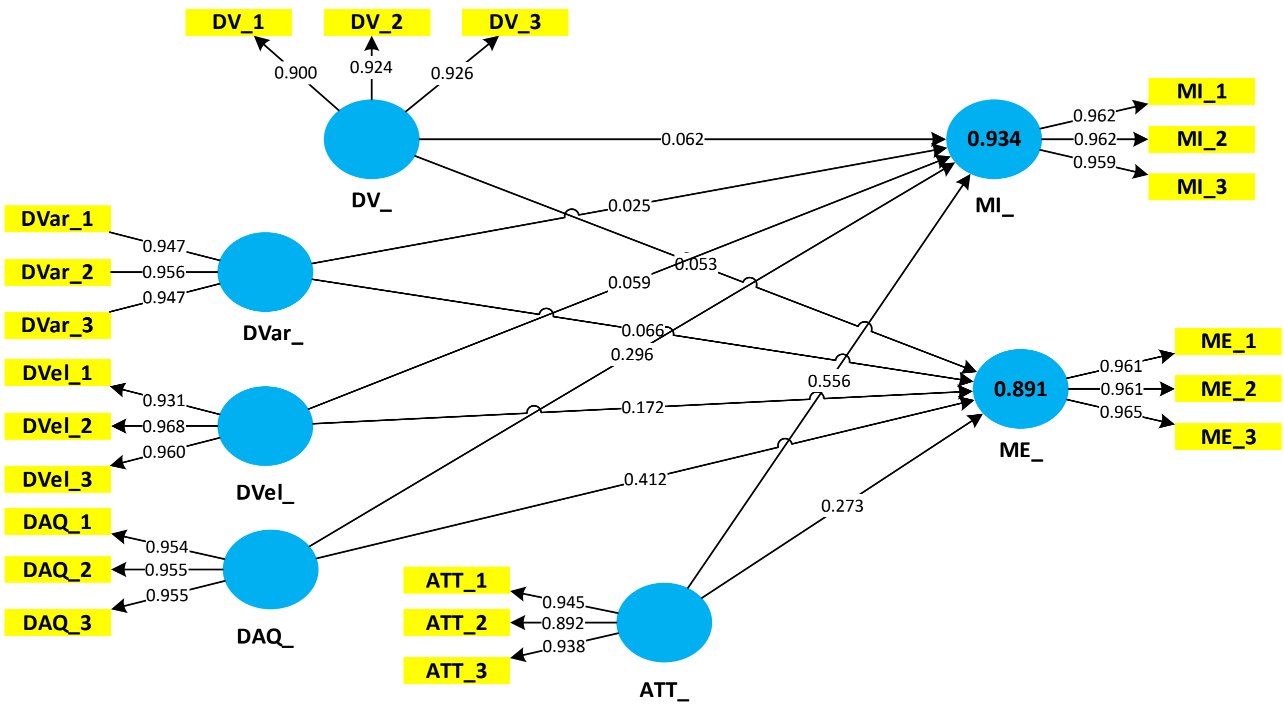

Fig. 2: Assessment of the measurement model (validity and reliability test)

Table 2 presents the results of the reliability and convergent validity assessments for the study's constructs. The primary indicators include loadings, VIF (Variance Inflation Factor), Cronbach's Alpha, composite reliability (rho_a), and the Average Variance Extracted (AVE).

According to Hair et al. (2014), loadings greater than 0.70 indicate good item reliability, which is confirmed across all constructs in Table 2. For example, the loadings for ATT_1 to ATT_3 (ranging from 0.892 to 0.945) and DAQ_1 to DAQ_3 (above 0.954) exceed the 0.70 threshold, suggesting that the indicators adequately represent the latent variables. This also holds for the other constructs, such as DV, DVar, DVel, ME, and MI. Cronbach's Alpha values are all above 0.70, meeting the internal consistency reliability criterion, as noted by Sarstedt et al. (2021). For instance, DAQ and ME exhibit high values (0.951 and 0.960, respectively), suggesting robust internal consistency. Similarly, the composite reliability scores are all above 0.90, further supporting the reliability of the constructs.

Convergent validity is confirmed through AVE values exceeding 0.50 for all constructs. For example, ATT (0.856) and MI (0.924) demonstrate that more than 50% of the variance in their indicators is explained by the latent constructs, which aligns with the recommendations of Ringle et al. (2023). Overall, Table 2 indicates the measurement model's strong reliability and convergent validity.

Table 2: Measurement model (reliability and convergence validity)

Variable	Items	Loadings (>0.70)	VIF	Cronbach's alpha (>0.70)	Composite reliability (rho_a)	AVE (>0.50)
ATT: Analytical tools and technologies	ATT_1	0.945	4.355	0.916	0.919	0.856
	ATT_2	0.892	2.521			
	ATT_3	0.938	3.999			
DAQ: Data accuracy and quality	DAQ_1	0.954	5.153	0.951	0.951	0.741
	DAQ_2	0.955	5.175			
	DAQ_3	0.955	5.041			
DV: Data volume	DV_1	0.900	2.707	0.906	0.916	0.841
	DV_2	0.924	3.294			
	DV_3	0.926	2.949			
DVar: Data variety	DVar_1	0.947	4.520	0.943	0.944	0.898
	DVar_2	0.950	4.694			
	DVar_3	0.947	4.307			
DVel: Data velocity	DVel_1	0.931	3.632	0.950	0.950	0.909
	DVel_2	0.968	7.829			
	DVel_3	0.960	7.013			
ME: Market efficiency	ME_1	0.961	5.799	0.960	0.960	0.926
	ME_2	0.961	6.129			
	ME_3	0.965	6.469			
MI: Market integration	MI_1	0.962	6.104	0.959	0.959	0.924
	MI_2	0.962	6.174			
	MI_3	0.959	5.696			

Table 3 shows the HTMT ratios, a modern method for assessing discriminant validity. Values below 0.90 are considered acceptable, as Sarstedt and Liu (2024) highlighted. In this case, all values fall below the 0.90 threshold, indicating that each construct is distinct. For instance, the HTMT value between ATT and DAQ is 0.773, while the highest value is between ATT and MI at 0.815, both well below the cutoff. The results suggest that discriminant validity is sufficiently established between constructs, which is crucial for ensuring that the constructs are not measuring the same concept. This finding is consistent with the guidelines provided by Hair et al. (2014), further supporting the distinctiveness of the constructs in the study.

Table 3: Heterotrait-Monotrait ratio (HTMT)-Matrix for discriminant validity

	ATT_	DAQ_	DV_	DVar_	DVel_	ME_	MI_
ATT_							
DAQ_	0.773						
DV_	0.787	0.806					
DVar_	0.727	0.739	0.758				
DVel_	0.785	0.714	0.714	0.756			
ME_	0.765	0.773	0.684	0.715	0.669		
MI_	0.815	0.777	0.692	0.721	0.676	0.778	

The HTMT (Heterotrait-Monotrait) ratio is used to assess discriminant validity. Values below 0.90 generally indicate adequate discriminant validity. In this table, the relationships between constructs like ATT, DAQ, DV, DVar, DVel, ME, and MI

The Fornell-Larcker criterion in Table 4 provides an additional measure of discriminant validity by comparing the square root of the AVE for each construct with the correlations between constructs. The diagonal values (representing the square root of the AVE) should be greater than the off-diagonal correlations for discriminant validity to be established (Sarstedt et al., 2021). In Table 4, the diagonal values are all higher than the corresponding off-diagonal values. For instance, the square root of the AVE for ATT is 0.925, which is greater than its correlation with DAQ (0.810) and other constructs. This pattern holds for all constructs, confirming discriminant validity according to the Fornell-Larcker criterion. Therefore, the model exhibits strong discriminant validity, reinforcing that each construct measures a distinct concept, as Ringle et al. (2023) recommended.

Table 5 presents the R-square and f-square values, which assess the model's explanatory power and the effect sizes of the independent variables on the dependent variables. The R-square values for ME (0.891) and MI (0.934) indicate that the model explains a substantial portion of the variance in these constructs. According to Hair et al. (2014), R-square values above 0.75 indicate a robust model fit, confirming the model's robustness in explaining market efficiency and integration. The f-square values indicate the effect sizes of individual variables on the dependent constructs. As per Sarstedt and Liu (2024), f-square values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. For instance, ATT significantly affects MI (0.665) and has a negligible effect on ME (0.097). Similarly, DVel has a moderate effect on ME (0.215) and a negligible effect on MI (0.143). These results suggest that ATT is a crucial driver of MI, while other factors like DVel and DAQ contribute to both ME and MI. Table 6 presents the results of the hypothesis testing, examining the influence of Big Data Analytics (BDA) and its components on MI and ME. Each hypothesis is tested based on the original sample estimate (O), T-statistics, p-values, and a decision regarding whether the hypothesis is accepted or rejected.

Table 4: Fornell-Larcker criterion for discriminant validity

	ATT_	DAQ_	DV_	DVar_	DVel_	ME_	MI_
ATT_	**0.925**						
DAQ_	0.810	**0.955**					
DV_	0.814	0.847	**0.917**				
DVar_	0.862	0.890	0.892	**0.948**			
DVel_	0.820	0.864	0.854	0.805	**0.953**		
ME_	0.906	0.930	0.830	0.871	0.925	**0.962**	
MI_	0.951	0.933	0.838	0.876	0.931	0.938	**0.961**

Note: The Fornell-Larcker criterion is used to evaluate discriminant validity by comparing the square root of the AVE (on the diagonal) with the correlations between constructs (off-diagonal). The diagonal values (bolded) represent the square root of AVE, and these should be higher than the off-diagonal correlations to demonstrate discriminant validity

Table 5: R-square and f-square values for model fit and effect size

	R-square	R-square adjusted	ATT	DAQ	DV	DVar	DVel	ME	MI
ME	0.891	0.890	0.097	0.103	0.005	0.125	0.215	/	/
MI	0.934	0.933	0.665	0.087	0.111	0.311	0.143	/	/

Table 6: Summary of hypotheses testing

	Hypotheses	O	T-statistics (|O/SD|)	P-values	Decision
H1	BDA-> MI	0.952	145.724	0.000	accept**
H1a	DV -> MI	0.062	1.739	0.042	accept**
H1b	DVar -> MI	0.025	0.484	0.628	reject*
H1c	DAQ-> MI	0.296	4.528	0.000	accept**
H1d	DVel -> MI	0.059	0.827	0.408	reject*
H1e	ATT -> MI	0.556	8.829	0.000	accept**
H2	BDA-> ME	0.952	145.724	0.000	accept**
H2a	DV -> ME	0.053	0.823	0.411	reject*
H2b	DVar -> ME	0.066	1.021	0.308	reject*
H2c	DAQ -> ME	0.412	4.505	0.000	accept**
H2d	DVel -> ME	0.172	1.684	0.042	accept**
H2e	ATT-> ME	0.273	3.664	0.000	accept**

*: $p < 0.05$; **: $p < 0.01$; O: Original sample; SD: Standard deviation

The overall relationship between BDA and MI (H1) is strongly supported, with a high original sample estimate of 0.952, a T-statistic of 145.724, and a p-value of 0.000. This confirms that BDA significantly and positively influences market integration. This suggests that BDA plays a critical role in enhancing the coordination and alignment of financial markets.

When examining the individual dimensions of BDA, the results are more varied. DV (H1a) is found to positively impact MI with a T-statistic of 1.739 and a p-value of 0.042, leading to the acceptance of this hypothesis. Although the effect size is relatively small (0.062), it indicates that the ability to process large volumes of data contributes to market integration.

However, DVar (H1b) and DVel (H1d) do not significantly influence MI. The T-statistics (0.484 for DVar and 0.827 for DVel) and p-values (0.628 for DVar and 0.408 for DVel) suggest that these variables do not have a meaningful impact on market integration, leading to the rejection of these hypotheses. This result may indicate that more than simply having a variety of data or speeding up data processing is needed to enhance market integration without other factors.

On the other hand, DAQ (H1c) and ATT (H1e) significantly influence MI. DAQ has a strong effect with a T-statistic of 4.528, a p-value of 0.000, and an original sample estimate of 0.296. This demonstrates that accurate and high-quality data is crucial for ensuring the alignment of markets. Similarly, ATT significantly affects MI (0.556), with a T-statistic of 8.829 and a p-value of 0.000, highlighting the importance of advanced AI and machine learning in facilitating market integration.

The influence of BDA on ME (H2) mirrors the results for MI, with a strong positive relationship. The original sample estimate is 0.952, and the T-statistic is 145.724, with a p-value of 0.000, confirming that BDA significantly enhances market efficiency.

For the individual BDA components, DV (H2a) and DVar (H2b) are again found to be insignificant in their effects on ME, with T-statistics of 0.823 and 1.021, respectively, and p-values above 0.05. These findings suggest that more than the amount of data processed and the variety of data types are required to improve market efficiency alone.

However, both DAQ (H2c) and DVel (H2d) positively affect ME. DAQ has a significant effect, with a T-statistic of 4.505 and a p-value of 0.000, showing that accurate and high-quality data are essential for optimizing market operations. Similarly, Data Velocity (H2d) positively impacts market efficiency, as indicated by a T-statistic of 1.684 and a p-value of 0.042, highlighting the role of fast data processing in maintaining updated and efficient market activities.

Lastly, ATT (H2e) also significantly enhances ME, with a T-statistic of 3.664, a p-value of 0.000, and an original sample estimate of 0.273. This suggests that advanced analytical tools are critical for improving operational efficiency and resource allocation in financial markets.

5. Discussion

The results unequivocally affirm that Big Data Analytics (BDA) plays a significant role in enhancing MI. This is evidenced by the acceptance of the primary hypothesis (H1) with a substantial effect size. This finding not only supports the assertions of Kumar et al. (2022) but also provides a deeper understanding of how BDA facilitates the development of sophisticated algorithms, thereby improving decision-making processes and enabling financial institutions to respond swiftly to market conditions. The study found that BDA provides financial institutions with better access to market trends, volatility, and price movements, which in turn helps align financial strategies across markets, thus promoting integration.

Among the discrete elements of Big Data Analytics (BDA), the investigation revealed that DAQ (H1c) and ATT (H1e) emerged as the most pivotal determinants of market integration. The findings imply that the integrity and precision of data, along with the application of sophisticated instruments such as artificial intelligence and machine learning, are crucial for upholding consistency and coherence across various markets. This conclusion aligns with existing literature, wherein Inamdar et al. (2021) underscored the significance of precise data and monitoring instruments in guaranteeing adherence to regulatory frameworks and promoting market transparency.

However, not all components of BDA were found to have a significant impact on market integration. DVar (H1b) and DVel (H1d) did not show a meaningful influence on MI, which contrasts with earlier research that suggests data diversity and speed are critical for market integration (Bose et al., 2023). One possible explanation for this discrepancy is that while variety and velocity may contribute to improved information flow, more is needed to ensure market cohesion with accurate and reliable data support. These findings suggest that the financial sector may prioritize data quality over the variety and speed of data regarding market integration. This nuance has yet to be explored fully in previous studies.

The significant role of DV (H1a) in market integration aligns with the views of Almawishir and Benlaria (2024), who argued that processing large amounts of data allows institutions to develop better algorithms and strategies. However, the relatively small effect size indicates that, while important, Data Volume plays a supporting rather than a leading role in fostering market integration. This finding further suggests that it is not just the quantity of data but its quality and the tools used to analyze it that drive integration in financial markets.

Based on prior scholarly investigations, the present study substantiates that Big Data Analytics (BDA) plays a pivotal role in augmenting ME (H2). BDA enhances the decision-making frameworks by affording market participants superior access to pertinent data, thereby diminishing information asymmetry and improving predictive proficiency. These results corroborate the assertions by Li et al. (2022), who contend that the capacity to process and scrutinize extensive data sets engenders more informed strategic decisions, ultimately enhancing market performance.

The study underscores the pivotal roles of DAQ (H2c) and ATT (H2e) in enhancing market efficiency. The importance of accurate and high-quality data in minimizing errors and inefficiencies in financial markets is well documented in the literature (Niu et al., 2021; Nisar et al., 2021). These findings not only reinforce the idea that financial markets require reliable data and advanced analytical tools to operate efficiently but also reassure the audience about the reliability of financial markets.

However, similar to market integration, the study found that DVar (H2b) and DV (H2a) do not significantly influence market efficiency. This contrasts with previous findings highlighting the importance of diverse data types in achieving better market outcomes (Martin and Nagel, 2022). One potential explanation is that having a wide variety of data sources only enhances efficiency if that data is properly integrated and analyzed using sophisticated tools. Additionally, while data volume can provide a competitive advantage, its impact on market efficiency may be limited if the data is not processed and utilized effectively.

The study also found that DVel (H2d) positively impacts market efficiency, although the effect size is modest. This finding aligns with the literature, where Ren (2022) argued that faster data processing enables quicker market adjustments, ensuring that prices reflect real-time information. However, it's important to note that the relatively small effect size suggests that while speed is critical, it must be complemented by data accuracy and advanced analytical capabilities to impact market efficiency directly. In other words, velocity alone may not significantly influence market efficiency, but when combined with accuracy and advanced tools, it can contribute to better market outcomes.

The findings of this study largely support the literature, particularly regarding the importance of data accuracy and the use of advanced tools in driving both market integration and efficiency. The strong effects of DAQ and ATT in both cases confirm the observations of Inamdar et al. (2021) and Nisar et al. (2021), who emphasized the critical role of high-quality data and sophisticated analytics in modern financial markets. Moreover, the confirmation that BDA positively influences market efficiency and integration aligns with the overarching consensus in the literature that big data is transformative for financial markets (Adesina et al., 2024). This reiteration of the importance of advanced tools in effective data use should make the audience feel confident about the future of financial analytics.

However, the findings diverge from earlier studies on the relatively low impact of data variety and data volume on market outcomes. While previous research (Bose et al., 2023) highlighted the importance of diverse data sources and large data sets, this study suggests that more than these factors require accurate data and advanced tools to process them. This nuanced understanding of BDA's role suggests that financial markets may prioritize quality and analysis over quantity and diversity in achieving better market outcomes. These findings open up new avenues for research, particularly in understanding the interplay between data quality, quantity, and variety, and the role of advanced analytical tools in shaping market outcomes.

6. Limitations and future research

This study has limitations. First, the data collection process was limited to specific regions within Saudi Arabia's financial sector, which may bias sample representativeness and limit generalizability. Since non-BDA professionals were excluded, the selection criteria may have caused selection bias. Expanding the sample to include banking, insurance, and fintech to capture more BDA applications and provide a more complete perspective should address these. The findings could be validated and strengthened by studying BDA in financial institutions in other regions with similar economic contexts, such as the Gulf Cooperation Council (GCC). However, it's crucial to understand that the urgency and importance of longitudinal studies cannot be overstated. They are critical for understanding how BDA affects market integration and efficiency as technology and market dynamics change. Finally, data security, privacy, and regulatory compliance are increasingly crucial to data-driven financial decision-making, so future research should examine them in the context of BDA in Saudi Arabia's financial sector.

7. Conclusion and recommendation

This study demonstrates that Big Data Analytics (BDA) is critical in improving financial market integration and efficiency within the Saudi financial sector, mainly through data accuracy and advanced analytical tools. However, data volume and variety show a more limited impact, indicating that the focus should be on data quality rather than quantity. Financial institutions in Saudi Arabia should prioritize investments in data quality and advanced tools such as AI to optimize market performance. Policymakers should ensure that the regulatory environment encourages innovation while safeguarding data accuracy and privacy. Future research should broaden the scope to include other regions and sectors better to understand BDA's overall impact on financial markets.

List of symbols

BDA	Big data analytics
AI	Artificial intelligence
SEM	Structural equation modeling
MI	Market integration
ME	Market efficiency
DV	Data volume
DVar	Data variety
DAQ	Data accuracy and quality
DVel	Data velocity
ATT	Analytical tools and technologies
VIF	Variance inflation factor
AVE	Average variance extracted
HTMT	Heterotrait-monotrait ratio
PLS-SEM	Partial least squares structural equation modeling

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Compliance with ethical standards

Ethical considerations

Informed consent was obtained from all participants, ensuring they were aware of the study's purpose and their rights, including confidentiality.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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