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Article

Dynamic modelling of intellectual capital efficiency and financial performance of Islamic banks: A panel and control-process approach

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Abstract: This study investigates the relationship between intellectual capital efficiency and the financial performance of Islamic banks in Malaysia by employing dynamic modeling and empirical panel analysis. In knowledge-driven financial systems, intellectual capital, which includes human capital, structural capital, and capital usage efficiency, has a significant impact on creating a long-term competitive edge. This study sets up a system of differential equations to anticipate how bank performance would change over time based on the parts of intellectual capital and how they are invested. Therefore, this captures both theoretical dynamics and real-world consequences. The theoretical model delineates equilibrium conditions and demonstrates the local asymptotic stability of the intellectual capital system. The study employs the Value-Added Intellectual Coefficient (VAIC) approach, examining an unbalanced panel dataset of 11 comprehensive Islamic banks in Malaysia from 2012 to 2023, resulting in 132 bank-year observations. To find out how intellectual capital affects financial success, we use fixed-effects panel regression with robust standard errors. We look at return on assets (ROA) and return on equity (ROE). The empirical findings demonstrate that the overall efficiency of intellectual capital exerts a positive and significant influence on bank profitability. When dispersed, human capital efficiency is found to be the most important factor affecting financial performance, followed by capital employed efficiency. Structural capital efficiency, on the other hand, has no statistically significant effect. The results are similar across different model setups and diagnostic tests. These results highlight the importance of knowledge resources and efficient capital deployment in enhancing the competitiveness and sustainability of Islamic banking institutions. This study contributes to the field by integrating dynamic system modeling with empirical banking analysis, providing policy implications for strategic investment in intellectual capital.

Keywords: knowledge-based resources; differential equation modelling; panel data analysis; banking profitability; human capital efficiency; financial system dynamics; Shariah-compliant finance

1. Introduction

The sources of competitive advantage in the financial services industry have been profoundly altered by the transformation of the global economy into a knowledge-based system. In this context, organizations' success is affected by intangible resources including knowledge, skill, organizational capacities, and creativity, as well as physical

and financial assets [1,2]. People often use the phrase "intellectual capital" to talk about these resources. Intellectual capital is a key factor in creating and maintaining value in knowledge-intensive fields like finance. Banks rely significantly on well-organized processes, cutting-edge information technology, and trained workers to follow the rules, manage risks, and offer financial services [1]. As a result, standard accounting-based performance measurements may not fully reflect the underlying factors that affect bank performance in today's financial system. This limitation has led to a growing interest in examining the function of intellectual capital in enhancing the efficiency and profitability of banks. The examination of intellectual capital is especially relevant inside Islamic organizations. Since Islamic banks operate under Shariah principles, they need people who know a lot about both conventional finance and Islamic law to structure compliant products, manage risks, and make sure that governance is honest. Thus, knowledge is not merely an operational input; it is an essential element of Islamic banking operations. Consequently, it is expected that intellectual capital will exert a greater influence on Islamic banks compared to other institutions [1,3].

While the theoretical significance is recognized, actual evidence about the relationship between financial success and intellectual capital in Islamic banking remains inconclusive [3,4]. The influence of individual intellectual capital components differs throughout countries and institutional contexts, even though much international research indicates a positive correlation. Furthermore, empirical studies focusing solely on Islamic institutions in Malaysia, a developed Islamic finance industry, are limited.

This study examines the impact of intellectual capital performance on the financial performance of Islamic institutions in Malaysia, thereby addressing this gap. Utilizing a value-added intellectual capital framework and panel data analysis, the study presents context-specific information that enhances the literature on Islamic banking and intellectual capital. Nonetheless, the findings also offer pragmatic insights for bank executives and policymakers aiming to enhance performance through the adoption of knowledge-driven methods. Previous studies utilized static econometric models to examine intellectual capital; nevertheless, financial performance in knowledge-based enterprises evolves dynamically over time. Consequently, modeling intellectual capital within a dynamic system paradigm facilitates a deeper understanding of how knowledge resources accumulate and influence financial results. Differential equation modeling is a useful way to record these interactions.

1.1. Dynamic intellectual capital modelling framework

The increasing importance of knowledge resources in banking systems suggests that financial performance should be analyzed as a dynamic process rather than a fixed outcome. Traditional empirical research often examines the relationship between intellectual capital and profitability using static econometric models. Nonetheless, these techniques may neglect the temporal growth of knowledge assets and their aggregate influence on organizational performance.

The study presents a dynamic modeling methodology that elucidates the impact of intellectual capital components on financial performance over time via a system of differential equations. Dynamic modeling methodologies are extensively

employed in economics, management science, and control theory to examine systems whose variables continually evolve and interact via feedback mechanisms [5, 6]. According to the intellectual capital literature, intellectual capital is categorized into three components: Human Capital Efficiency (HCE), Structural Capital Efficiency (SCE) and Capital Employed Efficiency (CEE). These components correspond to the Value-Added Intellectual Coefficient (VAIC) framework commonly applied in banking research [7,8].

Let:

- $P(t)$ denotes the financial performance of a bank at time t,
- $H(t)$ denotes human capital efficiency,
- $S(t)$ denotes structural capital efficiency, and
- $C(t)$ denotes capital employed efficiency.

Financial performance is modeled as a dynamic function of intellectual capital components:

$$\frac{dP(t)}{dt} = \alpha H(t) + \beta S(t) + \gamma C(t) - \delta P(t)$$

where $P(t)$ represents financial performance, $H(t)$ human capital efficiency, $S(t)$ structural capital efficiency, and $C(t)$ capital employed efficiency.

The initial three terms encapsulate the beneficial impacts of intellectual capital, but the concluding term signifies performance degradation resulting from operational inefficiencies, market competition, or legal limitations. In Islamic banking, human capital plays a crucial role due to the necessity for specialized knowledge in Shariah-compliant financial architecture and risk management [1]. Therefore, the coefficient correlated with human capital is anticipated to be very substantial.

1.2. Equilibrium and stability analysis of the intellectual capital system

The elements of intellectual capital are dynamic variables that change in reaction to investment choices and organizational learning processes. Human Capital Dynamics increases through training, recruiting, and organizational learning, yet diminishes over time due to knowledge obsolescence and personnel turnover [9]. The progressive development of human capital can thus be articulated as:

$$\frac{dH(t)}{dt} = \eta_1 I_H(t) - \lambda_1 H(t)$$

where:

- $I_H(t)$ denotes investment in human capital,
- η_1 represents the productivity of training and knowledge acquisition,
- λ_1 represents the depreciation rate of human capital.

Structural Capital includes the systems, processes, technology infrastructure, and knowledge management methods that a firm uses. Investing in organizational systems can boost structural capital, but it can also go down if technology becomes outdated or

regulations change. The structural capital dynamic equation is given by:

$$\frac{dS(t)}{dt} = \eta_2 I_S(t) - \lambda_2 S(t)$$

where:

- $I_S(t)$ represents investment in organisational infrastructure,
- η_2 represents the effectiveness of structural capital investment,
- λ_2 represents structural depreciation.

Capital employed efficiency shows how well money and other resources are used to create value. Better financial management and smart asset allocation can help improve capital efficiency. The dynamic evolution of capital efficiency can be expressed as:

$$\frac{dC(t)}{dt} = \eta_3 I_C(t) - \lambda_3 C(t)$$

where:

- $I_C(t)$ represents financial capital allocation,
- η_3 denotes capital productivity,
- λ_3 denotes efficiency decay due to financial misallocation.

1.3. System of differential equations

Integrating the equations above provides us with a dynamic intellectual capital system:

$$\begin{cases} \frac{dP}{dt} = \alpha H + \beta S + \gamma C - \delta P \\ \frac{dH}{dt} = \eta_1 I_H - \lambda_1 H \\ \frac{dS}{dt} = \eta_2 I_S - \lambda_2 S \\ \frac{dC}{dt} = \eta_3 I_C - \lambda_3 C \end{cases}$$

This system shows how the banking sector's financial results and knowledge resources work together. The model suggests that financial performance is affected by both current levels of intellectual capital and investment choices that determine future accumulation of intellectual capital.

Equilibrium Analysis

To examine the system's long-term behavior, we analyze the steady-state equilibrium, where all variables remain constant over time.

The steady-state conditions necessitate:

$$\frac{dP}{dt} = \frac{dy}{dH} = \frac{dt}{dS} = \frac{dt}{dC} = 0$$

We derive the following from the intellectual capital equations:

$$H^* = \frac{\lambda_1 \eta_1 I_H}{\mathrm{IH}}$$

$$S^* = \frac{\eta_2 I_S}{\lambda_2}$$

$$C^* = \frac{\eta_3 I_C}{\lambda_3}$$

Substituting these into the performance equation yields:

$$P^* = \frac{\alpha H + \beta S^* + \gamma C^*}{\delta}$$

This equilibrium solution indicates that the long-term performance of banks depends on the continuous investment in components of intellectual capital.

Standard techniques from nonlinear dynamic systems can be employed to evaluate the system's stability [5]. The system's Jacobian matrix is as follows:

$$J = \begin{bmatrix} -\delta & \alpha & \beta & \gamma \\ 0 & -\lambda_1 & 0 & 0 \\ 0 & 0 & -\lambda_2 & 0 \\ 0 & 0 & 0 & -\lambda_3 \end{bmatrix}$$

The eigenvalues of this matrix are:

$$-\delta, -\lambda_1, -\lambda_2, -\lambda_3$$

The eigenvalues are negative since all the parameters are positive and show rates of degradation or adjustment. The equilibrium point is therefore locally asymptotically stable. The outcome indicates that the banking system is progressing towards a stable equilibrium level of financial performance, shaped by the investment in intellectual capital. In addition to eigenvalue-based stability, the system's behavior can also be analyzed through its sensitivity to variations in initial conditions and parameters. Although negative eigenvalues guarantee local asymptotic stability, nonlinear systems can exhibit intricate transitional dynamics when exposed to significant shocks. This viewpoint aligns with the research on chaos and nonlinear dynamics, emphasizing that little fluctuations can influence system trajectories, even within stable regimes [10].

1.4. Optimal control of intellectual capital investment

Bank management decisions can be seen as a way to control the flow of intellectual capital to get the best financial results. The objective function can be written as:

$$\max_{I_H, I_S, I_C} \int_0^T \Pi\left(P(t)\right) e^{-rt} dt$$

subject to the dynamic constraints defined earlier.

Where:

- $\Pi\left(P(t)\right)$ represents bank profitability,
- r represents the discount rate.

The Hamiltonian is obtained by applying Pontryagin's Maximum Principle [6]:

$$H = \Pi(P) + \lambda_P(\alpha H + \beta S + \gamma C - \delta P)$$

In the most effective investment plan, the marginal productivity of intellectual capital is the same as its marginal cost. This paradigm shows that banks' performance depends on how well they use knowledge-based resources throughout time.

2. Methods

This study focuses on Islamic banks functioning in Malaysia, recognized as one of the most advanced Islamic finance sectors globally. The final sample comprises 11 fully operational Islamic banks from 2012 to 2023, contingent upon data availability. Malaysia has about 16 to 18 licensed Islamic banking institutions, some banks were left out since they failed to fully disclose all of their intellectual capital components, especially the staff costs needed to calculate VAIC, and they didn't have enough time-series observations. When necessary, established financial databases are used to add to audited yearly reports to get financial data. The empirical analysis's objectivity and comparability are improved by the utilization of audited financial statements, which is in accordance with previous research on intellectual capital in the banking sector.

The performance of intellectual capital is assessed through the Value-Added Intellectual Coefficient (VAIC) framework. The VAIC model is extensively utilized in banking research because of its practicality, transparency, and dependence on publicly accessible accounting data. It assesses the efficacy with which banks produce value with both tangible and intangible assets.

According to known literature, Value Added (VA) is calculated as the difference between total output and total input, with personnel expenses regarded as an investment in human capital rather than an expense. VAIC is divided into three efficiency components:

- **Human Capital Efficiency (HCE)**

$$HCE = \frac{VA}{HC}$$

where *HC* represents total personnel expenses. *HCE* reflects the ability of employees' knowledge, skills, and expertise to create value.

- **Structural Capital Efficiency (SCE)**

$$SCE = \frac{SC}{VA}$$

- **Capital Employed Efficiency (CEE)**

$$CEE = \frac{VA}{CE}$$

where *CE* stands for the book value of the physical and financial capital that has been used. *CEE* measures the extent to which banks use their physical assets.

The cumulative VAIC score is calculated as follows:

$$VAIC = HCE + SCE + CEE$$

This classification allows the analysis to evaluate both the overall effect of intellectual capital and the individual contributions of its components, consistent with prior research on Islamic banking and the banking industry.

Accounting-based profitability indicators are used to measure financial performance. They are often used in banking research since they may show how well a company runs and how well managers do their jobs.

- Return on Assets (ROA)

$$ROA = \frac{Net\ Profit}{Total\ Assets}$$

- Return on Equity (ROE)

$$ROE = \frac{Net\ Profit}{Shareholders'Equity}$$

These indicators include several parts of a bank's performance and are widely used in research on intellectual capital related to Islamic banks and financial institutions, as well as in discussions and outcomes. To separate the effect of intellectual capital on financial performance, many control variables often utilized in banking literature are included:

- Bank Size (SIZE): Natural logarithm of total assets, controlling for scale effects.
- Leverage (LEV): Ratio of total liabilities to total assets, capturing financial risk.
- Bank Age (AGE): Number of years since establishment, controlling for institutional maturity.

The incorporation of these variables reduces omitted variable bias and is consistent with previous empirical research in banking and intellectual capital. The subsequent baseline panel regression model is estimated to analyze the correlation between intellectual capital performance and financial performance:

$$FP_{it} = \alpha + \beta_1 VAIC_{it} + \sum \beta_k Controls_{it} + \varepsilon_{it} \quad (1)$$

where:

- FP_{it} represents the financial performance (ROA or ROE) of bank *i* at time *t*,
- $VAIC_{it}$ denotes intellectual capital performance,
- $Controls_{it}$ is a vector of bank-specific control variables,
- ε_{it} is the error term.

To analyze the varying impacts of intellectual capital components, the model is further disaggregated as follows:

$$FP_{it} = \alpha + \beta_1 HCE_{it} + \beta_2 SCE_{it} + \beta_3 CEE_{it} + \sum \beta_k Controls_{it} + \varepsilon_{it} \quad (2)$$

Diagnostic procedures and additional robustness

Detailed analysis of the components of intellectual capital that impact financial performance in Malaysian Islamic institutions is facilitated by the requirement. Given the panel structure of the dataset, the study employs panel data regression approaches to account for unobserved heterogeneity among banks. This approach has been extensively adopted in banking and intellectual capital studies to control for firm-specific effects [8, 11]. In accordance with prior empirical research in the banking sector [3,4], both Fixed Effects (FE) and Random Effects (RE) estimations are initially conducted to guarantee model robustness. The Hausman test is implemented to ascertain the appropriate model specification, as it facilitates the identification of potential correlations between explanatory variables and unobserved effects, thereby guaranteeing consistent estimation [12]. In order to mitigate potential heteroskedasticity and serial correlation concerns, which are prevalent in panel data involving financial institutions, robust standard errors are implemented [13].

This methodological framework is consistent with the most effective practices in banking and intellectual capital research, and it improves the reliability of statistical inference. Similarly, previous studies that have investigated the correlation between financial performance and intellectual capital in both Islamic and conventional banking contexts have implemented panel regression techniques in conjunction with robustness diagnostics, such as multicollinearity checks, alternative model specifications, and stability tests, to verify empirical findings [1,3,14]. Collectively, these methodologies guarantee that the estimated relationships are not precipitated by econometric issues or model misspecification, thereby enhancing the generalizability and credibility of the findings.

3. Results

Table 1 shows the descriptive statistics for the main variables used in the empirical analysis. It shows the mean, standard deviation, minimum, and maximum values for financial performance indicators, intellectual capital components, and bank-specific features.

Table 1. Descriptive Statistics of Financial Performance, Intellectual Capital, and Bank Characteristics.

Variable	Mean	Std. Dev.	Min	Max
ROA (%)	1.21	0.48	0.32	2.45
ROE (%)	10.84	3.96	2.10	18.75
VAIC	3.92	1.11	1.85	6.74
HCE	2.47	0.88	0.95	4.62
SCE	0.71	0.24	0.22	1.18
CEE	0.74	0.31	0.21	1.43
SIZE	16.94	0.86	15.32	18.41
LEV	0.88	0.04	0.76	0.94
AGE (years)	18.6	6.9	7	35

Descriptive statistics indicate that Malaysian Islamic banks exhibit stable profitability and small variations in intellectual capital efficiency. The mean of human capital efficiency is the greatest of the VAIC parts. This means that employee

competency is the most important factor in creating value in Islamic banks.

Based on **Table 2**, there are no issues with multicollinearity because all of the correlations are less than 0.85. Correlation studies reveal affirmative associations between intellectual capital indicators and profitability, devoid of notable multicollinearity issues.

Table 2. Correlation Matrix of Financial Performance and Intellectual Capital Variables.

Variable	ROA	ROE	VAIC	HCE	SCE	CEE
ROA	1.000					
ROE	0.68	1.000				
VAIC	0.54	0.49	1.000			
HCE	0.57	0.52	0.82	1.000		
SCE	0.21	0.18	0.41	0.36	1.000	
CEE	0.46	0.43	0.59	0.44	0.29	1.000

The regression findings that test the impact of intellectual capital on bank performance measured by Return on Assets (ROA) and Return on Equity (ROE) are shown in **Table 3**. The results show that Value Added Intellectual Coefficient (VAIC) has a positive and statistically significant effect on both ROA ($\beta = 0.213$, $t = 3.84$, $p < 0.01$) and ROE ($\beta = 1.746$, $t = 3.12$, $p < 0.01$) indicating that higher intellectual capital efficiency leads to better financial performance. The analysis of the individual components of VAIC indicates that Human Capital Efficiency (HCE) is the most influential factor, displaying positive and significant relationships with ROA ($\beta = 0.284$, $t = 4.21$, $p < 0.01$) and ROE ($\beta = 2.418$, $t = 3.96$, $p < 0.01$). Capital Employed Efficiency (CEE) likewise has a positive and substantial effect on ROA ($\beta = 0.198$, $t = 2.56$, $p < 0.05$) and ROE ($\beta = 1.926$, $t = 2.31$, $p < 0.05$), but Structural Capital Efficiency (SCE) does not have any meaningful link with either performance metric. Among the control variables, firm size (SIZE) is positively related with both ROA and ROE across all the models, suggesting that larger banks tend to have better financial performance. However, leverage (LEV) and firm age (AGE) are statistically insignificant. The models show a good explanatory power, with R^2 values from 0.38 to 0.46, and the important F-statistics support the overall robustness of the regression models. Overall, the results imply that intellectual capital, especially the efficiency of human capital, is very important for increasing bank profitability and shareholder returns.

The graphical analysis offers supplementary visual corroboration for the study's empirical findings. **Figure 1** depicts the correlation between overall intellectual capital efficiency (VAIC) and financial performance metrics (ROA and ROE), facilitating an intuitive evaluation of the association's direction and magnitude. The ascending trend evident in the scatter plots signifies a positive correlation, indicating that enhanced intellectual capital efficiency correlates with increased profitability in Islamic institutions.

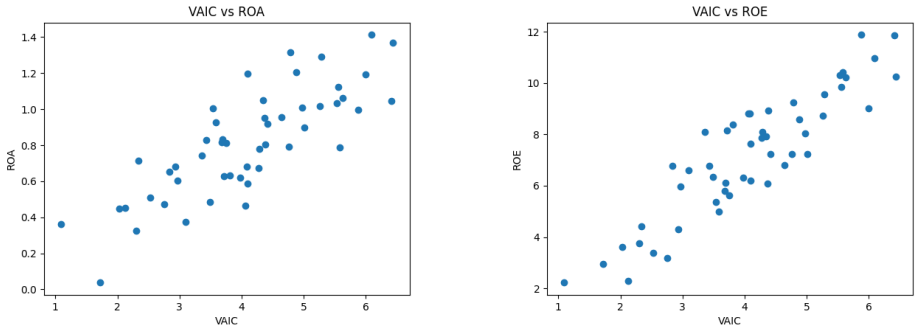
Figure 2 enhances this study by illustrating the relative contributions of the distinct components of intellectual capital—human capital efficiency (HCE), structural capital efficiency (SCE), and capital employed efficiency (CEE)—derived from the estimated regression coefficients. The comparison underscores the preeminent influence of human capital on financial success, succeeded by the efficiency of capital used, whilst

structural capital demonstrates a relatively feeble and statistically insignificant impact.

Table 3. Fixed-Effects Panel Regression Results: Impact of VAIC on Financial Performance.

Variable	Model 1: Aggregate intellectual capital model		Model 2: Intellectual capital components model	
	ROA	ROE	ROA	ROE
VAIC	0.213*** (3.84)	1.746*** (3.12)	—	—
HCE	—	—	0.284*** (4.21)	2.418*** (3.96)
SCE	—	—	0.061 (1.12)	0.441 (1.08)
CEE	—	—	0.198** (2.56)	1.926** (2.31)
SIZE	0.087** (2.44)	0.694** (2.27)	0.081** (2.18)	0.702** (2.11)
LEV	−0.642 (−1.35)	−4.288 (−1.29)	−0.611 (−1.28)	−4.813 (−1.41)
AGE	0.012 (0.74)	0.086 (0.69)	0.014 (0.81)	0.092 (0.73)
Constant	−1.921 (−1.46)	−14.384 (−1.38)	−1.754 (−1.29)	−13.972 (−1.31)
Bank Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	132	132	132	132
R^2	0.41	0.38	0.46	0.42
F-statistic	9.84***	8.72***	11.23***	9.95***

Note: Figures in parentheses are *t*-statistics. *** and ** denote significance at the 1% and 5% levels, respectively. Bank and year fixed effects are included in all models. The mean Variance Inflation Factor (VIF) is 2.41, indicating that multicollinearity is not a serious concern, as the value is well below the commonly accepted threshold of 10 [15].



(a) **(b)**

Figure 1. Correlation between intellectual capital efficiency and financial performance. **(a)** Scatter plot depicting the correlation between Value-Added Intellectual Coefficient (VAIC) and Return on Assets (ROA); **(b)** Scatter plot depicting the correlation between VAIC and Return on Equity (ROE). Visual representations illustrate the favorable correlation between intellectual capital efficiency and bank profitability.

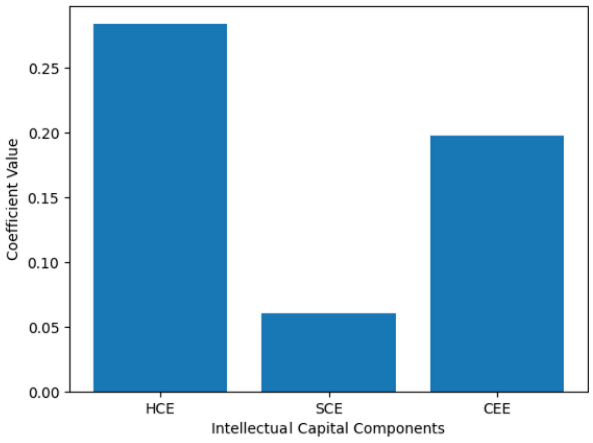


Figure 2. Contribution of Intellectual Capital Components to Financial Performance.

Bar chart shows the estimated regression coefficients of Human Capital Efficiency (HCE), Structural Capital Efficiency (SCE), and Capital Employed Efficiency (CEE) on financial performance. The figure highlights the dominant influence of human capital relative to other components.

To ensure the reliability and stability of the empirical results, various robustness and diagnostic tests were performed, as outlined in **Table 2**. Several additional diagnostic and robustness procedures were implemented to guarantee the validity, reliability, and robustness of the empirical findings. The highest correlation coefficient is between VAIC and HCE (0.82) among the independent variables. This is a relatively high correlation and is predicted because HCE is one of the components of VAIC. To minimize the potential multicollinearity issues, VAIC and its components (HCE, SCE and CEE) were evaluated in different regression models. Furthermore, the other correlation coefficients between the explanatory variables are less than the threshold of 0.70, showing that multicollinearity is probably not a severe issue [15]. Hence, the regression estimates are considered credible and not seriously affected by multicollinearity concerns.

Initially, the stability of the results was confirmed by estimating alternative model specifications. Disaggregated models that incorporate individual components—human capital efficiency (HCE), structural capital efficiency (SCE), and capital employed efficiency (CEE)—were analysed in addition to the baseline model that employs aggregate intellectual capital efficiency (VAIC). The results are not sensitive to model formulation, as evidenced by the consistency of coefficient signs and significance levels across these specifications. This is in accordance with the most effective methodologies in empirical banking and panel data research [12]. Secondly, the Variance Inflation Factor (VIF) was calculated to mitigate the potential for multicollinearity among explanatory variables. The regression models are clear that multicollinearity is not a concern, as the mean VIF value of 2.41 is significantly lower than the commonly accepted threshold of 10. This guarantees the interpretability and stability of the estimated coefficients [16].

Third, the utilization of robust standard errors was employed to address the prevalent issues of serial correlation and heteroskedasticity in panel data analysis. This modification guarantees that statistical inferences are still valid in the presence of non-constant variance and autocorrelation within panel units, as recommended in econometric literature [13]. Fourth, the Hausman specification test was implemented to ascertain the most suitable estimation technique for fixed-effects (FE) and random-effects (RE) models. The fixed-effects specification is strongly supported by the test results, suggesting that the explanatory variables are correlated with unobserved bank-specific heterogeneity. As a result, the fixed-effects estimator generates estimates that are both consistent and unbiased [17]. Fifth, alternative dependent variables were implemented to evaluate model stability. The regression analysis was conducted using both return on assets (ROA) and return on equity (ROE) as proxies for financial performance. The robustness of the findings is further substantiated by the persistence of statistically significant relationships across both measures, which confirms that the observed effects are not driven by a specific performance indicator. This is consistent

with prior intellectual capital and banking studies [18].

In order to verify the model's adequacy, supplementary diagnostic tests were implemented. These include the examination of residual distributions and the execution of specification tests to guarantee that no significant econometric assumptions are disregarded. Collectively, these diagnostic and robustness procedures offer compelling evidence that the empirical results are stable, reliable, and insensitive to alternative model assumptions or estimation methodologies [19].

4. Discussion

The empirical evidence indicates that intellectual capital performance markedly affects the financial performance of Islamic banks in Malaysia. The statistically significant positive relationship between the overall intellectual capital metric (VAIC) and both ROA and ROE indicate that banks that use intellectual capital more efficiently tend to have better financial results. This finding is consistent with the Resource-Based View, which emphasizes the importance of intangible, firm-specific resources in promoting enduring performance benefits [11,20].

The positive effect of bank size on profitability shows that Islamic banking has scale benefits, as bigger banks may make better use of their resources and find more ways to diversify. The minimal influence of leverage and bank age indicates that fluctuations in profitability are mostly driven by efficiency and knowledge-based factors, rather than capital structure or institutional age. Recent banking research has corroborated these findings, demonstrating that the efficacy of intellectual capital often exceeds traditional balance-sheet metrics in clarifying bank performance [14].

When the VAIC metric is broken down, human capital efficiency (HCE) is shown to be the most important part. It has a positive and statistically significant relationship with both ROA and ROE. This result supports Hypothesis H1a and shows how important it is for Islamic banking to have experienced workers, good managers, and specific Shariah knowledge. Islamic banks depend heavily on human judgment to create Shariah-compliant contracts, manage risk-sharing agreements, and make sure that both Shariah and regulatory rules are followed. Empirical studies from both Islamic and conventional banking contexts recognize human capital as the principal factor influencing financial performance [4,21].

Capital employed efficiency (CEE) shows a positive and statistically significant link to profitability, which supports Hypothesis H1c. This result shows that using financial and physical capital well increases intellectual capital, which leads to higher returns. In Islamic banking, which is based on asset-backed financing and risk-sharing, better capital allocation helps banks turn knowledge assets into profitable results. This result is consistent with prior studies demonstrating a synergistic relationship between intellectual capital and capital efficiency in financial institutions [11,20].

On the other hand, structural capital efficiency (SCE) has no statistically significant effect on financial performance, which means that Hypothesis H1b is not true. While organizational structures, procedures, and routines are crucial for operational stability and compliance, they do not appear to independently increase

profitability unless effectively leveraged through human capital. One possible explanation is that legal and governance requirements have made structural capital in Islamic banks mostly the same, which makes it harder for banks to tell how well they are doing. This method is in line with earlier studies that found that structural capital has little or unclear effects on bank profitability [12,14].

The robustness assessments further support the idea that these results are reliable. The findings are consistent across several profitability criteria, different model parameters, and the use of robust standard errors. Multicollinearity diagnostics indicate that the anticipated relationships are not influenced by heightened correlations among explanatory variables. The robustness tests together validate that the identified connections between intellectual capital, particularly human capital efficiency, and financial performance are reliable and not dependent on the employed model.

The results indicate that value generation in Malaysian Islamic banks is primarily driven by human competence and efficient capital utilization, rather than exclusively by organizational structures. This emphasizes the view that Islamic banking is fundamentally a knowledge-based field, where human capital is essential for transforming Shariah principles into enduring financial results. The considerable significance of human capital efficiency indicates that Islamic banks should perceive human capital development as a strategic investment. To improve decision-making, creativity, and risk management, it is important to keep people who are good at both finance and Shariah, give them clear paths for career growth, and keep training them. These findings suggest that investments in talent development should be viewed as long-term value-generating endeavors rather than mere short-term costs.

In addition, organizational structures and processes must be set up to make the best use of human skills. Structural capital should not be an independent driver of performance; instead, it should be an enabling tool that encourages information sharing and compliance with rules. The results show how important it is to create a knowledge-based Islamic banking system from a regulatory point of view. Efforts to encourage professional growth, certification, and better disclosure of intellectual capital can make the Islamic banking sector more open, strong, and competitive. This research finally contributes Malaysia-specific evidence to the intellectual capital literature. Subsequent research may examine dynamic effects, the role of Shariah governance, or expand the analysis to include non-financial outcomes like financial stability and social impact.

While the study effectively constructs a dynamic intellectual capital framework and illustrates the favorable correlation between intellectual capital efficiency and the financial performance of Islamic banks, the proposed dynamic model is predominantly theoretical, as it mainly emphasizes conceptual mathematical representations and empirical validation without adequately translating the framework into practical banking applications or regulatory implementation strategies. The system of differential equations and optimal control methodology elucidates the temporal evolution of human capital, structural capital, and capital employed efficiency, as well as their contributions to bank profitability. However, the study offers scant discourse

on the practical implementation of these findings by regulators and Islamic banking institutions within current governance and risk management frameworks.

Moreover, although the study underscores the significance of human capital efficiency and strategic investment in intellectual capital, there is an absence of actionable regulatory policies and operational measures for banks that could assist Islamic financial institutions in systematically incorporating intellectual capital management into their routine operations and long-term strategic planning. The paper advocates for the enhancement of talent development, governance frameworks, and knowledge-based systems; however, it fails to delineate explicit policy instruments, standardized disclosure mandates, performance metrics, or supervisory protocols that regulators, including central banks or Islamic financial authorities, might implement. Likewise, operational measures such as obligatory intellectual capital reporting standards, staff competency evaluation frameworks, Shariah knowledge certification systems, or adaptive monitoring tools for intellectual capital efficiency are not expressly articulated in the model.

Consequently, despite its robust theoretical and methodological contributions, the study exposes a considerable disparity between dynamic intellectual capital modeling and its practical application in the administration and regulation of Islamic banking. Subsequent research should concentrate on converting the theoretical framework into implementable regulatory policies, institutional governance structures, and operational performance metrics that Islamic banks and financial regulators can adopt to enhance long-term sustainability, competitiveness, and financial resilience.

The findings are robust; however, there are numerous opportunities for methodological improvement and future research. To begin, this study utilizes static panel estimation techniques. However, future research may benefit from the implementation of dynamic panel models, such as the Generalized Method of Moments (GMM), to explicitly account for potential endogeneity and persistence in financial performance. As bank profitability is inherently dynamic and influenced by past performance, the incorporation of latent dependent variables within a GMM framework could offer more profound insights into the temporal adjustment processes of financial outcomes and intellectual capital [22, 23]. Secondly, the scope of the present analysis is limited to in-sample estimation. Consequently, future research could expand the framework to encompass forecasting applications. The practical utility of the model for strategic planning and decision-making would be improved by the integration of predictive modeling techniques, which would enable researchers to assess the efficacy of intellectual capital indicators in predicting future bank performance [24]. Third, the generalizability and predictive accuracy of the proposed model could be evaluated using out-of-sample validation techniques, such as cross-validation or train-test data division. Empirical finance and econometrics frequently advocate for the implementation of such methodologies to mitigate the risk of overfitting and guarantee model reliability beyond the estimation sample [25]. Collectively, these extensions would enhance comprehension of the predictive and dynamic function of intellectual capital in Islamic banking systems.

The critical role of intellectual capital in shaping the financial performance of Islamic institutions has been further reinforced by recent empirical and theoretical developments. Zafar and Yasin [26] have conducted a comprehensive meta-synthesis that demonstrates the consistent existence of robust positive relationships between financial performance indicators, including return on assets (ROA) and return on equity (ROE), and intellectual capital components, particularly human capital efficiency (HCE) and capital employed efficiency (CEE). The research underscores the importance of intellectual capital in the development of value and the maintenance of a competitive edge in Islamic banking systems. It is crucial to note that structural capital, while it provides operational support and organizational stability, its independent impact on profitability is restricted unless it is effectively leveraged through human capital. This observation is in close alignment with the results of the current study, which establishes human capital as the most significant determinant of financial performance. This reinforces the strategic significance of knowledge-based resources in Islamic financial institutions.

Recent research has underscored the complementary role of governance mechanisms in improving the performance of banks, in addition to the direct effects of intellectual capital. Wahyudi et al. [27] have shown that the efficiency and profitability of Islamic banks in OIC countries are substantially enhanced by the interaction between corporate governance and intellectual capital. Their results indicate that governance structures, including effective boards, regulatory oversight, and transparency mechanisms, facilitate improved decision-making and accountability, thereby enhancing the productive utilization of intellectual capital. This perspective broadens the interpretation of the current study by suggesting that performance variations may not be entirely accounted for by intellectual capital alone unless it is accompanied by robust institutional frameworks. This suggests that to optimize the financial outcomes of Malaysian Islamic institutions, investments in human capital and knowledge systems should be accompanied by robust governance practices.

Recent developments in banking research have emphasized the necessity of utilizing dynamic modelling methods to accurately represent the changing nature of financial performance from a methodological perspective. Sadiq et al. [28] demonstrate that bank efficiency and profitability exhibit substantial persistence over time by employing a two-step system Generalized Method of Moments (GMM). This implies that past performance and resource allocation decisions have an impact on current outcomes. This is consistent with the theoretical framework that was developed in this study using differential equations and control processes, which posits that banking performance is inherently dynamic and path-dependent. The incorporation of dynamic modeling perspectives suggests that static models may underestimate the long-term consequences of intellectual capital accumulation. Therefore, this study provides a more comprehensive framework for comprehending the evolution of intellectual capital and its impact on financial performance over time through the integration of panel data analysis and dynamic system modeling. Collectively, these recent contributions fortify the empirical and methodological underpinnings of the current investigation and underscore the significance of incorporating intellectual capital theory, governance

mechanisms, and dynamic modeling methodologies to facilitate the advancement of Islamic banking research.

5. Conclusion

This study examined the influence of intellectual capital efficiency on the financial performance of Islamic banks in Malaysia by employing a dynamic intellectual capital model with fixed-effects panel regression analysis. Analysis of a sample of 11 Islamic banks from 2012 to 2023 reveals that intellectual capital significantly enhances bank profitability, as indicated by return on assets (ROA) and return on equity (ROE). The overall Value Added Intellectual Coefficient (VAIC) had a beneficial and significant effect on financial performance. Upon disaggregating intellectual capital into its constituent elements, human capital efficiency was identified as the predominant factor influencing profitability, succeeded by capital employed efficiency, whilst structural capital efficiency shown no statistically significant effect. These findings underscore the essential role of employee knowledge, skill, and efficient use of financial resources in establishing durable competitive advantages in Islamic banking organizations. The robustness and diagnostic tests further validated the dependability of the results, suggesting that the observed associations remain stable across various model configurations. The study suggests that intellectual capital, especially human capital, serves as a strategic asset for enhancing the competitiveness, profitability, and long-term sustainability of Islamic banks. This study enhances the literature on intellectual capital and Islamic banking by integrating dynamic systems modeling with empirical panel analysis, offering practical insights for bank managers and policymakers to focus on investments in knowledge development, talent management, and effective capital utilization as key factors influencing organizational performance.

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