Technical Efficiency and Intellectual Capital Islamic Banks in Indonesia

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Abstract

This study explores the impact of intellectual capital on the technical efficiency of Islamic banks in Indonesia, emphasizing the shift from traditional physical assets to intellectual resources like digital systems, technologies, and brand value. It analyzes nine Islamic banks out of fourteen in Indonesia from 2013 to 2022 using a two-stage data analysis method. The first stage involves the Data Envelopment Analysis (DEA) model to measure technical efficiency, while the second stage uses the fractional regression model (FRM) instead of the traditional Ordinary Least Squares (OLS) method. The research introduces the iB-VAIC coefficient as a new intellectual capital metric. DEA results show that the average efficiency score for Indonesian Islamic banks is 0.945, with only two banks achieving a perfect score. The FRM analysis indicates a significant link between intellectual capital (iB-VAIC) and technical efficiency, with different components of intellectual capital having varied impacts. The study finds a negative correlation between bank size and technical efficiency and provides insights for bank management and policy development in Islamic banking.

Keywords: data envelopment analysis, intellectual capital, technical efficiency

Introduction

The Islamic finance industry has demonstrated remarkable resilience and growth, particularly in the face of challenges posed by the COVID-19 pandemic during 2020-2021. According to the ICD-Refinitiv Islamic Finance Development Report 2022, the industry witnessed a 14% increase in total assets, with the subsequent year seeing assets surge to US $4 trillion, marking a 17% growth and surpassing pre-pandemic levels. Notably, Islamic banks, which constitute approximately 70% of the Islamic financial industry sectors, experienced a 17% growth, reaching US$ 2.8 trillion in assets (Gusna & Masdupi, 2021; Kovjanić & Vukadinović, 2021; Nuryaman, 2015; Özer et al., 2015; Waseem et al., 2018; Yousef Obeidat et al., 2017).

In the realm of banking, Intellectual Capital (IC) has emerged as a pivotal factor influencing performance and competitive advantage in today's economy. IC, a form of intangible asset, is crucial for companies as it facilitates wealth creation. The focus in banking has shifted from physical to intangible assets, with IC being central due to its role in enhancing the intrinsic value through employees' knowledge, skills, and business training.

This shift provides banks with a range of competitive advantages (Soewarno & Tjahjadi, 2020). Strategic implementation of IC enables banks to increase output, enhance product and service quality, optimize efficiency, stimulate sales and expansion, and strengthen relationships with customers and other stakeholders (Soewarno & Tjahjadi, 2020). Furthermore, the components of Value Added Intellectual Coefficient (VAIC), such as capital employed efficiency (CEE) and human capital efficiency (HCE), have a significant impact on the financial performance of Islamic financial institutions in India (Nawaz & Haniffa, 2017).

Numerous studies have underscored the importance of IC in companies, highlighting its role as a key to competitiveness (Korytko & Bryl, 2021; Myasoedov, 2021; Punda et al., 2021), a strategic performance tool (Gusna & Masdupi, 2021; Kovjanić & Vukadinović, 2021; Nuryaman, 2015; Özer et al., 2015; Waseem et al., 2018; Yousef Obeidat et al., 2017), an innovation catalyst (Allameh, 2018; Nejjari & Aamoum, 2020; Waseem et al., 2018), and a factor in enhancing business organization value (Abdulaali, 2018), firm value, and share price (Gareeva et al., 2018; Nuryaman, 2015; Salehi & Zimon, 2021). Additionally, IC contributes to competitive advantage (Gogan et al., 2016) and sustainable growth (Agustia et al., 2021).

In Islamic banking, efficiency is a critical concept, focusing on how services and products are delivered to consumers through optimal resource utilization. Efficiency reflects a business unit's ability to maximize output with given inputs or to minimize inputs while maintaining a certain level of output. This concept is measured through "output-oriented" and "input-oriented" approaches, the choice of which depends on the specific characteristics of the business unit (Jiao et al., 2015).

The issue of technical efficiency is paramount in the banking sector, as it provides insights into how banks utilize their resources to maximize profits through the creation of products and services for consumers. The banking sector, confronted with significant challenges including market competition and technical efficiency risks, must navigate these complexities effectively (Zhao et al., 2021). The role of technical efficiency is crucial in determining and indicating the stability of the banking sector (Adesina, 2019). Banks achieving high levels of technical efficiency can enhance their performance and secure a competitive advantage in the market. This efficiency can also serve as a metric for gauging economic efficiency. Various methods exist for determining technical efficiency, ranging from financial statement ratios to banking statistics, and employing both parametric and non-parametric approaches with production assumptions (Psillaki & Mamatzakis, 2017).

Banks are deemed efficient when they can produce outputs with fewer inputs, thereby reducing costs and risks while increasing profits and competitive advantage. Efficiency levels can be measured using the frontier approach, which helps identify factors contributing to inefficiency and opportunities for performance improvement (Rahmawati, 2015a). Islamic Banking, in addition to competing with conventional banks, faces rapid growth and competition within its sector. Efficiency measurement is a crucial tool for performance evaluation and sustaining competitiveness in a rigorous business environment. Recent studies indicate that Islamic banks may be more efficient than conventional banks (Al Parisi et al., 2021), with research by Yusuf et al. (2021) suggesting an increasing trend in the efficiency of Islamic banks.

Banking involves numerous activities, including fund collection and distribution, intermediary functions, financial analysis, investment advisory, risk management, portfolio management, and financial advisory. In managing these activities, banking

managers aim to maximize operational benefits. These activities invariably involve costs, considered as inputs, which are utilized to produce customer services, or outputs. Banks must aim to use minimal input resources to generate maximum outputs.

Banks provide services involving both tangible and intangible assets. However, the banking sector currently places greater emphasis on intellectual capital resources than on physical capital. While physical capital remains necessary for banking operations, intellectual capital is increasingly recognized as providing superior performance levels compared to competitors (Adesina, 2019; Meles et al., 2016).

Banks strive for operational resource efficiency, including labor, technology, and infrastructure. Higher operational efficiency can lead to greater profits from available resources. Efficient banks can thus allocate more resources to develop intellectual capital, such as innovative digital banking systems or technological advancements. Intellectual capital in banking encompasses various intangible assets like brands, technology, and knowledge. Banks focusing on enhancing their intellectual capital, through innovation or improved products and services, can gain a competitive edge. Good operational efficiency enables banks to invest more in these innovations (Ni et al., 2021).

Research indicates that intellectual capital positively impacts a firm's technical capabilities, with human capital being a significant contributor. This suggests that investments in human capital can bolster a bank's overall technical capabilities. Studies have found a positive relationship between intellectual capital and technical capabilities in Vietnamese banks, implying that high intellectual capital can enhance technical capabilities (Bataineh et al., 2022; Duho & Onumah, 2020; Vo & Tran, 2021). In summary, intellectual capital is crucial in the banking industry as it enables banks to innovate, manage risks, optimize resource allocation, enhance customer service, navigate regulations, and make strategic decisions. These factors are essential for both technical and allocative efficiency, which are vital for a bank's success and sustainability in a competitive and dynamic environment.

However, there is a insufficient body of research exploring the relationship between intellectual capital (IC) and technical efficiency, allocative efficiency, and cost efficiency in Islamic banks in Indonesia. Previous research on this topic is summarized in Table 1.

The motivation for this study arises from the identified research gap concerning the correlation of Intellectual Capital (IC) on the efficiency of Islamic banks in Indonesia. This research is distinguished from prior studies by its application of the iB-VAIC model, specifically tailored for Islamic Banking, as developed by Ulum et al. (2020). The study aims to explore two primary research questions: firstly, assessing the efficiency level of Islamic banks in Indonesia, and secondly, examining the relationship between IC and the efficiency level of these banks.

The objective of this study is to investigate and elucidate the influence and correlation of IC on technical efficiency within the Islamic banking sector in Indonesia. IC has been recognized as a crucial metric for measuring a company's performance or sustainability. The components of IC are believed to significantly enhance company performance. Superior IC, as an organizational resource, is instrumental in better managing the organization. Improved management of IC is hypothesized to correlate with enhanced organizational performance. Concurrently, the efficiency measurement commonly utilized in Indonesia is the Operating Expense-Operating Income (BOPO) ratio,

Table 1. Previous Research Intellectual Capital and Technical Efficiency

Author	Variable	Result
Duho (2019)	VAIC^{TM}, Technical Efficiency, SBM-TE,	IC has positive impact on SBM-TE, Human capital is main driver of TE.
Omunah & Duho (2020)	HCE, SCE, CEE, Technical Efficiency	IC instigates efficiency bank. Only HCE have significant effect to efficiency, two others insignificant.
Moutinho (2021)	HCE, SCE, CEE, size, leverage 1, leverage 2, leverage 3, technical efficiency (TE), pure technical efficiency (PTE)	SCE,CEE, size have significant negative relationship on TE, PTE. HCE has positive significant relationship on TE, PTE. Leverage 1 & Leverage 3 insignificant on TE, PTE. Leverage 3 has positive significant relationship on TE, PTE
Rahmat (2020)	VACA, VAHU, STVA, size, market share, BOPO	VACA, VAHU, STVA, size, market share have significant effect on BOPO
Adesina (2019)	VACA, VAHU, STVA, technical efficiency (TE), pure technical efficiency (PTE), cost efficiency (CE)	Only VAHU has positive related to TE, PTE & CE

Sources: Processed Data, 2023

which has been endorsed by regulators such as BI and OJK as a benchmark for banking efficiency.

Banking efficiency can be measured in terms of technical efficiency, allocative efficiency, and cost efficiency. Numerous studies have underscored the importance of measuring these three efficiencies (Duho, 2020; Ispriyahadi & Trierdianto, 220 C.E.; Maji & Hussain, 2021; Moutinho et al., 2020; Rahmat, 2020; Rahmawati, 2015a). However, few studies have directly linked IC management with efficiency levels (Duho & Onumah, 2020; Moutinho et al., 2021). This study aims to contribute to understanding how companies can leverage their IC to develop products or services efficiently and effectively, thereby adding value to the company and enabling banks to maximize output from their inputs and resources.

The Resource-Based View (RBV) Theory posits that a firm's competitive advantage is closely linked to its strategic resources. These resources, which can be tangible assets like land, buildings, and equipment, or intangible assets such as patents, brands, or work culture, are crucial in the modern economic era where companies are required to leverage intangible assets to stay competitive. To achieve superior financial performance, a company can build intangible assets such as intellectual capital (Soewarno & Tjahjadi, 2020).

RBV suggests that a company's resources, if valuable and rare, can provide a competitive advantage and drive long-term performance. These resources include all assets, capabilities, organizational processes, company attributes, information, and knowledge that enable the implementation of strategies to enhance efficiency and

effectiveness. Bontis (1999) categorizes IC into three main components: human capital, structural capital, and customer capital. Human capital includes knowledge, skills, experience, education, training, loyalty, and all aspects related to human resources in the company. Structural capital includes non-human assets used to meet market demand, patents, intangible assets, supporting information systems, databases, and organizational concepts. Customer capital, a part of the IC model, involves external relationships, including those with consumers, suppliers, and R&D. Thus, the management of intangible assets to the extent that it increases value for the company, achieving competitive advantage and enhancing productivity, is the essence of IC (Ulum, 2020). The synergy of human resources, innovation, and technology is integral to creating IC (Hatane et al., 2020).

Technical efficiency, meanwhile, is a metric assessing a company's ability to utilize its resource inputs to produce maximum output while minimizing waste. The unique and rare resources possessed by a company should be utilized as efficiently as possible to create competitive advantages and increase company value. Proper management of IC can indirectly improve the quality of inputs, enhance the efficiency of the production process, and foster innovation, as well as the development of new products and services. This, in turn, provides a competitive advantage for banks to meet market demands more efficiently and effectively (Anwar et al., 2019).

Intellectual Capital (IC) has been defined variously by researchers. Some view IC as a tool aiding companies in market competition, encompassing intellectual material such as knowledge, information, experience, and intellectual property for wealth creation (Andreeva & Garanina, 2017; Orlando et al., 2021; Ousama et al., 2019; Stewart & Ruckdeschel, 1998). The Organization for Economic Co-operation and Development (OECD, 1999) describes IC as the economic value of intangible assets, including structural and human capital. Bontis (1999) categorizes IC into three components: human capital, structural capital, and customer capital. Human capital extends beyond mere human resources, representing a crucial element in defining intangible assets that add economic and material value to an organization. Structural capital encompasses infrastructure, processes, patents, trademarks, corporate image, organization, information systems, and databases (Subaida et al., 2018). Customer capital, on the other hand, involves relationships between organizations and consumers, indicative of customer loyalty and satisfaction. Employees, equipped with various skills and abilities, play a vital role in delivering optimal service, understanding, and meeting customer needs (Ni et al., 2021). Knowledge and a strong reputation among consumers can lead to increased sales and enhanced company value (Kevser & Dogan, 2020). IC measurement is crucial in aiding managers to make more efficient decisions (Moutinho et al., 2021).

IC performance has been extensively researched. Studies have shown that IC in financial companies in Vietnam is higher than in non-financial companies (Tran & Vo, 2022), and IC positively affects the performance of software companies in the US, with human resources being a key efficiency driver (Nkambule et al., 2022a). IC influences various aspects, including company performance (D'Amato, 2021; Quach et al., 2020), SME performance in Malaysia (Khalique et al., 2018), performance of Islamic banks in the UK (Nawaz, 2019), and profitability of healthcare companies in India (Tiwari, 2022). Financial ratios, such as company profitability, are also believed to be influenced by a company's IC (Agustia et al., 2021; Prawitasari et al., 2018; Tripathy et al., 2015). However, IC's impact extends beyond financial statements (Lotfi et al., 2022); dimensions of IC like

social capital and knowledge sharing can drive innovation (Allameh, 2018) and contribute to company survival (Festa et al., 2021).

Assessing banks involves not only evaluating their performance but also measuring their efficiency in producing outputs from inputs. Developments in the financial market, financial innovation, automation, and deregulation are crucial factors in banking efficiency (Dong et al., 2014), especially in the era of technological advancement. Banks must control and analyze costs and revenues while also measuring the risk of uncertainty or loss in achieving targeted profit levels. Dang-Thanh (2010) identifies several types of bank efficiency measurements, including Technical Efficiency (TE), Pure Technical Efficiency (TPE), Scale Efficiency (SE), Cost Efficiency (CE), and Allocative Efficiency (AE).

Recent studies indicate that the efficiency of Islamic banks in Asian countries has been on the rise (Chowdhury & Haron, 2021; Mala et al., 2020; Nailah & Rusydiana, 2020; Safiullah, 2021; Serly & Handayani, 2020; Solihin et al., 2016). Data Envelopment Analysis results show that Islamic banks in Thailand and Malaysia consistently rank as highly efficient. Salami & Adeyemi (2017) support this, indicating high scale and technical efficiency in Malaysian Islamic banks. While Islamic banks in Indonesia have shown year-on-year improvements, they still fall below the average efficiency level of Islamic banks in ASEAN. Islamic banks in Arab countries also demonstrate superior efficiency compared to conventional banks (Rashwan & Ehab, 2016); Islamic banks across 28 countries during 2003-2018 have also been found to be very efficient (Safiullah, 2021).

Research directly linking IC with efficiency levels includes Tiwari (2022), who found that IC, using Modified VAIC, has a positive relationship with economic parameters (cost, revenue, and profit) efficiency in 37 BSE-listed Indian banks during 2005-2018. Nkambule et al. (2022) state that IC, encompassing Human Capital, Innovation Capital, Process Capital, and Customer Capital, significantly and positively affects the efficiency of software companies in the US. Duho (2020) discovered that IC positively impacts technical efficiency, with human resources being the main driver in the banks studied. Adesina (2019) found that among all IC components, only VAHU has a significant effect on TE, PTE, and CE. Moutinho et al. (2021) mention that IC in human capital significantly influences the efficiency level of 58 Iberian banks.

H_1 : iB-VAIC has a significant effect on technical efficiency
H_{1a} : iB-VACA has a significant effect on technical efficiency
H_{1b} : iB-VAHU has a significant effect on technical efficiency
H_{1c} : iB-STVA has a significant effect on technical efficiency

Research Method

This study encompasses all Islamic banks in Indonesia over the period from 2013 to 2022. As of the commencement of this study, there were 14 Islamic Commercial Banks (BUS) in operation. The sampling method employed is purposive sampling, with the criterion that the Islamic banks must regularly publish financial reports, including statements of financial position and income statements. Consequently, 9 Islamic Banks meeting this criterion were selected for the study, spanning a 10-year period (2013-2022), resulting in a total of 90 observations. The operational variables used include Intellectual Capital Islamic Bank (iB-VAIC) with components of iB-VACA, iB-VAHU, iB-STVA, and Size as independent variables, and Technical Efficiency as the dependent variable.

The rationale for focusing on Islamic banking is grounded in previous research findings. Studies have shown that Islamic banks exhibit higher profitability and more effective liquidity management compared to conventional banks (Khan et al., 2017). Additionally, other research suggests that Islamic banks may demonstrate greater efficiency, both in terms of overall and technical efficiency (Prima Sakti & Mohamad, 2018). The relationship between intellectual capital and financial performance in the Islamic banking industry is a relatively under-explored area, indicating a potential research opportunity (Ousama et al., 2019).

This research employs a two-stage analysis. The first stage involves calculating the level of technical efficiency using Data Envelopment Analysis (DEA), a non-parametric analysis technique. The result of this analysis is expressed as an interval score ranging from 0 to 1. Given that the dependent variable, technical efficiency, has an interval score of 0-1, it is not feasible to ascertain the relationship and influence of IC on technical efficiency using ordinary OLS regression. Therefore, the second stage of this research utilizes fractional regression, which is more suitable for examining the relationship between IC performance. The Fractional Regression Model (FRM), developed by Papke & Wooldridge (1996), has been validated by research such as that conducted by Moutinho et al. (2021).

FRM is typically employed to analyze data where the dependent variable is bounded between zero and one, making it ideal for examining proportions or fractional outcomes, such as ratios and percentages. Papke & Wooldridge (1996) demonstrated the use of FRM in their research on participation rates in a 401(k) plan. In their study, they applied a fractional regression model to analyze the correlation between performance and the information constituent (IC) in the second-stage DEA. This approach allowed them to estimate the impact of IC on the performance of the plan while accounting for the bounded nature of the variable. Their paper provides a comprehensive methodology of the model, and it is advisable to consult the original source for a deeper understanding of its application. The model is frequently used in analyzing performance variables and ICs.

Two methods are commonly used to assess efficiency levels: parametric and non-parametric approaches. The parametric approach typically employs the Stochastic Frontier Approach (SFA), while the non-parametric approach uses Data Envelopment Analysis (DEA). This study adopts the DEA method, aligning with previous studies (Chowdhury & Haron, 2021; Duho, 2020; Nurcahyani et al., 2022; Vidyarthi & Tiwari, 2019).

$$hs = \frac{\Sigma_{i=1}^{m} u_i.y_{is}}{\Sigma_{j=1}^{n} v_j.x_{js}} \quad \text{.....(1)}$$

Where hs represents efficiency, each Islamic Banks, m = total output
n = total input
y_{is} = total ouput i produced
x_{js} = total input j used
u_i = weight ouput i produced by Islamic banks
v_j = weight input j used by Islamic banks

The advantage of the DEA method is that it does not require a particular structure of the efficient frontier to estimate the efficiency level of a Decision Making Unit (DMU) in an organization or company. The DEA model also allows multiple input and output data (Diallo, 2018). The efficiency score of a bank is between 0 and 1, with the highest level of efficiency if it gets a higher DEA score. Furthermore, the lowest level of efficiency if it gets the lowest DEA score.

Table 2. Selected output and input variables for DMU

Ouput	Input
Total Productive Assets (Funding + Securities + saving other banks – Loan Loss Provision)	*Total Deposit *Employee Expenses

Sources: Processed Data, 2023

There are two models of efficiency measurement in DEA; the first assumes that DMU operates optimally or that additional inputs and outputs are the same (constant return to scale-CRS), also called the CCR (Charnes-Cooper-Rhodes) model. This model is a technical efficiency approach that shows the company's ability to optimize inputs at the best price and technology to produce output at the best price. Technical efficiency describes the firm's ability to choose the optimal combination of inputs at a specific price and technology. Technical efficiency focuses on the company's ability to use inputs to produce output with best practices. This model approach will be used in this study.

The second model assumes that not all DMUs operate optimally due to constraints. This model is commonly called the variable return to scale (VRS) or BCC (Bankers-Charnes-Cooper) model, where an increase in the number of inputs will not automatically increase the output by the same amount because the additional output could be higher or lower. There are several approaches to calculating input and output variables in banking, and each study can choose between them. The most commonly used approaches are the asset approach, the production approach, and the intermediation approach. (Kautsar & Sadalia, 2018)

This study uses the intermediation approach, as in the Chowdhury & Haron's (2021), where banks are intermediary institutions (Table 2). Bank activities when raising funds include obtaining funds from individuals, companies, or institutions, private or public, collected in the form of deposits, be it current accounts, savings, or deposits. In Islamic banks, this deposit contract can be a wadiah (for current accounts and savings) or a mudhorobah contract (for savings and deposits). The bank's obligation to provide profit sharing and bonuses to customers, according to the agreed contract.

Banks function as a channel of funds to channel funds to the public, individuals, companies, or private or public institutions that need funds in the form of financing, securities, or equity participation. Forms of financing in Islamic banks are mudharabah and musharakah profit sharing, murabahah sale and purchase, and ijarah (lease). This financing is a source of bank income because it earns profit sharing according to the agreed contract.

Output is calculated from total productive assets less loan loss provision. As stipulated by OJK No. 2/POJK.03/2022, productive assets are the provision or distribution of Bank funds to obtain income through savings in BI or other banks, investments in securities, financing, and equity participation. Input is the total funds raised by the bank and the costs required to pay labor to produce output.

This study uses iB-VAIC from (Ulum, 2013), which is a development of Pulic's VAIC because it is specifically for Islamic banking. Ulum (2013) modified Pulic's VAIC^{TM} (2000) by developing it into Islamic Banking - Value Added Intellectual Capital (iB-VAIC), which is specifically constructed based on the accounts in the financial statements of Islamic banks in Indonesia. VAIC^{TM} coefficient is designed for companies with general types of transactions. Meanwhile, Islamic banking has transactions that are relatively different from conventional banking.

Table 3. Intellectual Capital Coeffisient

	Definition	Measure
iB-VAIC	Islamic Banking - Value Added Intellectual Coefficient	iB-VACA + iB-VAHU + iB-STVA
iB-VACA	Value Added Capital Employed	$\frac{iB-VA}{CE}$
iB-VA	Value Added	
CE	Capital Employment	Book Value Asset
iB-VAHU	Value Added Human Capital	$\frac{VA}{HC}$
VA	Value Added	
HC	Human Capital	Labor Expenses
iB-STVA	Structure Capital Value Added	$\frac{SC}{VA}$
SC	Structure Capital	iB-VA - HC
VA	Value Added	
SIZE	Total Asset	Ln Total Asset

Source: Processed Data, 2023

This model starts with the company's ability to create value added (VA), which is an indicator of assessing business success and value creation. VA is calculated as the difference between output and input. VA = OUT - IN. OUT represents the total revenue earned from sharia activities, non-operating income. whereas IN includes all expenses used to generate revenue except employee costs. Table 3 explains the description of the independent variables in this study.

iB-VAIC is a coefficient that calculates the added value that the company will obtain, consisting of human capital efficiency, structure capital efficiency, and capital employed efficiency. The company will obtain added value from the resources owned, including employees, skills, and competencies possessed by these employees, systems, policies, and infrastructure available in the organization, as well as the value obtained on investment and available capital. Human capital is created by dividing the value added by the labour expense. Capital structure is obtained from the difference between value-added and labour expenses divided by value-added. Capital structure as a source of value-added while still calculating the financial and capital assets owned by the company. The efficiency of capital employed is obtained by dividing value added by book value of asset.

According to Ulum (2013), iB-VAIC can not only be used as a measure of IC performance for Islamic banking in Indonesia but it can also be used for ranking Islamic banking, for which there is no standardized performance score.

This study follows previous research by (Banker et al., 2019; Duho, 2020; Duho & Onumah, 2020; Moutinho et al., 2021) used a correlation regression model that can be used to estimate the impact of IC factors on efficiency scores.

$w_{it} = \omega 0 + \gamma 1 VAIC™ it + \gamma 2 SIZE_{i,t} + \varepsilon_{i,t}$ .....(2)

$= \omega 0 + \gamma 1 HCE_{i,t} + \gamma 2 SCE_{i,t} + \gamma 3 CEE_{i,t} + \delta 2 SIZE_{i,t} + v\upsilon_{i,t}$ .....(3)

Where w is the technical efficiency score ranging from 0 to 1, VAIC^{TM} indicates the coefficient of intellectual capital, HCE indicates the efficiency of human capital, SCE indicates the efficiency of structural capital, and CEE indicates the efficiency of capital employed. SIZE is the total assets owned by the bank as a control variable. In addition, α and ω are constants, γ are regression coefficients to be calculated and are error terms.

Result and Discussion

The first calculation determines the outputs and inputs as DMUs of all banks selected as samples. The output determined is Productive Assets; the inputs are deposits and labor costs. The mean value. of productive assets is Rp11,979,796 million, while deposits are Rp15,466,681 million, and labor costs are Rp252,163 million (Table 4). The mean variation of these three DMUs is quite significant, and it can be seen that each has a large standard deviation.

The statistic descriptive of variable technical efficiency using DEA (the oriented Scale assumption CRS model), iB-VAIC and size for each banks is shown in Table 5. An average comparison of each bank shows that no Islamic Banks achieve an efficiency rate of 1 for last 10 years. Bank Muamalat has the highest average TE of 0.9942, while BTPN Syariah has the lowest average TE of 0.8996. The average efficiency value of 9 Islamic banks in 2013-2022 is 0.945 or 94,5%. So, on average, Islamic banks in Indonesia can reduce the resources used by 5.5% to achieve optimal technical efficiency.

This score indicates an increase in the technical efficiency of Islamic banks in recent years. The upward trend of this score level is related to Industrial Revolution 4.0, which has encouraged banks to improve their technological capabilities to provide the best service for their customers. Banks are currently competing to provide services in the form of process automation to avoid the risk of human error, speed up the execution of operational tasks, and improve the efficiency and processing of transactions and services (Dastranj et al., 2018; Popelo et al., 2021). Various services can already be done by customers themselves, such as mobile account opening, transfers, payments, deposits and cash withdrawals at ATMs. In addition, data analysis, data security, AI-based services, digital transformation and reporting provide the advantage of increasing efficiency levels as long as they are well managed—the competitive advantage that banks have (Duho & Onumah, 2020).

The range of Technical Efficiency values shows that the minimum value is 0.8160 by BTPN Syariah, and the maximum value is one obtained by Aladin Bank and Muamalat Bank. Based on the Table 5 above, some banks have shown an increasing in the value of technical efficiency over the past ten years, such as BCA Syariah, BTPN Syariah, Bukopin Syariah, Panin Syariah and Victoria Syariah. While Bank Aladin Syariah shows a downward trend in the value of technical efficiency, and other banks are more volatile.

The minimum value of iB-VACA is -0.21, and the maximum is 0.19. Several banks get a minus iB-VACA value, namely Aladin Syariah, BJB Syariah, Bukopin Syariah, Panin Dubai and Victoria Syariah. The minimum value of iB-VAHU is -12.52, and the maximum value is 5.18, where the bank whose value is minus is the same as the bank whose

Table 4. Descriptive statistics output and ouput for DMU (expressed millions of Rupiah)

	N	Minimum	Maximum	Mean	Std. Deviation
Productive Asset	90	275,942	59,989,500	11,929,796	15,466,681
Total Deposit	90	1	53,496,985	9,338,885	13,247,863
Employee Expenses	90	15,370	1,174,614	252,163	315,567
Valid N (listwise)	90				

Source: Processed Data, 2023

Table 5. Descriptive statistics Technical Efficiency, ib-VAIC Coefficient (for each banks)

Bank	Statitic Descriptive	TE	ibVACA	IbVAHU	iBSTVA	Size
Aladin Syariah	Average	0.915	-0.003	-0.260	1.258	29.612
	Max	1.000	0.135	4.858	2.963	1.652
	Min	0.858	-0.207	- 12.516	-0.274	27.995
	STD	0.045	0.096	4.983	0.994	1.002
BCA Syariah	Average	0.952	0.023	1.709	0.404	29.611
	Max	0.981	0.028	2.097	0.523	31.753
	Min	0.913	0.020	1.339	0.253	27.952
	STD	0.021	0.002	0.236	0.086	1.119
BJB Syariah	Average	0.945	0.011	0.642	0.492	29.537
	Max	0.964	0.031	1.586	1.639	31.678
	Min	0.922	-0.053	-2.625	0.105	28.116
	STD	0.015	0.029	1.470	0.545	1.094
BTPN Syariah	Average	0.899	0.163	2.059	0.453	29.313
	Max	0.939	0.190	2.943	0.660	31.554
	Min	0.816	0.131	1.009	0.008	26.428
	STD	0.035	0.020	0.677	0.216	1.477
Bukopin Syariah	Average	0.955	0.009	0.733	4.959	29.451
	Max	0.962	0.020	1.556	46.921	31.567
	Min	0.946	-0.033	-2.446	0.013	27.874
	STD	0.006	0.016	1.202	14.749	1.0302
Mega Syariah	Average	0.946	0.042	2.018	0.393	29.788
	Max	0.994	0.062	5.182	0.807	31.706
	Min	0.914	0.020	1.063	0.059	27.218
	STD	0.025	0.015	1.219	0.234	1.202
Muamalat	Average	0.994	0.015	1.096	0.083	29.971
	Max	1.000	0.018	1.317	0.240	31.747
	Min	0.988	0.011	1.018	0.018	27.296
	STD	0.003	0.002	0.087	0.065	1.283
Panin Dubai Syariah	Average	0.968	-0.000	0.111	0.518	29.466
	Max	0.992	0.024	3.137	1.175	31.764
	Min	0.946	-0.095	-7.610	0.063	27.304
	STD	0.016	0.039	3.662	0.394	1.198
Victoria Syariah	Average	0.930	0.011	0.877	2.872	29.457
	Max	0.962	0.026	1.620	25.652	31.676
	Min	0.897	-0.004	-0.219	-3.823	27.911
	STD	0.018	0.009	0.647	8.309	1.069

Sources: Processed Data, 2023

iB-VACA value is minus. The minimum value of iB-STVA is -3.82 from Victoria Syariah Bank, while the maximum value is 49.92 from Bukopin Syariah Bank.

Table 6. Descriptive statistics Technical Efficiency and iB-VAIC Coefficeint

Variable	N	Minimum	Maximum	Mean	Std. Deviation
TE	90	0.82	1.00	0.95	0.04
ib-VACA	90	-0.21	0.19	0.03	0.06
ib-VAHU	90	-12.52	5.18	1.00	2.25
ib-STVA	90	-3.82	49.92	1.27	5.61
SIZE	90	26.43	31.77	29.58	1.13
Valid N (listwise)	90				

Sources: Processed Data, 2023

The mean and standard deviation are measures of data distribution (Table 6). The greater the standard deviation, the greater the spread of data from the mean. Some variables show that they have a large distribution of data away from the mean, while others are close to the mean. TE and Size variables as variables that have a data mix close to the mean, while the intellectual capital components (iB-VACA, iB-VAHU and iB-STVA) have a fairly large standard deviation, which indicates the data has a significant variation from the mean. If the technical efficiency is known through DEA analysis with an interval score range of 0-1, then the second stage is done using a fractional regression model (FRM).

Before running a regression, it is necessary to consider several assumptions, including residual normality, heteroscedasticity, multicollinearity, and autocorrelation. However, because this dependent variable uses an interval score of 0-1 and uses the fractional regression model (FRM) test, the normality assumption does not apply in this study. Papke & Wooldridge's (1996) research explains that fractional regression is used if the dependent variable is limited between 0-1 but not censored, so it does not require the assumption of normality, similar to what was conveyed by the research of Moutinho et al. (2020) and Ramalho et al.(2010).

The results of FRM analysis using Stata found that the model is free from multicollinearity with VIF values < 10 and tolerance > 0.1 show at Table 7. At the same time, the heteroscedasticity-free test in this study uses the Koenker-Basset (KB) test show at Table 8. This KB test, which is the same as other heteroscedasticity tests such as the Perk test, Breusch-Pagan-Goefrey test and white test, is based on squared residuals but not regressed on one or more regressors but regressed on the squared estimated value of the regressor. This KB test is like the Breusch-Pagan-Goefrey test, which is sensitive to the assumption of normality, so it does not depend on the assumption of normality (Gujarati & Porter, 2009:388). The KB test results show that the research model is free

Table 7. VIF and Toleance

	VIF	Tolerance
ib-VACA	1.92	0.522
ib-VAHU	1.91	0.524
ib-STVA	1.02	0.979
SIZE	10.2	0.980

Sources: Processed Data, 2023

Table 8. Koenker-Basset Test

Residual^2	Coef	Std Err	t	P>|t|
Model	-0.006	0.005	-1.130	0.260
Constanta	0.006	0.005	1.300	0.191
N_obs	90			
F (1, 88)	1.29			
Prob > F	0.259			
R-Squared	0.014			
Adj R-Squared	0.003			

Sources: Processed Data, 2023

from multicollinearity with prob> 0.05. The run test results also show that the model is free from autocorrelation with a prob value of 0.260> 0.05.

The results of the correlation matrix (Table 9) indicate the possibility of collinearity. If the value of the correlation coefficient is more than 0.80, then there is potential collinearity between the variables. Collinearity that occurs if not addressed will lead to invalid regression results. This correlation matrix shows the relationship between technical efficiency influenced iB-VAIC coefficient shows that there is no correlation value more than 0.80, so the concern of potential collinearity is not proven.

The results of the fractional regression model (FRM) analysis shown in Table 10 indicate that the IC performance relationship model has a significant effect on technical efficiency in Islamic banks with a prob level of 0.00 <0.05.

While the significance level of each variable is, iB-VACA has a significant negative effect on technical efficiency with a prob value of 0.00 <0.05. Variable iB-VAHU also has a significant positive effect on technical efficiency with a prob value of 0.003 <0.05. Likewise, the control size variable has a significant positive effect on technical efficiency with a prob value of 0.042 <0.05. Only the iB-STVA variable does not affect the level of technical efficiency.

The plot and summary prediction margin of fractional regression are shown in Table 11. Based on the Table 11, it can be said that the addition of 1% iB-VACA can reduce technical efficiency by 1.16%, the addition of 1% iB-VAHU will increase technical efficiency by 0.5%, and the addition of company size can increase technical efficiency by 16%,

This research seeks to explore the relationship between intellectual capital and technical efficiency, which has yet to be done much in Indonesia. Research in Indonesia on technical efficiency mainly discusses its relationship with performance (Ispriyahadi & Trierdianto, 220 C.E.; Kautsar & Sadalia, 2018; Marsondang et al., 2020; Octrina &

Table 9. Correlation Matrix Result

	TE	ib-VACA	ib-VAHU	ib-STVA	SIZE
TE	1.000				
ib-VACA	-0.304	1.000			
ib-VAHU	0.037	0.688	1.000		
ib-STVA	-0.020	-0.09	-0.101	1.000	
SIZE	0.212	-0.103	-0.080	-0.079	1.000

Sources: Processed Data, 2023

Priatmojo, 2023; Rahmawati, 2015b), stability (Rodoni et al., 2020). What distinguishes this study from the previous one is that researchers assess IC using the iB-VAIC coefficient developed by Ulum et al. (2013) for Islamic banks. In addition, this research seeks to explore through a two-stage analysis, namely first determining the level of technical efficiency through DEA. Second, conduct a fractional regression to see the relationship between IC and technical efficiency. The choice of fractional regression makes this research different from previous studies that used OLS. The reason for using fractional regression is that it is considered more appropriate to analyze when the dependent variable is a 0-1 interval, as in Papke & Wooldridge's reserach (1996). This regression is also considered more suitable for measuring two-stage DEA, where the dependent variable is in the interval 0-1. besides that, this regression is considered to answer the criticism of the use of tobit regression models that use interval variables in the presence of censored data (Raheli et al., 2017; Ramalho et al., 2010).

The results of the DEA analysis show that the average Islamic bank has a technical efficiency of 9.4% for the last ten years in 2013-2022. On average, Islamic banking in Indonesia has yet to show that Islamic banks' average technical efficiency level during 2013-2022 is 94.5%. This figure shows that, on average, Islamic banks in Indonesia have yet to reach efficiency. In general, the technical efficiency of Indonesia's Islamic banks is quite efficient (0.89–0.97) when using the category classification used by Rahmawati (2015) so it is necessary to improve the management of assets and resources to produce output with a better efficiency value. Only Aladin Syariah Bank (2019) and Muamalat Bank (2022) have experienced perfect technical efficiency of 1, It means that these two banks can utilize the DPK they have and use labor costs to get maximum output in the form of productive assets.

Many steps and efforts can be taken by management to improve technical efficiency. Banks must implement the right strategy to achieve the desired technical efficiency. Management needs to engage in analysis and ensure optimal service delivery, improve practices in banking management involving the board of directors, utilize intellectual capital, and use efficiency analysis techniques. These actions can result in better resource utilization, cost management and overall performance in the banking sector. Management can increase emphasis on production and operations analysis to improve efficiency (Bandyopadhyay, 2019). Management can analyze and optimize the production process of services and services for customers to identify inefficient areas and

Table 10. Fractional Regression Model

TE	Coefficient	Robust Std Err	z	P>|z|
ib-VACA	-5.515	1.045	-5.28	0.000
ib-VAHU	0.120	0.040	2.98	0.003
ib-STVA	-0.002	0.006	-0.37	0.709
SIZE	0.105	0.051	2.04	0.042
Constanta	-0.190	1.530	-0.12	0.901
N_obs	90			
Wald chi2 (4)	32.82			
Prob > chi2	0.0000			
Pseudo R2	0.012			

Sources: Processed Data, 2023

Table 11. Summary Prediction Margin of FRM

	Delta-Method			
	dy/ex	std err	z	P>|z|
ib-VACA	-0.011	0.002	-4.17	0.000
ib-VAHU	0.005	0.001	4.58	0.000
ib-STVA	-0.000	0.000	-0.35	0.724
SIZE	0.160	0.078	2.04	0.041
N_obs	90			

Sources: Processed Data, 2023

implement strategies to improve them. In addition, improving the quality of management practices can improve technical efficiency (Abdulla & Kumar, 2021).

For example, the bank with the lowest technical efficiency value was Bank Aladin in 2016, with a value of 81.6%, indicating that the use of deposit of 11.71 and HR costs of 24.39 to obtain an output of 12.463. So, it is necessary to improve the use of inputs in order to achieve technical efficiency by reducing the use of deposit by 2.15 and reducing human resources costs by 4.48. Unfortunately, the output used productive assets, this study cannot show how much the actual value of output, specifically for financing alone, should be used as a measurement. This is important because we can see how banks can utilize the deposits that have been collected from the public plus labor costs, resulting in maximum financing channeled to the public.

The result of FRM analysis shows that iB-VAIC and control variables simultaneously have a significant influence on technical efficiency scores. The study results are in accordance with the research of Tiwari (2022) dan Nkambule et al. (2022) VAIC and MVAIC has a significant positive relationship with efficiency. It is relationship means that banks who can manage their intellectual capital can improve technical efficiency. IC owned by banks can be the main capital to improve technical efficiency through innovation so that banks can produce, in this case, productive assets maximally by utilizing the inputs owned from deposits and labor costs. The value of productive assets is the total of financing, deposits at BI, and deposits at other banks. At the same time, the inputs in this study are third-party funds and labor costs. So, banks are required to utilize funds obtained from the community and labor costs to generate productive assets. The productive asset itself becomes the source of the bank's income, so if the bank can utilize the input to achieve the output as much as possible, then the efficiency level increases. The increase in the bank's efficiency level can improve the company's performance and competitive advantage.

While partially, it is known that iB-VACA has a positive significant effect on technical efficiency or hypothesis H_{1a} is accepted. iB-VACA is an indicator of the value added created by 1 unit of physical capital. If 1 unit of capital employed (CA) generates a greater return than other companies, then the company is better at utilizing its CA. The results contradict the research of Moutinho (2021), who found a significant negative relationship; Adesina (2019), and Onumah & Duho (2019), who found no relationship between ib-VACA and technical efficiency.

Meanwhile, the effect of ib-VAHU on technical efficiency is positively significant, which means that an increase in the added value of skills or knowledge received by bank employees can affect increasing added value for banks, thereby increasing technical efficiency. With the rapid development of digitalization, bank employees are also required

to have abilities and skills that are adaptive to technology so that the production process of bank services and services is more efficient and effective. All digitalization in the banking sector, especially digital mobile systems, technology updates, must be accompanied by an increase in knowledge and skills of employees, are key to being able to provide the best service for customers efficiently and effectively. It is the same with previous research, namely Duho & Onumah (2020), Onumah & Duho (2019), (Adesina, 2019) and Moutinho et al. (2021).

Meanwhile, the ib-STVA variable did not find its influence and relationship with technical efficiency, and this is in line with the research of Moutinho et al., (2021), Adesina (2019), and Duho & Onumah (2020) and Duho (2020). So, hypothesis H_{1c} is rejected. STVA is the added value obtained from the capital structure of 1 rupiah and is an indication of the success of the capital structure in creating value. In theory, the greater the contribution of human capital in creating value, the smaller the contribution of capital structure in this regard. The increase in capital structure in banking does not necessarily increase technical efficiency.

STVA as the coefficient of capital structure efficiency is calculated from the total equity of the bank to create the added value of the bank. It is known that banks in Indonesia have an obligation to maintain core capital in accordance with the provisions made by the authority. Some of the authority's policies for Islamic banks are on Tier 1 Capital, Minimum Capital Adequacy (CAR) regulations (*Kewajiban Penyediaan Modal Minimum* / KPMM), Minimum Saving in Bank Indonesia (*Giro Wajib Minimum* / GWM), Maximum Lending/Financing Limits (*Batas Maksimum Pemberian Pembiayaan* / BMPD) and the obligation to make Provision for Impairment Losses (*Cadangan Kerugian Penurunan Nilai* / CKPN). This rule requires Islamic banks in Indonesia to have firm capital to maintain bank stability and soundness. Banks will also use this core capital to expand their businesses by developing new products, using new technology, and conducting mergers and acquisitions

The control variable used is size, which also has a significant negative relationship with technical efficiency, as in Moutinho's research et al., (2021). So, hypothesis H_{1d} is accepted. Currently, banks no longer plan to add branches and switch to digital banks. Because almost all banking transactions can be done using mobile banking without having to go to the bank. Self-service services for customers are also increasingly provided by banks, such as opening their accounts, which leads to fewer queues at customer service, and the production process is faster and more efficient. For financing transactions, banks can also work with Islamic fintech in marketing loan products with faster and more efficient channels.

Conclusion

This study aims to determine the level of technical efficiency of Islamic banks and how IC affects them. The results showed that the ib-VAIC coefficient and its components together affect the technical efficiency of Islamic banks in Indonesia. Of the components of iB-VAIC, iB-VACA and iB-VAHU have a significant positive influence on the improvement of technical efficiency. Banking can take advantage of improving the ability and knowledge of employees as an integral part of creating innovations in the field of digitalization and technology in producing products and services effectively and efficiently. Variable size has a significant positive effect on technical efficiency because, currently, banks focus a lot on using non-physical resources through digitalization and technology, which is proven to

cause the process of products and services received by consumers to be more effective and efficient. The iB-STVA component shows that although capital structure is the main component of IC, it can only improve technical efficiency with an increase in human resources. In addition, the capital structure of banks is limited by various provisions from regulators that must be maintained. This study is limited to measuring only financing output in productive assets, so it cannot measure the bank's ability to use deposits collected from the public compared to financing to the public. So that further research can focus on the output of financing in accordance with the role of banks as a mediation function. In addition, next research does not only focus on IC numbers but can use Intellectual Capital Disclosure (IDC) so that it can accommodate other information that is not detected in IC.

References

Abdulaali, A. R. (2018). The Impact of Intellectual Capital on Business Organization. *Academy of Accounting and Financial Studies Journal*, *22*(6).

Abdulla, A., & Kumar, S. (2021). Technical efficiency and its determinants in the Indian meat processing industry. *The Indian Journal of Animal Sciences*, *91*(3). https://doi.org/10.56093/ijans.v91i3.114149

Adesina, K. S. (2019). Bank technical, allocative and cost efficiencies in Africa: The influence of intellectual capital. *The North American Journal of Economics and Finance*, *48*, 419–433. https://doi.org/10.1016/j.najef.2019.03.009

Agustia, D., Asyik, N. F., & Midiantari, N. (2021). Intellectual Capital Terhadap Financial Performance Dan Sustainable Growth. *EKUITAS (Jurnal Ekonomi Dan Keuangan)*, *5*(2). https://doi.org/10.24034/j25485024.y2021.v5.i2.4744

Al Parisi, S., Fahmi, I., & Andati, T. (2021). Efficiency VS the Maqasid Shariah Index: A Comparatif Study of Conventional and Islamic Banks in Indonesia. *Jurnal Aplikasi Bisnis Dan Manajemen (JABM)*, *7*(2), 255.

Allameh, S. M. (2018). Antecedents and consequences of intellectual capital. *Journal of Intellectual Capital*, *19*(5), 858–874. https://doi.org/10.1108/JIC-05-2017-0068

Andreeva, T., & Garanina, T. (2017). Intellectual Capital and Its Impact on the Financial Performance of Russian Manufacturing Companies. *Форсайт*, *11*(1), 31–40. https://doi.org/doi: 10.17323/2500-2597.2017.1.31.40

Anwar, M., Nidar, S. R., Komara, R., & Layyinaturrobaniyah, L. (2019). Rural bank efficiency and loans for micro and small businesses: evidence from West Java Indonesia. *International Journal of Emerging Markets*, *15*(3), 587–610. https://doi.org/10.1108/IJOEM-11-2017-0494

Bandyopadhyay, S. (2019). *Production and Operations Analysis*. CRC Press. https://doi.org/10.1201/9781351113670

Banker, R., Natarajan, R., & Zhang, D. (2019). Two-stage estimation of the impact of contextual variables in stochastic frontier production function models using Data Envelopment Analysis: Second stage OLS versus bootstrap approaches.

European Journal of Operational Research, *278*(2), 368–384. https://doi.org/10.1016/j.ejor.2018.10.050

Bataineh, H., Abbadi, S. S., Alabood, E., & Alkurdi, A. (2022). The effect of intellectual capital on firm performance: the mediating role of family management. *Journal of Islamic Accounting and Business Research*, *13*(5), 845–863. https://doi.org/10.1108/JIABR-02-2022-0032

Bontis, N. (1999). Managing organisational knowledge by diagnosing intellectual capital: framing and advancing the state of the field. *International Journal of Technology Management*, *18*(5/6/7/8), 433. https://doi.org/10.1504/IJTM.1999.002780

Chowdhury, M. A. M., & Haron, R. (2021). The efficiency of Islamic Banks in the Southeast Asia (SEA) Region. *Future Business Journal*, *7*(1), 16. https://doi.org/10.1186/s43093-021-00062-z

D'Amato, A. (2021). Does intellectual capital impact firms' capital structure? Exploring the role of firm risk and profitability. *Managerial Finance*, *47*(9), 1337–1356. https://doi.org/10.1108/MF-02-2020-0089

Dang-Thanh, N. (2010). Evaluating the Efficiency of Vietnamese Banking System: An Application Using Data Envelopment Analysis. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1626009

Dastranj, N., Ghazinoory, S., & Gholami, A. A. (2018). Technology roadmap for social banking. *Journal of Science and Technology Policy Management*, *9*(1), 102–122. https://doi.org/10.1108/JSTPM-07-2017-0029

Diallo, B. (2018). Bank efficiency and industry growth during financial crises. *Economic Modelling*, *68*, 11–22. https://doi.org/10.1016/j.econmod.2017.03.011

Dong, Y., Hamilton, R., & Tippett, M. (2014). Cost efficiency of the Chinese banking sector: A comparison of stochastic frontier analysis and data envelopment analysis. *Economic Modelling*, *36*, 298–308. https://doi.org/10.1016/j.econmod.2013.09.042

Duho, K. C. T. (2020). Intellectual capital and technical efficiency of banks in an emerging market: a slack-based measure. *Journal of Economic Studies*, *47*(7), 1711–1732. https://doi.org/10.1108/JES-06-2019-0295

Duho, K. C. T., & Onumah, J. M. (2020). Impact of intellectual capital on bank efficiency in emerging markets: evidence from Ghana. *International Journal of Banking, Accounting and Finance*, *11*(4), 435. https://doi.org/10.1504/IJBAAF.2020.10028856

Festa, G., Rossi, M., Kolte, A., & Marinelli, L. (2021). The contribution of intellectual capital to financial stability in Indian pharmaceutical companies. *Journal of Intellectual Capital*, *22*(2), 337–359. https://doi.org/10.1108/JIC-03-2020-0091

Gareeva, Y., Dranev, Y., & Kucherov, A. (2018). The Impact of Innovation Capital on Firm Values. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3110483

Gogan, L. M., Draghici, A., & Ivascu, L. (2016). *Technological Implications in the Development and Modelling of the Intellectual Capital* (pp. 1047–1058). https://doi.org/10.1007/978-3-319-18416-6_84

Gujarati, D. N., & Porter, D. C. (2009). *Basic Econometrics* (5th ed.). McGraw-Hill/Irwin.

Gusna, N., & Masdupi, E. (2021). *The Effect of Intellectual Capital (IC) on Financial Performance*. https://doi.org/10.2991/aebmr.k.210616.069

Hatane, S. E., Kuanda, E. S., Cornelius, E., & Tarigan, J. (2020). Corporate Governance, Market Share, and Intellectual Capital Disclosure: Evidence from the Indonesian Agriculture and Mining Sectors. *Jurnal Ilmiah Akuntansi Dan Bisnis*, *15*(1), 75. https://doi.org/10.24843/JIAB.2020.v15.i01.p07

Ispriyahadi, H., & Trierdianto, R. (220 C.E.). Analysis of Efficiency and Change of Productivity in The Indonesian Banking Industry Using Data Envelopment Analysis (DEA) and Malmquist Total Factor Productivity. *Jurnal Sekretari Dan Manajemen*, *4*(2).

Jiao, W., Fu, Z., Mu, W., Zhang, X., Lu, J., & Xu, M. (2015). Estimating technical efficiency of Chinese table grape wholesalers. *British Food Journal*, *117*(6), 1670–1688. https://doi.org/10.1108/BFJ-03-2014-0134

Kautsar, M. H., & Sadalia, I. (2018). Analisis Technical Efficiency Bank Umum Syariah Dengan Metode Stochastic Frontier Analysis. *Talenta Conference Series: Local Wisdom, Social, and Arts (LWSA)*, *1*(2), 367–376. https://doi.org/10.32734/lwsa.v1i2.209

Kevser, M., & Dogan, M. (2020). Analysis of the relationship between intellectual capital and firm performance: an empirical research on Borsa Istanbul. *Pressacademia*, *12*(1), 21–26. https://doi.org/10.17261/Pressacademia.2020.1341

Khalique, M., Bontis, N., Shaari, J. A. N. Bin, Yaacob, M. R., & Ngah, R. (2018). Intellectual capital and organisational performance in Malaysian knowledge-intensive SMEs. *International Journal of Learning and Intellectual Capital*, *15*(1), 20. https://doi.org/10.1504/IJLIC.2018.088345

Khan, I., Khan, M., & Tahir, M. (2017). Performance comparison of Islamic and conventional banks: empirical evidence from Pakistan. *International Journal of Islamic and Middle Eastern Finance and Management*, *10*(3), 419–433. https://doi.org/10.1108/IMEFM-05-2016-0077

Korytko, T., & Bryl, I. (2021). Intellectual capital of the enterprise and its evaluation in the conditions of digitalization. *Economy of Industry*, *1*(93), 92–110. https://doi.org/10.15407/econindustry2021.01.092

Kovjanić, M., & Vukadinović, P. (2021). Intellectual capital as a strategic performance with a focus on banks. *Bankarstvo*, *50*(1), 90–107. https://doi.org/10.5937/bankarstvo2101090K

Lotfi, A., Salehi, M., & Lari Dashtbayaz, M. (2022). The effect of intellectual capital on fraud in financial statements. *The TQM Journal*, *34*(4), 651–674. https://doi.org/10.1108/TQM-11-2020-0257

Maji, S. G., & Hussain, F. (2021). Technical efficiency, intellectual capital efficiency and bank performance in emerging markets: the case of India. *Journal of Advances in Management Research*, *18*(5), 708–737. https://doi.org/10.1108/JAMR-09-2020-0218

Mala, C. M. F., Rodoni, A., & Yaman, B. (2020). Turnitin market power and efficiency of islamic banking and conventional banking in indonesia. . Https://Digilib.Esaunggul.Ac.Id/. https://digilib.esaunggul.ac.id/public/UEU-Grey-14014-17_0103.pdf

Marsondang, A., Purwanto, B., & Mulyati, H. (2020). Pengukuran Efisiensi Serta Analisis Faktor Internal dan Eksternal Bank yang Memengaruhinya. *Jurnal Manajemen Dan Organisasi*, *10*(1), 48–62. https://doi.org/10.29244/jmo.v10i1.28860

Meles, A., Porzio, C., Sampagnaro, G., & Verdoliva, V. (2016). The impact of the intellectual capital efficiency on commercial banks performance: Evidence from the US. *Journal of Multinational Financial Management*, *36*, 64–74. https://doi.org/10.1016/j.mulfin.2016.04.003

Mensah Onumah, J., & Tornam Duho, K. C. (2019). Intellectual Capital: Its Impact on Financial Performance and Financial Stability of Ghanaian Banks. *Athens Journal of Business & Economics*, *5*(3), 243–268. https://doi.org/10.30958/ajbe.5-3-4

Moutinho, V., Madaleno, M., & Macedo, P. (2020). The effect of urban air pollutants in Germany: eco-efficiency analysis through fractional regression models applied after DEA and SFA efficiency predictions. *Sustainable Cities and Society*, *59*, 102204. https://doi.org/10.1016/j.scs.2020.102204

Moutinho, V., Vale, J., Bertuzi, R., Bandeira, A. M., & Palhares, J. (2021). A Two-Stage DEA Model to Evaluate the Performance of Iberian Banks. *Economies*, *9*(3), 115. https://doi.org/10.3390/economies9030115

Myasoedov, A. (2021). An Efficiency Model for Assessing Intellectual Capital. *Scientific Research and Development. Socio-Humanitarian Research and Technology*, *10*(1), 84–91. https://doi.org/10.12737/2306-1731-2021-10-1-84-91

Nailah, N., & Rusydiana, A. S. (2020). Efficiency And Stability Of Islamic Banking In Asean: DEA Window Analysis. *Tazkia Islamic Finance and Business Review*, *14*(1). https://doi.org/10.30993/tifbr.v14i1.211

Nawaz, T. (2019). Intellectual capital profiles and financial performance of Islamic banks in the UK. *International Journal of Learning and Intellectual Capital*, *16*(1), 87. https://doi.org/10.1504/IJLIC.2019.096934

Nawaz, T., & Haniffa, R. (2017). Determinants of financial performance of Islamic banks: an intellectual capital perspective. *Journal of Islamic Accounting and Business Research*, *8*(2), 130–142. https://doi.org/10.1108/JIABR-06-2016-0071

Nejjari, Z., & Aamoum, H. (2020). Intellectual Capital As A Generator Of Innovation In Companies: A Systematic Review. *Humanities & Social Sciences Reviews*, *8*(1), 464–479. https://doi.org/10.18510/hssr.2020.8158

Ni, Y., Cheng, Y.-R., & Huang, P. (2021). Do intellectual capitals matter to firm value enhancement? Evidences from Taiwan. *Journal of Intellectual Capital*, *22*(4), 725–743. https://doi.org/10.1108/JIC-10-2019-0235

Nkambule, N. A., Wang, W.-K., Ting, I. W. K., & Lu, W.-M. (2022a). Intellectual capital and firm efficiency of US multinational software firms. *Journal of Intellectual Capital*, *23*(6), 1404–1434. https://doi.org/10.1108/JIC-02-2021-0041

Nkambule, N. A., Wang, W.-K., Ting, I. W. K., & Lu, W.-M. (2022b). Intellectual capital and firm efficiency of US multinational software firms. *Journal of Intellectual Capital*, *23*(6), 1404–1434. https://doi.org/10.1108/JIC-02-2021-0041

Nurcahyani, A., Syarifudin, E., & Nani. (2022). Efficiency of Islamic Banks in Indonesia: Service Coverage, Business Size, Financing and Profitability During a Pandemic. *Journal of Finance and Islamic Banking*, *5*(2).

Nuryaman. (2015). The Influence of Intellectual Capital on The Firm's Value with The Financial Performance as Intervening Variable. *Procedia - Social and Behavioral Sciences*, *211*, 292–298. https://doi.org/10.1016/j.sbspro.2015.11.037

Octrina, F., & Priatmojo, H. E. (2023). Islamic bank efficiency: an efficiency method with SFA. *Jurnal Perspektif Pembiayaan Dan Pembangunan Daerah*, *10*(6), 379–394. https://doi.org/10.22437/ppd.v10i6.18250

OECD. (1999). *Measuring And Reporting Intellectual Capital From A Diverse Canadian Industry Perspective: Experiences, Issues and Prospects*.

Orlando, B., Mazzucchelli, A., Usai, A., Nicotra, M., & Paoletti, F. (2021). Are digital technologies killing future innovation? The curvilinear relationship between digital technologies and firm's intellectual property. *Journal of Intellectual Capital*, *22*(3), 587–609. https://doi.org/10.1108/JIC-03-2020-0078

Ousama, A. A., Hammami, H., & Abdulkarim, M. (2019). The association between intellectual capital and financial performance in the Islamic banking industry. *International Journal of Islamic and Middle Eastern Finance and Management*, *13*(1), 75–93. https://doi.org/10.1108/IMEFM-05-2016-0073

Özer, G., Ergün, E., & Yilmaz, O. (2015). Effects of Intellectual Capital on Qualitative and Quantitative Performance: Evidence from Turkey. *South African Journal of Economic and Management Sciences*, *18*(1), 143–154.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401(k) plan participation rates. *Journal of Applied Econometrics*, *11*(6), 619–632. https://doi.org/10.1002/(SICI)1099-1255(199611)11:6<619::AID-JAE418>3.0.CO;2-1

Popelo, O., Dubyna, M., & Kholiavko, N. (2021). World Experience In The Introduction Of Modern Innovation And Information Technologies In The Functioning Of Financial Institutions. *Baltic Journal of Economic Studies*, *7*(2), 188–199. https://doi.org/10.30525/2256-0742/2021-7-2-188-199

Prawitasari, D., Pratiwi, R. D., & Tristiarini, N. (2018). The Effect of Intellectual Capital Measurement on Profitability and Market Price. *Proceedings of the 1st*

Economics and Business International Conference 2017 (EBIC 2017). https://doi.org/10.2991/ebic-17.2018.30

Prima Sakti, M. R., & Mohamad, A. (2018). Efficiency, stability and asset quality of Islamic *vis-à-vis* conventional banks. *Journal of Islamic Accounting and Business Research*, *9*(3), 378–400. https://doi.org/10.1108/JIABR-07-2015-0031

Psillaki, M., & Mamatzakis, E. (2017). What drives bank performance in transitions economies? The impact of reforms and regulations. *Research in International Business and Finance*, *39*, 578–594. https://doi.org/10.1016/j.ribaf.2016.09.010

Punda, O. O., Arziantseva, D. A., & Zakharkevych, N. P. (2021). Theoretical essence and component structure of the intellectual capital of the enterprise. *Science, Technologies, Innovation*, *№3(19)*, 10–19. https://doi.org/10.35668/2520-6524-2021-3-02

Quach, H. H., Le, A. H., Nguyen, H. T. H., Vu, N. H., & Hoang, H. T. (2020). Intellectual Capital and Firm Performance in Vietnam 2012-2016. *International Journal of Learning and Intellectual Capital*, *17*(1), 1. https://doi.org/10.1504/IJLIC.2020.10023757

Raheli, H., Rezaei, R. M., Jadidi, M. R., & Mobtaker, H. G. (2017). A two-stage DEA model to evaluate sustainability and energy efficiency of tomato production. *Information Processing in Agriculture*, *4*(4), 342–350. https://doi.org/10.1016/j.inpa.2017.02.004

Rahmat, SIP. , M. H. (2020). Intellectual Capital, Bank Size, Bank Market Share, and Efficiency of Conventional Banks in Indonesia. *Revista CEA*, *6*(11), 71–88. https://doi.org/10.22430/24223182.1457

Rahmawati, R. (2015a). Strategi Peningkatan Efisiensi Biaya pada Bank Umum Syariah Berbasis Stochastic Frontier Approach dan Data Envelopment Analysis. *Buletin Ekonomi Moneter Dan Perbankan*, *17*(4), 457–480. https://doi.org/10.21098/bemp.v17i4.506

Rahmawati, R. (2015b). Strategi Peningkatan Efisiensi Biaya pada Bank Umum Syariah Berbasis Stochastic Frontier Approach dan Data Envelopment Analysis. *Buletin Ekonomi Moneter Dan Perbankan*, *17*(4), 457–480. https://doi.org/10.21098/bemp.v17i4.506

Ramalho, E. A., Ramalho, J. J. S., & Henriques, P. D. (2010). Fractional regression models for second stage DEA efficiency analyses. *Journal of Productivity Analysis*, *34*(3), 239–255. https://doi.org/10.1007/s11123-010-0184-0

Rashwan, M. H., & Ehab, H. (2016). Comparative Efficiency Study between Islamic and Traditional Banks. *Journal of Finance and Economics*.

Refinitiv, & IFDI. (2023). *ICD – Refinitiv Islamic Finance Development Report 2022*.

Rodoni, A., Medina, A. R., Yaman, B., & Sopyan, S. (2020). Efficiency And Stability Of Islamic Banking In ASEAN. *Al-Iqtishad: Jurnal Ilmu Ekonomi Syariah*.

Safiullah, M. (2021). Financial stability efficiency of Islamic and conventional banks. *Pacific-Basin Finance Journal*, *68*, 101587. https://doi.org/10.1016/j.pacfin.2021.101587

Salami, O. L., & Adeyemi, A. A. (2017). Malaysian Islamic Banks' Efficiency: An Intra-Bank Comparative Analysis Of Islamic Windows And Full-Fledged Subsidiaries. *International Journal of Business and Society*, *16*(1). https://doi.org/10.33736/ijbs.551.2015

Salehi, M., & Zimon, G. (2021). The Effect of Intellectual Capital and Board Characteristics on Value Creation and Growth. *Sustainability*, *13*(13), 7436. https://doi.org/10.3390/su13137436

Serly, V., & Handayani, D. F. (2020). Efficiency, Asset Quality and Stability: Comparative Study of Conventional Banks and Islamic Banks in Southeast Asia. *Proceedings of the 4th Padang International Conference on Education, Economics, Business and Accounting (PICEEBA-2 2019)*. https://doi.org/10.2991/aebmr.k.200305.045

Soewarno, N., & Tjahjadi, B. (2020). Measures that matter: an empirical investigation of intellectual capital and financial performance of banking firms in Indonesia. *Journal of Intellectual Capital*, *21*(6), 1085–1106. https://doi.org/10.1108/JIC-09-2019-0225

Solihin, S., Achsani, N. A., & Saptono, I. T. (2016). The Islamic Banking And The Economic Integration In ASEAN. *Buletin Ekonomi Moneter Dan Perbankan*, *19*(1), 81–106. https://doi.org/10.21098/bemp.v19i1.601

Stewart, T., & Ruckdeschel, C. (1998). Intellectual capital: The new wealth of organizations. *Performance Improvement*, *37*(7), 56–59. https://doi.org/10.1002/pfi.4140370713

Subaida, I., Nurkholis, N., & Mardiati, E. (2018). Effect Of Intellectual Capital And Intellectual Capital Disclosure On Firm Value. *Jurnal Aplikasi Manajemen*, *16*(1), 125–135. https://doi.org/10.21776/ub.jam.2018.016.01.15

Tiwari, R. (2022). Nexus between intellectual capital and profitability with interaction effects: panel data evidence from the Indian healthcare industry. *Journal of Intellectual Capital*, *23*(3), 588–616. https://doi.org/10.1108/JIC-05-2020-0137

Tran, N. P., & Vo, D. H. (2022). Do banks accumulate a higher level of intellectual capital? Evidence from an emerging market. *Journal of Intellectual Capital*, *23*(2), 439–457. https://doi.org/10.1108/JIC-03-2020-0097

Tripathy, T., Gil-Alana, L. A., & Sahoo, D. (2015). The effect of intellectual capital on firms' financial performance: an empirical investigation in India. *International Journal of Learning and Intellectual Capital (Inderscience Publishers (IEL))*, *12*(4), 342–371.

Ulum, I. (2013). Model Pengukuran Kinerja Intellectual Capital Dengan iB-VAIC Di Perbankan Syariah. *INFERENSI*, *7*(1), 185. https://doi.org/10.18326/infsl3.v7i1.185-206

Ulum, I. (2020). *Intellectual Capital - Model Pengukuran, Framework Pengungkapan dan Kinerja Organisasi* (4th ed.). Universitas Muhammadiyah Malang.

Ulum, I., Jati, A. W., Audina, M. I., & Prasetyo, A. (2020). The Influence of Firm's Characteristics on the Level of Intellectual Capital Disclosure of Indonesian Islamic Banking. *Proceedings of the 1st Annual Management, Business and*

Economic Conference (AMBEC 2019). https://doi.org/10.2991/aebmr.k.200415.002

Vidyarthi, H., & Tiwari, R. (2019). Cost, revenue, and profit efficiency characteristics, and intellectual capital in Indian Banks. *Journal of Intellectual Capital*, *21*(1), 1–22. https://doi.org/10.1108/JIC-05-2019-0107

Vo, D. H., & Tran, N. P. (2021). Intellectual capital and bank performance in Vietnam. *Managerial Finance*, *47*(8), 1094–1106. https://doi.org/10.1108/MF-03-2020-0143

Waseem, B., Loo-See, B., Adeel, A., & Riaz, A. (2018). Impact of intellectual capital on innovation capability and organizational performance: An empirical investigation. *Serbian Journal of Management*, *13*(2), 365–379. https://doi.org/10.5937/sjm13-16997

Yousef Obeidat, B., Bahjat Abdallah, A., Osama Aqqad, N., Akhoershiedah, A. H. O. M., & Maqableh, M. (2017). The Effect of Intellectual Capital on Organizational Performance: The Mediating Role of Knowledge Sharing. *Communications and Network*, *09*(01), 1–27. https://doi.org/10.4236/cn.2017.91001

Yusuf, A. A., Santi, N., & Rismaya, E. (2021). The Efficiency of Islamic Banks: Empirical Evidence from Indonesia. *The Journal of Asian Finance, Economics and Business*, *8*(4), 239–247.

Zhao, Y., Chupradit, S., Hassan, M., Soudagar, S., Shoukry, A. M., & Khader, J. (2021). The role of technical efficiency, market competition and risk in the banking performance in G20 countries. *Business Process Management Journal*, *27*(7), 2144–2160. https://doi.org/10.1108/BPMJ-12-2020-0570