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REVIEW PAPER

Technical efficiency in banks: a review of methods, recent innovations and future research agenda

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Abstract

Technical efficiency in banking is a critical aspect of the financial industry and has been widely studied using various measurement techniques. This systematic literature review offers a comprehensive examination of 305 studies on the application of technical efficiency measurement techniques in both Islamic and conventional banking sectors from 1989 to 2019. Our comprehensive analysis not only provides a broad view of the efficiency measurement literature but also outlines a future research agenda. Despite the extensive research in this field, several issues remain unresolved, including input–output selection, a comparison of efficiency between Islamic and conventional banks, limited cross-country studies, and a lack of exploration into the impact of regulation and Shariah principles. To address these gaps, this review highlights the most commonly used methods, variables, and findings and provides three key recommendations for future research. Three key themes emerge from our examination. *First*, there is a need to better understand and the application of new frontier techniques other than the traditional methods, which currently dominate the existing literature. *Second*, the intermediation approach is the most frequently used in variable selection, thus more studies with comparative findings with applications of production and value-added approaches are suggested. *Third*, the most frequently used input variables are 'labor', 'deposits' and 'capital', whilst 'loans' and 'other earning assets' are the most popular output variables. We recommend three vital directions for future research: (i) non-interest expenses to be included amongst the inputs, while non-interest income should be added to the list of outputs, especially when estimating efficiency scores of Islamic banks. (ii) The impact of environmental variables such as, *inter alia*, *Shariah* principles, country-specific factors, and management quality is suggested to be considered simultaneously in models measuring and comparing the efficiency of Islamic and conventional banks. (iii) The selection of performance metrics employed should be expanded to include both the standard efficiency scores and the Malmquist Total Factor Productivity Index (TFP). The paper concludes with research needs and suggests directions for future research.

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JEL Classification G21 · D20

1 Introduction

The study of bank efficiency is central to the growth and long-term sustainability of the banking sector (Chen et al. 2021; Ghosh et al. 1994; Ramly et al. 2017), and there has been an abundance of research on the topic (Abreu et al. 2019; Aliyu et al. 2017; Bhatia et al. 2018; Jiang et al. 2020; Lopes et al. 2021; Rahman et al. 2021; Shaikh and Memon 2021). Given the large volume of literature on this subject and the ongoing expansion of research, it is imperative to evaluate the recent advances and current state of knowledge in this field (Zhu et al. 2021). The objective of this study is to bridge a research gap by conducting a critical review of recent technical efficiency methods applied to both Islamic banks (IBs) and conventional banks (CBs). This review seeks to elucidate patterns and trends in the field, as well as identify the key factors that influence efficiency. Furthermore, this study aims to provide a roadmap for future research in this area.

Islamic finance has grown tremendously over the last decade, with Islamic banking being the largest segment of the industry, accounting for 71% of the global Islamic finance assets and 6% of global banking assets (Mordor Intelligence 2021). In 2017, there were 505 Islamic banks, including 207 Islamic banking windows, and the Islamic banking assets comprised 28.8% of the total assets in Asia, 42.3% in Gulf Cooperation Council (GCC), 25.1% in the Middle East and North Africa (MENA), 0.8% in Africa, and 3.5% in other countries. Iran (32.1%) and Saudi Arabia (20.2%) held the highest shares of the global Islamic banking assets, followed by Malaysia (10.8%), United Arab Emirates (UAE) (9.8%), Kuwait (6.3%), and Qatar (6.2%) (Islamic Financial Services Industry Stability Report 2019). The COVID-19 pandemic impacted the growth of the Islamic finance markets, with Sukuk being the most affected sector (Mordor Intelligence 2021).

The rapid growth of Islamic banking has been attributed to the continuing interest of policymakers and regulators around the world (Yilmaz and Gunes 2015). However, a direct comparison between IBs and CBs should be approached with caution, as the two groups may differ significantly in their goals and operational circumstances (Khan 1986; Khan and Mirakhor 1987; Dar 2003). The technical efficiency of banks has been analyzed in the literature using various parametric and non-parametric frontier techniques, as well as accounting ratio analysis (Jarboui 2016; Mahajan et al. 2020; Sellers-Rubio and Más-Ruiz 2015; Wang et al. 2015, 2021; Wijesiri et al. 2019). Although each approach has its own advantages and disadvantages, frontier approaches are generally considered to be superior to standard financial ratio analysis as they are equipped with statistical

tools (Iqbal and Molyneux 2005). However, there is no consensus in the literature on the best technique or on the selection of input–output variables, and no agreement on the sources of differences in efficiency scores.

To address the current research gaps and provide guidance to researchers, we conducted a systematic literature review of 18,461 articles on bank efficiency measurement. The review aims to identify the most commonly used variables, countries of focus, empirical methods, and research gaps in the technical efficiency of IBs and CBs, with a focus on the impact of scale efficiency, environmental variables, innovative methods, and selected variables. Our systematic literature review is based on the screening of articles from seven prestigious journals listed in various databases. This review is unique in that it synthesizes studies that applied both parametric and non-parametric frontier techniques, as well as accounting ratios, to measure bank efficiency.

Despite that there are literature review papers published on bank efficiency measurement (e.g., Abreu et al. 2019; Aliyu et al. 2017; Bhatia et al. 2018; Hassan and Aliyu 2018; Lampe and Hilgers 2015; Liu et al. 2016; Sharma et al. 2013), they are either mainly focusing on (i) efficiency and/or productivity measurement with an application of DEA and/or SFA disregarding the other methods applied or (ii) reviewing applications on Islamic or conventional banks independently. This paper is unique in this respect in that it introduces a synthesis of studies that applied parametric and non-parametric frontier techniques as well as accounting ratios to measure technical efficiency scores of Islamic and conventional banks.

Considering the application of the systematic literature review technique, this paper provides an in-depth review as a product of screening 18,461 research articles from prestigious journals listed on seven databases. Moreover, we aim to identify the most popular input–output variables in the existing bank technical efficiency literature, help address the research gaps by offering critical reflections and propose suggestions for future research. We, thus, classify bank efficiency measurement studies into six categories as follows: (i) regulation in IBs as Shariah principals; (ii) stability; (iii) scale efficiency; (iv) input/output variable selection; (v) methods to incorporate environmental variables into the analysis, and (vi) technical efficiency measurement of Islamic and/or conventional banks.

Our paper makes several noteworthy contributions to the existing literature on technical efficiency measurement in the Islamic and conventional banking sectors. First, we provide a comprehensive and up-to-date review of the recent literature, spanning an extensive 30-year period from 1989 to 2019. Through this rigorous review, we systematically identify and synthesize key findings, revealing gaps in the literature that warrant further investigation. Second, we elucidate significant divergences in the efficiency measurement techniques utilized in the literature, underscoring the need for standardized evaluation methods. By emphasizing these areas of divergence, we advance the understanding of technical efficiency evaluation and provide a foundation for future research directions and collaborations across diverse banking systems and countries. Third, we shed light on the crucial role played by specific environmental factors, including Shariah principles, stability, and economies of scale, in shaping efficiency outcomes. By incorporating both standard efficiency scores and the Malmquist Total Factor Productivity Index (TFP), our study

offers valuable insights for policymakers and researchers seeking to comprehensively evaluate and compare the performance metrics of Islamic banks with their conventional counterparts. In an attempt of evaluating the efficiency scores of IBs and CBs in numerous countries, researchers investigated the main drivers of efficiency disparities among these groups of banks. Therefore, we structured this study in a way that identifies the factors that need more investigation for future research. Although recent research has extended the investigation of bank technical efficiency to include the impact of the Covid-19 pandemic, we have deferred this topic for a future literature review paper. Our decision is informed by the period of study in this paper, which focuses on the years spanning 1989 to 2019, immediately preceding the onset of the pandemic.[1]

We argue that technical efficiency is a vital area to study as banks that are technically efficient are able to produce more outputs for a given level of inputs, such as labor, capital, and technology. This can help them reduce costs, increase profits, and remain competitive in the market. Some reasons to review technical efficiency studies in banks are as follows. First, the banking industry is highly regulated, and banks are often required to meet certain standards of efficiency in order to maintain their licenses and operate in the market. Second, banks operate in a highly competitive environment, and efficiency can be a key factor in determining which banks survive and thrive in the market. Third, the financial crisis of 2008 highlighted the importance of efficiency in banking, as many banks were found to be operating inefficiently and taking on excessive risks.

The rest of this paper is organized as follows: Sect. 2 introduces the research framework of the study, followed by the research method in Sect. 3, in which the selection criteria of the listed studies are explained. Section 4 reviews the existing literature on efficiency measurement methods identifying the main factors of the analysis and commonly used variable selection approaches. Section 5 highlights the main research gaps and areas for future research and Sect. 6 concludes.

2 Research framework

The COVID-19 pandemic has precipitated profound changes across the global economy, significantly impacting the banking sector. A substantial transition towards digital banking, alterations in customer borrowing and lending behavior, and the advent of new regulatory policies mark the sector's evolving landscape. This has consequently triggered an increasing interest in assessing the technical efficiency of banks during the pandemic period. Notably, research by Al Mamun et al. (2021) and Bele et al. (2021) has explored this in Bangladesh and Nigeria, respectively, revealing a significant

[1] The covid-19 pandemic represents a significant and unprecedented disruption to the global economy, and it is likely that the pandemic has had a significant impact on banking efficiency that has yet to be fully understood or quantified. Given the scope and magnitude of the pandemic's impact, it may be more appropriate to undertake a separate study that specifically focuses on the impact of the pandemic on banking efficiency. Additionally, by limiting the scope of the current study to the pre-pandemic period, it allows for a more focused and in-depth analysis of the technical efficiency patterns.

negative impact on banks' technical efficiency. Complementing this perspective, recent studies have furthered the understanding of this situation. For example, Boubaker et al. (2022) scrutinized the efficiency of 49 Islamic banks across ten countries during the pandemic, showing how input reduction could maintain efficiency amidst decreasing outputs. In addition, Shah et al. (2021) provided a comprehensive review of Islamic bank efficiencies, signifying the influence of variable choices and regional factors on efficiency, particularly during crises. Boubaker et al. (2023) elaborated on how Islamic banking, with its trade-off between reducing credit risk and increasing business risk due to higher operational costs, has contributed to banking sector fluctuations. Finally, Mateev et al. (2022) underscored the importance of efficiency and market competition in the performance of banks during the pandemic, emphasizing regulatory reforms that bolster efficiency to counter adverse impacts. While the present paper concentrates on the 1989–2019 period, we acknowledge the potential impact of the pandemic on bank technical efficiency. However, given the ongoing pandemic and limited data availability, it is premature to present conclusive results. The examination of the pandemic's impact on bank technical efficiency will, thus, be a focus of our future research.

This paper examines the literature on technical efficiency in Islamic and conventional banks from 1989 to 2019, using Tranfield et al.'s (2003) guidelines for conducting a systematic literature review. The analysis involves five steps: (1) Defining the topic and relevant keywords by exploring significant contributions to the subject and identifying selection criteria. (2) Conducting searches on seven scientific databases (JSTOR, Elsevier's Science Direct, Springer, Oxford Publishing, SCOPUS, Emerald Insight, and Wiley) for the terms 'bank efficiency', 'Islamic banks', and 'conventional banks' in combination with 'parametric' or 'non-parametric', with the search term 'bank efficiency' complementing terms like 'bank performance' and 'bank profitability' to obtain more relevant search results that cover studies using accounting ratios for bank efficiency measurement. (3) Screening and eliminating duplicates from the remaining articles and verifying their conformity to the predefined selection criteria; we developed a coding system, following Gough (2007), at this stage to ensure consistency among the two authors reviewing the data. (4) Examining the abstracts of all remaining articles for consistency with the selection criteria. (5) Following the review process of all remaining full papers in the dataset by the authors of this paper, we received third feedback from an academic scholar who has been in the research field of technical efficiency measurement over 25 years. (6) Creating summary tables accordingly. Table 1 summarizes the inclusion criteria, while excluding corporate governance, risk-adjusted efficiency, venture capital, management accounting, productivity measurement, hedging, joint ventures, managerial efficiency, and theoretical papers.

3 Research method

3.1 Databases and search results

A total of 18,461 articles in English were listed in the seven scientific databases specified, namely JSTOR, Elsevier's Science Direct, Springer, Oxford Publishing,

Table 1 Criteria for inclusion. *Source* Authors' own table

Characteristics	Inclusion criteria
Language	English
Timeframe	1989–2019
Databases	JSTOR (3605 papers), Elsevier's Science Direct (4136 papers), Springer (7944 papers), Oxford Publishing (189 papers), SCOPUS (39 papers), Emerald Insight (1947 papers) and Wiley (601 papers). Total of 18,461 papers are identified
Scope	Business, economics, finance, accounting
Content	Empirical research articles on technical efficiency in banking excluding corporate governance, risk-adjusted efficiency, venture capital, management accounting, productivity measurement, hedging, joint ventures, managerial efficiency and theoretical papers

SCOPUS, Emerald Insight, and Wiley. The use of multiple databases aims to avoid publication bias and ensure a comprehensive literature review. JSTOR is considered one of the most relevant databases for social sciences, according to George State University Library. Meanwhile, Scopus is the largest abstract and citation database of multidisciplinary peer-reviewed literature search, introduced by Elsevier Science in 2004, and is considered the best database as an alternative to Web of Science (WOS) in social sciences in terms of coverage, according to Norris and Oppenheim (2007). Moreover, Vieira and Gomes (2009) found that Scopus covers 20% more research than WOS. Consequently, this paper focused mainly on Scopus and Elsevier's Science Direct, rather than WOS. Additionally, Springer and JSTOR were observed to index a significant number of publications on bank efficiency measurement. Table 1 summarizes the number of papers identified in each database.

After a rigorous screening of titles and keywords, 435 articles were identified for the abstract screening stage. The majority of the excluded articles (18,026) were due to duplication (189), irrelevance to banking applications (6572), being theoretical studies (186), and not fitting the inclusion criteria (11,079). Following the abstract screening process, 113 articles were further excluded, leaving 322 articles, of which 10 were literature reviews and 312 were related to banking efficiency applications. Subsequently, 7 articles were excluded due to the use of different methods, resulting in a final sample of 305 articles for this study. To ensure the consistency of the data reviewing process, a coding system was created following Gough's (2007) recommendation. The weight of evidence concept was applied to make separate judgments on various review-specific criteria and combine them to form an overall judgment of the contributions of each study to answering the review question. Thus, a weight of evidence framework was established for bank technical efficiency measurement (Weight of Evidence A), a review-specific judgment of bank types (i.e., Islamic versus conventional banks) (Weight of Evidence B), and a review-specific judgment of application methods

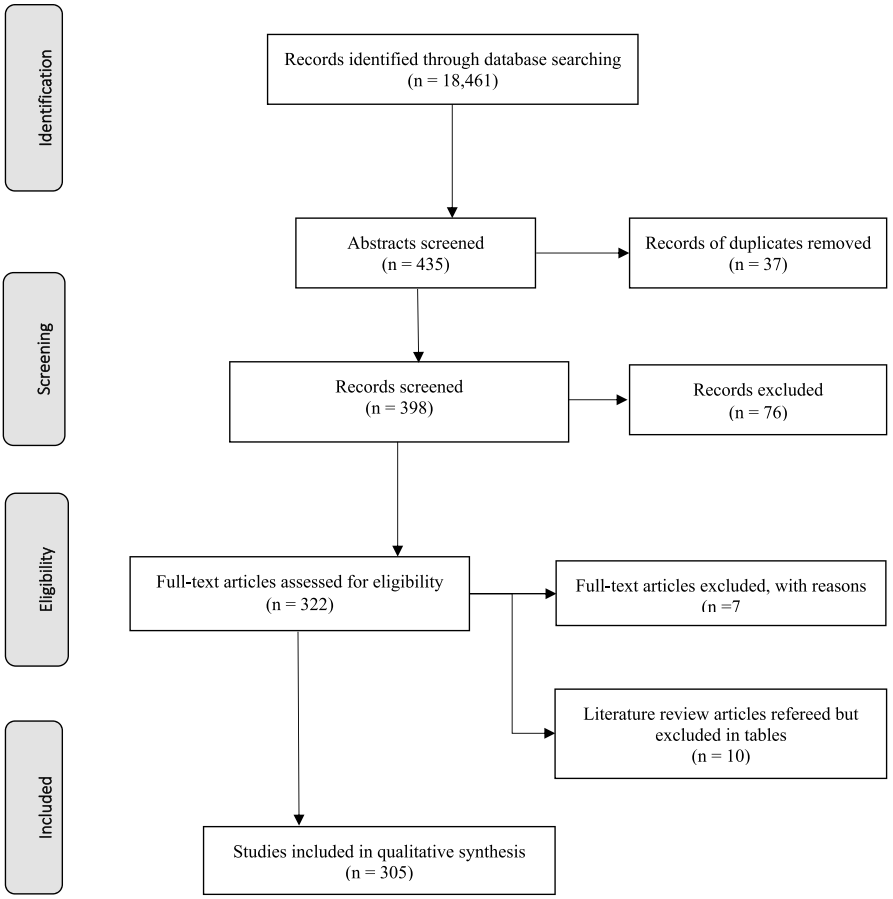

Fig. 1 PRISMA flow chart. *Notation*: Authors' own figure, adapted from Moher et al. (2009, 2010)

(Weight of Evidence C), as well as an overall judgment (Weight of Evidence D). To avoid overlooking significant contributions, we also screened the references cited at least five times in the selected 305 articles for their relevance to the criteria outlined in Table 1.

The PRISMA flow chart depicted in Fig. 1 demonstrates the selection process, which resulted in the inclusion of 305 articles that met all the pre-defined criteria. The subsequent analysis involved the collection of article characteristics such as the country of origin and research methodology. The empirical findings of the selected articles were then analyzed and categorized based on recurring themes. Additionally, the articles were analyzed in terms of the selection of input–output variables.

Table 2 Frequency statistics of reviewed studies. *Source*: Authors' own table

Methods	No. of papers (%)
Financial ratios	33 (11%)
Frontier methods	264 (89%)
Parametric	83 (28%)
SFA	65 (22%)
TFA	3 (1%)
DFA	15 (5%)
Non-parametric	181 (61%)
DEA	178 (60%)
FDH	3 (1%)
Two-stage	69 (23%)
Tobit	18 (26%)
GLS	12 (17%)
Bootstrap	9 (13%)
OLS	10 (15%)
Logit	3 (4%)
TOPSIS	3 (4%)
Fixed effect	6 (9%)
Other	8 (12%)
Field distribution	
Islamic banking papers	105 (35%)
Conventional banking papers	158 (51%)
Islamic versus conventional banking papers	42 (14%)
Total number of papers	305

This table presents efficiency methods and variable selection frequency statistics in %. Percentages under each of the inputs and outputs do not add to a 100% due to the overlap across different studies. Others category in the two-stage applications include generalized method of moments (GMM), seemingly unrelated regressions, random effects model (REM), fixed effect model (FEM), slack-based measure. Two-stage analysis is applied as a second stage econometric analysis in selective studies

3.2 Summary statistics of reviewed articles

The statistical data presented in Table 2 indicates that among the selected 305 articles, 89% of the studies preferred frontier methods for their technical efficiency estimations, with 28% utilizing parametric and 61% non-parametric methods. Specifically, the non-parametric DEA method was the most frequently used (60%), followed by SFA (22%) among the parametric methods. Moreover, two-stage techniques such as Tobit (26%) and GLS (17%) were the most commonly used methods to analyze the impact of environmental variables on efficiency scores. Interestingly, the least frequently used methods were the Thick Frontier Approach (TFA) (1%),

Free Disposable Hull (FDH) analysis (1%), and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (4%).

In terms of bank type, the analysis shows that 51% of the studies focused solely on conventional banks (CBs), while 35% of the studies analyzed the technical efficiency scores of Islamic banks (IBs) only. Furthermore, 14% of the studies compared the technical efficiency scores of IBs versus CBs. It is worth noting that the paper excluded ten literature review articles, as they did not meet the inclusion criteria of being banking application papers.

This literature review analyzed a total of 305 articles, which were published in 128 scientific journals. The majority of the articles were published in journals with a focus on business, economics, and finance. Notably, the Journal of Banking and Finance had the highest number of published articles (27), followed by the European Journal of Research (13), Managerial Finance (11), Expert Systems with Applications (8), the International Journal of Islamic and Middle Eastern Finance and Management (8), the Journal of Productivity Analysis (7), and Research in International Business and Finance (7).

4 Review of studies

4.1 Regulation as Sariah principals

Islamic banks (IBs) are subject to strict regulatory guidelines rooted in Shariah principles (Elamer 2017; Elamer et al. 2019). The unique characteristics of Islamic finance instruments can pose significant challenges for IBs in terms of efficiency and profitability. For instance, some of the specific forms of Islamic banking/finance, such as mudarabah (profit-sharing), murabaha (cost-plus), musharakah (joint-venture), bai-muajjal (deferred payment sale), ijarah (leasing), and istisna (processing and manufacturing contracts) may increase traditional agency conflicts, such as adverse selection and moral hazard problems, and worsen non-traditional agency problems by providing more opportunities for managerial expropriation of bank assets (Elamer 2017; Elamer et al. 2019).

However, some researchers have argued that these strict guidelines are also among the key factors that have enabled IBs to withstand the 2007/08 financial crisis better than most conventional banks (CBs) (Willison 2009; Yilmaz 2009; Hasan and Dridi 2010). These studies have also demonstrated that IBs have exhibited relatively high levels of efficiency and profitability during periods of financial uncertainty. Therefore, identifying the factors that account for the relatively higher performance metrics observed for IBs represents an important research agenda.

The extant literature indicates that the differences in the banking practices between Islamic and conventional banks account for the divergent efficiency and stability levels observed between the two types of banks. Islamic banking operates under the guidance of Shariah principles that prohibit the charging of interest (Hassan and Bashir 2003a, b, c). Instead, IBs generate earnings through transactional and intermediation contracts (El-Hawary et al. 2004). The main source of difference between Islamic and conventional banks is their approach to the use of money

(Al-Omar and Abdel-Haq 1996). In this regard, IBs are prohibited from charging interest and, therefore, offer alternative financial products and services that conform to the principles of Shariah law, which allows for profit and loss sharing (PLS) through instruments like Musharaka and Mudarabah.

Chong and Liu (2009) defined the PLS model as a system in which profits and losses are shared among banks, depositors, and borrowers. Murabaha, which is commonly used for financing real estate, consumer durables, and the acquisition of raw materials, equipment, or machinery, is the most popular method of Islamic financing (Ahmad and Haron 2002). Empirical research by Beck et al. (2013), Metwally (1997), and Olson and Zoubi (2008) has shown that the activities of IBs differ from those of CBs. However, Aggarwal and Yousef (2000), Chong and Liu (2009), Khan (2010), Ariff and Rously (2011), and Suzuki et al. (2020) have argued that there is no fundamental difference between the banking activities of IBs and CBs.

4.2 Stability

Bank efficiency measurement has been a topic of interest in academic research and policymaking for a considerable period, with a noticeable increase in attention following the global financial crisis. Therefore, investigating the relationship between banks' efficiency and stability has become an important topic. Issavi et al. (2018) employed DEA as the analysis method and the intermediation approach to select variables to examine the relationship between efficiency and stability of eleven Iranian private and public banks between 2004 and 2016. The findings suggested an inverse relationship between banks' efficiency and stability indexes, with bank stability significantly impacting financial stability in an economy.

The literature presents a lack of consensus on the stability of Islamic banks (IBs) compared to their conventional counterparts (CBs). Kuran (2004) indicated that the stability of IBs is not higher than CBs, while Kabir and Worthington (2017) found IBs to be less stable than CBs in their analysis of 16 developing economies between 2000 and 2012. Ghosh (2016) proposed that capital adequacy ratios and reserve requirements are the most important factors for bank stability, with Beck et al. (2013) and Khediri et al. (2015) corroborating that liquidity and capitalization ratios are better in IBs, thereby improving their stability. Abedifar et al. (2015) found this to be the case in their analysis of data from 553 banks in 24 countries, while Rahim and Zakaria (2013) confirmed this for Malaysian IBs.

The Organisation for Economic Co-operation and Development (OECD) (2010) reports that banks that rely primarily on interbank funding and money markets suffered severe losses during the global financial crisis. In contrast, IBs, which rely heavily on depository funding, proved to be more stable than CBs. Khan (1986) found that IBs apply 100% reserve for demand deposits and are expected to be more stable. However, high reserve requirements mean IBs have less available funds for investment, leading to lower efficiency compared to CBs.

4.3 Scale efficiency

Efficiency is a key aspect of the banking industry, and Islamic banks (IBs) have been subject to numerous studies examining their efficiency. One important component of efficiency is scale efficiency, which is the ability of a bank to optimize its operations in relation to its size. Several studies have investigated the impact of scale efficiency on the overall technical efficiency of IBs.

Havid and Setiawan (2015) found a statistically significant correlation between scale inefficiency and technical inefficiency in Indonesian IBs. Yildirim (2015) demonstrated that scale inefficiency is the most important cause of technical inefficiency in IBs in Malaysia. Rahman and Rosman (2013) examined IBs in Asian and MENA countries, concluding that IBs experienced scale efficiency problems. By reviewing numerous studies in the literature, Rahman and Rosman (2013) identified Malaysia as one of the most popular countries which attracted the interest of researchers on the efficiency of IBs relative to conventional banks (CBs). Rahman and Rosman (2013) also showed that Zainal and Ismail (2012), Ada and Dalkilic (2014), Yildirim (2015), Sufian et al. (2016) and Kamarudin et al. (2017a, b), Abdul-Majid et al. (2008, 2010) preferred stochastic frontier analysis (SFA) and Alrawashedh et al. (2014) chose financial ratios in measuring efficiency. Findings from these studies are mixed. For example, Alrawashedh et al. (2014) and Kamarudin et al. (2017a, b) noted that IBs are more efficient/profitable than CBs, contrary to the conclusions by Abdul-Majid et al. (2008, 2010, 2011a, b).

Comparing the Malaysian and Turkish banking sectors, Ada and Dalkilic (2014) utilized the Malmquist Total Factor Productivity (TFP) index as well as data envelopment analysis (DEA) and proposed that TFP change decreased in Turkey during 2010–2011 compared to 2009–2010, while it increased for most banks in Malaysia. In addition, scale efficiency was higher in Turkey during 2009 but lower for Malaysian banks in 2010 and 2011. Further, Yildirim (2015) identified scale efficiency as the main source of overall technical efficiency. This is similar to a report by Zainal and Ismail (2012) that the technical efficiency and scale efficiency of domestic IBs are higher, while foreign IBs operated at higher pure technical efficiency. Berger (2007) investigated bank efficiency differences in various countries and compared the efficiency divergence among foreign and domestically owned banks. Findings indicated that foreign-owned banks have a disadvantage compared to domestic banks in developing countries.

Singh and Fida (2015) investigated the technical efficiency of Omani commercial banks by using DEA. Technical efficiency scores were decomposed into pure and scale efficiency components. Results suggested that scale efficiency has a higher impact on technical efficiency than pure technical efficiency. In addition, the largest bank of Oman is experiencing decreasing returns-to-scale. In the second stage analysis, the impact of capital adequacy, bank size, liquidity, and profitability on efficiency is examined by using the Tobit model. Liquidity and profitability are found to be significant, whilst bank size is an insignificant factor in bank efficiency.

Several studies have applied both parametric and non-parametric methods to try to identify consistency among the results. These include, among others, Cummins and Zi (1998), Bauer et al. (1998), Hassan (2005, 2006), and Nguyen et al. (2016),

who concluded that average efficiency scores varied significantly among the methods. Even though efficiency scores and rankings of banks are similar among different parametric methods, studies confirmed that the findings from parametric and non-parametric methods are inconsistent and rankings of banks are diverse (Yildirim and Philippatos 2007; Maudos et al. 1999; Weill 2004, 2009). Perera et al. (2007), Hauner and Peiris (2008), and Camanho and Dyson (1999) found bank's size as the main factor on efficiency due to scale effects. Consistent with these studies, Shamsuddin and Xiang (2012) illustrated that large banks in Australia experienced higher cost and technical efficiency than small banks, whilst lower profit efficiency.

Last but not the least point on scale efficiency, Kassim et al. (2009) showed that IBs in Malaysia are more sensitive to monetary policy changes than CBs. In line with this finding, analyzing the Turkish banking sector, Ergeç and Arslan (2013) concluded that IBs are more sensitive to interest rate change than CBs. Therefore, sensitivity to interest rate changes could be suggested as another important factor that should be considered when measuring the efficiency scores of IBs (Table 3).

4.4 Variable selection

The process of selecting appropriate variables to measure banks' economies of scale, efficiency, and productivity is a complex undertaking due to the intangible nature of the products offered to customers (Olgu 2007). Within the literature, there is no consensus on how to select input and output variables, and the Production, Value-Added, and Intermediation approaches are the three primary methods utilized, as shown in Table 4.

In the Production approach, banks are defined as firms that convert labor and capital into deposits and loans. New variable selection applications have been introduced by Resti (1997), Favero and Papi (1995), Bauer et al. (1993), Berger and DeYoung (1997), and Swank (1996). The Value-Added method, on the other hand, classifies assets or liabilities as inputs or outputs depending on whether they create or destroy value (Berger and Humphrey 1992). Finally, the Intermediation approach perceives banks as firms that transfer money from depositors to borrowers.

Table 4 provides insight into the most commonly used inputs and outputs for measuring banks' economies of scale, efficiency, and productivity. The selected inputs include labor, deposits, personnel expenses, and physical capital, while off-balance-sheet items, loans, and other earning assets are commonly used as outputs. The selection of inputs, however, remains largely dependent on the investigator's preferences. Nonetheless, the literature provides evidence on the role of deposits as either inputs or outputs. Empirical tests conducted in various studies, such as Hughes and Mester (1993) and Hughes and Mester (2019), indicate that deposits typically function as inputs. Personnel expenses have also been highlighted as a crucial input variable by Chortareas et al. (2012), Drake and Hall (2003), and Lozano-Vivas et al. (2002), given their significant role in general and administration expenditures (Johnes et al. 2014). Table 5 presents a frequency distribution of input–output variable selection based on the approaches employed in the reviewed studies.

Table 3 Survey of studies on Islamic and conventional bank efficiency. *Source*: Authors' own table

Author/s	Countries	Method	Findings
Islamic bank efficiency studies			
Najjar (2013)	Bahrain	Financial Ratios	Corporate excellence identified in asset management and value equity shares
Saaid (2005)	Sudan	SFA	No comparison; IBs only
Saaid et al. (2003)	Sudan	SFA	No comparison; IBs only
Hassan (2005, 2006)	21 Islamic countries	SFA and DEA	No comparison; IBs only
Hassan and Hussein (2003)	Sudan	SFA	No comparison; IBs only
Hussein (2004)	Bahrain	SFA	No comparison between efficiency of IBs and CBs
Yudistira (2004)	Qatar, Jordan, UAE, Algeria, Malaysia, Bahrain, Yemen, Egypt, Sudan, Gambia, Kuwait and Indonesia	DEA	No comparison; IBs only
Zainal and Ismail (2012)	Malaysia	DEA	*TE:* domestic IBs > foreign IBs *SE:* domestic IBs > foreign IBs *PTE:* domestic IBs < foreign IBs
Viverita et al. (2007)	Qatar, Kuwait, Algeria, UAE, Bahrain, Yemen, Brunei, Jordan, Bangladesh, Egypt, Malaysia, Sudan and Indonesia	DEA	No comparison; IBs only
Kamarudin et al. (2017a, b)	Brunei, Indonesia, and Malaysia	DEA	*Efficiency:* domestic IBs > foreign IBs
Khediri et al. (2015)	Malaysia	Financial Ratios	*Profitability and liquidity:* IBs > CBs Risk: IBs < CBs
Alam (2013)	Egypt, Indonesia, Bahrain, Kuwait, Bangladesh, Malaysia, Qatar, Pakistan, Turkey, Saudi Arabia, UAE	DEA + SUR	Regulation, strict monitoring and increased supervision have a positive impact on IB efficiency. But, decreased efficiency observed with higher restrictions on IB` risk taking behaviour

Table 3 (continued)

Author/s	Countries	Method	Findings
Nguyen (2018)	Vietnam, Indonesia, the Philippines, Cambodia, Malaysia, Thailand	SFA	More income diversified banks have lower cost efficiency while more asset diversified ones have lower persistent cost efficiency. More funding diversified banks have higher profit efficiency. Both funding and asset diversified foreign banks are less profit efficient
Rossazana and Chiang (2016)	Malaysia	DEA + OLS	Competitive banking sector due to less market concentration and banks are operating below their capacity. Market concentration and bank efficiency determines profitability performance of banks
Chan et al. (2015)	Malaysia, Indonesia, Singapore, the Philippines, Thailand	DEA + GMM	There is a need for increased market discipline, monitoring and transparency
Islamic versus conventional bank efficiency studies			
Milhem and Istaiteyeh (2015)	Jordan	Financial Ratios	*Profitability:* IBs < CBs *Liquidity:* IBs > CBs *Efficiency:* IBs < CBs *Riskiness:* IBs < CBs
Alrawashedh et al. (2014)	Malaysia	Financial Ratios	*Profitability and productivity:* IBs > CBs
Saeed and Izzeldin (2016)	Bahrain, Qatar, Kuwait, UAE, Saudi Arabia, Bangladesh, Pakistan, Indonesia	SFA + VAR	CBs in GCC countries have lower efficiency with decreased default risk. An inverse relationship between profit efficiency and default risk for IBs. Efficiency and default risk are early warning indicators of IB stability
Said (2012)	USA and randomly chosen countries	DEA	No comparison between efficiency of IBs and CBs
Hamid (1999)	Bangladesh	Financial ratios	*Profitability and liquidity:* IBs > CBs *Productivity:* IBs > CBs

Table 3 (continued)

Author/s	Countries	Method	Findings
Hassan and Bashir (2003c)	21 Islamic countries	Financial ratios	*Asset quality:* IBs > CBs
			Capital adequacy: IBs > CBs
			Liquidity: IBs < CBs
Iqbal (2001)	12 Islamic banks from various countries	Financial ratios	Profitability: IBs > CBs
			Cost efficiency: IBs < CBs
			Growth rate in equity, deposits, investments and total assets of IBs > CBs
Kader et al. (2007)	UAE	Financial ratios	*Efficiency:* IBs > CBs
			Profitability: IBs > CBs
			Liquidity: IBs < CBs
			Risk: IBs < CBs
Saeed and Izzeldin (2016)	UAE, Qatar, Pakistan, Bahrain, Indonesia, Bangladesh, Saudi Arabia and Kuwait	SFA	CBs and banks from GCC experienced lower efficiency associated with a decrease in default risk but inversely related in IBs
Srairi (2010)	UAE, Qatar, Bahrain, Saudi Arabia, Oman and Kuwait	SFA	*Efficiency:* IBs < CBs
Zuhroh et al. (2015)	Indonesia	SFA	*Technical efficiency:* IBs > CBs
			Cost efficiency: IBs < CBs
Majid et al. (2003)	Malaysia	SFA	*Efficiency:* IBs = CBs
Mokhtar et al. (2006)	Malaysia	SFA	*Efficiency:* IBs < CBs
			IBs > Foreign > Domestic banks
Kamarudin et al. (2016a, b)	Bahrain, Oman, Kuwait, Saudi Arabia, Qatar, UAE	DEA + OLS	IBs are less efficient than CBs. Macroeconomic variables are important on revenue efficiency
Abdul-Majid et al. (2010)	Yemen, Indonesia, Bahrain, Sudan, Malaysia, Bangladesh, Tunisia, Iran, Lebanon, Jordan	SFA	*Efficiency:* IBs < CBs

Table 3 (continued)

Author/s	Countries	Method	Findings
Al-Jarrah and Molyneux (2005)	Saudi Arabia, Egypt, Bahrain and Jordan	SFA	Efficiency of IBs and CBs are measured but variation not tested
El-Gamal and Inanoglu (2005)	Turkey	SFA	*Efficiency:* IBs = CBs
Abdul-Majid et al. (2008, 2011a, b)	Malaysia	SFA	*Efficiency:* IBs < CBs
Batir et al. (2017)	Turkey	DEA + Tobit	*Efficiency*: IBs > CBs. Expenses and loan quality have significant negative impact on efficiency of CBs and positive on IBs. Total loans have a significant positive impact on efficiency of both IBs and CBs while external variables have a significant negative impact
Moin (2008)	Pakistan	Financial ratios	*Liquidity:* IBs = CBs
			Efficiency: IBs < CBs
			Profitability: IBs < CBs
			Risk: IBs < CBs
Sufian et al. (2012)	Malaysia	DEA	*Efficiency:* IBs > CBs
Ismail et al. (2013)	Malaysia	DEA	*Efficiency:* IBs < CBs
Johnes et al. (2009)	UAE, Kuwait, Bahrain, Saudi Arabia, Qatar and Oman	DEA	*Efficiency:* IBs > CBs
Kamarudin et al. (2016a, b)	GCC countries	DEA	*Efficiency:* IBs < CBs
Johnes et al. (2014)	18 Muslim countries	DEA, Meta Frontier Approach, and two stage approach	*Efficiency:* IBs > CBs
Mokhtar et al. (2007, 2008)	Malaysia	DEA	*Efficiency:* IBs < CBs
Shawtari et al. (2019)	Yemen	DEA + OLS	Bank margin steadily decreased except 2011. CBs have higher bank margin than IBs. Bank margins are not related with efficiency but are affected by capitalisation, size, cost of reserves and liquidity

Table 3 (continued)

Author/s	Countries	Method	Findings
Samad (2004)	Bahrain	Financial ratios	*Liquidity risk:* IBs < CBs
Samad and Hassan (1999)	Malaysia	Financial ratios	*Profitability:* IBs < CBs *Managerial efficiency:* IBs = CBs
Sarker (1999)	Bangladesh	Financial ratios	*Efficiency:* IBs = CBs
Scale efficiency			
Almaqtari et al. (2018)	India	Financial Ratios	Bank size, number of branches, assets management ratio, operational efficiency and leverage ratio are the most important bank specific factors on profitability. Macroeconomic factors have significant impact on ROA and ROE, but demonization has no impact on ROE
Huang et al. (2017)	China	Network SFA	Joint-stock banks are the most technically efficient while larger commercial banks are the least technically efficient
Yannick et al. (2016)	Cote d`Ivoire	DEA (window analysis)	Ivonian banks are inefficient in loan allocation *Efficiency:* Foreign banks > public banks Inefficiency is due to scale inefficiency
Ada and Dalkilic (2014)	Malaysia and Turkey	DEA, Malmquist	Average scale efficiency is higher in Turkey in 2009 but lower in 2010 and 2011 than Malaysian banks. TFP change decreased in Turkey during 2010–11 compared to 2009–2010, while increased in Malaysia except from 3 banks
Rahman and Rosman (2013)	MENA countries	DEA	Technical inefficiency of IBs is due to scale inefficiency
Rosman et al. (2014)	Middle Eastern and Asian countries	DEA	Most IB operate inefficiently at DRS, profitability and capitalization are the main determinants of IB efficiency

Table 3 (continued)

Author/s	Countries	Method	Findings
Saha et al. (2015)	Malaysia	DEA	Positive *relationship* between bank size, capital, profit and efficiency Negative *relationship* between expenses, non-performing loans and efficiency
Bauer et al. (1998)	US	DEA, SFA, TFA, DFA	Consistency among parametric approaches but inconsistency among non-parametric and parametric approaches
San-Jose et al. (2014)	Spain	DEA + OLS	Investment banks are socially more efficient than other banks, but they all have similar efficiency scores
Ownership structure			
Sufian and Kamarudin (2014)	Malaysia	DEA, Malmquist, Bootstrap	Domestic and foreign banks experienced productivity growth due to progress in technological change
Azad et al. (2017)	Malaysia	DEA + Bootstrap	Bank ownership, bank nature and GDP have significant impact on bank efficiency. IBs outperformed CBs
Chen et al (2018)	China	DEA + Support Vector Machine Regression	Overall efficiency is low due to ownership and cost structure. Policy implications proposed to improve corporate governance and credit allocation
Matousek and Taci (2004)	Check Republic	DFA	*Efficiency:* Foreign banks > other banks
Wanke et al. (2019)	Algeria, Egypt, Israel, Kuwait, Malta, Oman, Saudi Arabia, Bahrain, Iran, Jordan, Lebanon, Morocco, Qatar, UAE	Dynamic Network DEA	Bank type, origin and ownership impact efficiency levels differently in terms of profit sheet, balance sheet and financial health indicators and also culture and regulation barriers are important at country level

Table 3 (continued)

Author/s	Countries	Method	Findings
Fukuyama and Matousek (2011)	Turkey	Network DEA	Gap exists between efficiency scores of best and worst banks and there is no evidence of foreign banks having higher efficiency than domestic banks

Table 4 Survey of studies on input–output variable selection. *Source*: Authors' own Table

Author	Sample	Method	Approach	Inputs	Outputs
Alam (2013)	Egypt, Indonesia, Bahrain, Kuwait, Bangladesh, Malaysia, Qatar, Pakistan, Turkey, Saudi Arabia, UAE *From 2006 to 2010*	DEA + SUR	Intermediation	Personnel expenses Fixed assets Deposits Short-term funding	Total loans Total earning assets
Azad et al. (2017)	Malaysia *From 2010 to 2015*	3-Stage Network DEA	Intermediation	Node 1: equity, deposits Node 2: earning assets, interest expense Node 3: loans, non-interest expense	Node 1: earning assets, non-earning assets Node 2: loans, liquid assets Node 3: net income, loan loss provisions
Batir et al. (2017)	Turkey *From 2005 to 2013*	DEA + Tobit	Intermediation	Personnel expenses, fixed assets, total deposits	Total loans, OBS
Belanès et al. (2015)	Saudi Arabia, Bahrain, Qatar, Kuwait, UAE *From 2005 to 2011*	DEA	Intermediation	Salary expense, fixed assets, total deposits	Total loans, other revenues, liquid assets
Henriques et al. (2018)	Brazil *From 2012 to 2016*	DEA	Intermediation	Fixed assets, total deposits, personnel expenses	Total loans
Huang et al. (2017)	China *From 2002 to 2015*	Network SFA	Intermediation	Stage 1: price of labour, physical capital Stage 2: deposits, price of labour, physical capital	Stage 1: deposits Stage 2: total loans, investments, non-interest income
Kamarudin et al. (2017a, b)	Malaysia, Brunei, Indonesia *From 2006 to 2014*	DEA	Intermediation	Deposits, labour, capital	Loans, investments
Rossazana and Chiang (2016)	Malaysia *From 2000 to 2011*	DEA + OLS	Intermediation	Personnel expenses, deposits, short-term funding	Total loans, OEA

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Miah and Uddin (2017)	Bahrain, Qatar, Kuwait, UAE, Saudi Arabia *From 2005 to 2014*	Ratio analysis, SFA, OLS	Intermediation	Cost of labour, cost of capital	Loans, securities
Saeed and Izzeldin (2016)	Bahrain, Qatar, Kuwait, UAE, Saudi Arabia, Bangladesh, Pakistan, Indonesia *From 2002 to 2010*	SFA + VAR	Intermediation	Net total loans, OEA	Price of physical capital, price of labour, price of financial capital
San-Jose et al. (2014)	Spain *From 2000 to 2011*	DEA + OLS	Intermediation	Equity, total assets, total deposits	Profit, risk, social contracts, no of jobs, consumer credit
Zimková (2014)	Slovakia *2012*	DEA	Intermediation	Fixed assets, deposits, no of employees	Earning assets
Chan et al. (2015)	Malaysia, Indonesia, Singapore, the Philippines, Thailand *From 1998 to 2012*	DEA + GMM	Intermediation	Expenses, interest expense, other non-interest expense	Interest income, investments, income from OBS
Kamarudin et al. (2016a, b)	Bahrain, Oman, Kuwait, Saudi Arabia, Qatar, UAE *From 2007 to 2011*	DEA + OLS	Intermediation	Personnel expenses, deposits	Loans, income
Ada and Dalkilic (2014)	Malaysia and Turkey *From 2009 to 2011*	DEA Malmquist	Intermediation	Total equity Total assets	Net income/loss Total deposits
Al-Jarrah (2007)	Saudi Arabia, Egypt, Bahrain and Jordan *From 1992 to 2000*	DEA	Intermediation	Physical capital Labour Deposits	Loans Off-balance sheet Other earning assets (OEA)
Al-Jarrah and Molyneux (2005)	Egypt, Saudi Arabia, Bahrain and Jordan *From 1992 to 2000*	SFA	Intermediation	Deposit Labour Physical capital	Total costumer loans Off-balance sheet items

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Al-Muharrami (2007)	GCC countries *From 1993 to 2002*	DEA	Intermediation	Fixed assets Deposits Equity Labour	OEA Total loans Off balance sheet items Other operating incomes
Ariff and Can (2008)	China *From 1995 to 2004*	DEA Tobit	Intermediation	Physical capital Total deposits Number of employees	Investments Total loans
Ataullah and Le (2006)	India *From 1992 to 1998*	DEA	Intermediation	Interest expenses Operating expenses	Loans and advances Investment Interest income Operating income
Athanassopoulos (1997)	Greece Questionnaire	DEA	Intermediation	Non-interest expense Interest expense Employees ATMs terminals	Non -interest income
Athanassopoulos and Curram (1996)	UK Questionnaire	DEA Neural Networks	Intermediation	Counter transactions ATMs Potential Market Employees	Insurance policies sold Loans sales Investments
Avkiran (2009)	UAE *2005*	Network DEA	Intermediation	Non-interest expenses Interest expense	Non-interest income Interest income
Ayadi et al. (1998)	Nigeria *From 1991to 1994*	DEA	Intermediation	Total deposits Interest on deposits Personnel expenses	Non-interest income Total loans Interest income
Barros et al. (2011)	China *From 1998 to 2008*	DEA	Intermediation	Deposits Number of employees Total assets	Securities Loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Barros et al. (2012)	Japan *From 2000 to 2007*	Russell Directional Distance Function	Intermediation	Total deposits Physical capital Number of full time employees	Total loans
Batir et al. (2017)	Turkey *From 2005 to 2013*	DEA	Intermediation	Personnel expenses Fixed assets Total deposits	Off balance sheet items Total loans
Battacharya et al. (1997)	India *From 1986 to 1991*	DEA SFA	Intermediation	Operating expenses Interest expense	Investments Deposits Advances
Beccalli et al. (2006)	Spain, France, Italy, Germany, UK *From 1999 to 2000*	DEA SFA	Intermediation	Total expenses	OEA Total loans
Bos et al. (2009)	European countries and USA *From 1993 to 2005*	SFA	Intermediation	Physical capital Financial capital Labour	Investments Loans Off-balance sheet items
Brockett et al. (1997)	USA *From 1984 to 1985*	DEA CAMEL	Intermediation	Total deposits Interest expenses Furniture and equipment Buildings	Loans net of unearned income Allowances for loan losses
Canhoto and Dermine (2003)	Portugal *From 1990 to 1995*	DEA	Intermediation	Physical capital Number of employees	Assets/liabilities Loans Interbank securities Deposits
Casu and Girardone (2009)	Spain, Italy, France, UK and Germany *From 2000 to 2005*	SFA and DEA	Intermediation	Interest paid Non-interest expense Total personnel expenses Other administrative expenses	OEA Total loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Casu and Molyneux (2003)	Italy *From 1996 to 1999*	DEA	Intermediation	Labour Deposits Capital	OEA Total loans
Chen and Yeh (2000)	Taiwan *1996*	DEA	Intermediation	Staff Deposits Assets	Non-interest income Provision of loan Portfolio investment
Chen et al. (2005)	China *From 1993 to 2000*	DEA	Intermediation	Capital Non-interest expenses Interest expenses	Non-interest income Deposits Loans
Chortareas et al. (2012)	27 EU countries *From 2001 to 2009*	DEA	Intermediation	Personnel expenses Fixed assets Deposits	OEA Total loans
Degl`Innocenti et al. (2017)	Top 1000 banks worldwide *From 2004 to 2010*	Order-M Approach	Intermediation	Total customer deposits Fixed assets Number of employees	Total securities Gross loans
Delis and Papanikolau (2009)	Bulgaria, Slovenia, Estonia, Romania, Check Republic, Lithuania, Poland, Hungary, Slovakia and Latvia *From 1994 to 2005*	DEA	Intermediation	Total deposits Operating expenses (non-interest and personnel expenses)	Total securities Total loans
Emrouznejad and Anouze (2010)	GCC countries *2009*	DEA	Intermediation	Total assets Deposits Capital	Net profit Loans
English et al. (1993)	USA *1982*	Shephard` distance function	Intermediation	Borrowings Capital Deposits Labour	Commercial loans Investments income Consumer loans Real estate loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Favero and Papi (1995)	Italy *1991*	DEA	Intermediation	Employees Capital Loanable funds Deposits	Non-interest income Loans Investments in securities
Fukuyama (1993)	Japan *1990*	DEA	Intermediation	Deposits Capital Employees	Other revenues Loan revenue
Fukuyama (1996)	Japan *1992*	DEA	Intermediation	Deposits Labour Capital	Securities Loans
Fukuyama and Matousek (2011)	Turkey *From 1991 to 2007*	Network DEA	Intermediation	Capital Labour	Securities Loans
Gardener et al. (2011)	Thailand, Malaysia, Indonesia, the Philippines and Vietnam *From 1998 to 2004*	DEA	Intermediation	Personnel expenses Fixed assets Deposits	OEA Net loans
Isik and Hassan (2002)	Turkey *From 1988 to 1996*	DEA and Economic Frontier Approach	Intermediation	Deposits Capital Labour	OEA Off balance sheet items Short-term loans Long-term loans
Isik and Hassan (2003)	Turkey *From 1988 to 1996*	DEA	Intermediation	Deposits Labour Physical capital	OEA Loans Off-balance sheet items
Johnes et al. (2014)	18 Muslim countries *From 2004 to 2009*	DEA, Meta Frontier Approach	Intermediation	General expenses Deposits Equity Fixed assets	OEA Total loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Kablan and Yousfi (2003)	UK, Jordan, Iran, UAE, Kuwait, Sudan, Qatar, Egypt, Lebanon, Tunisia, Yemen, Saudi Arabia, Bahrain, Brunei, Malaysia and Pakistan *From 2011 to 2008*	SFA	Intermediation	Labour Physical capital Deposits	Net loans Net liquid assets Securities
Kamarudin et al. (2016a, b)	Bangladesh *From 2004 to 2011*	DEA	Intermediation	Deposits Labour Capital	Loans Investments
Kamarudin et al. (2017a, b)	Brunei, Indonesia and Malaysia *From 2006 to 2014*	DEA	Intermediation	Total deposits Labour Capital	Loans Investments
Lang and Welzel (1996)	Germany *From 1989 to 1992*	Translog Cost Function	Intermediation	Fixed assets Total cost Volume of labour Deposits Price of labour Price of deposits Price of capital No of employees Volume of deposits	Cash Real estate Short term loans to non-banks Fees and commissions Loans to banks Bonds Investment Long term loans to non-banks Number of offices Revenue from sales
Le (2017)	Vietnam *From 2008 to 2015*	DEA	Intermediation	Operating expenses Physical capital Deposits	Total loans Securities Off balance sheet items
Lee and Chih (2013)	China *From 2004 to 2011*	DEA, Tobit	Intermediation	Fixed assets Deposits	Investments Loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Mahesh and Rajeev (2009)	India *From 1985 to 2004*	SFA	Intermediation	Fixed assets Deposits Labour Borrowings	Non-interest income Investments Credits Interest margin
Mamatzakis et al. (2008)	Slovenia, Slovakia, Hungary, Latvia, Poland, Lithuania, Check Republic, Cyprus, Malta and Estonia	SFA	Intermediation	Borrowed funds Labour	OEA Loans
Matousek and Taci (2004)	Check Republic *From 1993 to 1998*	DFA	Intermediation	Average price of funds Average price of capital Average annual salary per employee	Average volume of demand deposits Average volume of loans
Mester (1996)	USA *From 1991 to 1992*	SFA	Intermediation	Deposits Labour Funding Physical capital	Agricultural loans Private loans to individuals Other loans Real estate loans Commercial and industrial loans Lease financing receivable
Miah and Uddin (2017)	GCC countries From *2005 to 2014*	Fin. Ratios, SFA, OLS	Intermediation	Cost of labour Cost of capital	Loans Securities
Mokhtar et al. (2006)	Malaysia *From 1997 to 2003*	SFA	Intermediation	Operating expenses Personnel and other expenses Total deposits	Securities
Mokhtar et al. (2008)	Malaysia *From 1997 to 2003*	DEA	Intermediation	Total deposits Total overhead expenses	Total earning assets

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Mostafa (2009)	IBs in middle East *2005*	DEA	Intermediation	Assets Equity	Net profits ROA ROE
Moualhi (2015)	MENA *From 2006 to 2012*	DEA	Intermediation	Assets Total deposits	Investments Total income Total loans
Nguyen et al. (2016)	Vietnam *From 2000 to 2014*	DEA and SFA	Intermediation	Personnel Fixed assets Total deposits	OEA Net loans
Nikiel and Opiela (2002)	Poland *From 1997 to 2000*	DFA	Intermediation	Price of labour Interest rates on funds	Securities Household loans Business loans
Olson and Zoubi (2011)	10 MENA countries *From 2000 to 2008*	Translog Cost Function	Intermediation	Deposits, Labour Physical capital	Loans Securities
Ong et al. (2011)	Malaysia *From 2002 to 2009*	DEA	Intermediation	Total deposits Fixed assets	Total loans Total investments
Oral and Yolalan (1990)	Turkey *From 1976 to 1986*	DEA	Intermediation	Personnel expense Administrative expense Depreciation Interest expense	Interest earned Non-interest income
Pasioursa (2008)	95 countries *2003*	DEA, Tobit	Intermediation	Interest and non-interest expense Equity Total deposits	Non-interest income OEA Loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Rekik and Kalai (2018)	Malaysia, Egypt, Yemen, Syria, Sudan, Jordan, Iraq, Lebanon, Tunisia, Kuwait, UAE, Qatar, Bahrain, Saudi Arabia *From 1999 to 2012*	Financial ratios, Regression, SFA	Intermediation	Deposits Physical capital labour	Securities Liquid assets Net loans
Saeed and Izzeldin (2016)	Saudi Arabia, Kuwait, Bahrain, Qatar, Bangladesh, Pakistan, Indonesia and UAE *From 2002 to 2010*	SFA	Intermediation	Price of physical capital Price of labour Price of financial capital	Net total loans Other earning assets
Şakar (2006)	Turkey *From 31 December 2002 to 31 March 2005*	DEA Malmquist	Intermediation	Branch numbers Employees per branch Assets Loans Deposits	Interest income/assets Non-interest income/assets ROA Interest income/operating income ROE
Sufian (2006)	Malaysia *From 2001 to 2004*	DEA	Intermediation	Total deposits Labour Fixed assets	Income Total loans
Sufian (2009a)	Malaysia *1997*	DEA	Intermediation	Labour Capital Interest expenses	Deposits Loans Investments
Sufian and Abdul Majid (2007)	Malaysia *From 2002 to 2003*	DEA	Intermediation	Interest Income Non-interest income	Personal expenses Non-interest expenses
Sufian and Kamarudin (2014)	Malaysia *From 1998 to 2008*	DEA	Intermediation	Total deposits Capital Labour	Total loans Investments Non-interest income

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Sufian et al. (2012)	Malaysia *From 1998 to 2008*	DEA	Intermediation	Deposit Labour Physical capital	Loans Investments Off-balance sheet items
Sufian et al. (2013)	Malaysia *From 2006 to 2010*	DEA	Intermediation	Deposits Number of employees Physical capital	Loans Investments
Sufian et al. (2016)	Malaysia *From 1999 to 2008*	DEA	Intermediation	Total deposits Capital Labour	Total loans Investments Non-interest income
Tecles and Tabak (2010)	Brazil *From 2000 to 2007*	SFA	Intermediation	Deposits Number of employees Fixed assets Equity	Other non-interest fee based incomes Investments Loans and advances
Thoraneenitiyan and Avkiran (2009a, b)	Philippines, Indonesia, Thailand, South Korea and Malaysia *From 1997 to 2001*	DEA	Intermediation	Deposits Labour Capital Physical capital	Loans Investment and OEA Off-balance sheet items Fee income
Yannick et al. (2016)	Cote d`Ivoire *From 2008 to 2010*	DEA Window analysis	Intermediation	Deposits	Loans
Yildirim and Philippatos (2007)	12 transition countries *From 1993 to 2000*	SFA, DFA	Intermediation	Labour Deposits Physical capital	Investments Loans Deposits
Yilmaz and Gunes (2015)	Turkey *From 2007 to 2013*	DEA	Intermediation	Total deposits Capital	Total loans Total income Investments
Yin et al. (2013)	China *From 1999 to 2010*	SFA	Intermediation	Equity Deposits Fixed assets	Pre-tax profit or loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Zhang et al. (2012)	China *From 1999 to 2008*	SFA	Intermediation	Interest expenses Non-interest expenses Net value of fixed assets	Net interest income Non-interest income Total deposits OEA Total loans
Hall et al. (2012)	Hong Kong *From 2000 to 2006*	DEA	Intermediation / Production	Total operating expenses Fixed assets Total provisions	Other operating income Net commissions Total loans OEA Trading income
Kenjegalieva et al. (2009)	Eastern European countries *From 1999 to 2003*	DEA	Intermediation/ Production	Loan loss provisions Labour Capital Deposits	Other income Net commissions OEA Loans
Holod and Lewis (2011)	Top tier bank holding companies *From 1986 to 2008*	DEA, Network DEA	Intermediation/production	Number of employees Fixed assets (Deposits)	OEA Total loans (Deposits)
Drake et al. (2009)	Japan *From 1995 to 2002*	DEA	Intermediation/Production/Revenue based	Total other operating expenses Total provision Total non-interest expense Total deposits Total operating expenses	Other operating income Net commission Total OEA Non-interest income Total loans
Shawtari et al. (2019)	Yemen *From 2009 to 2013*	DEA + OLS	No defined approach	Not identified	Not identified
Cherchye et al. (2001)	EU countries *1997*	FDH and DEA	No defined approach	Operating costs Equity capital Debt capital	Total earning assets (securities)

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Halme et al. (2014)	Finland *From 2007 to 2010*	FDH, FDH value efficiency	No defined approach	Investment services Financial services	Work of the sales force
Quaranta et al. (2018)	Italy *2014*	DEA, Collinearity, Clustering, Deterministic Frontier Model, Deterministic SF, SFA, DEA	No defined approach	Operating costs Number of employees	Total financial assets
Chen et al (2018)	China *From 2008 to 2011*	DEA + Support Vector Machine Regression	Production	Loans, equity, operational costs, personnel expenses, no of employees, no of branches, depreciation	Total assets, fixed assets, gross loans, total securities, total customer deposits, pre-tax profit, net-interest income, total-non-interest income
Wanke et al. (2019)	Algeria, Egypt, Israel, Kuwait, Malta, Oman, Saudi Arabia, Bahrain, Iran, Jordan, Lebanon, Morocco, Qatar, UAE *From 2009 to 2013*	Dynamic Network DEA	Production	Net loans, total earning assets, non-earning assets, loan loss provisions	Net interest margin, equity, income
Du and Sim (2016)	China, Indonesia, Russia, India, Malaysia, Thailand *From 2002 to 2009*	DEA	Production	Fixed assets, total non-interest expense, interest expense	Net interest income, other operating income
Lozano-Vivas et al. (2002)	10 European countries *1993*	DEA	Production	Personnel expenses Non-interest expenses	OEA Deposits Loans

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Paradi et al. (2011)	Canada *2001*	DEA, Slacks-Based measure	Production (1) Intermediation (2)	Other resources (1) Labour (1) Net non-performing (2) Loans (2) Fixed assets (2) Funding (2) Deposits (2)	Loans (1) Others (1) Deposits (1) Investments (2) Mortgages (2) Loans (2)
Azad et al. (2017)	Malaysia *From 2009 to 2013*	DEA + Bootstrap	Production, Intermediation and Value Added	Production: interest expense, salary expense, operating expense Intermediation: total capital, total deposits, salary expense Value-Added: total capital, salary expense, interest expense	Production: interest income, net income Intermediation: total loans Value-Added: total deposits, total loans
Nguyen (2018)	Vietnam, Indonesia, the Philippines, Cambodia, Malaysia, Thailand *From 2007 to 2014*	SFA	Value-Added	Labour, capital, funds	Loans to customer, interbank loans, OEA

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Carvallo and Kasman (2017)	Argentina, Bolivia, Chile, Costa Rica, Ecuador, Bahamas, Brazil, Colombia, Dominican Republic, Guatemala, Mexico, Paraguay, Trinidad and Tobago, Venezuela, El Salvador, Honduras, Panama, Peru, Uruguay *From 1999 to 2013*	SFA	Value-Added	Price of labour and physical capital, price of borrowed funds	Total loans, OEA, total deposits, OBS
Bauer et al. (1998)	US *From 1977 to 1988*	DEA, SFA, TFA, DFA	Value-Added	Labour Physical capital Time deposits Purchased funds	Demand deposits Real estate loans Instalment loans Commercial loans
Berg et al. (1992)	Norway *From 1980 to 1989*	DEA Malmquist	Value-Added	Buildings Material Labour Machine	Short- term loans Long-term loans Demand deposits Time deposits Other services
Berg et al. (1993)	Finland, Norway and Sweden *1990*	DEA	Value-Added	Capital Labour	Number of branches Loans Deposits
DeYoung (1997)	USA *From 1984 to 1994*	DFA	Value-Added	Physical capital Borrowed funds Price of labour	Fee-based income Transactions Deposits Total loans
Dietsch and Lozano-Vivas (2000)	Spain and France *From 1988 to 1992*	DFA	Value-Added	Labour Financial factor Physical capital	Loans Assets Deposits

Table 4 (continued)

Author	Sample	Method	Approach	Inputs	Outputs
Giokas (1991)	Greece *1988*	DEA Cobb–Douglas	Value-Added	Utilized branch space Operating expenses Labour	Number of transactions
Golany and Storbeck (1999)	USA *From 1992 to 1993*	DEA	Value-Added	Labour Operating expenses Economic status Market size Competitive activities	Deposits No of accounts per customer Loans
Mukherjee et al. (2002)	India *From 1996 to 1999*	DEA	Value-Added	Net worth Borrowings Operating expenses Employees Number of branches	Non-interest income Interest income Deposits Advances Net profit
Resti (1997)	Italy *From 1988 to 1992*	DEA SFA	Value-Added	Employees Capital	Non-interest income Deposits Loans
Zhao and Murinde (2011)	Nigeria *From 1993 to 2008*	DEA Conjectural variations regression	Value-Added	Interest expenses Non-interest expenses Financial capital	Deposits Loans
Sufian (2009b)	Thailand and Malaysia *From 1992 to 2003*	DEA	Value-Added and Intermediation	Labour Capital Interest expenses	Deposits Loans Investments

Table 5 Statistics on variable selection. *Source*: Authors' own Table

Variable selection			
Inputs	%	Outputs	%
Intermediation approach (81%)			
Labour	68	Loans	79
Deposits	72	Other earning assets	25
Capital	40	Investments	30
Assets	30	Interest income	5
Interest expense	18	Non-interest income	16
Non-interest expense	11	Off balance sheet items	14
Value-added approach (12%)			
Labour	90	Loans	82
Capital	64	Other earning assets	90
Deposits	9	Non-interest income	18
Interest expense	18		
Operating expense	27		
Production approach (7%)			
Labour	50	Loans	100
Non-interest expense	33	Other earning assets	83
		Deposits	50

Magrianti (2011) conducted a study that compared the efficiency scores of Indonesian Islamic banks (IBs) and conventional banks (CBs) using different variable selection approaches. The results revealed that CBs had above-average efficiency scores when assets and production methodologies were employed, whereas IBs had higher efficiency scores than average when the intermediation approach was used. The study also found that the Intermediation approach was the most commonly used approach (81%), followed by the Value-Added approach (12%) and the Production approach (7%). 'Labor' was the most frequently selected input variable, while 'loans' was the most frequently chosen output variable. The review suggests that including both 'interest expense' and 'non-interest expense' as inputs, and 'interest income' and 'non-interest income' as outputs, could significantly affect efficiency scores when comparing IBs and CBs.

4.5 Incorporating environmental variables

Efficiency measurement methods were initially applied in individual country studies. However, in the last decade, cross-country studies have become more popular in order to capture the impact of country-specific characteristics, such as regulation, market structure, macroeconomic conditions, and various bank-specific factors. Studies such as Pastor et al. (1997), Fecher and Pestieau (1993), and Berg et al. (1993) employed common or country frontiers, using both Data Envelopment Analysis (DEA) and the Distribution Free Approach (DFA) in their cross-country

analyses. Nevertheless, they failed to account for the potential influence of environmental variables over which bank managers have no control. Applying a common frontier assumes that all decision-making units use the same technology, which could lead to misleading results (Chaffai et al. 2001). Therefore, Pastor et al. (1997) and Chaffai et al. (2001) recommend incorporating a range of environmental variables in empirical modelling of banking efficiency, including customers' ease of access to banking services, intermediation, concentration, and average capital ratios.

Altunbas and Chakravarty (1998), Cavallo and Rossi (2001), and Carbo et al. (2003) were among the first to conduct cross-country studies on European countries. Subsequent studies examined transition countries (Bonin et al. 2005; Kasman 2005), countries in Latin America and the Caribbean (Carvallo and Kasman 2005), developing countries (Boubakri et al. 2005; Clarke et al. 2005), and the achievements of Asian countries (Karim 2001; Williams and Nguyen 2005). More recently, researchers have compared the performance of Islamic banks (IBs) with conventional banks (CBs) in response to the increasing use of Islamic banking in many countries (Alpay and Hassan 2007; Al-Jarrah and Molyneux 2005; Yudistira 2004; Brown 2003; Hassan 2003). However, controlling for environmental variables remains a controversial issue.

The "two-stage" methodology is often used to control for environmental factors. In this method, efficiency scores measured in "stage one" using either of the frontier techniques or the financial ratios discussed in the previous sections are regressed on selected environmental factors in "stage two." Bashir (1999, 2001) used a two-stage approach to confirm the fundamental components of performance among IBs using Middle Eastern bank-level data. The results suggest that bank-specific factors such as non-interest-earning assets, customer short-term funding, and overheads influence banks' estimated efficiency scores. Bashir (1999, 2001) also recommended a negative correlation between bank deposits (measured as share reserves) and performance metrics.

A bootstrap approach is generally used in the second stage of analysis. However, Casu and Molyneux (2003) used it in the first stage to demonstrate the correlation among the covariates of the second-stage regression and error terms from the first stage. Brissimis et al. (2008) and Delis and Papanikolaou (2009) created an algorithm that relied on a double bootstrap procedure. Other models used to detect the impact of environmental variables on bank efficiency include Logit, Gaussian and Markov, and Bootstrap-Tobit, which were employed by Pastor (2002) and Casu and Girardone (2004), Wang and Huang (2007), and Casu and Molyneux (2003) and Hahn (2007) respectively. Several studies have utilized a two-stage approach to examine bank efficiency, with a focus on the Malaysian banking sector. Ismail et al. (2013), Saha et al. (2015), Defung et al. (2016), Sufian et al. (2016), and Wanke et al. (2016a, b, c) are among the most recent studies that have used this approach. With the exception of Defung et al. (2016), which employed Tobit to examine Indonesian banks, the other studies have focused on the Malaysian banking sector. The first two studies used Tobit, while Sufian et al. (2016) preferred Bootstrapping and Wanke et al. (2016a, b, c) utilized TOPSIS. According to Table 2, Tobit regression was the most commonly used two-stage technique (about 26% of the reviewed studies), followed by Generalized Least Squares (GLS), which accounted for around

17% of studies. The remaining 32% of studies employed various techniques such as Bootstrap, Ordinary Least Squares (OLS), and TOPSIS.

A number of studies, including those by Sufian and Noor (2009), Ismail et al. (2013), and Saha et al. (2015), have used a two-stage Data Envelopment Analysis (DEA) approach (DEA and Tobit). Sufian and Noor (2009) examined the efficiency of Islamic Banks (IBs) in the Middle East and North Africa (MENA) and Asian countries between 2001 and 2006. They found that loans, size, capitalization, and profitability were positively correlated with bank efficiency, while non-performing loans were negatively correlated. Saha et al. (2015) focused solely on the efficiency scores of Conventional Banks (CBs) in Malaysia between 2005 and 2012, and their findings were consistent with those of Sufian and Noor (2009). Ismail et al. (2013) analyzed both CBs and IBs in Malaysia between 2006 and 2009. They found that CBs had higher efficiency scores than IBs, and that there was a negative relationship between equity, size, and efficiency of IBs, but a positive relationship for CBs. Interestingly, a positive relationship was found to exist between expenses and efficiency in both IBs and CBs.

Azad et al. (2017) conducted a recent study that used a network DEA (NDEA), a three-stage DEA approach, to measure and compare the efficiency scores of IBs and CBs in the Malaysian banking sector between 2010 and 2015. They found that IBs performed better than CBs in terms of profitability and production, while the opposite was true in terms of intermediation. This study is important, as it highlights the limited application of NDEA in the examination of bank efficiency, which has been noted by Avkiran (2015) and Kao (2014). Kao (2014) has also argued that dynamic NDEA is rarely used in practice. Table 6 summarizes the studies that have used a two-stage analysis approach.

4.6 Islamic versus conventional bank technical efficiency

This paper reviews studies that examine the technical efficiency of Islamic banks (IBs) or conventional banks (CBs) or compare the technical efficiency of both types of banks. The studies analyzed in this paper are authored by Bader (2007), Kamarudin et al. (2017a, b), Le (2017), Aghimien et al. (2016), Islam et al. (2013), Hassan (2005), Brown and Skully (2005), Yudistria (2004), Nguyen et al. (2016), Yannick et al. (2016), Ozkan-Gunay et al. (2013), Assaf et al. (2013), Bos and Kool (2006), Weill (2004), Miah and Uddin (2017), Batir et al. (2017), Kamarudin et al. (2016a, b), Alrawashedh et al. (2014), Johnes et al. (2014), Abdul-Majid et al. (2008, 2010, 2011a,b), Al-Jarrah and Molyneux (2005), Hussein (2004), and Al-Shammari (2003).

The literature has utilized various financial ratios to evaluate bank performance, and research indicates that the relative performance of Islamic banks (IBs) and conventional banks (CBs) differs depending on the financial data analyzed. Popular financial ratios include debt-to-equity, return on investment (ROI), return on equity (ROE), and return on assets (ROA). Some studies, including Miah and Uddin (2017), Khediri et al. (2015), and Alrawashedh et al. (2014), support the assertion that IBs are more profitable, liquid, and less risky than CBs. However, others such as

Table 6 Survey of studies incorporating environmental variables. *Source*: Authors' own Table

Method used	Author/s	Sample
Tobit	Ariff and Can (2008)	China *From 1995 to 2004*
	Azad et al. (2017)	Malaysia *From 2010 to 2015*
	Avkiran (2009)	New Zealand and Australia *From 1996 to 2003*
	Batir et al. (2017)	Turkey *From 2005 to 2013*
	Casu and Molyneux (2003)	UK, Italy, Germany, France and Spain, *From 1993 to 1997*
	Chang and Chiu (2006)	Taiwan *From 1996 to 2000*
	Defung et al. (2016)	Indonesia *From 1998 to 2008*
	Drake et al. (2006)	Hong Kong *From 1995 to 2001*
	Fukuyama and Weber (2009)	Japan *From 2002 to 2005*
	Hahn (2007)	Austria *From 1996 to 2002*
	Hauner (2005)	Germany, Austria *From 1995 to 1999*
	Ismail et al. (2013)	Malaysia *From 2006 to 2009*
	Johnes et al. (2009)	Malaysia

Table 6 (continued)

Method used	Author/s	Sample
	Laurenceson and Qin (2008)	China *From 2001 to 2006*
	Lee and Chih (2013)	China *From 2004 to 2011*
	Pasioursa (2008)	95 countries *2003*
	Pastor (2002)	Spain, Italy, France, Germany *From 1988 to 1994*
	Saha et al. (2015)	Malaysia *From 2005 to 2012*
Ordinary least square (OLS)	Ataullah and Le (2006)	India *From 1992 to 1998*
	Chen et al (2018)	China *From 2008 to 2011*
	Chan et al. (2015)	Malaysia, Indonesia, Singapore, the Philippines, Thailand *From 1998 to 2012*
	Fung (2006)	US *From 1996 to 2003*
	Kamarudin et al. (2016a, b)	Bahrain, Oman, Kuwait, Saudi Arabia, Qatar, UAE *From 2007 to 2011*
	Nikiel and Opiela (2002)	Poland *From 1997 to 2000*
	Rossazana and Chiang (2016)	Malaysia *From 2000 to 2011*
	Shawtari et al. (2019)	Yemen *From 1996 to 2011*

Table 6 (continued)

Method used	Author/s	Sample
	Saeed and Izzeldin (2016)	Bahrain, Qatar, Kuwait, UAE, Saudi Arabia, Bangladesh, Pakistan, Indonesia *From 2002 to 2010*
	Weill (2004)	Spain, France, Switzerland, Italy and Germany, *From 1992 to 1998*
Generalized method of moments (GMM)	Ataullah and Le (2006)	India *From 1992 to 1998*
	San-Jose et al. (2014)	Spain *From 2000 to 2011*
	Wang and Huang (2007)	Taiwan *From 1982 to 2001*
GLS	Aysan and Ceyhan (2008)	Turkey *From 1990 to 2006*
	Dogan and Fausten (2003)	Malaysia *From 1989 to 1998*
	Isik (2007)	Turkey *From 1981 to 1990*
	Isik and Hassan (2002)	Turkey *1988, 1992, 1996*
	Kyj and Isik (2008)	Ukraine *From 1998 to 2003*
	Maudos et al. (2002)	10 EU countries *From 1993 to 1996*
	Molyneux et al. (2013)	Transition countries *From 1994 to 2002*
	Mukherjee et al. (2001)	US *From 1984 to 1990*

Table 6 (continued)

Method used	Author/s	Sample
	Sanyal and Shankar (2011)	India *From 1997 to 2004*
	Sufian (2011a, b)	Malaysia *From 1993 to 2006*
	Tanna (2009)	75 countries *From 2000 to 2004*
	Yildirim and Philippatos (2007)	12 Central and East European countries *From 1993 to 2000*
Fixed effects model	Aysan and Ceyhan (2008)	Turkey *From 1990 to 2006*
	Dogan and Fausten (2003)	Malaysia *From 1989 to 1998*
	Isik (2007)	Turkey *From 1981 to 1990*
	Isik and Hassan (2002)	Turkey *1988, 1992, 1996*
	Sufian (2011a, b)	Malaysia *From 1993 to 2006*
	Tanna (2009)	75 countries *From 2000 to 2004*
Bootstrap	Alam (2013)	Egypt, Indonesia, Bahrain, Kuwait, Bangladesh, Malaysia, Qatar, Pakistan, Turkey, Saudi Arabia, UAE *From 2006 to 2010*
	Brissimis et al. (2008)	10 new EU countries *From 1994 to 2005*
	Casu and Molyneux (2003)	UK, Italy, Germany, France and Spain, *From 1993 to 1997*

Table 6 (continued)

Method used	Author/s	Sample
	Defung et al. (2016)	Indonesia *From 1998 to 2008*
	Delis and Papanikolaou (2009)	Bulgaria, Slovenia, Estonia, Romania, Check Republic, Lithuania, Poland, Hungary, Slovakia and Latvia *From 1994 to 2005*
	Azad et al. (2017)	Malaysia *From 2009 to 2013*
	Fukuyama and Matousek (2011)	Turkey *From 1991 to 2007*
	Hahn (2007)	Austria *From 1996 to 2002*
	Sufian et al. (2016)	Malaysia *From 1999 to 2008*
Logit	Casu and Girardone (2002)	Italy *From 1996 to 1999*
	Kumar and Gulati (2008)	India *From 1993 to 2006*
	Pastor (2002)	Spain, Italy, France, Germany *From 1988 to 1994*
TOPSIS	Wanke et al. (2016a, b, c)	Malaysia *From 2009 to 2013*
AR, Markov and correlation	Wang and Huang (2007)	Taiwan *From 1982 to 2001*
Slack-based measure	Paradi et al. (2011)	Canada *2001*
Random effects model (REM)	Johnes et al. (2014)	18 Muslim countries *From 2004 to 2009*

Table 6 (continued)

Method used	Author/s	Sample
SUR	Alam (2013)	Egypt, Indonesia, Bahrain, Kuwait, Bangladesh, Malaysia, Qatar, Pakistan, Turkey, Saudi Arabia, UAE *From 2006 to 2010*
3-stage network DEA	Azad et al. (2017)	Malaysia *From 2009 to 2013*
Support vector machine regression	Batir et al. (2017)	Turkey *From 2005 to 2013*
VAR	Miah and Uddin (2017)	Bahrain, Qatar, Kuwait, UAE, Saudi Arabia *From 2005 to 2014*

Milhem and Istaiteyeh (2015) demonstrate that IBs are less profitable and efficient than CBs. Sufian and Kamarudin (2016) propose that banks operating in more economically globalized nations generally have better performance metrics than their counterparts in economically protected countries.

Nienhaus (1988) discovered that Islamic banks (IBs) and conventional banks (CBs) had comparable achievements in terms of asset size, profit, and capital. Hamid (1999) proposed that IBs outperformed CBs in liquidity, profitability, productivity, and risk management. Samad and Hassan (1999) attributed this to a higher investment in government-backed securities and a higher equity-to-assets ratio. Nevertheless, the return on equity and return on assets were not significantly different for both types of banks. Iqbal (2001) compared private IBs with CBs and observed that IBs achieved greater growth in total equity, deposits, investments, total assets, and profits. However, they were less cost-efficient in terms of the total expense-to-income ratio.

In Pakistan, Moin (2008) conducted a study that found IBs and CBs had similar liquidity figures. However, the IBs in the sample were less efficient and profitable than the average for CBs, which was attributed to the IBs being younger and less experienced than CBs. Bashir (1999, 2001) corroborated these findings and identified higher costs of obtaining adequate capital ratios, loan portfolios, non-interest-earning assets, and short-term financing as crucial factors contributing to the decreasing profitability of IBs. Moreover, Hassan and Bashir (2003a, b, c) suggested that IBs' inferior asset quality compared to CBs also affects their performance.

However, Samad (2004) challenged the findings of Hassan and Bashir (2003a, b, c), stating that IBs in Bahrain are less exposed to liquidity risks due to the restrictive Shariah-compliant principles, which promote more conservative lending. Samad's study examined the performance of IBs versus CBs in Bahrain and found no significant differences in their profitability or liquidity estimates. Nevertheless, there was a significant disparity in the credit performance of both types of banks. Kader et al. (2007) observed that IBs in UAE experienced rapid growth in selected performance metrics due to the sharing of profit and loss (SPL) principle. This indicates that IBs and CBs have different characteristics in practice and should be regulated and controlled differently. The authors also suggested that IBs are generally more efficient and profitable but less liquid and less risky than CBs.

Mokhtar et al. (2006) utilized the Stochastic Frontier Analysis (SFA) approach to investigate the overall average efficiency of IBs in Malaysia, revealing that IBs were less efficient than CBs despite significant growth in asset size, deposits, and financing compared to CBs. Furthermore, the study concluded that domestic banks were less efficient than foreign banks, regardless of organizational charter. This finding was supported by Srairi (2010), who confirmed that Western banks in the Gulf Cooperation Council (GCC) countries were more cost and profit-efficient than their domestic Islamic bank counterparts.

Al-Shammari (2003) evaluated the impact of bank types and country dummy variables such as the quality of loans and capital to directly influence inefficiency. The study concluded that IBs and CBs in GCC countries were significantly less efficient than IBs. Alpay and Hassan (2007) found that, on average, IBs in Turkey were more efficient than CBs, despite having limited Shariah-compliant investment

opportunities. However, unlike CBs, the productivity and technical efficiency of IBs reduced over time. In line with Alpay and Hassan (2007), Omar et al. (2007) suggested that IBs in Indonesia operate at higher profit efficiency scores compared to Western banks in the country.

Ariff and Can (2008) found that Islamic banks (IBs) and Western banks operate at similar efficiency scores, except for the age of the bank, where older Western banks are less cost-efficient compared to their Islamic bank peers. They also found that older banks are more efficient than newer banks due to their larger asset size and more experience.

In Malaysia, Kamarudin et al. (2008) discovered that the overall cost efficiency of Islamic financial institutions is lower than that of conventional banks (CBs). However, Magrianti (2011) and Rosyadi and Fauzan (2011) both reported that, in Indonesia, IBs are more efficient than CBs when the Intermediation approach is employed.

Studies on the impact of mergers and acquisitions (M&A) on bank efficiency have yielded mixed results. While Al-Khasawneh (2013) found that bank mergers have a positive correlation with efficiency gains, Montgomery et al. (2014) disagreed. Le (2016) reported no efficiency gains from M&A for both IBs and CBs in Vietnam, and Le (2017) found that efficiency scores improved in most acquired banks but showed no clear pattern in acquiring banks.

Different studies have shown contrasting results on the efficiency of IBs compared to CBs. Abdul-Majid et al. (2008, 2010, 2011a, b), Havid and Setiawan (2015), Johnes et al. (2009, 2014), Kamarudin et al. (2016a, b), Milhem and Istaiteyeh (2015), Mokhtar et al. (2007, 2008), and Srairi (2010) suggested that IBs are less efficient than CBs. In contrast, Al-Muharrami (2008), Alrawashedh et al. (2014), Batir et al. (2017), Khediri et al. (2015), Er and Uysal (2012), and Zuhroh et al. (2015) found that IBs are more efficient/profitable than CBs.

In GCC countries, Aghimien et al. (2016), Kamarudin et al. (2016a, b), Saeed and Izzeldin (2016), and Miah and Uddin (2017) compared the efficiency scores of IBs and CBs. Aghimien et al. (2016) proposed that banks in GCC countries operated at optimal scale, indicating constant or decreasing returns to scale in large banks and constant or increasing returns to scale in smaller banks. Kamarudin et al. (2016a, b) found that IBs are less efficient than CBs, consistent with the findings of Srairi (2010). Saeed and Izzeldin (2016) discovered that CBs from GCC countries had lower efficiency scores but a decrease in default risk.

Dijkstra's (2017) dissertation examines the relationship between bank economies of scale and scope and various factors such as government intervention, corporate strategy, and market power. The empirical findings reveal a positive relationship between economies of scale and mixed relationship with economies of scope.

5 Research gaps and suggestions for future research

Based on the findings of this paper, several future research paths could be identified, and recommendations can be offered. First, IBs can increase their technical efficiency scores by using their stronger stability advantage which may require

regulatory flexibility in terms of asset requirements. Even though it can be suggested as an important topic both for IBs and CBs, studies reviewed in this paper focused mostly on efficiency measurement leaving stability and liquidity issues deeply unexplored. Our study broadens the technical efficiency research spectrum by suggesting diverse methodologies, contexts, and variables, including the less explored influence of interest rate changes and nuanced regulatory practices on Islamic Banks (IBs). While IBs do not directly interact with interest, economy-wide interest rate variations indirectly affect their efficiency by modifying the overall economic context. Importantly, we argue that the distinct business model of IBs, underpinned by principles such as risk-sharing and prohibition of interest, calls for a more considered regulatory approach. Rather than adopting a 'one-size-fits-all' strategy, regulators should account for the unique operational and risk profiles of IBs. Standard banking regulations like minimum capital requirements and capital conservation buffers, while universally applicable, could be fine-tuned to address the specific risks inherent to IBs, such as those amplified by extraordinary events like a pandemic. Thus, a regulatory framework considering aspects like capital adequacy, liquidity risk management, and customer protection should be informed by the distinct characteristics of Islamic banking.

Secondly, due to their structural differences and investment limitations by the *Shariah* principles, we recommend that IBs should be regulated and treated differently thank CBs by the authorities. This is an important policy implication that needs to be addressed in future studies which attempt to evaluate and compare the performance metrics of IBs with their conventional counterparts. Thirdly, even though investment accounts of IBs are operating on PLS principles, losses in the asset side are absorbed by equity holders. To the best of our knowledge, this may create uncertainty about the level of transparency and disclosure, which has not been clearly researched in the existing literature.

Fourthly, comparative studies of the results obtained by using different variable selection approaches are scarce. The highest proportion of studies applied the Intermediation approach in defining input–output variables, whilst studies comparing efficiency scores of both IBs and CBs with different approaches is very limited. The consistency among the efficiency scores with various input–output variable combinations can be extended in future research. Fifthly, in terms of methodological applications, future research could be extended to cover more cross-country empirical investigations using both the TFA and the DFA as parametric frontier methods.

Other areas for further research could comprise, *inter alia*: (i) a comparison of the robustness of different methods used in calculating banks' efficiency scores. Evidence from existing literature shows that the three groups of methods reviewed in this paper produced diverse efficiency scores. (ii) The inclusion of non-interest expense in the choice of input variables and non-interest income in the list of output variables could have an important impact on the estimated efficiency scores, particularly for IBs. Then, the contribution of environmental factors such as *Shariah* principles, country-specific characteristics and management quality should be considered concurrently when estimating bank efficiency scores. (iii) The selection of performance metrics employed should be expanded to include both the standard efficiency scores and the Malmquist Total Factor Productivity Index (TFP). Such should help

policymakers to achieve a more accurate rating of banks in terms of their productivity and efficiency management. A summary of research gaps and recommendations for possible future research directions is presented in Table 7.

6 Conclusions

In this paper, we presented a comprehensive systematic literature review of 305 studies focusing on the 1989–2019 period. We collected the sample after a careful review of 18,461 articles from seven leading databases by following the PRISMA flowchart. Our aim was to critically evaluate the recent technical efficiency methods of Islamic banks (IBs) and conventional banks (CBs), highlight patterns and trends, identify significant factors on bank efficiency and offer a guide to researchers as a summary of existing studies by emphasizing opportunities for future research.

Our review identified several important findings with practical and theoretical implications. First, there is mixed evidence on which group of banks i.e. IBs or CBs are more efficient; whilst more recent papers on cross-country analysis found no difference between the two types of banks. Therefore, regulators and policymakers should consider the mixed findings when evaluating the performance of different types of banks, and more research is required to reach a more definitive conclusion on this issue. Second, several studies concluded that a two-stage procedure is a more appropriate method for estimating bank efficiency since it allows for the simultaneous inclusion of variables that capture the impact of bank-specific factors as well as regional and environmental conditions, which may be incorporated more in future studies. Thus, practitioners and academics should consider employing a two-stage procedure to capture a more comprehensive view of bank efficiency. Third, our review found that applications of parametric and non-parametric techniques produce different efficiency scores. But remarkably, studies comparing findings from different methods are very limited, indicating a potential area for further research, particularly incorporating consistency tests on findings. Therefore, researchers should consider comparing different methods to provide a more comprehensive analysis of bank efficiency. Fourth, our review found that many studies applied DEA as a non-parametric method and SFA as a parametric method. However, applications of other innovative methods such as TFA, DFA and FDH in the bank efficiency context are less frequent. Therefore, there is a need for new methodological applications, and researchers should explore innovative methods to capture a more comprehensive view of bank efficiency.

Fifth, there is no consensus in the literature on the procedure for selecting input and output variables. The Intermediation approach is the most widely applied method in which ‘labor’, ‘deposits’ and ‘capital’ are the most widely chosen input variables, whilst ‘loans’ and ‘other earning assets’ are the most frequently used output variables. Other approaches such as Value-Added and Production can be employed at the same time for a comparative analysis. Thus, practitioners and academics should consider multiple approaches to selecting input and output variables to provide a more comprehensive analysis of bank efficiency.

Table 7 Research gap and future research fields. *Source*: Authors' own table

Theme	Research gap	Future research
Variable selection	There is no consensus on input–output variable selection. Comparative studies using different approaches is scarce. 81% of reviewed studies applied Intermediation approach	Different variable selection approaches can be applied to the same dataset to identify the divergence among efficiency scores as future research
IBs versus CBs efficiency	There is mixed evidence in the reviewed studies from different countries on which group of banks are more efficient	Future research can investigate and identify the environmental and country specific factors on why one group of banks is more efficient than the other. Further research is needed to investigate the impact of ownership structure
Cross-country studies	There is no clear findings in cross-country studies	Future research can include regulatory factors, liquidity, solvency and financial riskiness in multi-stage analysis
Methodology	Most of the studies focused on either parametric or non-parametric analysis Literature is dominated by DEA and SFA applications	Parametric and non-parametric methods may generate different results. Therefore, application of different methods to the same dataset is suggested as future research FDH, TFA, DFA and stochastic frontier methods are suggested
Robustness	Very limited number of studies applied more than one technique to measure efficiency	Application of various techniques supported by robustness check for consistency is proposed
Regulation	IBs follow strict Shariah principals. Impact of these principals compared to regulator principals for CBs have not been identified	Future research can focus on the impact of specific regulatory differences among IBs and CBs
Efficiency versus productivity	Efficiency and productivity methods may rank banks differently. Studies mainly focus on either efficiency or productivity measurement	There is a need for further research on applying both efficiency and productivity methods such as Malmquist total Productivity Index to investigate consistency
Scale efficiency	Various groups of banks behave differently due to asset size	Scale efficiency can be an important factor to be identified in future research
Accounting/financial ratios	There is no clear evidence on which group of banks are performing better	Future research can disaggregate the accounting/financial ratios in multi-stage applications which can introduce interesting insights to bank efficiency
Two-stage analysis	Only 20% of reviewed studies applied a two (multi)-stage analysis mainly using Tobit or GLS	Bootstrap, OLS, Logit or TOPSIS can be applied in future research
Input variables	Labour, deposits, and capital are the main inputs selected	Future research can consider non-interest expense in input selection
Output variables	Loans and other earning assets are the main outputs selected	Future research can consider non-interest income in output selection

While this review contributes to the literature on bank efficiency by providing a comprehensive analysis of technical efficiency methods used in Islamic and conventional banks, there are some limitations to our study. First, the sample size may not be fully representative of all studies on technical efficiency in Islamic and conventional banks, as we focused on papers published in seven databases only. Second, our review only covers studies published between 1989 and 2019, and it is possible that there have been developments in technical efficiency methods since then, especially after COVID-19 era. It is worth noting that the COVID-19 pandemic has had a significant impact on the banking industry and may have affected the efficiency of banks in various ways. Future research in this area may investigate the effects of the pandemic on bank efficiency and performance. Third, our review focused on technical efficiency and did not consider other forms of efficiency such as scale efficiency and cost efficiency. Fourth, we did not consider the impact of external factors such as macroeconomic conditions, regulatory frameworks, and political stability on bank efficiency, which could be explored in future studies. Finally, while we identified several important research gaps and opportunities, the suggestions for future research are not exhaustive and should be considered as indicative rather than definitive.

In conclusion, this review provides a summary of the recent technical efficiency methods of IBs and CBs, highlights patterns and trends, identifies significant factors on bank efficiency and offers a guide to researchers as a summary of existing studies by emphasizing opportunities for future research. The practical and theoretical implications of this review can help practitioners, academics, and policymakers better evaluate the performance of different types of banks, and contribute to a more comprehensive understanding of bank efficiency.

References

Abdul-Majid M, Saal DS, Battisti G (2010) Efficiency in Islamic and conventional banking: an international comparison. J Prod Anal 34(1):25–43

Abdul-Majid M, Saal DS, Battisti G (2011a) Efficiency and total factor productivity change of Malaysian commercial banks. Serv Ind J 31(13):2117–2143

Abdul-Majid M, Saal DS, Battisti G (2011b) The impact of Islamic banking on the cost efficiency and productivity change of Malaysian commercial banks. Appl Econ 43(16):2033–3054

Abdul-Majid M, Saal DS, Battisti G (2008) The efficiency and productivity of Malaysian banks: an output distance function approach. Aston Business School Research Paper R, P0815

Abedifar P, Ebrahim S, Molyneux P, Tarazi A (2015) Islamic banking and finance: recent empirical literature and directions for future research. J Econ Surv 29(4):637–670

Abreu E, Kimura H, Sobreiro V (2019) What is going on with studies on banking efficiency? Res Int Bus Financ 47:195–219
Ada AA, Dalkilic N (2014) Efficiency analysis in Islamic banks: a study for Malaysia and Turkey. BDDK J Bank Financ Mark 8(1):9–33
Aggarwal RK, Yousef T (2000) Islamic banks and investment financing. J Money Credit Bank 32:93–120
Aghimien PA, Kamarudin F, Hamid F, Noordin B (2016) Efficiency of Gulf Cooperation Council Banks. Rev Int Bus Strateg 26(1):118–136
Ahmad N, Haron S (2002) Perceptions of Malaysian corporate customers towards Islamic banking products & services. Int J Islam Financ Serv 3(4):1–16
Alam N (2013) Impact of banking regulation on risk and efficiency in Islamic banking. J Financ Rep Account 11(1):29–50
Aliyu S, Hassan MK, Mohd Yusof R, Naiimi N (2017) Islamic banking sustainability: a review of literature and directions for future research. Emerg Mark Financ Trade 53(2):440–470
Al-Jarrah I (2007) The use of DEA in measuring efficiency in Arabian banking. Banks Bank Syst J 2(4):21–30
Al-Jarrah I, Molyneux P (2005) Efficiency in Arabian banking, Islamic perspectives on wealth creation. Edinburgh University, Edinburgh, pp 97–117
Al-Khasawneh JA (2013) Pairwise X-efficiency combinations of merging banks: analysis of the fifth merger wave. Rev Quant Financ Acc 41(1):1–28
Almaqtari F, Al-Homaidi E, Tabash M, Farhan N (2018) The determinants of profitability of Indian commercial banks: a panel data approach. Int J Financ Econ 24(1):168–185
Al-Muharrami S (2007) The causes of productivity change in GCC banking industry. Int J Product Perform Manag 56(8):731–743
Al-Muharrami S (2008) An examination of technical, pure technical and scale efficiencies in GCC banking. Am J Finance Account 1(2):152–166
Al-Omar F, Abdel-Haq (1996) Islamic banking: theory, practice and challenges. Oxford University Press, Karachi
Alpay S, Hassan MK (2007) A comparative efficiency analysis of interest free financial institutions and conventional banks: a case study on Turkey. Economic research forum, working paper series, 0714
Alrawashedh M, Sabri SRM, Ismail MT (2014) The significant financial ratios of the Islamic and conventional banks in Malaysia region. Res J Appl Sci Eng Technol 7(14):2838–2845
Al-Shammari SH (2003) Structure-conduct-performance and efficiency in Gulf Cooperation Council. Ph.D. thesis, University of Wales, Bangor
Altunbas Y, Chakravarty SP (1998) Efficiency measures and the banking structure in Europe. Econ Lett 60(2):205–208
Ariff M, Can L (2008) Cost and profit efficiency of Chinese banks: a nonparametric analysis. China Econ Rev 19(2):260–273
Ariff M, Rosly SA (2011) Islamic banking in Malaysia: unchartered waters. Asian Econ Policy Rev 6(2):301–319
Assaf AG, Matousek R, Tsionas EG (2013) Turkish bank efficiency: Bayesian estimation with undesirable outputs. J Bank Finance 37(2):506–517
Ataullah A, Le H (2006) Economic reforms and bank efficiency in developing countries: the case of the Indian banking industry. Appl Financ Econ 16(9):653–663
Athanassopoulos AD (1997) Service quality and operating efficiency synergies for management control in the provision of financial services: evidence from Greek bank branches. Eur J Oper Res 98(2):300–313
Athanassopoulos AD, Curram SP (1996) A comparison of data envelopment analysis and artificial neural networks as tools for assessing the efficiency of decision making units. J Oper Res Soc 47(8):1000–1016
Avkiran NK (2009) Opening the black box of efficiency analysis: an illustration with UAE banks. Omega 37(4):930–941
Avkiran NK (2015) An illustration of dynamic network DEA in commercial banking including robustness tests. Omega 55:141–150
Ayadi F, Adebayo A, Omolehinwa E (1998) Bank performance measurement in a developing economy: an application of data envelopment analysis. Manag Financ 24:5–16
Aysan AF, Ceyhan SP (2008) What determines the banking sector performance in globalised financial market? The case of Turkey. Phys A Stat Mech Its Appl 387(7):1593–1602

Azad A, Kian-Teng K, Talib M (2017) Unveiling black-box of bank efficiency. Int J Islam Middle East Finance Manag 10(2):149–169
Bader MK (2007) Cost, revenue and profit efficiency of conventional banks: evidence from nineteen developing countries. In: Ariff M, Shamsher M, Hassan T (eds) Capital markets in emerging markets: Malaysia (chapter 25). McGraw-Hill, Kuala Lumpur
Barros C, Chen Z, Liang Q, Peypoch N (2011) Technical efficiency in the Chinese banking sector. Econ Model 28(5):2083–2089
Barros CP, Managi S, Matousek R (2012) The technical efficiency of the Japanese banks: non-radial directional performance measurement with undesirable output. Omega 40(1):1–8
Bashir AM (1999) Risk and profitability measures in Islamic banks: the case of two Sudanese banks. Islam Econ Stud 6(2):1–24
Bashir A (2001) Assessing the performance of Islamic banks: some evidence from the Middle East, topics in Middle Eastern and North African economies, unpublished paper. In: Proceedings of the Middle East Economic Association
Batir TE, Volkman DA, Gungor B (2017) Determinants of bank efficiency in Turkey: participation banks versus conventional banks. Borsa Istanbul Rev 17(2):86–96
Battacharya A, Lovell CAK, Sahay P (1997) The impact of liberalisation on the productive efficiency of Indian commercial banks. Eur J Oper Res 98:332–345
Bauer PW, Berger AN, Humphrey DB (1993) Efficiency and productivity growth in US banking. Meas Prod Effic Tech Appl 1:386–413
Bauer PW, Berger AN, Ferrier GD, Humphrey DB (1998) Consistency conditions for regulatory analysis of financial institutions: a comparison of frontier efficiency methods. J Econ Bus 50:85–114
Beccalli E, Casu B, Girardone C (2006) Efficiency and stock performance in European banking. J Bus Financ Account 33(1–2):245–262
Beck T, Demirgüç-Kunt A, Merrouche O (2013) Islamic vs. conventional banking: business model, efficiency and stability. J Bank Finance 37(2):433–447
Belanès A, Ftiti Z, Regaïeg R (2015) What can we learn about Islamic banks efficiency under the subprime crisis? Evidence from GCC Region. Pac Basin Finance J 33:81–92
Bele S, Zerihun B, Tilahun G (2021) The impact of COVID-19 on the financial performance of banks: evidence from Ethiopia. J Econ Bus 113:105996
Berg S, Forsund F, Jansen E (1992) Malmquist indices of productivity growth during the deregulation of Norwegian banking, 1980–89. Scand J Econ 94(Supplement):211–228
Berg SA, Førsund FR, Hjalmarsson L, Suominen M (1993) Banking efficiency in the Nordic countries. J Bank Finance 17(2–3):371–388
Berger AN (2007) International comparisons of banking efficiency. Financ Mark Inst Instrum 16(3):119–144
Berger AN, DeYoung R (1997) Problem loans and cost efficiency in commercial banks. J Bank Finance 21(6):849–870
Berger AN, Humphrey DB (1992) Measurement and efficiency issues in commercial banking. In: Output measurement in the service sectors. University of Chicago Press, pp 245–300
Bhatia V, Basu S, Mitra SK, Dash P (2018) A review of bank efficiency and productivity. Opsearch 55:557–600
Bonin JP, Hasan I, Wachtel P (2005) Bank performance, efficiency and ownership in transition countries. J Bank Finance 29(1):31–53
Bos JWB, Kool CJM (2006) Bank efficiency: the role of bank strategy and local market conditions. J Bank Finance 30:1953–1974
Bos J, Koetter M, Kolari J, Kool C (2009) Effects of heterogeneity on bank efficiency scores. Eur J Oper Res 195:251–261
Boubaker S, Le TDQ, Ngo T (2022) Managing bank performance under COVID-19: a novel inverse DEA efficiency approach. Int Trans Oper Res 30(5):2436–2452
Boubaker S, Uddin MH, Kabir SH, Mollah S (2023) Does cost inefficiency in Islamic banking matter for earnings uncertainty? Rev Acc Financ 22(1):1–36
Boubakri N, Cosset JC, Fischer K, Guedhami O (2005) Privatization and bank performance in developing countries. J Bank Finance 29(8–9):2015–2041
Brissimis SN, Delis MD, Papanikolaou NI (2008) Exploring the nexus between banking sector reform and performance: evidence from newly acceded EU countries. J Bank Finance 32(12):2674–2683
Brockett PL, Charnes A, Cooper WW, Huang ZM, Sun DB (1997) Data transformations in DEA cone ratio envelopment approaches for monitoring bank performances. Eur J Oper Res 98(2):250–268

Brown K (2003) Islamic banking comparative analysis. Arab Bank Rev 5(2):43–50
Brown K, Skully M (2005) Islamic banks: a cross-country study of cost efficiency performance, accounting, commerce and finance. Islam Perspect J 8(1–2):43–79
Camanho AS, Dyson RG (1999) Efficiency, size, benchmarks and targets for bank branches: an application of data envelopment analysis. J Oper Res Soc 50:903–915
Canhoto A, Dermine J (2003) A note on banking efficiency in Portugal, new vs. old banks. J Bank Finance 27(11):2087–2098
Carbo V, Humphrey SD, Rodríguez F (2003) Deregulation, bank competition and regional growth. Reg Stud 37:227–237
Carvallo O, Kasman A (2005) Cost efficiency in the Latin American and Caribbean banking systems. Int Financ Mark Inst Money 15:55–72
Carvallo O, Kasman A (2017) Convergence in bank performance: evidence from Latin American banking. N Am J Econ Finance 39:127–142
Casu B, Girardone C (2009) Does competition lead to efficiency? The case of EU commercial banks. Cass Business School, working paper series, WP 01/09
Casu B, Molyneux P (2003) Comparative study of efficiency in European banking, Wharton school research paper, no 17
Casu B, Girardone C (2002) A comparative study of the cost efficiency of Italian bank conglomerates. Manag Finance 28(9):3–23
Casu B, Girardone C (2004) Financial conglomeration: efficiency, productivity and strategic drive. Appl Financ Econ 14:687–696
Cavallo L, Rossi SPS (2001) Scale and scope economies in the European banking systems. J Multinatl Financ Manag 11(4–5):515–531
Chaffai ME, Dietsch M, Lozano-Vivas A (2001) Technological and environmental differences in the European banking industries. J Financ Res 19(2–3):147–162
Chan S, Koh E, Zainir F, Yong C (2015) Market structure, institutional framework and bank efficiency in ASEAN 5. J Econ Bus 82:84–112
Chang TC, Chiu YH (2006) Affecting factors on risk-adjusted efficiency in Taiwan's banking industry. Contemp Econ Policy 24(4):634–648
Chen T, Yeh T (2000) A measurement of bank efficiency, ownership and productivity changes in Taiwan. Serv Ind J 20(1):95–109
Chen X, Skully M, Brown K (2005) Banking efficiency in China: application of DEA to pre-and post-deregulation eras: 1993–2000. China Econ Rev 16(3):229–245
Chen Z, Matousek R, Wanke P (2018) Chinese bank efficiency during the global financial crisis: a combined approach using satisficing DEA and support vector machines☆. N Am J Econ Finance 43:71–86
Chen X, You X, Chang V (2021) FinTech and commercial banks' performance in China: a leap forward or survival of the fittest? Technol Forecast Soc Change 166:120645
Cherchye L, Kuosmanen T, Post T (2001) FDH directional distance functions with an application to European commercial banks. J Prod Anal 15:201–215
Chong BS, Liu MH (2009) Islamic banking: interest-free or interest-based? Pac Basin Finance J 17(1):125–144
Chortareas GE, Girardone C, Ventouri A (2012) Bank supervision, regulation and efficiency: evidence from the European Union. J Financ Stab 8:292–302
Clarke G, Cull R, Shirley MM (2005) Bank privatization in developing countries: a summary of lessons and findings. J Bank Finance 29(8–9):1905–1930
Cummins JD, Zi H (1998) Comparison of frontiers efficiency methods: an application to the US life insurance industry. J Prod Anal 10:131–152
Dar H (2003) Handbook of international banking. Edward Elgar (**Chap. 8**)
Defung F, Salim R, Bloch H (2016) Has regulatory reform had any impact on bank efficiency in Indonesia?: A two-stage analysis. Appl Econ 48(52):5060–5074
Degl'Innocenti M, Matousek R, Sevic Z, Tzeremes NG (2017) Bank efficiency and financial centres: Does geographical location matter? J Int Financ Mark Inst Money 46:188–198
Delis MD, Papanikolaou NI (2009) Determinants of bank efficiency: evidence from a semi-parametric methodology. Manag Finance 35(3):260–275
DeYoung R (1997) A diagnostic test for the distribution-free efficiency estimator: an example using U.S. commercial bank data. Eur J Oper Res 98(2):243–249

Dietsch M, Lozano-Vivas A (2000) How the environment determines banking efficiency: a comparison between French and Spanish industries. J Bank Finance 24(6):985–1004
Dijkstra M (2017) Economies of scale and scope in banking: Effects of government intervention, corporate strategy and market power. Amsterdam University Press
Dogan E, Fausten D (2003) Productivity and technical change in Malaysian banking: 1989–1998. Asia-Pac Finan Mark 10:205–237
Drake L, Hall MJ (2003) Efficiency in Japanese banking: an empirical analysis. J Bank Finance 27(5):891–917
Drake L, Hall MJB, Simper R (2006) The impact of macroeconomic and regulatory factors on bank efficiency: a non-parametric analysis of Hong Kong's banking system. J Bank Finance 30:1443–1466
Drake L, Hall MJB, Simper R (2009) Bank modelling methodologies: a comparative non-parametric analysis of efficiency in the Japanese banking sector. J Int Financ Mark Inst Money 19:1–15
Du K, Sim N (2016) Mergers, acquisitions, and bank efficiency: cross-country evidence from emerging markets. Res Int Bus Financ 36:499–510
Elamer AA, Ntim CG, Abdou HA, Zalata AM, Elmagrhi M (2019) The impact of multi-layer governance on bank risk disclosure in emerging markets: the case of Middle East and North Africa. In: Accounting forum, vol 43(2). Routledge, pp 246–281
Elamer AA (2017) Empirical essays on risk disclosures, multi-level governance, credit ratings, and bank value: evidence from MENA banks. Doctoral dissertation, University of Huddersfield
El-Gamal MA, Inanoglu H (2005) Inefficiency and heterogeneity in Turkish banking: 1990–2000. J Appl Economet 20(5):641–665
El-Hawary D, Grais W (2004) Regulating Islamic financial institutions: the nature of the regulated, 3227. World Bank Publications
Emrouznejad A, Anouze AL (2010) DEA/C&R: DEA with classification and regression tree: a case of banking efficiency. Expert Syst (**in press**)
English M, Grosskopf S, Hayes K, Yaisawarng S (1993) Output allocative and technical efficiency of banks. J Bank Finance 17:349–366
Er B, Uysal M (2012) Turkiyedeki geleneksel bankalar ve islami bankalarin karsilastirmali etkinlik analizi: 2005–2010 donemi degerlendirmesi. Ataturk Universitesi Iktisadi Ve Idari Bilimler Dergisi 26(3–4):365–387
Ergeç EH, Arslan BG (2013) Impact of interest rates on Islamic and conventional banks: the case of Turkey. Appl Econ 45(17):2381–2388
Favero CA, Papi L (1995) Technical efficiency and scale efficiency in the Italian banking sector: a non-parametric approach. Appl Econ 27(4):385–395
Fecher F, Pestieau P (1993) Efficiency and competition in OECD financial services. In: Fried HO, Schmidt SS (eds) The measurement of productive efficiency: techniques and applications. Oxford University Press, Oxford, pp 374–385
Fukuyama H (1993) Technical and scale efficiency of Japanese commercial banks: a non-parametric approach. Appl Econ 25(8):1101–1112
Fukuyama H (1996) Returns to scale and efficiency of credit associations in Japan: a nonparametric frontier approach. Jpn World Econ 8(3):259–277
Fukuyama H, Matousek R (2011) Efficiency of Turkish banking: two-stage network system. Variable returns to scale model. Int Financ Mark Inst Money 21:75–91
Fukuyama H, Weber WL (2009) A directional slacks-based measure of technical inefficiency. Socioecon Plan Sci 43(4):274–287
Fung MK (2006) Scale economies, X-efficiency, and convergence of productivity among bank holding companies. J Bank Finance 30:2857–2874
Gardener E, Molyneux P, Nguyen-Linh H (2011) Determinants of efficiency in South East Asian banking. Serv Ind J 31:2693–2719
Ghosh S, McGuckin JT, Kumbhakar SC (1994) Technical efficiency, risk attitude, and adoption of new technology: the case of the US dairy industry. Technol Forecast Soc Change 46(3):269–278
Ghosh AR, Ostry JD, Chamon M (2016) Two targets, two instruments: Monetary and exchange rate policies in emerging market economies. J Int Money Finance 60:172–196
Giokas D (1991) Bank branches operating efficiency: a comparative application of DEA and loglinear model. Omega 19:549–557
Golany B, Storbeck J (1999) A data envelopment analysis of the operational efficiency of bank branches. Interfaces 29:14–26

Gough D (2007) Weight of evidence: a framework for the appraisal of the quality and relevance of evidence. Res Pap Educ 22(2):213–228
Hahn FR (2007) Domestic mergers in the Austrian banking sector: a performance. Appl Financ Econ 17:185–196
Hall MJ, Kenjegalieva KA, Simper R (2012) Environmental factors affecting Hong Kong banking: a post-Asian financial crisis efficiency analysis. Glob Financ J 23:184–201
Halme M, Korhonen P, Eskelinen J (2014) Non-convex value efficiency analysis and its application to bank branch sales evaluation. Omega 48:10–18
Hamid MA (1999) Islamic banking in Bangladesh: expectations and realities. In: International conference on Islamic economics in the 21st Century: Kuala Lumpur, Malaysia
Hasan M, Dridi J (2010) The effects of the global crisis on Islamic and conventional banks: a comparative study. IMF working paper, WP/10/201
Hassan MK (2006) The X-efficiency in Islamic banks. Islam Econ Stud 13(2):49–77
Hassan M, Aliyu S (2018a) A contemporary survey of Islamic banking literature. J Financ Stab 34:12–43
Hassan MK, Hussein KA (2003) Static and dynamic efficiency in the Sudanese banking system. Rev Islam Econ 14:5–48
Hassan MK, Bashir AM (2003a) Determinants of Islamic banking profitability, ERF paper
Hassan MK, Bashir AHM (2003b) Determinants of Islamic banking profitability. In: Paper presented at the 10th ERF annual conference, 16–18 December, Morocco
Hassan MK, Bashir AHM (2003c) Determinants of Islamic banking profitability. In: 10th ERF annual conference, Morocco, vol 7, pp 2–31
Hassan MK (2003) Cost, profit and X-efficiency of Islamic banks in Pakistan, Iran and Sudan. In: International seminar on Islamic banking: risk management, regulation and supervision, September 30–October 2, Jakarta, Indonesia
Hassan K (2005) The cost, profit and X-efficiency of Islamic banks. In: Presented at ERF's (economic research forum) 12th annual conference, Cairo, Egypt
Hauner D (2005) Explaining efficiency differences among large German and Austrian bank. Appl Econ 37(9):969–980
Hauner D, Peiris SJ (2008) Banking efficiency and competition in low income countries: the case of Uganda. Appl Econ 40(21):2703–2720
Havid SAH, Setiawan C (2015) Bank efficiency and non-performing financing (NPF) in the Indonesian Islamic banks. Asian J Econ Model 3(3):61–79
Henriques I, Sobreiro V, Kimura H, Mariano E (2018) Efficiency in the Brazilian banking system using data envelopment analysis. Future Bus J 4(2):157–178
Holod D, Lewis HF (2011) Resolving the deposit dilemma: a new DEA bank efficiency model. J Bank Finance 35:2801–2810
Huang T, Lin C, Chen K (2017) Evaluating efficiencies of Chinese commercial banks in the context of stochastic multistage technologies. Pac Basin Financ J 41:93–110
Hughes JP, Mester LJ (2019) Modeling, evidence, and some policy implications. In: The Oxford handbook of banking, p 229
Hughes JP, Mester LJ (1993) A quality and risk-adjusted cost function for banks: evidence on the "too-big-to-fail" doctrine. J Prod Anal 4(3):293–315
Hussein KH (2004) Banking efficiency in Bahrain: Islamic versus conventional banks. Islamic Development Bank, Islamic Research and Training Institute, research paper, 68
Iqbal M (2001) Islamic and conventional banking in the nineties: a comparative study. Islam Econ Stud 8:1–27
Iqbal M, Molyneux P (2005) Efficiency in Islamic banking. In: Thirty years of Islamic banking. Palgrave Macmillan studies in banking and financial institutions. Palgrave Macmillan, London
Isik I (2007) Bank ownership and productivity developments: evidence from Turkey. Stud Econ Financ 24:115–139
Isik I, Hassan K (2002a) Technical, scale and allocative efficiencies of Turkish banking industry. J Bank Finance 26(4):719–766
Isik I, Hassan MK (2003) Efficiency, ownership and market structure, corporate control and governance in the Turkish banking industry. J Bus Financ Acc 30:1363–1421
Islam J, Rahman MA, Hasan MH (2013) Efficiency of Islamic banks a comparative study on South-East Asia and South Asian region. In: Proceedings of the 9th Asian business research conference, held on 20–21 December, 2013 at BIAM Foundation, Dhaka, Bangladesh

Islamic Financial Services Industry Stability Report (2019) Islamic Financial Services Board, Kuala Lumpur, Malaysia. https://www.ifsb.org/download.php?id=5231&lang=English&pg=/index.php
Ismail F, Abd. Majid MS, Ab. Rahim R (2013) Efficiency of Islamic and conventional banks in Malaysia. J Financ Rep Account 11(1):92–107
Issavi M, Tari F, Ansari SH, Amozad KH (2018) The relationship between the stability and technical efficiency of Iranian banks in the years (2004–2016)
Jarboui S (2016) Managerial psychology and transport firms efficiency: a stochastic frontier analysis. RMS 10(2):365–379
Jiang X, Yao Y, Feng W (2020) The effects of regulatory changes on efficiency and risk-taking behavior in Chinese banks: evidence from a metafrontier analysis. J Financ Stab 49:100757
Johnes J, Izzeldin M, Pappas V (2014) A comparison of performance of Islamic and conventional banks 2004–2009. J Econ Behav Organ 103:S93–S107
Johnes J, Izzeldin M, Pappas V (2009) The efficiency of Islamic and conventional banks in the Gulf Cooperation Council (GCC) countries: an analysis using financial ratios and data envelopment analysis. LUMS working papers series 2009/023, Lancaster University Management School
Kabir MN, Worthington AC (2017) The 'competition–stability/fragility'nexus: a comparative analysis of Islamic and conventional banks. Int Rev Financ Anal 50:111–128
Kablan S, Yousfi O (2003) What drives efficiency of Islamic banks among regions? J Appl Bus Res 29(5):1411–1420
Kader JM, Asaporta AJ, AL-Maghaireh A (2007) Comparative financial performance of Islamic banks vis-à-vis conventional banks in the UAE. Thunderbird Int Bus Rev 47(5):127–135
Kamarudin F, Badrul HS, Mohammad S, Rohani M (2008) Assessing production efficiency of Islamic banks and conventional bank Islamic windows in Malaysia. Int J Bus Manag 1(1):31–48
Kamarudin F, Sufian F, Nassir A (2016a) Global financial crisis, ownership and bank profit efficiency in the Bangladesh's state owned and private commercial banks. Contaduría y Administración 61(4):705–745
Kamarudin F, Sufian F, Nassir AM (2016b) Does country governance foster revenue efficiency of Islamic and conventional banks in GCC countries? Eur Med J Bus 11(2):181–211
Kamarudin F, Sufian F, Loong F, Anwar N (2017a) Assessing the domestic and foreign Islamic banks efficiency: insights from selected Southeast Asian countries. Future Bus J 3(1):33–46
Kamarudin F, Sufian F, Loong FW, Aina N, Anwar M (2017b) Assessing the domestic and foreign Islamic banks efficiency: insights from selected Southeast Asian countries. Future Bus J 3:33–46
Kao C (2014) Network data envelopment analysis: a review. Eur J Oper Res 239(1):1–16
Karim RAA (2001) International accounting harmonization, banking regulation, and Islamic banks. Int J Account 36(2):169–193
Kasman A (2005) Efficiency and scale economies in transition economies. Emerg Mark Finance Trade 41(2):60–81
Kassim SH, Majid MSA, Yusof RM (2009) Impact of monetary policy shocks on the conventional and Islamic banks in a dual banking system: evidence from Malaysia. J Econ Cooper Dev 30(1):41–58
Kenjegalieva K, Simper R, Weyman Jones T (2009) Efficiency of transition banks: inter-country banking industry trends. Appl Financ Econ 19(19):1531–1546
Khan M (1986) Islamic interest-free banking. IMF Staff Pap 33:1–27
Khan HUZ (2010) The effect of corporate governance elements on corporate social responsibility (CSR) reporting: empirical evidence from private commercial banks of Bangladesh. Int J Law Manag 52(2):82–109
Khan M, Mirakhor A (1987) Theoretical studies in Islamic banking and finance. IRIS Books, Houston
Khediri KB, Charfeddine L, Youssef SB (2015) Islamic versus conventional banks in the GCC countries: a comparative study using classification techniques. Res Int Bus Finance 33:75–98
Kumar S, Gulati R (2008) Evaluation of technical efficiency and ranking of public sector banks in India: an analysis from cross-sectional perspective. Int J Product Perform Manag 57(7):540–568
Kuran T (2004) Why the Middle East is economically underdeveloped: historical mechanisms of institutional stagnation. J Econ Perspect 18(3):71–90
Kyj L, Isik I (2008) Bank x-efficiency in Ukraine: an analysis of service characteristics and ownership. J Econ Bus 60:369–393
Lampe H, Hilgers D (2015) Trajectories of efficiency measurement: a bibliometric analysis of DEA and SFA. Eur J Oper Res 240(1):1–21
Lang G, Welzel P (1996) Efficiency and technical progress in banking. Empirical results for a panel of German Cooperative Banks. J Bank Finance 20:1003–1023

Laurenceson J, Qin F (2008) Has minority foreign investment in China's banks improved their cost efficiency? Chin World Econ 16(3):57–74
Le TD (2016) Do bank mergers and acquisitions improve technical efficiency of Vietnamese commercial banks? In: Paper presented at 28th Australasian finance and banking conference, PhD Forum, Sydney, Australia
Le TD (2017) Financial soundness of Vietnamese commercial banks: an CAMELS approach. Working paper
Lee TH, Chih SH (2013) Does financial regulation affect the profit efficiency and risk of banks? Evidence from China`s commercial banks. N Am J Econ Finance 26:705–724
Liu JS, Lu LY, Lu W-M (2016) Research fronts in data envelopment analysis. Omega 58:33–45
Lopes SM, Flor LM, Duarte A (2021) The impact of COVID-19 on the operational efficiency of European banks. Res Int Bus Financ 58:101376
Lozano-Vivas A, Pastor TJ, Pastor MJ (2002) An efficiency comparison of European banking systems operating under different environmental conditions. J Prod Anal 18:59–77
Magrianti T (2011) Perbandingan Efisiensi BUS dengan Bank Konvensional di Indonesia, Iqtishodia Jurnal Ekonomi Islam Republika, 25
Mahajan V, Nauriyal DK, Singh SP (2020) Domestic market competitiveness of Indian drug and pharmaceutical industry. RMS 14(3):519–559
Mahesh H, Rajeev M (2009) Producing financial services: an efficiency analysis of Indian commercial banks. J Serv Res 8(2):7–29
Majid MA, Nor NG, Said FF (2003) Efficiency of banks in Malaysia. In: Proceedings of the fifth international conference on Islamic Economics and Finance, 2, Bahrain, pp 405–416
Mamatzakis E, Staikouras C, Filippaki AK (2008) Bank efficiency in the new European Union member states: Is there convergence? Int Rev Financ Anal 17:1156–1172
Mamun MA, Lawrey R, Raza SA, Tchana FK (2021) The impact of COVID-19 pandemic on the banking sector: some evidence from Australia. Res Int Bus Financ 57:101329
Mateev M, Sahyouni A, Al-Masaeid T (2022) Bank performance before and during the COVID-19 crisis: Does efficiency play a role? Rev Manag Sci (Advance online publication)
Matousek R, Taci A (2004) Efficiency in banking: empirical evidence from the Czech Republic. Econ Plan 37:225–244
Maudos J, Pastor JM, Serrano L (1999) Total factor productivity measurement and human capital in OECD countries. Econ Lett 63(1):39–44
Maudos J, Pastor JM, Perez F, Quesada J (2002) Cost and profit efficiency in European banks. J Int Financ Mark Inst Money 12(1):33–58
Mester LJ (1996) A study of bank efficiency taking into account risk preferences. J Bank Finance 20:1025–1045
Metwally MM (1997) Economic consequences of applying Islamic principles in Muslim societies. Int J Soc Econ 24(7/8/9):941–957
Miah MD, Uddin H (2017) Efficiency and stability: a comparative study between Islamic and conventional banks in GCC countries. Future Bus J 3(2):172–185
Milhem MM, Istaiteyeh RMS (2015) Financial performance of Islamic and conventional banks: evidence from Jordan. Glob J Bus Res 9(3):27–41
Moher D, Liberati A, Tetzlaff J, Altman DG (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 151(4):264–269
Moher D, Liberati A, Tetzlaff J, Altman DG (2010) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg 8(5):336–341
Moin MS (2008) Performance of Islamic banking and conventional banking in Pakistan: a comparative study, finance (University of Skovde)
Mokhtar SA, Naziruddin A, Syed M-H (2006) Efficiency of Islamic banking in Malaysia: a stochastic frontier approach. J Econ Cooper 27(2):37–70
Mokhtar HSA, Abdullah N, Alhabshi SM (2007) Technical and cost efficiency of Islamic banking in Malaysia. Rev Islam Econ 11(1):5–40
Mokhtar HSA, Abdullah N, Alhabshi SM (2008) Efficiency and competition of Islamic banking in Malaysia. Humanomics 24(1):28–48
Molyneux P, Nguyen LH, Xie R (2013) Foreign bank entry in South East Asia. Int Rev Financ Anal 30:26–35
Montgomery H, Harimaya K, Takahashi Y (2014) To big to succeed? Banking sector consolidation and efficiency. J Int Financ Mark Inst Money 32:86–106

Mordor Intelligence (2021) Islamic finance market-growth, trends, Covid-19 impact and forecasts (2022–2027)
Mostafa M (2009) Modeling the efficiency of top Arab banks: A DEA–neural network approach. Expert Syst Appl 36(1):309–320
Moualhi M (2015) Efficiency in Islamic banking: evidence from MENA region. Int J Islamic Econ Finance Stud 1(2):5–21
Mukherjee K, Ray SC, Miller SM (2001) Productivity growth in large US commercial banks: the initial post-deregulation experience. J Bank Finance 25(5):913–939
Mukherjee A, Nath P, Pal MN (2002) Performance benchmarking and strategic homogeneity of Indian banks. Int J Bank Market 20(3):122–139
Najjar NJ (2013) Can financial ratios reliably measure the performance of banks in Bahrain. Int J Econ Finance 5(3):152–163
Nguyen T (2018) Diversification and bank efficiency in six ASEAN countries. Glob Finance J 37:57–78
Nguyen TPT, Nghiem SH, Roca E, Sharma P (2016) Bank reforms and efficiency in Vietnamese banks: evidence based on SFA and DEA. Appl Econ 48(30):2822–2835
Nienhaus V (1988) The performance of Islamic banks: trends and cases. In: Mallat C (ed) Islamic law and finance. Graham and Trotman, London
Nikiel E, Opiela T (2002) Customer type and bank efficiency in Poland: implications for emerging market banking. Contemp Econ Policy 20:255–271
Norris M, Oppenheim C (2007) Comparing alternatives to the Web of Science for coverage of the social sciences' literature. J Informet 1(2):161–169
Olgu O (2007) Productivity decomposition in European banking with accession economies: an application of parametric & nonparametric Malmquist techniques. Ph.D. thesis, University of Leicester, Management School, Leicester, UK
Olson D, Zoubi T (2008) Using accounting ratios to distinguish between Islamic and conventional banks in the GCC region. Int J Account 43(1):45–65
Olson D, Zoubi TA (2011) Efficiency and bank profitability in MENA countries. Emerg Mark Rev 12(2):94–110
Omar MA, Majid MSA, Rulindo R (2007) Efficiency and productivity performance of the National Private Banks in Indonesia. Gadjah Mada Int J Bus 9(1):1–11
Ong S, Theng LY, Teh B (2011) A comparison on efficiency of domestic and foreign banks in Malaysia: DEA approach. J Bus Manag Dyn 1(4):3–49
Oral M, Yolalan R (1990) An empirical study on measuring operating efficiency and profitability of bank branches. Eur J Oper Res 46(3):282–294
Ozkan-Gunay EN, Gunay ZN, Gunay G (2013) The impact of regulatory policies on risk taking and scale efficiency of commercial banks in an emerging banking sector. Emerg Mark Financ Trade 49:80–98
Paradi JC, Rovatt S, Zhu H (2011) Two-stage evaluation of bank branch efficiency using data envelopment analysis. Omega 39:99–109
Pasioursa F (2008) International evidence on the impact of regulations and supervision on banks` technical efficiency: an application of two-stage data envelopment analysis. Rev Quant Financ Account 30:187–223
Pastor JM (2002) Credit risk and efficiency in the European banking system: a three-stage analysis. Appl Financ Econ 12:895–911
Pastor J, Perez F, Quesada J (1997) Efficiency analysis in banking firms: an international comparison. Eur J Oper Res 98(2):395–407
Perera S, Skully M, Wickramanayake J (2007) Cost efficiency in South Asian banking: the impact of bank size, state ownership and stock exchange listings. Int Rev Finance 7(1–2):35–60
Quaranta AG, Raffani A, Visani F (2018) A multidimensional approach to measuring bank branch efficiency. Eur J Oper Res 266:746–760
Rahim SRM, Zakaria RH (2013) Comparison on stability between Islamic and conventional banks in Malaysia. J Islam Econ Bank Finance 9(3):131–149
Rahman ARA, Rosman R (2013) Efficiency of Islamic banks: a comparative analysis of MENA and Asian countries. J Econ Cooper Dev 34(1):63–92
Rahman ML, Hasan MM, Alam MN (2021) Risk and profitability analysis of Islamic and conventional banks during COVID-19: a case study from Bangladesh. J Islam Account Bus Res 12:564–592
Ramly Z, Chan SG, Mustapha MZ, Sapiei NS (2017) Women on boards and bank efficiency in ASEAN-5: the moderating role of the independent directors. RMS 11(1):225–250

Rekik M, Kalai M (2018) Determinants of banks' profitability and efficiency: Empirical evidence from a sample of Banking Systems. J Bank Financ Econ 1(9):5–23
Resti A (1997) Evaluating the cost-efficiency of the Italian banking system: what can be learned from the joint application of parametric and nonparametric techniques. J Bank Finance 21:221–250
Rosman R, Wahab N, Zainol Z (2014) Efficiency of Islamic banks during the financial crisis: an analysis of Middle Eastern and Asian countries. Pak Basin Finance J 28:76–90
Rossazana AR, Chiang SN (2016) Market structure and performance of Malaysian banking industry. J Financ Report Account 14(2):158–177
Rosyadi I, Fauzan, (2011) Komparatif Efisiensi Perbankan Syariah dan Perbankan Konvensional di Indonesia. Benefit Jurnal Manajemen Dan Bisnis 15(2):129–147
Saaid AE (2005) Allocative and technical inefficiency in Sudanese Islamic banks: an empirical investigation. In: Iqbal M, Wilson R (eds) Islamic perspectives on wealth creation. Edinburgh University Press, Edinburgh, pp 142–154
Saaid AEE, Rosly SA, Ibrahim MH, Abdullah N (2003) The X-efficiency of the Sudanese Islamic banks. IIUM J Econ Manag 11(2):123–141
Saeed M, Izzeldin M (2016) Examining the relationship between default risk and efficiency in Islamic and conventional banks. J Econ Behav Organ 132:127–154
Saha A, Ahmad NH, Dash U (2015) Drivers of technical efficiency in Malaysian banking: a new empirical insight. Asian-Pac Econ Lit 29(1):161–173
Said A (2012) Comparing the change in efficiency of the Western and Islamic banking systems. J Money Invest Bank 23:149–180
Şakar B (2006) A study on efficiency and productivity of Turkish banks in Istanbul stock exchange using Malmquist DEA. J Am Acad Bus 8(2):145–155
Samad A (2004) Performance of interest free Islamic banks vis-à-vis interest-based conventional banks of Bahrain. J Econ Manag 12(2):1–25
Samad A, Hassan MK (1999) The performance of Malaysian Islamic Bank during 1984–1997, an exploratory study. Int J Islam Financ Serv 1(3):1–14
San-Jose L, Retolaza J, Torres Pruñonosa J (2014) Efficiency in Spanish banking: a multistakeholder approach analysis. J Int Financ Mark Inst Money 32:240–255
Sanyal P, Shankar R (2011) Ownership, competition and bank productivity: an analysis of Indian banking in the post reform period. Int Rev Econ Finance 20(2):225–247
Sarker MA (1999) Islamic banking in Bangladesh: performance, problems, and prospects. Int J Islam Financ Serv 1(3):15–35
Sellers-Rubio R, Más-Ruiz FJ (2015) Economic efficiency of members of protected designations of origin: sharing reputation indicators in the experience goods of wine and cheese. RMS 9(1):175–196
Shah SAA, Sukmana R, Fianto BA (2021) Efficiencies in Islamic banking: a bibliometric and theoretical review. Int J Product Qual Manag 32(4):458–501
Shaikh SA, Memon SM (2021) Impact of COVID-19 on financial performance of banks: empirical evidence from Pakistan. J Asian Finance Econ Bus 8(2):325–334
Shamsuddin A, Xiang D (2012) Does bank efficiency matter? Market value relevance of bank efficiency in Australia. Appl Econ 44(27):3563–3572
Sharma D, Sharma AK, Barua MK (2013) Efficiency and productivity of banking sector: a critical analysis of literature and design of conceptual model. Qual Res Financ Mark 5(2):195–224
Shawtari F, Ariff M, Abdul Razak S (2019) Efficiency and bank margins: a comparative analysis of Islamic and conventional banks in Yemen. J Islam Account Bus Res 10(1):50–72
Singh D, Fida B, A. (2015) Technical efficiency and its determinants: an empirical study on banking sector of Oman. Probl Perspect Manag 13(1):168–175
Srairi S (2010) Cost and profit efficiency of conventional and Islamic banks in GCC countries. J Prod Anal 34(1):45–62
Sufian F (2006) The efficiency of the Islamic banking industry in Malaysia: foreign vs domestic banks. Rev Islam Econ 10(2):27–53
Sufian F (2009a) Determinants of bank efficiency during unstable macroeconomic environment: empirical evidence from Malaysia. Res Int Bus Finance 23(1):54–77
Sufian F (2009b) The impact of the Asian financial crisis on bank efficiency: the 1997 experience of Malaysia and Thailand. J Int Dev 22:866–889
Sufian F (2011a) Benchmarking the efficiency of the Korean banking sector: a DEA approach. Benchmarking Int J 18(1):107–127

Sufian F (2011b) The nexus between financial sector consolidation, competition and efficiency: empirical evidence from the Malaysian banking sector. IMA J Manag Math 22(4):419–444
Sufian F, Akbar Noor Mohamad Noor M (2009) The determinants of Islamic banks' efficiency changes: empirical evidence from the MENA and Asian banking sectors. Int J Islam Middle East Finance Manag 2(2):120–138
Sufian F, Kamarudin F (2014) Efficiency and returns to scale in the Bangladesh Banking Sector: empirical evidence from the slack-based DEA method. Eng Econ 25(5):549–557
Sufian F, Kamarudin F (2016) The impact of globalisation on the performance of banks in South Africa. Rev Int Bus Strateg 26(4):517–542
Sufian F, Kamarudin F, Noor NHHM (2012) Determinants of revenue efficiency in the Malaysian Islamic banking sector. J King Abdulaziz Univ Islam Econ 25:2
Sufian F, Kamarudin F, Noor NHHM (2013) Assessing the revenue efficiency of domestic and foreign Islamic banks: empirical evidence from Malaysia. Jurnal Pengurusan 37(1):77–90
Sufian F, Kamarudin F, Nassir A (2016) Determinants of efficiency in the Malaysian banking sector: Does bank origins matter? Intellect Econ 10:38–54
Sufian F, Abdul Majid MZ (2007) Bank ownership, characteristics and performance: a comparative analysis of domestic and foreign Islamic banks in Malaysia. Munich Personal RePEc Archive
Suzuki Y, Uddin SS, Islam AR (2020) Incentives for conventional banks for the conversion into Islamic banks: evidence from Bangladesh. J Islam Account Bus Res 11(2):273–287
Swank J (1996) Theories of the banking firm: a review of the literature. Bull Econ Res 48(3):173–207
Tanna S (2009) The impact of foreign direct investment on total factor productivity growth: international evidence from the banking industry. Manag Financ 35(3):297–311
Tecles PL, Tabak BM (2010) Determinants of bank efficiency: the case of Brazil. Eur J Oper Res 207(3):1587–1598
Thoraneenitiyan N, Avkiran N (2009a) Measuring the impact of restructuring and country-specific factors on the efficiency of post-crisis East Asian banking systems: integrating DEA with SFA. Socioecon Plan Sci 43(4):240–252
Thoraneenitiyan N, Avkiran NK (2009b) Measuring the impact of measuring bank performance in the current evolving financial marketplace structuring and country-specific factors on the efficiency of post-crisis east Asian banking systems: integrating DEA with SFA. Socioecon Plan Sci 43(4):240–252
Tranfield D, Denyer D, Smart P (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review. Br J Manag 14(3):207–222
Vieira E, Gomes J (2009) A comparison of Scopus and Web of Science for a typical university. Scientometrics 81(2):587–600
Viverita V, Brown K, Skully M (2007) Efficiency analysis of Islamic banks in Africa, Asia and the Middle East. Rev Islam Econ 11(2):5–16
Wang MH, Huang TH (2007) A study on the persistence of Farrell's efficiency measure under a dynamic framework. Eur J Oper Res 180:1302–1316
Wang H, Zhu D, Koppenjan J (2015) A research on relations between governance modes and efficiency in China's urban bus transport service. RMS 9(4):661–680
Wang WK, Lu WM, Kweh QL, Nourani M, Hong RS (2021) Interlocking directorates and dynamic corporate performance: the roles of centrality, structural holes and number of connections in social networks. RMS 15(2):437–457
Wanke P, Abul Kalam AMD, Barros CP (2016a) Predicting efficiency in Malaysian Islamic banks: a two-stage TOPSIS and neural networks approach. Res Int Bus Finance 36:485–498
Wanke P, Azad M, Barros C (2016b) Efficiency factors in OECD banks: a ten-year analysis. Expert Syst Appl 64:208–227
Wanke P, Azad M, Barros C, Hassan M (2016c) Predicting efficiency in Islamic banks: an integrated multicriteria decision making (MCDM) approach. J Int Financ Mark Inst Money 45:126–141
Wanke P, Abul Kalam Azad M, Emrouznejad A, Antunes J (2019) A dynamic network DEA model for accounting and financial indicators: a case of efficiency in MENA banking. Int Rev Econ Finance 6:52–68
Weill L (2004) Measuring cost efficiency in European banking: a comparison of frontier techniques. J Prod Anal 21:133–152
Weill L (2009) Convergence in banking efficiency across European countries. J Int Financ Mark Inst Money 19(5):818–833

Wijesiri M, Martínez-Campillo A, Wanke P (2019) Is there a trade-off between social and financial performance of public commercial banks in India? A multi-activity DEA model with shared inputs and undesirable outputs. RMS 13(2):417–442
Williams J, Nguyen N (2005) Financial liberalisation, crisis and restructuring: a comparative study of bank performance and bank governance in South East Asia. J Bank Finance 29(8–9):2119–2154
Willison B (2009) Technology trends in Islamic investment banking. Islam Finance News 6:19
Yannick GZS, Hongzhong Z, Thierry B (2016) Technical efficiency assessment using data envelopment analysis: an application to the banking sector of Cote d`Ivoire. Procedia Soc Behav Sci 235:198–207
Yildirim I (2015) Financial efficiency analysis in Islamic banks: Turkey and Malaysia models. J Econ Finance Account 2(3):289–300
Yildirim HS, Philippatos G (2007) Efficiency of banks: recent evidence from the transition economies of Europe, 1993–2000. Eur J Finance 13(2):123–143
Yilmaz A, Gunes N (2015) Efficiency comparison of participation and conventional banking sectors in Turkey between 2007–2013. Procedia Soc Behav Sci 195:383–392
Yılmaz D (2009) Islamic finance during and after the global financial crisis Islamic finance—during and after the global financial crisis Istanbul
Yin H, Yang J, Mehran J (2013) An empirical study of bank efficiency in China after WTO accession. Glob Finance J 24:153–170
Yudistira D (2004) Efficiency in Islamic banking: an empirical analysis of eighteen banks. Islam Econ Stud 12(1):2–19
Zainal SN, Ismail M (2012) Islamic banking efficiency: a DEA approach. In: Paper presented at 3rd international conference on business and economics research proceeding, 12–13 March, Bandung, Indonesia
Zhang J, Wang P, Qu B (2012) Bank risk taking, efficiency, and law enforcement: evidence from Chinese city commercial banks. China Econ Rev 23:284–295
Zhao T, Murinde V (2011) Bank deregulation and performance in Nigeria. Afr Dev Rev 23(1):30–43
Zhu X, Hu R, Zhang C, Shi G (2021) Does Internet use improve technical efficiency? Evidence from apple production in China. Technol Forecast Soc Chang 166:120662
Zimková E (2014) Technical efficiency and super-efficiency of the banking sector in Slovakia. Procedia Econ Finance 12:780–787
Zuhroh I, Ismail M, Maskie G (2015) Cost efficiency of Islamic banks in Indonesia: a stochastic frontier analysis. Procedia Soc Behav Sci 211:1122–1131

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