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Citation for published version:

Iddouch, K, El Badraoui, K & Ouenniche, J 2023, 'Landscape of research on the efficiency profiles of Islamic banks using DEA: Survey, classification and critical analysis of the literature', *International Journal of Business*, vol. 28, no. 3. [https://doi.org/10.55802/IJB.028\(3\).004](https://doi.org/10.55802/IJB.028(3).004)

Digital Object Identifier (DOI):

[10.55802/IJB.028\(3\).004](https://doi.org/10.55802/IJB.028(3).004)

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Publisher's PDF, also known as Version of record

Published In:

International Journal of Business

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Landscape of Research on the Efficiency Profiles of Islamic Banks using DEA: Survey, Classification and Critical Analysis of the Literature

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ABSTRACT

The purpose of this survey paper is to paint the landscape of research on the efficiency profiles of Islamic banks with a focus on Data Envelopment Analysis (DEA) studies. This paper uses a comprehensive systematic literature review to survey 80 relevant papers published between 2004 and 2021. Such landscape is organised around classifications of types of measures of efficiency and their analyses, types of DEA analyses, types of DEA modelling frameworks and models, evaluation approaches and choice of variables for the specification of DEA models, and drivers of efficiency. To the best of our knowledge, no survey on the drivers of efficiency has ever been conducted. In this paper, we overcome this gap in the context of Islamic banking and back up previous findings with relevant theories. In addition, we unify the literature terminology-wise. Finally, a critical analysis of the literature is provided along with methodological gaps, inconsistencies, and future research directions.

JEL Classification: G21, C44, C61

Keywords: DEA, efficiency, Islamic banks, drivers of efficiency, literature survey

I. INTRODUCTION

The banking industry, as a critical player in the financial sector, is one of the most important drivers of financial stability and economic growth in both developed and developing countries. It stems its growing pivotal role from its multifaceted functions consisting of primary functions (i.e., a bank as a financial intermediary and as a money creator) and secondary functions (i.e., insurance of liquidity and monitoring of credit risk). Given banks' critical role, there has been an increasing interest among various stakeholders such as regulators, policymakers, investors, and academics to identify their best practices and to assess their performance profiles. As pointed out by several authors (e.g., Spong et al., 1995; Berger and Mester, 2003), global restructuring trends in the financial industry (e.g., banking consolidation and deregulation movements, rapid technological advances in banking operations) along with the increased competition for financial services suggest that an increasingly efficient and effective use of resources is key to banks' success and survival. In addition, the financial stability of a banking system depends on the ability of banks to operate closer to their best-practice frontier; therefore, greater efficiency is expected to translate into enhanced stability through reduced likelihood of bank default and improved asset quality (Berger and DeYoung, 1997). Furthermore, the investigation of bank efficiency is useful in identifying sources of inefficiencies so that stakeholders such as policymakers and bank managers may undertake reforms and develop appropriate strategic actions. Also, efficiency studies provide valuable benchmarking information to bank managers, which can be exploited to improve bank performance (Izzeldin et al., 2021). Much like Conventional banks, the efficiency of Islamic banks is an important aspect to investigate especially since the findings of studies are mixed; to be more specific, there is no clear-cut evidence that Islamic banks are equally, more, or less efficient (respectively, resilient) than Conventional banks.

The Sharia-compliant business model of Islamic banks provides ground for support of both higher and lower efficiency as compared to their conventional peers (Beck et al., 2013; Bitar et al., 2020). On one hand, Islamic banks are likely to experience higher efficiency levels than Conventional banks, as they are involved in asset-based financing – a robust link between finance and the real economy – and are therefore less exposed to losses related to financial derivatives or conventional financial institutions' securities. Furthermore, in recent years, Islamic banks have paid much attention to the improvement of managerial competencies and the reputation of Islamic financial products, enabling them to recoup efficiency lost due to *modus operandi* (Johnes et al., 2014). On the other hand, Islamic banks are likely to experience lower efficiency levels than Conventional banks as, for example, many Islamic financial products are tailored (less standardised) to fit clients' requirements, which results in an increase of Islamic banks' administrative and operational costs (Johnes et al., 2014); Islamic banks are required to comply with international regulatory standards (e.g., Basel Accords) as well as with Islamic regulatory frameworks (e.g., IFSB, AAOIFI), which may result in additional compliance costs (Bitar et al., 2017). In a nutshell, there is no clear-cut evidence on whether Islamic banks are equally, more, or less efficient than Conventional banks. This has given rise to numerous empirical studies on Islamic banks' efficiency, with the objective of assessing their efficiency profiles and identifying their efficiency drivers. Traditionally, the efficiency profiles of banks have been assessed using total

productivity measures (i.e., ratio of a weighted linear combination of outputs to a weighted linear combination of inputs); however, these measures make use of subjective weights which are fixed across all banks. To overcome these issues, Data Envelopment Analysis (DEA) was proposed by Charnes et al. (1978). DEA is a non-parametric, mathematical programming-based, frontier-oriented, benchmarking methodology for the relative performance evaluation of entities or units of assessment commonly referred to in the DEA jargon as Decision Making Units (DMUs). Alternative non-parametric methods to DEA would be Multi-Criteria Decision Analysis (MCDA) methods or more specifically MCDA benchmarking methods where the emphasis is on ranking banks. Unlike DEA, MCDA methods are not concerned with the efficiency profiles of banks. Alternative parametric methods to DEA would be stochastic frontier analysis (SFA). Unlike DEA which benchmarks against the best performers, SFA benchmarks against the average performer. DEA has proved very popular in assessing the efficiency profiles of banks – whether Conventional or Islamic, with hundreds of studies conducted so far. In addition, given data/sample size limitations in Islamic banking, a non-parametric methodology such as DEA is more desirable. To the best of our knowledge, six survey papers by Hassan and Aliyu (2018), Chaffai (2021), Ikra et al. (2021), Maradin et al. (2021), Rusydiana et al. (2021) and Shah et al. (2021) covering DEA analyses in Islamic banking have been published so far – see Table 1 for a summary of key points. Despite the merit of each of these surveys, our survey paper differs significantly from them as the focus of ours is on a detailed reporting and analysis of the literature on Islamic banking efficiency, using DEA as the main methodology along with detailed classifications of types of measures of efficiency and their analyses, types of DEA analyses, types of DEA modelling frameworks and models, evaluation approaches and choice of variables for the specification of DEA models, and drivers of efficiency.

Of particular importance to existing and newcomers to the field are the following contributions. First, we provide a detailed analysis of all evaluation approaches or bank behaviour models, their typical inputs and outputs, a new classification of the inputs and outputs used in empirical studies into meaningful categories, and some implementation issues of these approaches in the Islamic banking context. Second, we provide a new classification of the drivers of Islamic banks' efficiency along with an in-depth analysis of the findings of empirical studies and potential explanations in light of relevant theories. The aim of the above-mentioned classifications is to provide researchers in the field, especially newcomers, with tools to assist them with the design decisions of their own empirical studies. Third, we provide a critical analysis of the literature covered in our survey both methodologically and in terms of their empirical findings and attempt to explain the reasons behind mixed findings. Fourth, we identify methodological shortcomings and research gaps as well as terminological issues, which are meant to improve future methodological choices and to help in identifying potential future research directions. Last, but not least, we provide detailed summary tables of the papers covered in our survey which provide an outlook of aspects of the literature at a glance. In sum, our survey provides an up-to-date comprehensive painting of the landscape of research on efficiency of Islamic banking using DEA analyses along with a variety of useful classifications and tables to inform researchers' decisions when designing their empirical studies as well as a critical analysis of several aspects of research on Islamic banking efficiency. The remainder of this paper unfolds as follows. Section 2 discusses the research methodology used to conduct this survey. Section 3 provides a survey of the

literature on the efficiency profiles of Islamic banks along with several classifications, and Section 4 provides a critical analysis of the literature including methodological shortcomings and inconsistencies as well as research gaps. Finally, Section 5 concludes the paper.

Table 1
Summary of Key Points of Previous Survey Papers on Islamic Banking Efficiency

Author(s) & Year	Survey methodology	Period of analysis	Sample size	Focus of the survey
Hassan and Aliyu (2018)	Traditional literature review	1983 – 2017	The coverage of Islamic banks' efficiency is limited to 31 papers, of which 16 papers use a DEA methodology	The survey paper provides a review of the empirical literature on Islamic banking covering a wide range of topics including the efficiency of Islamic banks. It mainly reports a broad classification of methodologies along with a brief summary of some of the main findings and highlights the mixed nature of these findings. It also identifies some research gaps and future research directions.
Chaffai (2021)	Meta-regression analysis	2006 – 2019	35 papers, of which 18 papers use DEA methodology	The survey paper focuses on comparative efficiency studies between Islamic banks and Conventional banks using DEA and SFA methodologies. The coverage of this paper is limited and focuses only on comparative studies, and thus ignores papers focusing on Islamic banks only. In addition, it highlights the mixed nature of the findings and performs a meta-regression analysis in an attempt to explain such discrepancies in the findings.
Ikra et al. (2021)	Bibliometric analysis and content analysis	2000 – 2020	278 papers, of which the number of DEA-based studies is not provided	The survey paper uses bibliometric and content analysis techniques to identify research streams and influential authors and journals as well as some gaps in the literature on Islamic banking efficiency.
Maradin et al. (2021)	Traditional literature review	2004 – 2020	30 paper using DEA methodology	The survey paper provides a brief descriptive account on efficiency and productivity studies in Islamic banking industry using DEA.
Shah et al. (2021)	Bibliometric analysis and content analysis	2003 – 2019	99 papers, of which the number of DEA-based studies is not provided	The survey paper focuses on both efficiency and productivity of Islamic banks using various methodological frameworks (e.g., DEA, SFA). It highlights regional efficiency trends and drivers of efficiency. It also provides an overall analysis integrating various themes emerging from literature.
Rusydiana et al. (2021)	Bibliometric analysis	2004 - 2019	201 papers including both DEA studies and DEA-based MPI studies	The survey paper focuses on both efficiency and productivity of Islamic banks considering both DEA and DEA-based MPI methodologies. It provides general descriptive analytics about trends of the efficiency and productivity topic, the covered topics, visualisation, and other descriptive statistics.

II. RESEARCH METHODOLOGY

The literature is surveyed using a comprehensive systematic literature review to summarize, classify and analytically criticise the relevant literature on efficiency

assessment in the Islamic banking industry using DEA as the main methodology. To proceed, our selection process of research studies on DEA in Islamic banking to cover in our survey is performed into two stages: (1) identification and retrieval of papers from Web of Science (WoS) database, and (2) identification and retrieval of supplementary papers from Google Scholar, ResearchGate and SSRN. The WoS core collection database is used as the main source of information for our literature survey. With considerable care, we looked for and retrieved research studies on DEA in Islamic banking from this database. This search process began with the use of rigorous, well-defined, and combined keywords to ensure that no relevant material is missed. Three main attempts of the keywords have been carried out. The first attempt includes “DEA” AND “efficiency” AND “Islamic banks”; the second attempt includes “Islamic banking” AND “DEA”; and the third attempt includes “data envelopment analysis” AND “Islamic banks” AND “efficiency”. The papers were extracted in April 2020, followed by several monthly systematic updates until December 2021. The outcome was 67 documents consisting of 56 published articles, 6 proceedings papers, 4 early access articles, and 1 book chapter. All the documents are published in the English language. The 67 documents were then carefully screened resulting in 43 most relevant papers to our survey. The 21 papers discarded were out of the scope of our study (e.g., consider only Conventional banks, focus on productivity rather than efficiency), and 3 papers with no full text available. Although WoS is the largest citation-based academic database available, some DEA papers published in other journals are not encompassed in this database (Lampe and Hilgers, 2015). Therefore, Google Scholar, ResearchGate, and SSRN were used to supplement our sample with 37 additional relevant papers, which resulted in a final sample of 80 papers published over the period 2004-2021. Figure (a) in Appendix A depicts the distribution of DEA papers in Islamic banking in our final sample and clearly shows that the publications in this area tend to follow a cyclical pattern with an increasing trend over time.

III. LANDSCAPE OF RESEARCH ON THE EFFICIENCY PROFILES OF ISLAMIC BANKS

Our survey of the academic literature on the efficiency of Islamic banks revealed, on one hand, that the research problems addressed are mainly concerned with (1) the assessment of the efficiency of Islamic banks over a specific period of analysis and (2) the comparison of the efficiency of Islamic banks and their Conventional counterparts over a specific period of analysis. On the other hand, the following research questions were addressed: How does the efficiency of Islamic banks, or both Islamic and Conventional banks, behave over a specific period of analysis? What are the sources of inefficiencies of Islamic banks, or both Islamic and Conventional banks? How does the efficiency of Islamic banks, or both Islamic and Conventional banks, behave around specific events? Are there any significant differences in efficiency between different groups of banks (e.g., Islamic vs. Conventional) or categories of bank features (e.g., foreign vs. domestic Islamic banks)? What drives the efficiency profiles of Islamic banks? Do the drivers of efficiency differ across different groups of banks or different categories of features? In the remainder of this section, we shall summarise the literature related to the main research problems and questions.

A. Types of Efficiencies, Their Analyses and Their Drivers

Several types of efficiencies were investigated; namely, overall technical efficiency (OTE), as estimated by CCR models (e.g., Yudistira, 2004; Johnes et al., 2009; Kaffash et al., 2018; Wanke et al., 2019; Alsharif, 2021), pure technical efficiency (PTE), as estimated by BCC models (e.g., Grigorian and Manole, 2005; Hassan, 2006; Sufian and Habibullah, 2010; Kaffash et al., 2020), scale efficiency (SE), as measured by the ratio of OTE to PTE (e.g., Hassan, 2006; Mobarek and Kalonov, 2014; Belanès et al., 2015; Shahwan and Habib, 2021), cost efficiency (CE), as estimated by cost-based objective DEA models (e.g., Hassan, 2006; Mokhtar et al., 2007; Johnes et al., 2014; Anagnostopoulos et al., 2020), revenue efficiency (RE), as estimated by revenue-based objective DEA models (e.g., Hassan, 2006; Al-Khasawneh et al., 2012; Kamarudin et al., 2014; Alsharif, 2021), profit efficiency (PE), as estimated by profit-based objective DEA models (e.g., Hassan, 2006; Sufian et al., 2013; Alqahtani et al., 2017), and allocative efficiency (AE), as measured by the ratio of CE to OTE (e.g., Ahmad and Luo, 2010; Batir et al., 2017). The distribution of the 80 DEA studies on Islamic banking covering each of these efficiency measures is depicted in Figure (b) in Appendix A, which suggest that these studies on Islamic banking are well diversified in that they respond to the informational needs of a variety of stakeholders including managers, investors, and regulators. To be more specific, managers are a priori interested in all these types of efficiencies; however, in practice, they tend to prioritise PTE, as it reflects their managerial skills, and PE, as it affects their bonuses. On the other hand, investors tend to prioritise PE; however, the major shareholders such as institutional investors or insiders go beyond PE to consider for example PTE, OTE and SE to name a few. Finally, regulators tend to prioritise CE, as it affects their regulatory policies and the efficiency of banking regulations.

The efficiency measures or scores mentioned above were then analysed by relevant category or group to find out whether there are any significant differences in efficiency between different groups of banks or categories of features. The different groups of banks that have been compared were chosen based on (1) the type of bank; i.e., Islamic vs. Conventional banks (e.g., Grigorian and Manole, 2005; Kaffash et al., 2018; Wanke et al., 2019; Azad et al., 2021), (2) the type of operating structure (*modus operandi*) of the bank; i.e., fully-fledged Islamic banks vs. Islamic windows (e.g., Mokhtar et al., 2007; Salami and Adeyemi, 2015), where Islamic windows refer to Conventional banks offering Islamic banking products and services, and (3) the geographic location or countries they operate in, which could be divided into four main categories: (a) the first category consists of single country-focused studies (e.g., Mokhtar et al., 2007; Yilmaz and Güneş, 2015; Abdul-Wahab and Haron, 2017), (b) the second category consists of multi-country focused studies (e.g., Grigorian and Manole, 2005; Noor and Ahmad, 2012a; Wanke et al., 2019), (c) the third category consists of regional focused studies (e.g., Al-Muharrami, 2008; Alqahtani et al., 2017; Zeineb and Mensi, 2018), and (d) the fourth and last category consists of multi-region focused studies comparing the efficiency scores of Islamic banks in different regions (e.g., Yudistira, 2004; Sufian et al., 2008).

As to the categories of bank features, the efficiency scores have been analysed based on (1) the ownership type of the bank; e.g., domestic vs. foreign, state-owned vs. privately-owned (e.g., Alqahtani et al., 2017; Anagnostopoulos et al., 2020), (2) the size of the bank; i.e., small vs. large/big (e.g., Yudistira, 2004; Alsharif, 2021), (3) the age of

the bank; i.e., old vs. new (e.g., Hassan et al., 2009), (4) the listing status of the bank; i.e., quoted vs. unquoted banks (e.g., Johnes et al., 2014), and (5) whether a bank was involved in a mergers and acquisitions (M&A) activity; i.e., merged vs. unmerged banks (Wanke et al., 2019).

Other studies were concerned with specific events and their potential impact on bank efficiency. These events could be divided into several categories depending on whether they are global, regional, or country-specific. Examples of events considered include financial crises such as the global financial crisis (GFC) of 2007-2009 (e.g., Rosman et al., 2014; Belanès et al., 2015; Asmild et al., 2019), Asian Financial Crisis (AFC) of 1997-1998 (Noor and Ahmad, 2012b), Persian Gulf political crisis of 2003 (Kaffash et al., 2020), De Novo foreign banks entry on the Malaysian Islamic banking industry (Sufian and Habibullah, 2010), and financial liberalisation (Mokhtar et al., 2008).

Another category of studies is concerned with identifying the drivers of efficiency (e.g., Yudistira, 2004; Assaf et al., 2011; Alam, 2013; Johnes et al., 2014; Alqahtani et al., 2017; Batir et al., 2017; Daly and Frikha, 2017; Kaffash et al., 2018; Shawtari et al., 2018; Zeineb and Mensi, 2018; Kamarudin et al., 2019; Wanke et al., 2019; Kaffash et al., 2020) and finding out whether they differ across different types of banks (e.g., Hassan, 2006; Abu-Alkheil et al., 2012; Rahman and Rosman, 2013; Shawtari et al., 2015; Alqahtani et al., 2017; Miah and Uddin, 2017; Mezzi, 2018; Shawtari et al., 2018) or different categories of features (e.g., Yudistira, 2004; Alqahtani et al., 2017; Samad, 2019). The identification of drivers of efficiency is mainly undertaken using regression frameworks such as Pooled or Panel regressions (OLS, GLS, GMM, fixed effects, random effects) (e.g., Mokhtar et al., 2007; Rahman and Rosman, 2013; Johnes et al., 2014; Kamarudin et al., 2016; Daly and Frikha, 2017; Kaffash et al., 2018; Kamarudin et al., 2019; Mohd Noor et al., 2020), Seemingly Unrelated Regression (Alam, 2013; Zeineb and Mensi, 2018), Tobit censored regression (e.g., Sufian and Abdul-Majid, 2008; Noor and Ahmad, 2012a; Noor and Ahmad, 2012b; Rosman et al., 2014; Abbas et al., 2016), Bootstrapped truncated regression (Assaf et al., 2011; Alqahtani et al., 2017), and a Robust regression methodology which combines bootstrapped Tobit, Simplex, Beta, and Simar and Wilson truncated bootstrapped regressions (Wanke et al., 2019).

B. Types of DEA Analyses and Modelling Frameworks

In terms of methodological approaches for assessing the efficiency profiles of banks, two main approaches stand out as the dominant methodological frameworks, namely, DEA and SFA. Recall that DEA is a non-parametric methodology, whereas SFA is a parametric one. Within the DEA-based studies, which is the focus of our survey, further typical classifications of the literature are around the type of DEA analysis, i.e., single stage analyses, two-stage analyses, three-stage analyses, and metafrontier analyses, and the type of DEA models, i.e., static black-box models, dynamic black-box models, static network models, and dynamic-network models.

In terms of type of DEA analysis, single stage analyses, which aim at assessing the efficiency profiles of banks or equivalently estimating their efficiency scores by solving a specific DEA model, were predominantly used in the literature (e.g., Grigorian and Manole, 2005; Al-Muharrami, 2008; Bahrini, 2017; Asmild et al., 2019), followed by two-stage analyses which aim at identifying the drivers of efficiency by regressing in the second stage the efficiency scores computed in the first stage on a set of potential

drivers using a specific regression framework (e.g., Yudistira, 2004; Rosman et al., 2014; Batir et al, 2017; Kaffash et al., 2020). It is worth mentioning that in the DEA literature, there are terminological issues regarding two-stage DEA analyses and models. As pointed out by Henriques et al. (2020) in a recent survey and critical analysis of two-stage DEA in banking, there are two types of two-stage DEA analyses referred to by the authors as internal two-stage DEA models and external two-stage DEA models, where the former refers to network DEA models where the internal production process is modelled as a two-stage process, whereas the latter refers to the actual two-stage DEA analysis where the efficiency scores are estimated in the first stage and then in the second stage these scores are regressed on potential drivers. Our use of two-stage DEA analysis terminology is consistent with the external one. As to three-stage analyses, where one is concerned with purging the variables used for the specification of DEA models from the effect of the environment, so far, no research studying the Islamic banking context has ever used this type of analysis. Note that three-stage analyses are designed to address the issue of heterogeneity of the operating environments of banks especially in multi-country or multi-region studies. As to the heterogeneity of Islamic banks due to their characteristics or features, metafrontier analyses are most appropriate for addressing this type of heterogeneity; however, only one study by Johnes et al. (2014) adopted this type of DEA analysis in Islamic banking. See Figure (c) in Appendix A for the distribution of DEA studies on Islamic banking by type of DEA analysis.

As to the type of DEA models, static black-box models (i.e., CCR, BCC) were predominantly used. In their study, Azad et al. (2021) opened the black-box by using a static network SBM model to compute the efficiency scores of Malaysian Islamic and Conventional banks, whereas Wanke et al. (2019) took account of both the internal structure of banks and the time dynamics by using a dynamic-network SBM model to estimate the efficiency scores of banks. To the best of our knowledge, no efficiency study of Islamic banks used an actual dynamic black-box model to estimate the efficiency scores of banks except for Shawtari et al. (2015, 2018) who used black-box window analysis to unveil time dynamics of efficiency.

C. Evaluation Approaches and the Choice of Variables for DEA Models' Specification

The design of a DEA analysis and its findings depend on various decisions or choices made by the researcher or analyst. Amongst these choices, the type of evaluation approach, also referred to as bank behaviour model (Ahn and Le, 2014), is one of the most important choices as it shapes the selection of the key variables for the specification of a DEA model. How banks are conceptualised has been a topic of debate for several decades. The banking literature suggests that two main views of banks are mostly adopted (Ahn and Le, 2014). The first view considers banks as rational investors and portfolio theory is used for their analysis; in sum, the focus of banks is on managing financial assets and thus banks are looked at from a pure financial perspective. The second view considers banks as financial firms and theories of the firm are used for their analysis; in sum, the focus of banks is on managing operations and thus banks are looked at from a pure operating perspective and therefore are involved in the process of transforming inputs into outputs, which is more suitable for DEA studies. The general banking literature classifies the efficiency evaluation perspectives or approaches into six

categories; namely, the intermediation approach or IA for short (e.g., Ferrier and Lovell, 1990; Favero and Papi, 1995; Berger and Humphrey, 1997; Berger and Mester, 2003; Drake et al., 2006), the asset approach or AA for short (e.g., Favero and Papi, 1995), the production approach or PA for short (e.g., Ferrier and Lovell, 1990; Berger and Humphrey, 1997), the profit-oriented approach or POA for short (e.g., Berger and Mester, 2003), the value-added approach or VAA for short (e.g., Pastor et al., 1997), and the user-cost approach or UCA for short (e.g., Hancock, 1985). However, to the best of our knowledge, in the Islamic banking literature only four types of approaches were adopted; namely, IA (e.g., Yudistira, 2004; Hassan, 2006; Johnes et al., 2014; Kaffash et al., 2018), PA (e.g., Mostafa, 2011; Musa et al., 2020), AA (Shah and Masood, 2017), and a hybrid approach (HA) consisting of a combination of PA, IA and POA modelled as divisions of a network (Azad et al., 2021). We refer the reader to Table 2 for a summary description of each approach including its conceptual model and typical inputs and outputs used by researchers for their implementations of the conceptual models. Figure (d) in Appendix A depicts the distribution of the conceptual models identified in the Islamic banking literature using DEA, where IA stands out to be the most employed approach, followed then by PA, AA, and HA, which are the least used ones. This is consistent with the findings of several literature surveys in the Conventional banking context (e.g., Ahn and Le, 2014; Ahmad et al., 2020; Henriques et al., 2020).

Note that IA is by far the most commonly used perspective, as evidenced in the comprehensive reviews by Berger and Humphrey (1997) and Fethi and Pasiouras (2010). In Islamic banking efficiency literature, our review has further confirmed its widest usage – see Figure (d) in Appendix A on the proportions of evaluation approaches used in Islamic banking efficiency literature using DEA. IA views banks as financial intermediaries in the economy (Sealey and Lindley, 1977), takes account of information from both the balance sheet and the income statement which are publicly available and can be easily accessed by the researcher, and can take account of off-balance sheet information (e.g., Al-Muharrami, 2008; Bader et al., 2008; Hassan et al., 2009; Batir et al., 2017). Furthermore, this approach effectively considers the interest-related activities that differentiate banks from other types of businesses (Ahn and Le, 2014), and has the merit to better evaluate the competitive viability of banks through the minimisation of both interest and non-interest expenses for a given level of output (e.g., Berger et al., 1987; Ferrier and Lovell, 1990).

However, despite its widespread use in bank efficiency studies, the implementations by researchers of IA have a number of limitations. First, most studies consider deposits as an input used to produce earning assets and thus ignore their important role in providing liquidity and deposit-based services such as safekeeping; however, the conceptual model of IA does not include this limitation, as suggested by the implementation of Ouenniche and Carrales (2018) who argue that these implementation choices penalise the very means by which banks collect funds. Note that one of the consequences of this implementation choice is that it tends to underestimate the efficiency scores of banks with large deposits and fewer loans. Second, IA implementations mainly focus on interest-related activities (i.e., traditional banking activities) while discarding non-interest-related activities as well as risk management aspects which nowadays are gaining increasing importance in banking (Allen and Santomero, 2001; Hakenes, 2004). Once again, note that the conceptual model of IA does not include this limitation, which is the result of researchers' implementation choices.

Table 2
Summary of Conceptual Models of Banks – Commonly Referred to As Evaluation Approaches or Perspectives – and Typical Inputs and Outputs Chosen for Their Implementations

Approach	Conceptual Model	Typical Inputs	Typical Outputs
IA	Banks are viewed as financial intermediaries who collect funds to provide financial services and expand assets.	Services provided to depositors or creditors (e.g., interest or financing related activities) Non-financial resources such as labour and fixed assets Costs (operating expenses: interest or financing costs and non-Interest or non-financing costs)	Services provided to borrowers or debtors (e.g., loans or financing)
AA	Banks are viewed as financial intermediaries between liability holders and those who receive bank funds.	Liabilities (deposits and other liabilities)	Assets (loans and other assets)
PA	Banks are viewed as production units who transform inputs into outputs or produce deposit accounts and loan services.	Labour; capital; and materials (do not include interest expenses)	Deposit accounts (e.g., demand deposits, time and savings deposits) Loan services (i.e., commercial loans, real estate loans, instalment loans)
POA	Banks are viewed as revenue generating units which aim at maximising profit and thus capture the final monetary effect of the financial intermediation function.	Choices of inputs are based on the bank's ability to manage costs (credit costs) and expenses (employee expenses; other non-interest expenses; interest expenses; loan loss provisions; general and administrative expenses)	Choices of outputs are based on the bank's ability to generate revenue (net interest income; net commission income; total other income; lending revenues)
UCA	Banks are viewed as producers of financial services with the aim of minimising the user cost of liabilities and assets or maximising the economic return.	Any financial instrument whose return on an asset is lower than the opportunity cost of funds or the financial cost of the liability is greater than its opportunity cost; that is, Balance sheet items with positive user costs (e.g., time deposits such as term deposit accounts)	Any financial instrument whose return on an asset exceeds the opportunity cost of funds or the financial cost of the liability is less than its opportunity cost; that is, balance sheet items with negative user costs (e.g., loans, demand deposits such as checking accounts)
VAA	Banks are viewed as value-added generating units which aim at maximising the economic value-added of every banking activity in order to obtain competitive viability.	Non-financial resources such as labour and physical capital Financial resources such as purchased funds for the intermediation process (e.g., due to other financial institutions, trading liabilities, and short-term borrowings)	All categories of liabilities and assets with substantial value-added (e.g., deposits – including time, saving and demand; loans – including real estate, commercial and instalment; and investments – including securities)

Notes: IA, AA, PA, POA, UCA, and VAA denote Intermediation Approach, Asset Approach, Production Approach, Profit-Oriented Approach, User Cost Approach and Value-added approach, respectively.

The actual limitation of IA is that it only captures banks' role as financial intermediaries who transfer funds from savers/depositors to investors/borrowers (i.e., microeconomic role) and thus, as pointed out by Berger and Humphrey (1997), this approach ignores the major macroeconomic role of banks in the economy as money creators; in sum, the macroeconomic efficiency of banks is ignored in their evaluation under IA. In order to compare how Islamic banks and Conventional banks are conceptualised under IA, it is important to stress out that Conventional banks gain money from the spread between lending-based activities and borrowing-based interest activities, while Islamic banks do not deal in interest-based activities but have a comparable markup that is specified in terms of debt-based instruments (e.g., Murabaha, Salam, Istisnā, Ijarah) and equity-based instruments such as profit- and loss-sharing instruments; i.e., Musharaka, and profit-sharing instruments; i.e., Muḍārabah (Johnes et al., 2018; Mezzi, 2018). Thus, IA also conceptualises Islamic banks as providers of financial intermediation services who collect deposits and other liabilities (e.g., Sukuks' issuance) and invest these funds in productive sectors of the economy, yielding returns that are interest-free (Sufian and Noor, 2009). The typical inputs and outputs chosen by researchers for the implementations of the conceptual model of IA are summarised in Table 2, where loans in Conventional banking are replaced by financing in Islamic banking, interest related activities are replaced by financing related activities, and Interest expenses and non-Interest expenses are replaced by Financing expenses and non-Financing expenses, respectively (Shawtari et al., 2015, 2018). Note that these changes in terminology are meant to reflect the non-use of usury (Riba) in Islamic banking (Krueger, 2019), as required by the regulatory bodies of Islamic banks (Accounting and Auditing Organization for Islamic Financial Institutions or AAOIFI and Islamic Financial Services Board or IFSB). To be more specific, in Islamic banking, financing (balance sheet items) includes amongst other items Murabaha financing, Ijarah financing, Salam financing, and Istisnā financing.¹ With respect to the income statement, there are four categories of items: (1) financing income typically includes income from Islamic financing (e.g., Murabaha, Ijarah, Salam) and investment activities (i.e., Muḍārabah and Musharaka), income from investments in Islamic Sukuks, income from international Murabaha with the Central Bank, and income from investment and Wakala deposits with financial institutions; (2) non-financing income mainly includes fee and commission income; (3) financing expenses include income distributed to restricted depositors/investors, income distributed to unrestricted depositors/investors; and (4) non-financing (operating) expenses include staff costs, depreciation and amortisation, other operating expenses. As to Conventional banking, loans (balance sheet items) include total loans and advances to individual/retail customers, total loans and advances to corporate entities, loans and advances to governments and public sectors, loans held-for-sale (part of customer loans); interest income (income statement items) includes interest income on bank deposits to banks, interest income on cash and balances with central banks, interest income on financial asset held for trading, interest income on investment securities; non-interest income (income statement items) includes fee and commission income; interest expenses (income statement items) include interest expense on customer deposits, interest expense on debt securities, interest expense on subordinated debt securities; and

¹ For definitions of Islamic financial contracts, we refer the reader to the glossary of the Islamic Financial Services Board (IFSB) (<https://www.ifsb.org/terminologies.php>)

non-interest expenses (income statement items) include staff expenses, depreciation and amortisation expenses, and other operating expenses.

The AA, viewed by some authors as a variant of the IA (Favero and Papi, 1995), is the least used approach in bank efficiency literature using DEA and, to the best of our knowledge, only one paper (Shah and Masood, 2017) adopted this approach in Islamic banking efficiency studies. The conceptual model of AA views banks as financial intermediaries between liability holders and those who receive bank funds (Berger and Humphrey, 1992). AA focuses on balance sheet information, i.e., assets and liabilities, employs the value of intermediated funds measures; namely, assets and liabilities, and discards financial income measures; namely, costs and revenues. In terms of input and output specification in the implementations of this approach by researchers, typical inputs include in addition to deposits, labour and physical capital, other interest-bearing liabilities (borrowings), as well as non-interest-bearing liabilities. On the output side, in addition to loans, other earning assets such as securities and other investments, are considered. AA has fewer pros such as its appropriateness for large banks that purchase funds from other banks and large institutional depositors and transform them into loans (Jimborean and Brack, 2010). However, it has several shortcomings: (a) it does not take account of the substantial services provided to depositors by considering deposits and other liabilities as inputs (to be minimised) when these inputs are the very means by which banks collect funds (Ouenniche and Carrales, 2018) and thus penalises both large and small banks by undervaluing the overall contribution of these banking activities; (b) it ignores non-traditional activities such as trading activities; for example, buying and selling securities (Favero and Papi, 1995), and (c) it typically relies on stock information which is subject to measurement bias (respectively, volatility bias) when historical costs model (respectively, fair-value model) is used to value balance sheet items.

The PA comes as the second most used banking conceptual model after IA, as demonstrated by the general banking efficiency literature, on one hand, and the Islamic banking efficiency studies (e.g., Mostafa, 2011; Musa et al., 2020; Shahwan and Habib, 2021), on the other hand (see Figure (d) in Appendix A). PA views banks as production units (Benston, 1965) who transform inputs into outputs or produce deposit accounts and loan services and thus takes account of the importance of deposits in the banking industry by considering them as outputs. PA emphasises the importance of operational resources and thus is suitable for assessing the efficiency profiles of the branches of financial institutions. PA has been the subject of several criticisms such as (1) it does not capture the fundamental purpose and distinguishing feature of a bank, which is intermediation (Berger and Humphrey, 1997), (2) interest expenses, which account for a big chunk of overall banking costs, are not taken account of as this approach focus is on the operating aspects of the production process of banks, (3) it does not take account of off-balance sheet information (Bernou, 2005) and thus ignores an important source of risk for banks, and (4) it requires extra-accounting figures such as the number of accounts and transactions and other flow data which are not usually published or made easily available to external evaluators (Ahn and Le, 2014). However, this approach avoids the argument on the role of deposits.

The POA – sometimes referred to as an “income-based” or a “revenue-based” approach, is another variant of IA (Ouenniche and Carrales, 2018). It views banks as revenue generating units who aim at maximising profit and thus capture the final monetary effect of the financial intermediation function. This approach is less popular in

Islamic banking efficiency studies (see Figure (d) in Appendix A). POA uses income statement information as this approach is built on the cost-revenue relationship. The implementations of this approach conceptual model generally distinguish between interest and non-interest costs as inputs and interest and non-interest revenues as outputs (e.g., Sturm and Williams, 2004; Das and Ghosh, 2009). Its pros can be summarised in the following points (Ahn and Le, 2014): (1) it attempts to capture the monetary impacts of financial intermediation at the end of the process and thus focuses on the bottom line, (2) it takes account of total costs and total revenues coming from both traditional activities and non-traditional and other operating activities of the bank and thus allows for the identification of additional sources of inefficiency; that is, whether inefficiencies are caused by financing activities, non-interest activities, or operating activities and (3) it avoids the argument on the role of deposits. The weakness of the POA however is that it strictly focuses on the cost-revenue relationship and thus it singles out the role of banks in a profit-maximising perspective when banks do perform other functions.

The UCA was proposed in response to concerns about the opportunity costs of holding financial assets or liabilities for a period of time (Hancock 1985, 1986). This approach is not extensively used in the banking literature, and to the best of our knowledge, it was not adopted in the Islamic banking efficiency literature using DEA. UCA views banks as producers of financial services aiming at minimising the user cost (Donovan, 1978; Barnett, 1980) of liabilities and assets or maximising the economic return. UCA provides clear-cut definitions of inputs and outputs (Ahn and Le, 2014) in that the inputs are assets (e.g., labour, fixed assets) or liabilities (e.g., time deposits) with positive user cost, i.e., assets and liabilities that contribute to banks expenses, and the outputs are assets (e.g., loans) and liabilities (e.g., demand deposits) with negative user cost, i.e., assets and liabilities which contribute to banks revenues. UCA also has its own limitations such as (a) the calculation of user costs is a relatively complex and time-consuming process and requires data which might not be readily available and (b) user costs are subject to change over time due, for example, to changes in interest rates resulting in a change in inputs and outputs (Berger and Humphrey, 1992).

Finally, unlike UCA which is based on the opportunity costs, VAA is based on the operating costs (Berger and Humphrey, 1992), focuses on the economic aspect of banking activities based on value added, and views banks as value-added generating units which aim at maximising the economic value-added of every banking activity to obtain competitive viability. To the best of our knowledge, this approach was not adopted in the Islamic banking efficiency literature using DEA. VAA takes account of non-traditional activities as a source of substantial value-added, but there is no quantitative standard to determine which level of value-added is considered as substantial and thus there is no clear-cut specification of input and output factors, the calculation of value-added is a complex process, and the value-added of different activities varies across different types of banks and over time (Ahn and Le, 2014).

D. Variables Used for the Specification of DEA Models in Islamic Banking and Their Classifications

In this section, we provide a general classification of the variables used for the specification of DEA models; that is, inputs, outputs, links, and carry-overs (see Figure 1), which reflects the type of measures (i.e., absolute vs. relative), the nature of measures

(i.e., accounting vs. extra-accounting measures), and the source of data (i.e., on-balance sheet, off-balance sheet, income statement). Note that all relative measures used in the DEA literature on Islamic banking are composite measures, also referred to as combined measures, in that they use data from both the balance sheet and the income statement. Obviously, the choice of inputs, outputs, links, and carry-overs is shaped by the evaluation approach under consideration. Table 2 and Appendix B provide the typical inputs and outputs according to the conceptual model of the approach and the specific inputs, outputs, links, and carry-overs used by researchers in their implementations of conceptual models in the Islamic banking literature, respectively. Our analysis of the evaluation approaches used for the specification of inputs and outputs has revealed some interesting percentages – see Appendix B. Taking, for instance, IA, total deposits, physical capital, personnel expenses, and deposits & short-term funding are the most widely used inputs, whereas total loans, other earning assets, investments, and total income are the most widely used outputs. These percentages confirm the consistency of most efficiency studies with the rationale of IA.

E. Drivers of Efficiency in Islamic Banking and Their Classification

After the estimation of the efficiency scores of Islamic banks in the first stage, these scores are regressed upon a set of exogenous variables in the second stage to identify the main drivers of efficiency. Although two-stage DEA analyses are gaining more importance in the banking literature (Emrouznejad and Yang, 2017), to the best of our knowledge, no literature survey on the drivers of efficiency has ever been conducted. In this section, we overcome this gap in the context of Islamic banking. Amongst the 33 papers performing a two-stage DEA analysis, 9 were discarded as they used a pooled sample of both Islamic and Conventional banks without interaction terms in their regression framework and thus the drivers identified are not specific to Islamic banks. The drivers of efficiency of banks, in the Islamic banking literature, can be categorised into two categories – internal environment-related, which are bank-specific factors, and external environment-related, which are country-specific factors. On one hand, the internal environment-related variables are controlled by the managers of the bank and reflect their various internal policies and decisions. On the other hand, the external environment-related variables are not under the control of the bank management being factors reflecting the country's economic and legal environment. In this section, we shall provide a classification of the drivers of efficiency used in the DEA literature on Islamic banking into meaningful categories along with the percentage of studies that used each variable (see Appendix C).

As shown in Appendix C, internal environment variables are further divided into several sub-categories; namely, (1) bank liquidity variables, which reflect the ability of the bank to meet its financial obligations as they fall due; (2) bank profitability measures, which capture the overall performance of the bank using ratios such as ROA and ROE; (3) bank cost efficiency variables, which capture the ability of the bank to manage its expenses; e.g., operating costs; (4) bank business model variables, which reflect the extent to which banks are able to diversify their activities among traditional and non-traditional banking operations; (5) bank risk variables, which represent the risks banks are exposed to such as credit risk, market risk, and insolvency risk; (6) bank governance variables, which capture the characteristics of the board of directors and the Shariah board,

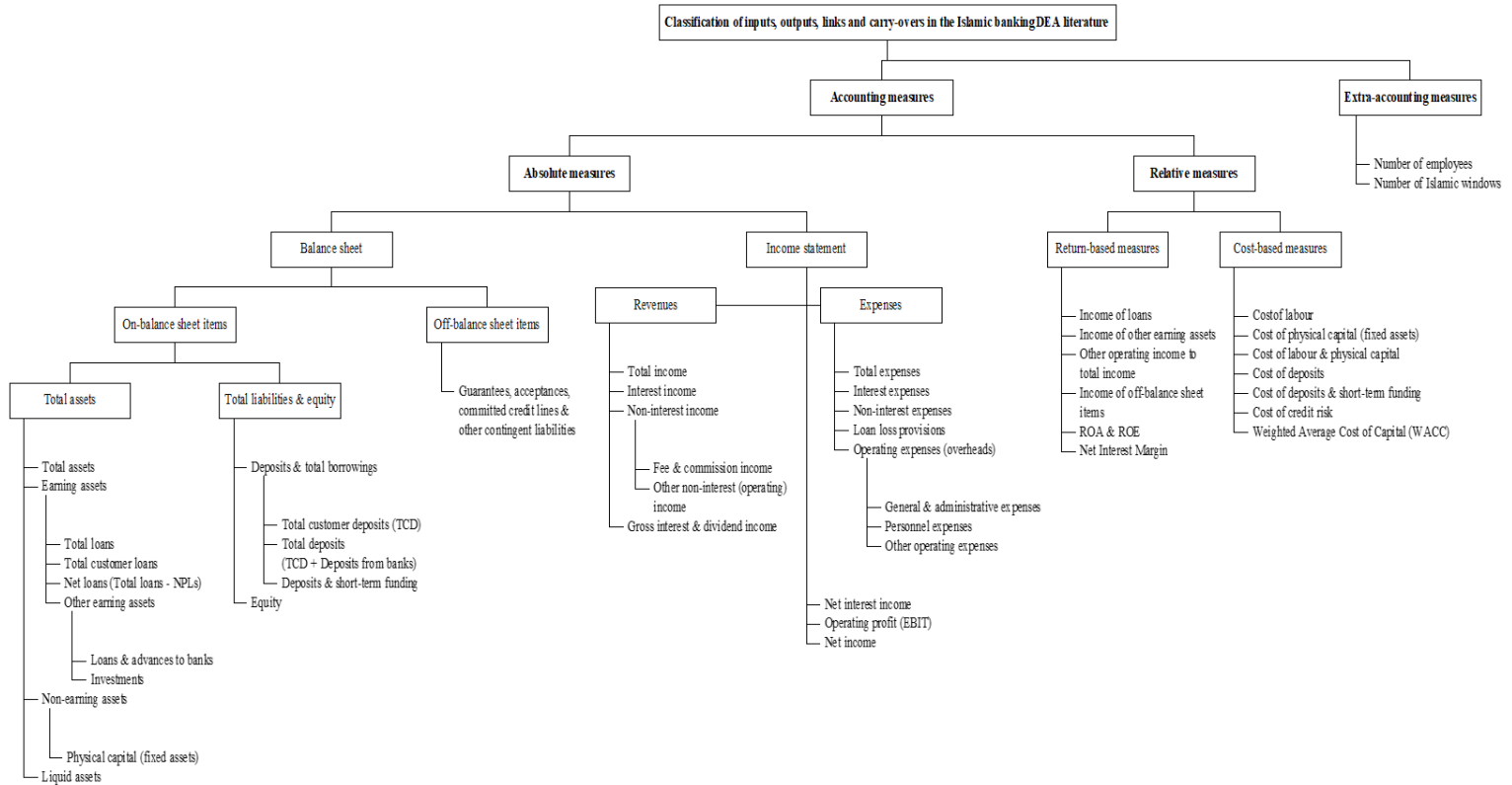
respectively (e.g., size of the board, proportion of independent directors on the board) and bank ownership type (e.g. domestic vs. foreign; public vs. private) and its concentration; and (7) bank intrinsic variables, which capture those characteristics that are inherent to the bank such as bank size and age, bank type (Islamic vs. Conventional), listing status (quoted vs. unquoted), and modus operandi (fully-fledged Islamic banks vs. Islamic windows). On the other hand, external environment variables are further divided into (1) macroeconomic variables, which capture trends in the economy, (2) country governance variables, which consist of six major dimensions provided by the World Bank; i.e., government effectiveness, rule of law, regulatory quality, political stability and absence of violence, voice and accountability, and control of corruption, and (3) regulatory and supervision variables, which consist of a set of regulatory and supervision indicators set by the Bank for International Settlements such as supervisory power, capital requirements, activity restrictions, and private monitoring. Hereafter, we shall summarise and analyse some of the main findings by subcategory of drivers. We refer the reader to Figure (e)² in Appendix A depicting the distribution of the drivers of efficiency in two-stage DEA analysis in the Islamic banking literature.

1. Bank Liquidity Variables

Research studies on Islamic banking efficiency using DEA have reported mixed findings regarding the relationship between bank liquidity and efficiency profiles of Islamic banks. Kamarudin et al. (2019) found that there is a significant positive relationship between total loans to total assets ratio (TL/TA) and RE of Malaysian Islamic banks, which is consistent with the idea that more loans would generate more revenue. Notice that TL/TA is a reverse proxy of liquidity; therefore, the less liquid banks tend to experience higher RE as liquidity is allocated to lending activities. However, Sufian and Kamarudin (2015) found a significant negative relationship between TL/TA and RE of Islamic banks operating in Southeast Asian countries, which suggests that loans are a secondary source of revenue compared to other sources such as investments and securities. In addition, in general, the size of liquidity buffers should reflect the opportunity cost of holding liquid assets (e.g., cash and cash equivalents) rather than expanding loan portfolios, as liquid assets generally yield a relatively low return, resulting in decreased efficiency gains (Berger and Mester, 1997). On the other hand, Hassan (2006) and Mezzi (2018) found a significant positive relationship between TL/TA and OTE of Islamic banks. Furthermore, Alam (2013) found that liquidity, as proxied by the ratio of liquid assets to short-term deposits, has a positive impact on OTE of Islamic banks. Finally, Kamarudin et al. (2016) found no significant relationship between liquidity, as proxied by TL/TA, and RE of Islamic banks. Similarly, Mohd Noor et al. (2020) came to the same conclusion regarding the relationship between TL/TA and OTE of Islamic banks.

² For the sake of clarity, only the most used drivers of efficiency (at least three times) are reported in Figure (e) in Appendix A.

Figure 1
 General Classification of the Variables (Inputs, Outputs, Links, Carry-overs) Used in the Specification of DEA Models in the Islamic Banking Literature



Note: See Appendix B on how the relative measures are computed.

2. Bank Profitability Variables

All studies examining the effect of profitability, mostly measured by return on assets (ROA), on various types of efficiencies of Islamic banks have reached different conclusions. The common conclusion being a significant positive association between profitability and efficiency profiles of Islamic banks. To be more explicit, Hassan (2006), Sufian and Abdul-Majid (2008), Sufian and Noor (2009), Noor and Ahmad (2012b), Farandy et al. (2017) and Mezzi (2018) reported that profitability influences positively and significantly OTE of Islamic banks. Furthermore, Hassan (2006) and Sufian and Abdul-Majid (2008) found that profitability exerts a significant positive effect on PTE and SE of Islamic banks. Hassan (2006) found ROA to have a significant positive effect on CE and AE of Islamic banks. The positive correlation between profitability and efficiency profiles of Islamic banks suggests that highly profitable banks are more likely to enjoy high creditworthiness. These banks are then more appealing to depositors than those with lower levels of profitability, creating incentive for banks to be more efficient (Sufian and Habibullah, 2010). However, Yudistira (2004), Rahman and Rosman (2013), Rosman et al. (2014), Alqahtani et al. (2017), Batir et al. (2017) and Prima Sakti and Mohamad (2018) found no significant relationship between profitability and different types of efficiency measures of Islamic banks in different contexts investigated in their respective studies. Finally, Anagnostopoulos et al. (2020) have used total income and other income as proxies for bank profitability and reported their statistically significant positive effect on both CE and RE of MENA region Islamic banks.

3. Bank Cost Efficiency Variables

The association between management quality and efficiency profiles of Islamic banks is far from being consensual. Empirical results by Kamarudin et al. (2019) and Sufian and Kamarudin (2015) provided evidence that the ratio of total non-interest expenses to total assets, as a reverse proxy of management quality, has a significant negative effect on RE of Islamic banks, which suggests that poorly managed banks with regards to operating costs tend to exhibit lower RE. Likewise, Sufian and Abdul-Majid (2008) and Mezzi (2018) found that the ratio of total non-interest expenses to total assets is negatively and significantly correlated with the OTE, PTE and SE of Islamic banks. This outcome is consistent with the empirical findings of Conventional banking efficiency studies (e.g., Pasiouras and Kosmidou, 2007; Olson and Zoubi, 2011; Rosman et al., 2014). This adheres to the fact that having less administrative overheads helps banks to have more capital available to originate more loans and therefore be more efficient (Alqahtani et al., 2017). This finding is also in congruence with the bad management hypothesis (Berger and DeYoung, 1997), since the management quality measure reflects good management qualities, a negative sign of this measure would signal poor senior management practices in managing input utilisation and day-to-day operations. On the other hand, Batir et al. (2017) found a significant positive relationship between management quality and AE and CE of Islamic banks. This is consistent with Molyneux and Thornton (1992) who suggest that increased profits gained by more efficient banks might be redirected to more productive human capital in the form of higher payroll expenditures. The remaining studies found no significant relationship between the quality of management and OTE (Sufian and Noor, 2009; Abbas et al., 2016; Mohd Noor et al., 2020), CE (Alqahtani et

al., 2017), PE (Alqahtani et al., 2017) and RE (Kamarudin et al., 2016) of Islamic banks. Other less commonly used measures of bank cost efficiency include cost of physical capital, cost of labour, and capital intensity. Alqahtani et al. (2017) reported that capital intensity, as measured by the ratio of fixed assets to labour costs, has no significant correlation with CE and PE of Islamic banks operating in GCC region. Likewise, Anagnostopoulos et al. (2020) pointed out that both cost of physical capital and labour cost have no statistically significant association with CE and RE of Islamic banks in several MENA countries.

4. Bank Business Model Variables

The traditional banking activities have favoured models reliant on lending activities, whereas nowadays banks increasingly engage in non-traditional banking activities which generate income from fees and commissions such as insurance, asset management and trading. With respect to Islamic banking, Beck et al. (2013) reported that Islamic banks have a significantly higher share of fee-based income than Conventional banks, which suggest that they are more involved in non-traditional banking activities. Furthermore, Shahimi et al. (2006) reported that increasingly Islamic banks are using non-traditional Islamic contracts such as Wakalah (agency contract), Kafalah (custodial services and guarantees), and Hawalah (transfer of debt) to diversify their banking activities.

The empirical studies on the association between proxies of bank business models and efficiency profiles of Islamic banks revealed conflicting results. More explicitly, Alqahtani et al. (2017) found that non-traditional banking activities, as proxied by the ratio of other earning assets to total assets, have a significant and positive correlation with CE and PE of GCC Islamic banks. This finding suggests that banks which rely on non-traditional activities would drive their cost and profit efficiencies up (Olson and Zoubi, 2011). Similarly, Kamarudin et al. (2016) found that the ratio of non-interest income to total assets as a proxy of non-traditional banking activities is positively and significantly related to RE of Islamic banks. However, Sufian and Abdul-Majid (2008), Sufian and Noor (2009), Noor and Ahmad (2012a) and Abbas et al. (2016) provided evidence that traditional banking activities, as proxied by TL/TA, have a significant positive relationship with OTE of Islamic banks, suggesting that lending activities drive positively the efficiency of Islamic banks. Sufian and Abdul-Majid (2008) reached the same conclusion with regards to PTE of Islamic banks. Batir et al. (2017) and Abbas et al. (2016) however concluded that the correlation between bank business model, as proxied by TL/TA, and the efficiency profiles of Islamic banks in their study is not significant at the customary thresholds. Finally, Daly and Frikha (2017) found that income diversity of Islamic banks, as proxied by 1 minus the absolute value of the ratio of net interest income (NII) minus other operating income (OOI) to total operating income (TOI), has a significant positive impact on OTE. Thus, banks with well diversified portfolios of activities exhibit higher levels of OTE.

5. Bank Risk Variables

The relationship between bank risk and the efficiency of Islamic banks has been investigated with respect to two types of risk, namely, insolvency risk, and credit risk.

With respect to insolvency risk, several proxies were used in the Islamic banking

efficiency literature using DEA, namely, leverage intensity, capital adequacy ratio, and Z-score. Studies on the relationship between leverage intensity and Islamic banks' efficiency reached mixed results. To be more specific, the empirical findings by Sufian and Noor (2009), Noor and Ahmad (2012b), Rahman and Rosman (2013), Rosman et al. (2014), Abbas et al. (2016), Batir et al. (2017) and Samad (2019) suggest that the leverage intensity, as measured by the ratio of total shareholders' equity to total assets of the bank, has a significant positive relationship with OTE of Islamic banks. When considering the source of inefficiencies of Islamic banks, Rahman and Rosman (2013) further decomposed OTE into PTE and SE and found a significantly positive impact of leverage intensity on PTE of Islamic banks but not on SE. Rosman et al. (2014) found, however, that both components of OTE are positively and significantly correlated with leverage intensity of Islamic banks. In addition, Sufian and Kamarudin (2015) and Kamarudin et al. (2016) provided evidence that there is a significant positive correlation between leverage intensity and RE of Islamic banks. The positive sign implies that highly capitalised banks tend to exhibit higher efficiency scores, which is in line with the findings of Williams (2004) and Altunbas et al. (2007) in the context of Conventional banking. From a theoretical standpoint, these results are consistent with the moral hazard hypothesis (Mester, 1996), which considers that more capitalised banks have less moral hazard incentives; that is, less incentives to transfer risk to shareholders, and thus engage in more risky transactions. As a result, more capitalised banks have higher CE than less capitalised ones which incur more costs (e.g., higher loan screening costs as a result of higher bad loans and more managerial efforts, and higher loan loss provisions). However, Sufian and Abdul-Majid (2008), Daly and Frikha (2017) and Mohd Noor et al. (2020) found that leverage intensity is negatively and significantly correlated with OTE of Islamic banks, suggesting that more efficient Islamic banks, *ceteris paribus*, tend to rely less on equity financing. Finally, Sufian and Abdul-Majid (2008) found that leverage intensity has a statistically significant negative effect on PTE of Islamic banks, which is consistent with the disciplinary role of the liabilities.

The capital adequacy ratio, also known as Capital to Risk Weighted Assets Ratio where capital is the sum of Tier 1 capital and Tier 2 capital, is a measure of how much capital a bank has available to prevent it from defaulting on its financial obligations. In Islamic banking efficiency literature using DEA, to the best of our knowledge, Alqahtani et al. (2017) and Farandy et al. (2017) are the only two research studies that investigated the relationship between capital adequacy ratio and bank efficiency. Alqahtani et al. (2017) found that the capital adequacy ratio is negatively and significantly correlated with CE and PE of Islamic banks. This backs up the claim that over-capitalised banks are less cost and profit efficient, as they miss out on opportunities of offering additional loans (Staub et al., 2010). Note that this finding is not consistent with the moral hazard theory, whereby banks with a thicker layer of capital are more risk averse resulting in improved cost and profit efficiency. However, Farandy et al. (2017) found that capital adequacy ratio has no significant effect on OTE of Islamic banks.

As to the relationship between z-score, as a reverse proxy for the bank's probability of failure (larger z-score values indicate lower insolvency risk), and banks' efficiency in Islamic banking, DEA studies reached two conflicting conclusions. Zeineb and Mensi (2018) and Mohd Noor et al. (2020) found that insolvency risk is negatively and significantly associated with OTE of Islamic banks, whereas Mezzi (2018) found a positive and significant relationship between insolvency risk and OTE of Islamic banks.

The negative sign indicates that banks with relatively lower insolvency risk tend to be more efficient.

As to credit risk, several measures were used in the Islamic banking literature on efficiency, namely, the ratio of non-performing loans (NPLs) to total loans, the ratio of loan loss provisions³ (LLPs) to total loans, the ratio of loan loss reserves⁴ (LLRs) to total loans, the ratio of LLRs to total deposits, the ratio of NPLs to total assets, and the ratio of LLPs to net interest revenue. Credit risk reflects asset quality in that it captures the risk exposure from loans granted by a bank. Despite the mixed findings, most studies concluded to the negative effect of credit risk on Islamic banks' efficiency. To be more explicit, Alam (2013), Sufian and Kamarudin (2015), Kamarudin et al. (2016) and Kamarudin et al. (2019) provided evidence that credit risk is negatively and significantly correlated with RE of Islamic banks from several geographical locations. Alqahtani et al. (2017) found a significant negative impact of credit risk on CE and PE of Islamic banks. Likewise, Sufian and Noor (2009), Noor and Ahmad (2012a), Johnes et al. (2014), Batir et al. (2017) and Samad (2019) found that credit risk is negatively correlated with OTE of Islamic banks. This negative relationship implies that a lower borrowers' default risk would lead banks to issue more loans and thus become more efficient. In addition, a lower credit risk has been associated with increased profit margins which may lead to higher efficiency. However, Rosman et al. (2014) found a significant positive impact of credit risk on OTE, PTE and SE of Islamic banks. Furthermore, Noor and Ahmad (2012b) found that credit risk has a significant positive effect on OTE of Islamic banks. According to Rosman et al. (2014), this positive sign would suggest that highly efficient Islamic banks tend to be more prudent, and consequently, record high LLPs. Finally, a very limited number of studies indicated that there is no correlation between credit risk and various types of efficiency measures of banks (Mokhtar et al., 2007; Sufian and Abdul-Majid, 2008; Farandy et al., 2017; Prima Sakti and Mohamad, 2018).

6. Bank Governance Variables

Three major dimensions of bank governance were investigated in the DEA literature on Islamic banking: (1) bank ownership (i.e., foreign vs. domestic Islamic banks, state-owned vs. privately-owned Islamic banks, and concentration of capital), (2) characteristics of the board of directors (i.e., board size, board independence, CEO duality), and (3) characteristics of the Shariah supervisory board (i.e., size of SSB).

Research studies concerned with examining the association between bank ownership and efficiency of Islamic banks have revealed mixed results. To be more specific, Sufian et al. (2014) and Kamarudin et al. (2019) found that domestic Islamic banks are less RE than their foreign peers in Malaysia, which is consistent with Lensink et al. (2008) and Berger et al. (2009) in the Conventional banking context. Sufian and Abdul-Majid (2008) also came to the same conclusion in terms of OTE, PTE and SE. However, Sufian and Kamarudin (2015) found that domestic Islamic banks exhibit a significantly higher RE when compared to their foreign counterparts in Southeast Asian countries. As to the impact of the state ownership on the efficiency profiles of Islamic banks, Alqahtani et al. (2017) found that GCC state-owned Islamic banks do not differ

³ LLPs are deductions from gross interest income in the profit and loss statement.

⁴ LLRs are yearly accumulations of LLPs in the balance sheet.

significantly from their privately-owned counterparts with respect to both their CE and PE. This finding is not in line with the empirical findings of Berger et al. (2009) and Tecles and Tabak (2010) in Conventional banking, on one hand, and the agency theory hypothesis which expects the state-owned Islamic banks to be less cost and profit efficient (Staub et al., 2010), on the other hand. Alqahtani et al. (2017) also found that foreign ownership has a significant negative impact on CE but not on PE of Islamic banks in their sample. This is consistent with the home field advantage hypothesis (Berger et al., 2000), whereby foreign banks may face issues related to differences in regulatory and supervisory environment, and also to some organisational and operational issues in managing remotely their structure. As to the concentration of capital, proxied by the percentage of capital held by majority shareholders, Mezzi (2018) found it to be positively correlated with OTE of Islamic banks in MENA and Southeast Asia regions.

As to the governance of Islamic banks, Mezzi (2018) and Zeineb and Mensi (2018) have examined the impact of the features of the two-tier governance structure of Islamic banks on their OTE; namely, board size, size of the SSB, board independence, and CEO-duality. With respect to the board size, Mezzi (2018) found it to be positively and significantly correlated with OTE. This finding is in line with resource dependence theory (Pfeffer and Salancik, 1978; Sherer and Lee, 2002), which asserts that larger boards are preferred, as they would contribute to the enhancement of a bank's ability to establish linkages with other banks and would secure essential resources (Hillman et al., 2000; Daily et al., 2002). The size of SSB, as proxied by the number of Shariah scholars in the SSB, is reported to have no effect on OTE. However, Zeineb and Mensi (2018) reported that the size of SSB impacts negatively OTE of Islamic banks, which suggests that small SSBs are more efficient than large ones in their advisory and monitoring duties. As to the board independence, proxied by the percentage of independent members of the board of directors (i.e., members who are not part of the executive team and are not involved in day-to-day management of the bank), Mezzi (2018) found it to contribute significantly to the enhancement of OTE of Islamic banks. Finally, regarding CEO duality, Zeineb and Mensi (2018) provided evidence that CEO duality has a negative effect on OTE of GCC Islamic banks, which put forward the idea that when CEO serves as a chairman in the board, the bank still has a low level of efficiency.

7. Bank Intrinsic Variables

Bank size, as proxied by the natural logarithm of total assets, is one of the most encountered drivers of efficiency in the Islamic banking DEA literature. The empirical findings with regards to the impact of bank size on the efficiency profiles of Islamic banks have yielded mixed results. The common findings suggest that bank size is positively and significantly associated with the efficiency profiles of Islamic banks. To be more specific, Yudistira (2004), Sufian and Abdul-Majid (2008); Sufian and Noor (2009), Noor and Ahmad (2012a), Noor and Ahmad (2012b), Alam (2013), Johnes et al. (2014), Farandy et al. (2017) and Mezzi (2018) provided evidence that bank size has a significant positive effect on OTE of Islamic banks from different geographical locations. When considering the decomposition of OTE, it was found that size of the bank has a significant positive impact upon PTE (Hassan, 2006; Rahman and Rosman, 2013; Rosman et al., 2014) and SE (Hassan, 2006) of Islamic banks. Along the same vein, Sufian and Kamarudin (2015), Kamarudin et al. (2016) and Kamarudin et al. (2019) found that there is a significant

positive correlation between bank size and RE of Islamic banks. In addition, Alqahtani et al. (2017) concluded that CE of Islamic banks in GCC region is positively and significantly associated with their size, which implies that larger banks have better control over their costs compared to small ones (Mezzi, 2018). This positive relationship is in congruence with the economies of scale argument (Wheelock and Wilson, 1995; Hughes and Mester, 2013). Similar outcome is found by Alqahtani et al. (2017) in terms of the association between bank size and PE of Islamic banks in GCC region. However, Rahman and Rosman (2013), Rosman et al. (2014), Batir et al. (2017), Daly and Frikha (2017) and Samad (2019) provided evidence that bank size has a significant negative effect on OTE of Islamic banks. Moreover, Rahman and Rosman (2013) and Rosman et al. (2014) found that SE of Islamic banks is negatively correlated with bank size. In support of the aforementioned argument, several authors argued that larger banks are complex and costly to manage, resulting in increased cost of operations (e.g., Kaparakis et al., 1994; Isik and Hassan, 2002; Drake and Hall, 2003). Finally, the study of Hassan (2006) and Prima Sakti and Mohamad (2018) found no significant relationship between bank size and OTE of Islamic banks.

Concerning the association between the number of Islamic banks' branches and their efficiency, Farandy et al. (2017) found that OTE tends to fall down as the number of branches increases, which is inconsistent with the economies of scale argument. However, Samad (2019) found that the number of bank branches is a significant factor in the improvement of OTE of Islamic banks.

As to market power, DEA studies investigating the relationship between market power, as proxied by the natural logarithm of total deposits, natural logarithm of total loans, or the ratio of bank deposits to total deposits in the country, and efficiency profiles of Islamic banks have reached mixed findings. The first category of findings point to a statistically significant positive relationship between market power and the efficiency profiles of Islamic banks. More specifically, Sufian and Kamarudin (2015) found that RE of Southeast Asian Islamic banks has a positive linkage with market power. Likewise, Daly and Frikha (2017) found market power to be positively and significantly related to OTE of Islamic banks. The second category of findings point to a statistically significant negative relationship between market power and OTE (Yudistira, 2004; Sufian and Abdul-Majid, 2008; Sufian and Noor, 2009), PTE (Sufian and Abdul-Majid, 2008), SE (Sufian and Abdul-Majid, 2008), and RE (Kamarudin et al., 2019) of Islamic banks respectively, which is in line with the Quiet life hypothesis (Liem, 2019) according to which banks with superior market power tend to make less effort to lower their costs at the expense of their efficiency. The third and last category of findings by Noor and Ahmad (2012a), Noor and Ahmad (2012b) and Abbas et al. (2016) point to no evidence of any association between market power and OTE of Islamic banks located in different countries. Note however that a more appropriate proxy of market power would be the Lerner Index.

With regards to the impact of the age of the Islamic bank on its efficiency profile, Abbas et al. (2016) reported that bank age has a significant positive effect on OTE of Pakistani Islamic banks. This positive relationship is in congruence with learning by doing argument put by (Mester, 1996), which asserts that banks would become more efficient as they gain more experience.

Bank type, as proxied by a dummy variable, was introduced in two-stage DEA analysis to capture potential efficiency differences between Islamic and Conventional

banks. Most studies in this regard found that Islamic banks are more efficient than Conventional banks. More specifically, Johnes et al. (2014) found that Islamic banks are more technically efficient than Conventional banks. Along the same line, Anagnostopoulos et al. (2020) found that Islamic banks are more cost and revenue efficient than Conventional ones., which is consistent with Beck et al. (2013)'s findings suggesting that Islamic banks are less efficient than their Conventional counterparts. However, Yahya et al. (2012) found that Islamic banks do not differ significantly from their Conventional counterparts from an OTE perspective.

With respect to the effect of the listing status of a bank, as represented by a binary variable, on its efficiency profile, Alqahtani et al. (2017) found that quoted Islamic banks are more cost and profit efficient than non-quoted ones. This finding could be explained by high regulation standards and disclosure requirements with which listed banks should comply, which results in better governance (Farazi et al., 2011). However, Yudistira (2004) found that listed Islamic banks are less technically efficient than non-listed ones. Another study by Johnes et al. (2014) provided evidence that listing status has no impact on OTE of Islamic banks.

8. Macroeconomic Variables

Numerous macroeconomic factors (e.g., Gross Domestic Product (GDP), GDP growth, inflation rate) were used in two-stage DEA analyses either as divers of efficiency or to control for changes in the macroeconomic environment in cross-country studies.

Studies investigating the impact of GDP, as a measure of a country's economic development and business cycles, on the efficiency profiles of Islamic banks have yielded mixed results. On one hand, a common finding suggests that GDP has a significant positive effect on OTE (Sufian and Noor, 2009; Noor and Ahmad, 2012b), RE (Sufian and Kamarudin, 2015; Kamarudin et al., 2019), CE (Alqahtani et al., 2017), and PE of Islamic banks (Alqahtani et al., 2017). This could be attributed to the favourable macroeconomic conditions which cause higher demand for loans and lower credit losses (as the solvency of the borrowers would improve), leading to increased efficiency levels (Sufian and Habibullah, 2010). This positive sign is consistent with the argument that the well-being of the banking industry is associated with the economic growth (Levine, 1997; Rajan and Zingales, 1998; Pasiouras and Kosmidou, 2007). On the other hand, Mohd Noor et al. (2020) found a negative impact of GDP on OTE of Islamic banks, whereas Sufian and Abdul-Majid (2008) found a non-significant effect of GDP on OTE, PTE, and SE of Islamic banks and Kamarudin et al. (2016) found a non-significant relationship between GDP and RE of Islamic banks. As to GDP per capita, Rahman and Rosman (2013) found it to exert a significant positive effect on OTE, PTE, and SE of Islamic banks. However, Johnes et al. (2014) found that there is no significant relationship between GDP per capita and the OTE of Islamic banks. Mixed results were also obtained when the national economic performance is proxied by the GDP growth. More specifically, Alam (2013), Johnes et al. (2014) and Abbas et al. (2016) reported a significantly positive impact of GDP growth on OTE of Islamic banks, while the findings of Batir et al. (2017) with this regard suggest that the country's economic development impacts negatively and significantly OTE. However, Mezzi (2018) found that there is no correlation between GDP growth rate and OTE of Islamic banks. Finally, Johnes et al.

(2014) also reported that the stock market capitalisation to GDP ratio⁵, where stock market capitalisation is the total market capitalisation of all listed firms of the country, impacts negatively and significantly OTE of Islamic banks. Noor and Ahmad (2012) however found no significant evidence for a nexus between stock market capitalisation to GDP and OTE of Islamic banks.

Like GDP, inflation, as proxied by Consumer Price Index (CPI), is among the most commonly used macroeconomic indicators in two-stage DEA analyses in the Islamic banking literature. Evidence from some studies shows that inflation is negatively and significantly related to OTE (Batir et al., 2017) and RE of Islamic banks (Sufian and Kamarudin, 2015; Kamarudin et al., 2019). However, Alqahtani et al. (2017) reported a significant positive impact of inflation on both CE and PE of Islamic banks. As argued by Perry (1992), inflation could be expected or unexpected. If inflation is anticipated, banks will be able to adjust their interest rates accordingly, resulting in revenues increasing more rapidly than costs (i.e., positive impact on bank efficiency), whereas if inflation is unanticipated, the slow adjustment of interest rates by banks would lead to a faster rise of bank costs than its revenues (i.e., negative impact on bank efficiency). Finally, some other studies found no significant relationship between inflation and OTE (Noor and Ahmad, 2012b; Johnes et al., 2014; Abbas et al., 2016; Mohd Noor et al., 2020) and RE (Kamarudin et al., 2016) of Islamic banks, respectively.

A couple of studies examined the extent to which Islamic banks' efficiency could be affected by market concentration as proxied either by the concentration ratio of the largest banks in terms of assets, or by the Normalised Herfindahl Index (HHI). Once again, the results which stem from these studies are mixed. Johnes et al. (2014) found that a concentrated banking market contributes to the improvement of OTE of Islamic banks. This is coherent with the Structure-Conduct-Performance (SCP) hypothesis (Bain, 1956), which suggests that banks in highly concentrated markets tend to collude and earn monopoly profits. However, other empirical studies by Abbas et al. (2016) and Mohd Noor et al. (2020) conclude to the absence of any statistically significant relationship between market concentration and OTE of Islamic banks. Likewise, Kamarudin et al. (2016) came to the same conclusion on the relationship between market concentration and RE of GCC Islamic banks.

Finally, some authors investigated the impact of some major systemic events on the efficiency scores of Islamic banks. Alqahtani et al. (2017) found that changes in annual oil prices are positively correlated with CE and PE of Islamic banks in GCC countries. As to the impact of the global financial crisis (GFC) of 2007-2009 on the efficiency of Islamic banks, Noor and Ahmad (2012b) found that the Islamic banks from 25 countries experienced a significant decline in their OTE during the GFC period. However, Mezzi (2018)'s results did not show any impact of GFC on OTE, PTE and SE of Islamic banks in MENA and Southeast Asian countries. Regarding the Asian Financial Crisis (AFC) of 1997-1998, Noor and Ahmad (2012b) found that AFC has a significant positive impact on OTE of Islamic banks, which could be explained by the fact that, during financial panic periods, Islamic banks are less prone to deposit withdrawals and tend to attract deposits, on one hand, and grant more loans during financial panics and their lending decisions are less sensitive to changes in deposits, on the other hand, thus

⁵ Stock market capitalisation to GDP ratio indicates whether the stock market is over or undervalued compared to the historical average.

resulting in an increased OTE (Farooq and Zaheer, 2015).

9. Country Governance Variables

Kamarudin et al. (2016) and Daly and Frikha (2017) investigated the impact of the cross-sectional differences in country governance on Islamic banks' efficiency. Kamarudin et al. (2016) examined the impact of six worldwide country governance indicators (i.e., voice and accountability, political stability and absence of violence, government effectiveness, rule of law, regulatory quality, and control of corruption) on RE of GCC Islamic banks. Their findings suggest that four out of the six country governance dimensions, namely, voice and accountability, political stability and absence of violence, regulatory quality, and government effectiveness drive positively RE of GCC Islamic banks. However, Daly and Frikha (2017) provided evidence that government effectiveness and regulatory quality have no impact on OTE of Islamic banks. Last, but not least, the existence of a Central Shariah Supervisory Board was found by Mezzi (2018) to positively and significantly impact OTE of Islamic banks.

10. Regulatory and Supervision Variables

The Islamic banking industry is governed by different regulatory and supervisory bodies. It is therefore crucial to capture the impact of the cross-sectional differences in both regulatory and supervisory frameworks on the efficiency of Islamic banks when conducting cross-country studies. Alam (2013) and Mohd Noor et al. (2020) have examined four main indices of the regulatory and supervisory frameworks, namely, activity restrictions, supervisory power, private monitoring, and capital requirement, on OTE of Islamic banks. Their findings suggest that tighter activity restrictions, stricter powerful official supervision, and stricter private monitoring tend to boost OTE towards higher levels. However, when it comes to the impact of capital requirement on OTE, the findings are mixed. More specifically, Alam (2013)'s findings exhibit a significant positive impact of capital requirement on OTE, whereas Mohd Noor et al. (2020) reported a significant negative effect. This counter-intuitive finding of Mohd Noor et al. (2020) suggests that in countries where capital standards are set too high, banks are more likely to be highly capitalised and less risky, and therefore their management tend to put less effort to enhance bank technical efficiency.

IV. CRITICAL ANALYSIS OF THE ISLAMIC BANKING EFFICIENCY LITERATURE AND RESEARCH GAPS

Our survey and analysis of the empirical literature on the efficiency profiles of Islamic banks using DEA revealed several methodological gaps and shortcomings as well as mixed findings.

The methodological gaps identified as part of our survey and critical analysis of the literature on Islamic banking using DEA could be summarised as follows. The first gap identified in the literature is the lack of black-box and dynamic SBM analyses and thus so far, the efficiency profiles of Islamic banks and related findings ignored inefficiencies related to slacks. Also, except for Wanke et al. (2019), dynamic network analyses have not been used in efficiency studies of Islamic banks and thus the

methodologies used so far ignore the time dynamics present in the real-world settings, on one hand, and the internal structure of banks, on the other hand. In sum, the current literature fails to properly identify the sources of inefficiencies of banks as a result of mostly using static black-box models. The second gap is in relation to the types of efficiencies investigated in that no paper has studied a variety of efficiency measures (i.e., overall technical efficiency, pure technical efficiency, scale efficiency, cost efficiency, profit efficiency, revenue efficiency, and allocative efficiency) to provide a holistic idea about the sources of inefficiencies of Islamic and Conventional banks to all stakeholders (e.g., managers, shareholders, investors, regulators, policymakers). The third gap is with respect to the lack of studies that consider all or most of the six evaluation approaches under which the efficiency profiles of banks are estimated. The relevance of such a study lies in the perspectives it covers and the information it would provide to different groups of stakeholders.

As to the shortcomings, first, the findings of all cross-country or cross-regional studies are environmentally biased in that they ignore the effect of differences in the banking operating environments between countries and regions, which could be addressed using a three-stage DEA analysis to purge the efficiency scores from the effect of the environment. Second, with the exception of the study by Johnes et al. (2014), which takes account of the heterogeneity of Islamic banks due to their characteristics or features, the remaining studies ignore this heterogeneity. Third, our analysis of the evaluation approaches or conceptual models of Islamic banks revealed some inconsistencies between the conceptual models and their implementation decisions; for example, within the production approach, interest expenses were used as inputs which is inconsistent with the conceptual model of this approach. In addition, some papers used variables which are either totally or partially embedded in others, which might have an effect on the discriminatory power of DEA analyses. Examples of totally embedded variables include “total expenses” and “personnel expenses”; and “current assets” and “total assets”. Examples of partially embedded variables include “staff costs” and “administration expenses”; and “gross interest and dividend income” and “total non-interest operating income”. Furthermore, some papers did not specify which approach or rationale that has guided their choices of inputs and outputs. Also, several papers did not provide a clear definition or proxy for the inputs and/or outputs used in their DEA models. For instance, some authors used “capital” to refer to “equity”, while others used it to refer to “physical capital” (fixed assets). Another example is in regard to “labour” which was used to designate interchangeably either “personnel expenses” or “number of employees”. Also, many papers failed to provide a justification of their choices of variables for the specification of DEA models or drivers of efficiency. Fourth, in general, bank intrinsic variables are typically used as control variables in single country studies, whereas bank intrinsic variables as well as external environment variables are typically used as potential drivers of efficiency in multi-country or multi-regional studies. However, our analysis of the DEA literature on Islamic banking revealed that although some variables, whether internal (e.g., bank size) or external (e.g., GDP) environment related, could be used as control variables, most studies did not use them as such but instead considered them as drivers of efficiency in their second stage analysis except for a few studies that were explicitly clear in their use (Sufian and Kamarudin, 2015; Kamarudin et al., 2016; Alqahtani et al., 2017; Kaffash et al., 2018; Kamarudin et al., 2019). To be more specific, in heterogeneous samples (e.g., samples consisting of banks with significantly different

sizes, cross-country samples with significant differences in their economic environments), bank intrinsic variables as well as external environment variables should be used as control variables to neutralise the impact of the characteristics inherent to internal and external environments of banks on the actual drivers of efficiency unless a metafrontier analysis is used to estimate the efficiency scores. Fifth, in two-stage analyses, many studies choose drivers which have already been considered in the specification of the DEA model used for estimating the efficiency scores, which is methodologically unsound as this choice would result in a spurious regression. Sixth, most studies concerned with the identification of the drivers of efficiency in the second stage of a two-stage DEA analysis use a regression framework (e.g., Pooled or Panel regressions estimated using OLS, GLS, or GMM with or without fixed effects and/or random effects; Seemingly Unrelated Regression; Tobit censored regression; Bootstrapped truncated regression), where some authors put forward some justifications for their choice of a specific regression framework. However, there is recent evidence provided by Banker et al. (2019) that OLS outperforms bootstrapped truncated regression. Also, several studies point to a potential endogeneity between some drivers of efficiency, such as bank market structure; i.e., bank market power and bank market concentration (e.g., Tan et al., 2021), ownership structure (Nguyen et al., 2016) and listing status (Nguyen et al., 2016), and bank efficiency scores. For instance, the SCP hypothesis suggests that efficiency depends on market structure, while Efficient Structure Hypothesis (Demsetz, 1973) claims a reverse impact (simultaneity effect as a source of endogeneity). Another example is the possibility of an endogeneity bias in the evaluation of the impact of foreign ownership on efficiency, since foreign investors tend to target the most efficient banks in M&A (selection effect as a source of endogeneity). Another source of endogeneity is omitted variable bias which arises when an omitted (or latent) driver of efficiency (e.g., managers' skills, bank culture) exists which correlates with one or more drivers and affects the efficiency scores (omitted variable as a source of endogeneity). This suggest that coefficients estimated in two-stage DEA analysis without controlling for possible endogeneity of the drivers of efficiency are likely to be biased and inconsistent, which may provide misleading interpretations with respect to theoretical assertions. However, a very limited number of studies on DEA in Islamic banking have attempted to address these potential endogeneity issues in their two-stage DEA analysis, using either seemingly unrelated regression (Alam, 2013; Zeineb and Mensi, 2018) or system GMM estimator approach (Kamarudin et al., 2016). In addition, our survey showed that, endogeneity tests, such as the Durbin-Wu-Hausman test, are not systematically performed to check whether endogeneity among the drivers would have deleterious effects on coefficient estimates from standard regressions. Seventh, our literature survey revealed that many authors use the wrong accounting and/or finance terminology in specifying some of their inputs and outputs. In fact, several authors have labelled expenses associated with some inputs such as "deposits", "physical capital" and "labour" as "price of deposits", "price of physical capital" and "price of labour", respectively. However, the correct terminology should instead be "cost of deposits", "cost of physical capital" and "cost of labour", respectively. Similarly, some authors have termed the relative revenue of some outputs such as "loans" and "other earnings assets" as "price of loans" and "price of other earning assets", respectively. Nevertheless, the term "income" sounds more appropriate from a financial standpoint than the term "price" in reflecting the percentage revenue earned by banks from lending and other banking activities. In our

classifications of the variables used for the specification of DEA models, our reporting uses the correct accounting and/or finance terminology. Also, authors tend to confuse two-stage DEA analyses and two-stage DEA models. Here we would like to emphasise that two-stage DEA models are actually network DEA models with two divisions referred to as stages. Last, but not least, a reasonable number of studies on Islamic banking efficiency that compare different groups of banks or different categories of bank features did not use any statistical tests, whether parametric (e.g., ANOVA, t-test) or non-parametric tests (e.g., Kolmogorov-Smirnov test, Mann-Whitney), to check the statistical significance of differences.

As to the mixed findings identified as part of our survey and critical analysis of literature on Islamic banking using DEA, they could be divided into two categories: mixed efficiency findings and mixed effects of drivers of efficiency. The mixed efficiency findings with respect to different types of efficiencies (i.e., OTE, PTE, SE, CE, PE, RE and AE) fall into several categories depending on the feature or characteristic under consideration (i.e., bank type: Islamic vs Conventional; and ownership type: foreign vs domestic) and could be summarised as follows: (a) Islamic banks are more efficient than Conventional banks; (b) Islamic banks are less efficient than Conventional banks; (c) there is no significant difference in efficiency between Islamic banks and their Conventional counterparts; (d) domestic Islamic banks are more efficient than foreign Islamic banks; and (e) domestic Islamic banks are less efficient than foreign Islamic banks. As an illustration of these conflicting results, Ahmad and Luo (2010), Shawtari et al. (2015), Yilmaz and Güneş (2015), Batir et al. (2017), Erfani and Vasigh (2018), Prima Sakti and Mohamad (2018), Musa et al. (2020) and Azad et al. (2021) revealed that Islamic banks are more overall technically efficient than Conventional banks, whilst Mokhtar et al. (2007, 2008), Ahmad and Abdul Rahman (2012), Mobarek and Kalonov (2014), Abbas et al. (2016), Majeed and Zanib (2016), Abdul-Wahab and Haron (2017), Doumpos et al. (2017), Shah and Masood (2017), Kaffash et al. (2018), Khan et al. (2018), Haque et al. (2020), Alsharif (2021) and Azad et al. (2021) came to the opposite conclusion. Other studies found a non-significant association (Grigorian and Manole, 2005, Shahid et al., 2010; Yahya et al., 2012; Asmild et al., 2019; Shahwan and Habib, 2021). Numerous studies neither provide sufficient or holistic explanation for these mixed findings nor back up their findings by relevant theories and/or previous empirical evidence. Further analysis of these findings and their sources of differences revealed that these inconsistencies in findings could be attributed to differences in sample composition, period of analysis, sources of data or databases, inconsistencies in the reporting of data providers, evaluation approaches and selection of variables for the specification of DEA models, and types of DEA models used for estimating the efficiency profiles of banks. Furthermore, Chowdhury et al. (2021) and Izzeldin et al. (2021) suggest that the plurality in conclusions in bank efficiency studies especially regarding the type of the banks is partially attributed to the sample selection issues that studies in this area suffer from. To be more specific, most studies on Islamic banking efficiency boost their sample size by performing cross-country studies. This increase in sample size however induces significant heterogeneity biases, since the countries under investigation are subject to different economic conditions as well as different accounting and banking regulatory frameworks. In addition, Beck et al. (2013) and Asmild et al. (2019) pointed out that consensus in the findings is difficult to reach due to the issue of heterogeneity in Sharia-compliant product implementation across various jurisdictions. On the other hand, the

mixed effects of drivers of efficiency (i.e., statistically significant positive relationship, statistically significant negative relationship, or no statistically significant relationship) could be due to the use of different proxies for the same driver, the type of efficiency measure used as a response variable and how it is estimated, and the variables used for the specification of the DEA model for its estimation, the regression framework used as well as differences in sample composition and period of analysis.

V. CONCLUSION AND FUTURE RESEARCH AGENDA

In this review and critical analysis paper, we provided a painting of the landscape of research on Islamic banking efficiency using DEA and proposed several classifications and critical analyses of great significance for researchers in the field, namely, classifications of methodologies and models, classifications of variables for the specification of DEA models per evaluation approach, classifications of drivers of efficiency and regression frameworks, and classification of empirical findings. In addition, upon analysis of the findings and their mixed nature, we unveiled some potential sources of these inconsistencies in findings amongst studies. In addition, we provided an explanation of the mixed findings in light of both relevant theories and related empirical evidence. Furthermore, we performed a critical analysis of the literature and identified some methodological gaps and shortcomings to be addressed in future research. Last, but not least, we used the correct accounting and/or finance terminology and unified the terminology in reporting on the variables whether those used for the specification of DEA models or the drivers of efficiency. Despite the relatively increasing trend of studies using DEA to assess Islamic banks' efficiency, this area still remains thoroughly unexplored due to several unaddressed research gaps we have identified in the literature. It may be of great importance if future research explores the following research directions. First, so far, the findings of all cross-country and cross-regional studies on Islamic banking efficiency are biased in that they ignore the effect of differences in the banking operating environments between countries or regions, on one hand, and ignore differences in Islamic banks' characteristics, on the other hand. Therefore, future research in this regard should address this issue of heterogeneity using the appropriate methodologies; that is, three-stage analyses and/or metafrontier analyses. Second, future research should account for time dynamics present in the real-world settings as well as the internal structure of banks by performing dynamic network DEA analyses which would provide stakeholders with more insights regarding the sources of inefficiencies. Finally, future studies could use clustering techniques to identify more relevant clusters to use within metafrontier analyses.

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APPENDIX

Appendix A: Trend and Distributions of Publications on DEA in Islamic Banking Efficiency

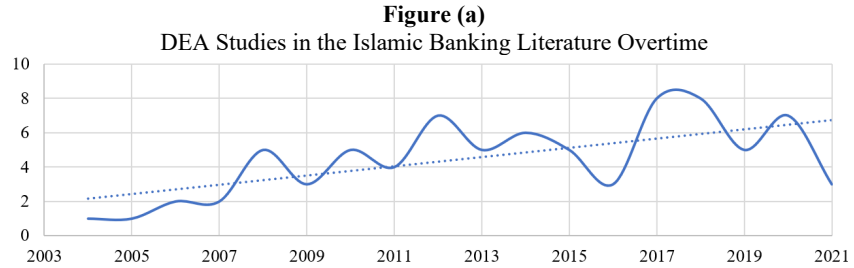


Figure (b)
Distribution of DEA Studies on Islamic Banking by Type of Efficiency Measure

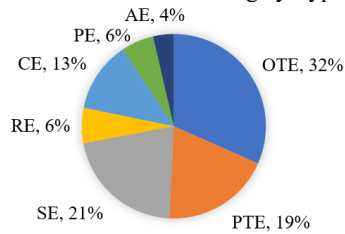


Figure (c)
Distribution of DEA Studies on Islamic Banking by Type of DEA Analysis

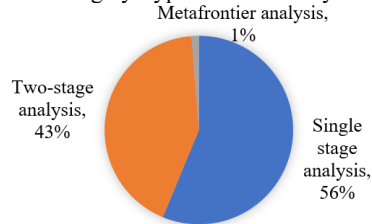


Figure (d)
Evaluation Approaches Used in Islamic Banking Efficiency Literature

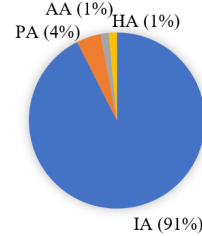
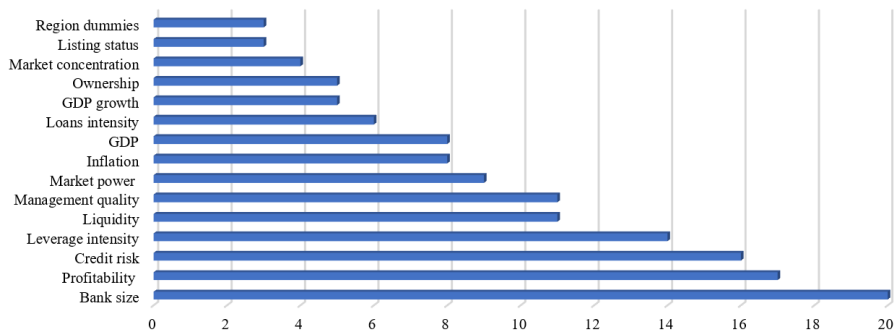


Figure (e)
Distribution of the Drivers of Efficiency in Two-stage DEA Analysis in the Islamic Banking Literature



Appendix B: Classification of Variables (Inputs, Outputs, Links, and Carry-overs) in Islamic Banking DEA Literature by Type of Evaluation Approach

First Level classification	Second Level classification	Third Level classification	Inputs	Outputs	Links	Carry-overs
Panel A: Intermediation approach (IA)						
Accounting measures	Absolute measures	Balance sheet	Total deposits (63%)	Total earning assets (5%)	N/A	N/A
			Customer deposits (5%)	Total loans (78%)		
	Deposits & short-term funding (25%)	Loans & advances to banks (8%)				
Accounting measures	Income statement		Deposits & total borrowings (6%)	Total customer loans (2%)	N/A	N/A
			Equity (17%)	Net loans (8%)		
			Physical capital (64%)	Other earning assets (31%)		
Accounting measures	Composite measures	Return-based measures	Total assets (16%)	Investments (25%)	N/A	N/A
				Liquid assets (5%)		
				Off-balance sheet items (8%)		
Accounting measures	Income statement		Total expenses (3%)	Total income (22%)	N/A	N/A
			Interest expenses (3%)	Interest income (6%)		
			Non-interest expenses (2%)	Non-interest income (6%)		
Accounting measures	Income statement		Operating expenses (6%)	Net fees & commissions income (2%)	N/A	N/A
			General & administration expenses (6%)	Gross interest & dividend income (9%)		
			Personnel expenses (63%)	Operating income (2%)		
Accounting measures	Income statement		Loan loss provisions (2%)	Other operating income (9%)	N/A	N/A
			Other operating expenses (5%)	Net income (9%)		
Accounting measures	Composite measures	Return-based measures	-	<i>Income of loans (16%)</i>	N/A	N/A
				-Interest income to total loans		
				<i>Income of other earning assets (6%)</i>		
Accounting measures	Composite measures	Return-based measures		-Other operating income to other earning assets	N/A	N/A
				-Other operating income to total income (9%)		
				<i>Income of off-balance sheet items (3%)</i>		
Accounting measures	Composite measures	Return-based measures		-Net fee & commission income to off-balance sheet items	N/A	N/A

			<i>Cost of deposits (20%)</i>			
			–Interest expenses to total deposits			
			<i>Cost of deposits & short-term funding (5%)</i>			
			–Total non-interest expenses on deposit and non-deposit funds divided by customer deposits and short-term funding			
			<i>Cost of labour (22%)</i>			
		Cost-based measures	–Personnel expenses to total funds			
			–Personnel expenses to total assets	-	N/A	N/A
			–Staff costs to total number of employees			
			<i>Cost of physical capital (14%)</i>			
			–Other operating expenses to fixed assets			
			–Depreciation expenses to fixed assets			
			<i>Cost of labour and physical capital (2%)</i>			
			–Personnel and other overhead expenses to total assets			
			<i>Cost of credit risk (2%)</i>			
			–Loan loss reserves (LLRs) to total loans			
Extra-accounting measures	-	-	Number of employees (5%)	N/A	N/A	N/A
			Number of Islamic windows (2%)			
Panel B: Production approach (PA)						
			Customer deposits (33%)			
		Balance sheet	Physical capital (67%)	Total loans (33%)	N/A	N/A
			Equity (33%)	Total deposits (33%)		
			Total assets (33%)			
Accounting measures	Absolute measures	Income statement	Total expenses (33%)	Total income (33%)	N/A	N/A
			Non-interest expenses (33%)	Net interest income (33%)		
				Net income (33%)		
		Return-based measures	-	ROA (33%)	N/A	N/A
				ROE (33%)		
		Cost-based	N/A	-		

		measures				
Extra-accounting measures	-	-	N/A	N/A	N/A	N/A
Panel C: Asset approach (AA)						
Accounting measures	Absolute measures	Balance sheet	Total deposits (100%) Capital employed for all banking institutions (100%)	Loans & advances to banks (100%)	N/A	N/A
		Income statement	Administration expenses (100%)	Net interest income (100%)	N/A	N/A
	Composite variables	Return-based measures	-	Net interest margin (100%)	N/A	N/A
		Cost-based measures	Average deposit rate for deposit accounts (100%) Average per employee administration expenses (100%) Weighted Average Cost of Capital (WACC) (100%)	-	N/A	N/A
Extra-accounting measures	-	-	N/A	N/A	N/A	N/A
Panel D: Hybrid approach (PA, IA, POA)						
Accounting measures	Absolute measures	Balance sheet	Total deposits (100%) Equity (100%)	Liquid assets (100%) Non-earning assets (100%)	Loans (100%) Earning assets (100%)	N/A
		Income statement	Interest expenses (100%) Non-interest expenses (100%)	Loan loss provisions (100%) Net income (100%)	N/A	N/A
	Composite variables	Return-based measures	N/A	N/A	N/A	N/A
		Cost-based measures	N/A	N/A	N/A	N/A

Extra-accounting measures	-	-	N/A	N/A	N/A	N/A
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Notes: (a) % refers to the proportion of papers that used each variable (inputs, outputs, links, and carry-overs) within each approach. Only variables used in studies where the evaluation approach was specified by the authors are reported in this table; (b) Liquid assets is computed as the sum of cash and balances at central banks, liquid investments, and loans and advances to banks; (c) net interest income is the difference between total interest income and total interest expenses; (d) operating profit is the difference between total operating income and total operating expenses; (e) Total income refers to the total income, which is the sum of interest and non-interest income.

Appendix C: Classification of the Drivers of Efficiency in the Islamic Banking DEA Literature (23 Studies Using Two-stage Analysis) along with the Percentage of Studies That Used each Variable

First Level Classification	Second Level Classification	Drivers of efficiency	Proxy of the driver	% of time use across studies	
Internal environment variables	Bank risk variables	Credit risk (asset quality)	Non-performing loans (NPLs) to total loans	73%	
			Loan loss provisions (LLPs) to total loans		
			Loan loss reserves (LLRs) to total deposits		
			LLRs to total loans		
			LLPs to net interest income		
	Bank probability variables	Leverage intensity	Total shareholders' equity to total assets	65%	
			Risk of insolvency	Z-score	9%
			Total capital adequacy ratio	(Tier 1 + Tier 2) to risk-weighted assets	9%
			Return on assets (ROA)	Operating income to total assets	54%
				Net income to total assets	
Bank liquidity variables	Liquidity	Return on equity (ROE)	Net income to total shareholders' equity	13%	
		Total income	Interest plus non-interest income	5%	
		Other income	Not specified	5%	
			Liquid assets to total liabilities	50%	
			Liquid assets to total assets		

			Total loans to total assets	
			Total loans to total deposits	
			Non-interest expenses to total assets	
			Operating expenses to net income	50%
			Other operating expenses to total assets	
			Personnel and non-interest expenses to total assets	
Bank cost efficiency variables		Management quality		
		Capital intensity	Fixed assets to labour costs	5%
		Cost of physical capital	Depreciations to total assets	5%
		Cost of cash reserves	Provisions to total deposits	5%
		Cost of labour	Salaries to number of employees	5%
Bank business model variables		Traditional banking activities	Total loans to total assets	27%
		Non-traditional banking activities	Other earning assets to total assets	5%
		Income diversity	$1 - \text{abs}((\text{net interest income} - \text{other operating income})/\text{total operating income})$	5%
			Non-interest income to total assets	
Bank governance variables		Shariah Supervisory Board (SSB)	Size of the SSB	5%
		Board size	The number of directors in the BoD	9%
	Board of Directors (BoD)	Board independence	The % of members of the BoD (i.e., members who are not part of the executive team of the bank)	5%
		CEO duality	1 if the CEO and Chairman are held by the same person, 0 otherwise	5%
		State vs. private ownership	1 for state-owned bank, 0 otherwise.	7%
	Bank ownership	Foreign vs. domestic ownership	1 for domestic Islamic bank, 0 otherwise.	18%
		Concentration of capital	The % of capital held by majority shareholders	5%

Bank intrinsic variables	Bank size	Natural logarithm of total assets	86%	
	Number of branches	n/a	9%	
	Bank market power	Natural logarithm of total deposits	36%	
		Natural logarithm of total loans		
	Bank age	Years of operations	5%	
	Bank type (Islamic vs. Conventional)	0 for Islamic banks, 1 otherwise.	9%	
	Listing status (quoted vs. unquoted)	1 if the bank is listed on a stock market, 0 otherwise.	14%	
External environment variables	Macroeconomic variables	GDP	The monetary value of all the final goods and services produced in a specific time period	36%
		GDP per capita	GDP of a country divided by its total population	9%
		GDP growth	The % change in GDP between two time periods	23%
		Inflation	The annual % change in CPI	36%
		Market concentration	Computed using Herfindahl–Hirschman Index (HHI)	18%
		Oil price changes	Natural log of average annual oil prices	5%
		Stock market capitalisation to GDP	Total market capitalisation of all listed firms of the country to GDP	9%
		Global Financial Crisis	1 for 2009, 0 otherwise	9%
		Asian Financial Crisis	1 for 1998, 0 otherwise	5%
		Banking system liquidity	Liquid assets to total deposits	14%
			Bank credits to bank deposits	
		Year dummies	Banking system liquid assets to total assets	9%
		Region dummies	Allow for changes in banking efficiency over time	14%
		Allow for differences in efficiency between regions		

	Banking system efficiency	Banking system operating expenses to total assets	5%
	Banking system risk	Banking system LLPs to total loans	5%
	Existence of a central SSB	1 if a central SSB exists in the country, 0 otherwise	5%
	Voice and accountability	The citizens' participation in selecting their government, freedom of expression, freedom of association and free media.	5%
Country governance variables	Political stability and absence of violence	The stability in the politics but with the likelihood that the government would be destabilised or overthrown by unconstitutional or violent means.	5%
	Government effectiveness	The credibility of the government's commitment to such policies.	9%
	Regulatory quality	The ability of the government to formulate and implement good policies and regulations that permit and promote private sector development.	9%
	Rule of law	Refers to those agents who have confidence in and abide by the rules of society.	5%
	Control of corruption	Controls which public power is exercised for corruption.	5%
Regulatory and supervision variables	Supervisory Power	Captures the extent to which official supervisory authorities have authority to take corrective and preventive measures to sort out problems.	9%
	Activity Restrictions	Includes restrictions on securities, insurance, and real estate activities plus restrictions on the ability of banks to own and monitor nonfinancial firms.	9%
	Capital Requirement	Assesses the extent to which banks must meet regulatory capital requirements in relation specific rules.	9%
	Private Monitoring	Captures the degree to which private sector bank monitoring effects bank performance and fragility.	9%