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Risk-adjusted efficiency and corporate governance: Evidence from Islamic and conventional banks

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Abstract

Previous studies have compared the efficiency of Islamic banks with their conventional counterparts using a common efficiency frontier and ignoring risks, in spite of the two bank groups operating under different technological, market and institutional conditions. We overcome this issue by estimating efficiency using the stochastic meta-frontier model for a large international sample, and show that compared to conventional banks, Islamic banks are 4 percentage points more cost efficient, but 17 percentage points less profit efficient on a risk-adjusted basis. For both bank types, higher bank risk reduces cost efficiency but increases profit efficiency, implying that risks contribute more to generating revenues than inflating costs. Having a stronger Shariah supervisory board is conducive to improving Islamic banks' profit efficiency. Our findings are robust to accounting for potential endogeneity in the governance-efficiency relationship.

Keywords: Cost efficiency, Profit efficiency, Islamic banking, Shariah supervisory board, Stochastic meta-frontier.
JEL classification: D24, G21, G28, G34

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1. Introduction

Bank efficiency has been a topic of considerable interest in the literature in the last two decades (Berger & Mester, 1997; Bos & Schmiedel, 2007; Lee & Huang, 2017). Over the last decade, a number of studies have compared the efficiency of Islamic banks with their conventional counterparts (Hassan, 2006; Srairi, 2010; Johnes, Izzeldin & Pappas, 2014; Saeed & Izzeldin, 2016; Alqahtani, Mayes & Brown, 2017; Bitar, Hassan & Walker, 2017). Prior studies overlooked the difference in efficient frontiers under which Islamic and conventional bank groups operate, and the potential trade-off between risk and efficiency for these bank groups. As well, no previous study examined how regular board governance and Shariah supervisory board (SSB) composition such as size, academic qualifications and reputation of SSB members influence Islamic banks' efficiency. This study addresses these gaps in the literature by comparing Islamic and conventional banks' cost and profit efficiency under a stochastic meta-frontier framework proposed by Huang & Liu (2014).

The extant literature examines cost and profit efficiency of Islamic and conventional banks using a common frontier, which assumes that both bank groups operate in the same financial landscape, facing the same input/output prices with no constraints in adopting the available production technologies. However, Islamic banks operate under Islamic principles with a two-tier governance structure in a financial landscape differing from that of their conventional counterparts with regard to product portfolio, production technology, customer base, and institutional conditions. The cross-group comparison of efficiency using a common efficiency frontier may provide spurious findings, which can be avoided using a meta-frontier. This approach estimates the group-specific frontiers and a meta-frontier that envelops all group-specific frontiers (discussed in detail in Section 4). Specifically, we adapt Huang et al.'s (2014) stochastic production meta-frontier framework for developing stochastic meta-frontier (SFM) cost and profit models.

Johnes et al. (2014) employ a non-parametric alternative to the SMF model to examine the technical efficiency of Islamic banks. Their method was proposed by Charnes, Cooper & Rhodes (1981), Battese, Rao & O'Donnell (2004) and O'Donnell, Rao & Battese (2008). Any deviation of a bank's performance from that of its better performing peers is attributed to inefficiency with no allowance for random errors. Hence, we use the SMF model to mitigate confounding random errors in measured inefficiency and allow the simultaneous determination of inefficiency and its sources. More specifically, we decompose the meta-efficiency of a bank into: (i) efficiency relative to its group-specific frontier; and (ii) proximity of its group-specific frontier to the meta-frontier. For ease of interpretation, we label the first component group-specific cost (profit) efficiency, while the second component is the cost (profit) gap ratio.[1]

Our study's focus is on cost and profit efficiency because they provide 'the best economic foundation for analyzing efficiency of financial institutions because they are based on economic optimization in reaction to market prices and competition, rather than being based solely on the use of technology' (Berger & Mester, 1997, p. 898). In theory, the key principle of an Islamic business should be to emphasise social welfare (Ali, Al-aali & Al-owaihan, 2013), but in practice profit maximisation remains the overriding motive, even in Saudi Arabia (Kayed & Hassan, 2011). Furthermore, Hassan (2006, p. 50) notes that 'regardless of a bank's underlying philosophy, its long run sustainability depends on economic efficiency'. Reducing costs and generating profits can be considered legitimate goals for an Islamic bank as long as they are pursued within Islam's ethical boundaries (Chapra, 1979, 2001). These boundaries aim to achieve a balance between economic efficiency and distributive justice by mitigating the negative externalities resulting from self-interest maximising behaviour of individual economic units.

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[1] Bitar et al. (2017) used a common DEA frontier method to estimate *gross efficiency* and a group-specific DEA frontier to estimate *net efficiency* (see footnote 6 on p. 21 of their paper). However, the use of a stochastic meta-frontier analysis was beyond the scope of their study.

Estimating efficiency without taking into account corresponding risk can label a high–risk bank as being more efficient than a bank utilising more resources for risk mitigation (Mester, 1996; Berger & De Young, 1997). Achieving increased efficiency by assuming greater risk may expose banks to financial distress (Chen, 2012). Safiullah and Shamsuddin (2018) find that Islamic banks have lower credit risk, lower insolvency risk, higher liquidity risk, but similar operational risk relative to their conventional counterparts. Uddin, Kabir & Mollah (2017) show that Islamic banks do face a higher earnings risk. The risk differences between Islamic and conventional banks provide an additional motivation to estimate risk-adjusted efficiency. We uncover the potential trade-off between risk and efficiency by estimating the cost and profit efficiency of Islamic and conventional banks both with and without adjusting for risks. These are credit risk, liquidity risk, operational risk and insolvency risk, which together provide a comprehensive picture of bank risk exposures.[2]

This study also adds to the broader literature regarding the effect of corporate governance on conventional banks' performance (see Erkens, Hung & Matos, 2012; Pathan & Faff, 2013; King, Srivastav & Williams, 2016; Vallascas, Mollah & Keasey, 2017). A similar line of research has also emerged for Islamic banks, which have an additional layer of internal corporate governance known as Shariah supervisory board (SSB) governance. The SSB is entrusted with monitoring and ensuring that all financing, investment and profit distribution decisions comply with Islamic principles, including the prohibitions of interest, excessive risk-taking and economic activities that are deemed illicit by Islam (e.g., adult entertainment, alcoholic beverages, gambling, pork products, intoxicating drugs, tobacco, and defence products). Hence, the SSB attributes can potentially influence Islamic banks'

[2] Bitar et al. (2017) control their technical efficiency measure for credit risk, while we control our cost and profit efficiency measures for credit risk, liquidity risk, operational risk and insolvency risk.

efficiency and risk. Therefore, we examine how regular board governance as well as SSB governance affect risk-adjusted cost and profit efficiency.

Our study differs from Mollah et al. (2017) in that they examine the effect of regular board governance rather than SSB governance on Islamic banks' performance. Mollah and Zaman (2015) evaluate the effect of SSB size on performance (measured by return on equity, return on assets and Tobin's Q), while we examine the effects of three aspects of Shariah supervisory governance—SSB size, academic qualifications of the SSB members, and SSB members' reputation. The latter two attributes capture the resource provision role of SSB members. Our research has practical significance because it is not enough for Islamic banks to know whether a larger SSB leads to an improvement or deterioration in performance; they also need to know what type of board members should be added to or removed from an SSB so that better performance is obtained. Mollah and Zaman (2015) measure performance by return on equity, return on assets and Tobin's Q. More recently, Mollah et al. (2017) measure performance by return on assets. These studies focus on factors determining the average performance of banks, while our paper aims to provide performance benchmarks by applying the stochastic meta-frontier approach. Doing so may enable individual banks to assess their cost and profit performance relative to their best-performing peers throughout the banking industry.

In Table 1, we place contributions of our paper in the context of prior key studies on Islamic banks' cost and profit efficiency. El-Gamal and Inanoglu (2005) and Abdul-Majid et al. (2011) investigate cost efficiency in the context of Turkey and Malaysia, respectively, but they adjust their efficiency scores only for credit risk. Other studies focus on a specific region (Srairi, 2010; Alqahtani et al., 2017) or a relatively large cross-section of countries but with a now outdated sample period, 1990-2005 (Bader et al., 2008; Mohamad, Hassan & Bader, 2008; Hassan, Mohamad & Bader, 2009). The latter group of studies has not documented the evolution of bank efficiency that occurred during the last decade, one which witnessed the Islamic banking industry's substantial growth. In sum, none of the previous efficiency studies employs a stochastic meta-frontier analysis, examines the role of both regular board governance and SSB governance, or adjusts efficiency measures for liquidity risk, operational risk and insolvency risk. This study fills in these gaps in the literature.

[Insert Table 1]

We provide evidence on cross-sectional and temporal variation in bank efficiency using a matched-pair sample of 188 Islamic and conventional banks from 28 countries over the period 2003-2014. The key findings of our study are as follows. On a risk-adjusted basis, Islamic banks are much more cost efficient but have lower profit efficiency compared to conventional banks. Thus, an Islamic bank's profit inefficiency stems not from its inability to make the best use of inputs given their prices, but from its lack of revenue generating ability. The latter may be due to religious constraints faced by Islamic banks with respect to financial products and pricing of those products. These constraints may have diminished their customer base, ability to exploit economies of scope and market power. SSB members with higher academic qualifications and reputation are found to improve both cost and profit efficiency in Islamic banks.

The rest of this paper is structured as follows. The hypotheses are developed in Section 2. Data and summary statistics of the relevant variables are presented in Section 3. Sections 4 and 5 discuss the stochastic cost meta-frontier models and the corresponding results. The stochastic profit meta-frontier models and results are explained in Sections 6 and 7. Section 8 presents the additional test results and finally Section 9 draws conclusions.

2. Are Islamic banks more efficient than conventional banks?

This section proposes three testable hypotheses related to the efficiency of Islamic banks and its determinants.

2.1 Islamic banking and efficiency

The observance of Shariah (Islamic principles) in banking is the key feature that differentiates Islamic banks from conventional banks. As per Shariah guidelines, Islamic banks are expected to perform intermediation functions through profit-and-loss sharing (PLS) contracts with depositors and borrowers instead of interest-based contracts as occurs in conventional banks. Under a PLS arrangement contracting parties share the risks, but under an interest-based contract the risks are shifted to borrowers. The PLS arrangement may compel Islamic banks to incur additional monitoring costs to reduce moral hazard of borrowers who have an opportunity to share ex-post losses with lenders. Also, the cost of initiating a PLS contract may be much higher than that of an interest-based loan contract because Islamic banks may incur sunk costs to evaluate the relevant project's economic feasibility and negotiating mutually acceptable terms and conditions of the PLS contract. Islamic banks may also face competitive disadvantages due to religious constraints in adjusting their input-output mixes in response to changes in market conditions, particularly market interest rate changes. Shariah-compliant banking products are an imperfect substitute for conventional banking products, which may lead to differences in product prices and hence profit efficiency between the two bank groups. Furthermore, Islamic banks' market share is less than 15% in 20 out of 31 countries where Islamic and conventional banks co-exist (IFSB, 2016). The resulting power difference in product markets may contribute to profit efficiency differentials between the two bank groups.

Islamic banks may also incur higher costs when developing Shariah–compliant products. Additional operating costs associated with ongoing Shariah compliance include, among others: remuneration of Shariah supervisory board members and Shariah auditors; the cost of training employees about Shariah compliance; and maintaining the Shariah compliance status. Islamic banks are prohibited from assuming excessive risk and investment in industries (e.g., tobacco, alcohol, gambling, and defense products) that are deemed harmful to society (Iqbal & Mirakhor, 2011). The portion of earnings generated from Shariah non–compliant sources is regarded as impure earnings and cannot be used to acquire assets. Thus, Islamic banks operate in a different financial landscape under religious constraints, which may result in a different efficiency level compared to their conventional counterparts. We therefore propose the following hypothesis:

H_1: There is a difference in efficiency between Islamic and conventional banks.

2.2 Bank risk and efficiency

The production decision of banks involves not only choosing the optimal levels of inputs and outputs but also the levels of risk (Hughes, 1999; Chen, 2012). Banks might increase their cost and profit efficiencies by economising on credit evaluation costs and making unduly risky loans. Consequently, the measurement of cost and profit efficiencies may be obscure when no account is taken of credit risk. This may label banks taking greater risk as more efficient than banks employing additional resources on credit risk reduction activities such as loan screening, collateral evaluation, and monitoring of borrowers' businesses (Mester, 1996).

Furthermore, banks may be interested in making sub–optimal liquidity choices to reduce the opportunity cost associated with holding more liquid assets. Here the differences in liquidity risk–taking across banks can result in different levels of cost and profit efficiencies (Altunbas et al., 2000). It is also plausible that banks spending more resources to reduce potential operational risk arising from internal fraud, technology, legal or environmental shocks are likely to be less cost and profit efficient. Moreover, banks may adopt risk mitigation strategies to reduce potential insolvency risk or a costly episode of financial distress, which can also increase operating costs (Koutsomanoli-Filippaki & Mamatzakis, 2009). The expense associated with risk mitigation strategies may increase cost and profit inefficiencies unless risk factors are considered in efficiency estimation. Consequently, risk–adjusted efficiency scores are likely to be different from risk-unadjusted efficiency scores. However, Islamic banks' efficiency levels are presumed to be less sensitive to the adjustment of risks compared to conventional banks. This is because Islamic banks operate under the Shariah guidelines that prohibit excessive risk-taking, including speculation and gambling (Khan, 2010; Hassan & Aliyu, 2018). We therefore put forward the following two hypotheses:

H_{2a}: Risk-taking affects efficiency of banks.

H_{2b}: Risk-taking exerts a stronger effect on conventional banks' efficiency than that of Islamic banks.

2.3 Shariah supervisory board and efficiency in Islamic banks

Islamic banks have a two-tier governance structure – the regular board of directors and Shariah supervisory board. The regular board of directors acts like a conventional bank board, but operates within the religious parameters set out by the SSB. The role of the SSB is to embed Islamic principles at all levels of management with regard to employing inputs, and producing and pricing outputs.

The SSB members have an incentive to provide an appropriate level of due diligence to enhance their reputation in the market for Shariah experts. They are also religiously motivated to fulfill the fiduciary duty in pursuit of improving Islamic banks' efficiency. In line with the resource dependence theory (Pfeffer & Salancik, 1978), we argue that SSB members with higher academic qualifications and reputations are well placed to advise bank managers on their perceived Shariah knowledge gaps. This in turn may create synergetic capital in Islamic banks and thereby increase their efficiency. However, the effects of SSB on the efficiency of Islamic banks could be contingent on the extent to which they are capable of playing supervisory versus advisory roles. SSBs' influence on the decision-making processes and hence the efficiency levels may be weakened if Islamic banks' management consider them merely an advisory board. As well, the structural separation between SSB and board of directors could impede the boards' internal coordination and knowledge exchange necessary for Shariah–compliant decision-making. Taken together, we propose the following non-directional hypothesis:

H_3: SSB supervision affects Islamic banks' efficiency.

3. Data description and summary statistics of variables

3.1 Data

This study includes 188 Islamic and conventional banks from 28 countries. To construct the sample, fully-fledged Islamic banks are selected first from each country with a dual-banking system[3] and then using average bank size, they are matched with their conventional counterparts to mitigate sample selection bias. Bank size is measured by total assets. This process results in a sample of 188 banks—94 Islamic and 94 conventional. We consider data over the period 2003–2014. Our study period begins in 2003 because there were only a few Islamic banks prior to 2003. There are 1270 bank-year observations. Figure 1 depicts the distribution of bank-year observations by country. Malaysia is at the forefront of Islamic banking. About 16% of our bank-year observations come from Malaysia, which is followed by Bahrain, Pakistan, Bangladesh and United Arab Emirates. Although Iran is a global leader in Islamic banking, it is excluded from our sample because there are no

[3]The Bankscope database categorises 175 banks from 35 countries as Islamic banks. However, this category includes all Islamic banks, conventional banks with an Islamic window, and non-bank Islamic financial institutions. We include only fully fledged Islamic banks to ensure comparability with conventional banks and to maintain consistency across the sample. GICS are applied to include Islamic banks, and cross-checked with each country's central bank's categorisation of banks.

conventional banks in Iran, making it impossible to construct a matched sample for that country. As expected, our sample is overrepresented by banks from Muslim majority countries. Among non-Muslim majority countries, the United Kingdom is emerging as a hub of Islamic banking, providing close to 4% of total bank-year observations. Data on output quantities, input prices, risk measures, total cost and profits, total assets, public listing status are obtained from the Bankscope database. The data for SSB composition, board governance and bank age are hand-collected from the annual reports published on the websites of respective banks. We collect data for the banking industry-specific and country-level macroeconomic variables from World Bank's World Development Indicators database.

[Insert Figure 1]

3.2 Measurement of variables

This subsection defines variables employed in estimating cost and profit efficiencies and their determinants. The corresponding empirical models are presented in the forthcoming sections. Three sets of variables are used in estimating efficiencies. These are bank outputs, input prices and risk measures. Corporate governance attributes, bank financial characteristics, and banking industry-specific and macroeconomic variables are used as determinants of inefficiencies.

The variables related to output quantities, input prices and risk measures are used in modelling efficiency. Output quantities and input prices are specified following the intermediation approach of Sealey and Lindley (1977), which - unlike the production approach - considers banks as financial intermediaries that borrow funds from surplus economic units and transform them into earning assets. This is a widely used approach in the bank efficiency literature (Berger & Mester, 1997). The output variables are as follows: (i) total amount of customer loans; (ii) other earning assets comprising loans and advances to banks, other securities, dollar value of derivatives (where applicable)[4] and other investments; and (iii) non–interest income consisting of net gains (losses) on trading and derivatives, net gains (losses) on other securities, net insurance income, net fees and commissions and other operating income. The non–interest income is used as a proxy for off–balance sheet (OBS) items since it is heavily influenced by OBS activities. The omission of OBS items can understate actual bank outputs because they do constitute a significant component of banking business (Clark & Siems, 2002). As for input prices, the price of deposits is the ratio of interest expense to total deposits, the price of physical capital is the ratio of non-interest expense (operating expenses minus personnel expenses) to total fixed assets, and the price of labour is the ratio of personnel expenses to total assets. Ideally, the price of labour should be personnel expenses divided by number of employees, but due to the unavailability of the number of total employees for the full sample, we use total assets as the denominator following Saeed and Izzeldine (2016).

Referring to the risk variables, credit risk is defined as the ratio of loan–loss reserves to gross loans (Sun & Chang, 2011). Liquidity risk is the ratio of liquid assets to deposits and short-term funding (Altunbas et al., 2000). This ratio is an inverse measure of liquidity risk. Following Sun and Chang (2011), we measure operational risk by asset return volatility, which is the three–year rolling standard deviation of return on assets. Return on assets is the net income after tax scaled by total assets. Insolvency risk is defined as, $\mathrm{Z\text{–}score}_{it} = (\mathrm{ROA}_{it} + \mathrm{CAR}_{it}) \,/\, \mathrm{SDROA}_{it}$, where ROA is the return on assets, CAR is the capital-to-asset ratio and SDROA is the standard deviation of ROA. The Z-score$_{it}$ is bank $i's$ distance from

[4] We use the dollar value of derivatives (where applicable) as estimated by Bankscope. In general, the Shariah law generally prohibits derivatives because they are considered excessively risky and a vehicle for speculation in which a long/short position can be taken or closed without exchanging the underlying financial asset or commodity (Khan, 2010; Hassan & Aliyu, 2018). However, Islamic banks can use some derivatives such as forward contracts for hedging an underlying economic transaction (Warde, 2000; Ayub, 2002). Additionally, there are some Islamic versions of short sale contracts and options labelled as *Bai al Urbun* (down payment or earnest money sale), which can be used by Islamic banks (for details see Khan, 2010; El-Gamal, 2006).

insolvency at time t, where a higher Z-score indicates a lower insolvency risk (Laeven & Levine, 2009).

Variables relating to corporate governance, bank-specific financial characteristics, banking industry and macroeconomic characteristics are used as determinants of cost and profit inefficiencies. A board governance index is used as a measure of regular corporate governance for both bank groups. This index is constructed as the average of eight individual attributes of the board of directors.[5] For Islamic banks, we consider three attributes of the SSB as determinants of inefficiencies: size, academic qualifications and reputation of SSB members. SSB size is the total number of SSB members, and academic qualifications of SSB members is the number of SSB members with doctorate degrees, as a percentage of the total SSB members. We follow Berger et al. (2014) to measure academic qualifications in terms of doctorate degrees because other qualifications (e.g., Bachelor and Master) are nested within a doctorate degree. SSB members' reputation is the number of reputable Shariah scholars on the SSB of a bank, as a percentage of the total SSB members. An SSB member is labelled as a reputable Shariah scholar if he/she is a current or former member in at least one of the international Shariah standard–setting institutions, for example the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI) and the Islamic Financial Services Board (IFSB).

Bank size is measured by the log of total assets. Bank age is 2014 (the last year of our study period) minus the year when the bank was established. The dummy variable for

[5] More specifically, the BG index is equal to the average of eight dummy variables for board attributes, expressed in percentage. The dummy variables for each of the board attributes are defined as equal to one when they meet the corresponding board governance standard as suggested by Aggarwal et al. (2010), and zero if otherwise. The board governance standards are as follows: (i) a board size between 5 and 16; (ii) more than 50% of the directors are independent non-executive directors; (iii) a separate CEO and chairman; (iv) the above industry average percentage of board members with financial expertise; (v) the above industry average percentage of board of directors with three or more directorship positions; (vi) a separate audit committee with a minimum of two board members; (vii) the audit committee chairman is an independent non-executive director; and (viii) a separate risk management committee with at least two board members.

publicly traded banks takes a value of one if a bank is listed on a stock exchange, and zero if otherwise. The bank concentration ratio is measured by the percentage of total banking assets held by the three largest banks. The growth rate of per capita GDP serves as an additional control variable. Lastly, a trend variable, taking the value of 1 for 2003, 2 for 2004 and so on, has been considered to examine time variation in inefficiency.

3.3 Descriptive statistics

Table 2 presents descriptive statistics of variables for each bank group. Panel A of this table shows that Islamic banks have, on average, $203.924 million total cost and $89.725 million pre-tax profits, which correspond to 37.62% and 36.29% of conventional banks' total costs and pre-tax profits, respectively. Panels B and C reveal that the average levels of outputs are lower but input prices are higher in Islamic banks compared to their conventional counterparts. The differences in means are also statistically significant for all output quantities and input prices, indicating that a typical Islamic bank has a smaller scale of operation with little market power in the input markets than that of a typical conventional bank. The differences may be due to the newness of Islamic banks and their smaller customer base compared to conventional banks.

Regarding the bank risk variables, Panel D reports that the mean credit risk for Islamic banks (4.46%) is slightly lower than that for conventional banks (4.99%) but this difference is statistically insignificant. The ratio of liquid assets to deposits and short-term funding is 52.27% for Islamic banks and 33.23% for conventional banks. This difference is statistically significant, implying that Islamic banks have greater liquidity and hence less liquidity risk. Islamic banks have a higher asset return volatility (a measure of operational risk) than conventional banks but the difference is statistically significant only at the 10% level. The mean Z-score is 1.48 for Islamic banks and 1.59 for conventional banks. This difference is statistically significant at the 1% level, indicating that Islamic banks have higher insolvency risk.

Finally, the last panel of Table 2 reports the summary statistics on determinants of inefficiencies. The summary statistics for our Islamic banks sample show that, on average, Islamic banks have four members on their SSB with a maximum of 14 members, and 57.66% of Shariah board members have a doctorate degree. It is also observed that 19.25% of SSB members of Islamic banks are internationally reputed Shariah scholars. The board governance index suggests that conventional banks have better corporate governance systems in place compared to their Islamic counterparts. The comparison of bank financial characteristics reveals that Islamic banks are smaller in size and also younger in age when compared with conventional banks. The average age of Islamic banks is about half that of conventional banks. The descriptive statistics indicate that 53.5% of conventional banks and 46% of Islamic banks are publicly traded. The mean bank concentration ratio shows that 69.63% of banking assets are held by the three largest banks. The average growth rate of per capita GDP is 1.67% with a standard deviation of 4.03, indicating a large variation over the sample period.

[Insert Table 2]

4. Difference in cost efficiency between Islamic and conventional banks

4.1 Stochastic cost meta-frontier model

We adapt the stochastic production meta-frontier framework of Huang et al. (2014) for modelling the stochastic cost and profit meta-frontier models. Figure 2 illustrates the cost meta-frontier model. The cost meta-frontier envelops the bank group-specific cost frontiers (frontiers 1 and 2) from below. Let Y_{jit} and C_{jit} denote, respectively, output and actual total cost of bank *i* in group *j* in year *t*. In Figure 2, at an output level Y_{jit}, the difference between a bank's actual total cost C_{jit} and the cost meta-frontier $f_t^M(X_{jit})$ comprises three components: the cost gap ratio, $CGR_{it}^j = \frac{f_t^M(X_{jit})}{f_t^j(X_{jit})}$; the group-specific cost efficiency, $CE_{it}^j = \frac{f_t^j(X_{jit})}{f_t^j(X_{jit})e^{u_{jit}}} = e^{-u_{jit}}$; and the random error component, $e^{-v_{jit}} = \frac{f_t^j(X_{jit})e^{u_{jit}}}{C_{jit}}$. That is, $\frac{f_t^M(X_{jit})}{C_{jit}} = CGR_{it}^j \times CE_{it}^j \times e^{-v_{jit}}$, where, X_{jit} refers to the vector of bank output quantities and input prices. By accounting for the random error component, the meta-cost efficiency (cost efficiency of an individual bank relative to the meta-frontier) can be defined as $MCE_{jit} = \frac{f_t^M(X_{jit})e^{v_{jit}}}{C_{jit}} = CGR_{it}^j \times CE_{it}^j$, where $0 < CGR_{it}^j \leq 1$. The closer the value of the CGR to 1, the lower the cost gap between the group-specific frontier and meta-frontier, and higher the meta-cost efficiency. The CGR may arise from a gap in production technology as well as a gap in allocative inefficiency with respect to input prices.

[Insert Figure 2]

To estimate the stochastic cost meta-frontier, we first specify the group-specific stochastic cost frontier model:

$$InC_{jit} = Inf_t^j(X_{jit}) + v_{jit} + u_{jit} \tag{1}$$

where, C_{jit} is the observed total cost of bank *i* in group *j* in year *t*; X_{jit} is the vector of outputs and input prices; v_{jit} contains the two–sided error $v\sim$ N $(0,\sigma_v^{j2})$ capturing the effects of random error or statistical noise, which are independent of u_{jit}; and $u_{jit}$is a non–negative random variable, representing the cost inefficiency in production.

Let $\hat{f}_t^j(X_{jit})$ be the corresponding fitted value of the group j's specific frontier, $f_t^j(X_{jit})$. The group jth cost efficiency can be estimated by the following conditional expectation:

$$CE_{it}^j = E(e^{-u_{jit}}|\varepsilon_{jit}) \tag{2}$$

where, ε_{jit} will be substituted by its estimates of composite residuals, $\hat{\varepsilon}_{jit} = InC_{jit} - In\hat{f}_t^j(X_{jit})$. The true value of $f_t{}^j(X_{jit})$ in Eq. (1) is unobservable, which is related to its fitted value as:

$$In\hat{f}_t^j(X_{jit}) = Inf_t{}^j(X_{jit}) + v_{jit}^M \quad (3)$$

where v_{jit}^M is the estimation error. As the meta-frontier envelops group-specific cost frontiers, $f_t{}^j(X_{jit})$, their relationship can be expressed as:

$$f_t{}^j(X_{jit}) = f_t{}^M(X_{jit})e^{u_{jit}^M}, \forall\, j, i, t \quad (4)$$

where the term, $u_{jit}^M \geq 0$ measures the cost gap between the bank group-specific cost frontier and cost meta-frontier. As the disturbance term is omitted in Eq. (4), plugging Eq. (3) into (4) we obtain:

$$In\hat{f}_t^j(X_{jit}) = Inf_t{}^M(X_{jit}) + v_{jit}^M + u_{jit}^M \quad (5)$$

Eq. (5) resembles the stochastic frontier regression and is therefore treated as the stochastic meta-frontier (SMF) regression, in which v_{jit}^M is normally distributed as $v_{jit}^M \sim$N $(0,\sigma_{v^M}^2)$, which is independent from u_{jit}^M. The term u_{jit}^M is a non-negative random variable representing the cost gap or the inefficiency component of the gap between the bank group-specific cost frontier and cost meta-frontier. Cost gap can also be defined as, $\left[1 - \frac{f_t{}^M(X_{jit})}{f_t{}^j(X_{jit})}\right]$, where $\frac{f_t{}^M(X_{jit})}{f_t{}^j(X_{jit})}$ measures the cost gap ratio (CGR). Using the similar formula to Eq. (2), the CGR in the cost meta-frontier is computed by the conditional expectation as:

$$CGR_{it}^j = E(e^{-u_{jit}^M}|\varepsilon_{jit}^M) \leq 1 \quad (6)$$

where, $\varepsilon_{jit}^M = v_{jit}^M + u_{jit}^M = In\hat{f}_t^j(X_{jit}) - Inf_t{}^M(X_{jit})$ are the composite error of Eq. (5). Thus, the stochastic cost meta-frontier approach consists of two stochastic frontier regressions as reported in Eq. (1) and Eq. (5), and the meta-cost efficiency (MCE_{jit}) resulting from the product of CE_{it}^{j} and CGR_{it}^{j} obtained from Eq. (2) and Eq. (6).

We then modify Eq. (1) and Eq. (5) as follows to estimate the stochastic risk–adjusted cost frontier and cost meta-frontier models, respectively:

$$InC_{jit} = Inf_t^j\left(X_{jit}, r_{jit}\right) + v_{jit} + u_{jit} \quad (7)$$

$$In\hat{f}_t^j\left(X_{jit}\right) = Inf_t^M\left(X_{jit}, r_{jit}\right) + v_{jit}^M + u_{jit}^M \quad (8)$$

where r_{jit} represents the risk measures (liquidity risk, credit risk, operational risk and insolvency risk) of the ith bank in the jth group at the tth period. The risk-adjusted cost efficiency and CGR are estimated in a manner similar to those for risk-unadjusted efficiency.

4.2 Model specification

We use the translog functional form for the stochastic frontier model to estimate both group-specific and meta-frontier efficiency. The translog specification for the stochastic cost frontier model in Eq. (1) can be presented as:

$$\ln\frac{C_{it}}{w_3} = \alpha_0 + \sum_{g=1}^{3}\alpha_g \ln\left(y_{git}\right) + \sum_{m=1}^{2}\beta_m \ln\left(\frac{w_{mit}}{w_3}\right) + \frac{1}{2}\sum_{g=1}^{3}\sum_{h=1}^{3}\gamma_{gh}\ln(y_{git})\ln(y_{hit}) + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\delta_{mn}\ln\left(\frac{w_{mit}}{w_3}\right)\ln\left(\frac{w_{nit}}{w_3}\right) + \sum_{g=1}^{3}\sum_{m=1}^{2}\theta_{gm}\ln\left(y_{git}\right)\ln\left(\frac{w_{mit}}{w_3}\right) + v_{it} + u_{it}, \quad (9)$$

where $\ln C_{it}$ is the logarithm of total costs, comprising interest expenses, personnel expenses, other administrative expenses and other operating expenses; y_g refers to gth output and w_m is mth input price (see section 3.2 for definitions of input prices and outputs); $\alpha, \beta, \gamma, \delta, \theta$ are parameters to be estimated; v_{it} and u_{it} represent the pure noise and inefficiency components of the composite error term, respectively.

To estimate the cost frontier model in Eq. (1) with this translog form, the standard symmetric restrictions are applied to the second–order parameters or translog portion of the model as, $\gamma_{gh} = \gamma_{hg}$ and $\delta_{mn} = \delta_{nm}$. Furthermore, the cost function should be linearly homogeneous in input prices to satisfy the duality theorem. Thus, following the study by Berger and Mester (1997), total cost (C), price of deposits (w_1) and price of physical capital (w_2) are normalised by the price of labour (w_3) to ensure the linear homogeneity in input prices.

Eq. (9) is the risk-unadjusted model that does not control for bank risk. To control for risk, this equation is augmented by four bank risk variables as follows:

$$\ln\frac{C_{it}}{w_3} = \alpha_0 + \sum_{g=1}^{3}\alpha_g \ln(y_{git}) + \sum_{m=1}^{2}\beta_m \ln\left(\frac{w_{mit}}{w_3}\right) + \frac{1}{2}\sum_{g=1}^{3}\sum_{h=1}^{3}\gamma_{gh}\ln(y_{git})\ln(y_{hit}) + \frac{1}{2}\sum_{m=1}^{2}\sum_{n=1}^{2}\delta_{mn}\ln\left(\frac{w_{mit}}{w_3}\right)\ln\left(\frac{w_{nit}}{w_3}\right) + \sum_{g=1}^{3}\sum_{m=1}^{2}\theta_{gm}\ln(y_{git})\ln\left(\frac{w_{mit}}{w_3}\right) + \sum_{k=1}^{4}\rho_k \ln(r_{kit}) + \frac{1}{2}\sum_{k=1}^{4}\sum_{s=1}^{4}\tau_{ks}\ln(r_{kit})\ln(r_{sit}) + \sum_{k=1}^{4}\sum_{g=1}^{3}\varphi_{kg}\ln(r_{kit})\ln(y_{git}) + \sum_{k=1}^{4}\sum_{m=1}^{2}\omega_{km}\ln(r_{kit})\ln\left(\frac{w_{mit}}{w_3}\right) + v_{it} + u_{it}$$

(10)

where, r_k represents the four distinct risk variables, r_1 is the credit risk, r_2 is the liquidity risk, r_3 is the operational risk and r_4 is the insolvency risk. Here, an additional restriction is imposed to meet the symmetry condition for the second–order parameter of the risk factors, that is $\tau_{ks} = \tau_{sk}$. We first estimate the above-mentioned translog frontier models separately for each bank group. The estimates from both groups are then pooled to estimate efficiency of a bank group compared to the meta-frontier. When estimating meta-frontier efficiency, we also apply the translog functional form but replace the dependent variable by the fitted value, $In\hat{f}_t^j(X_{jit})$.[6] We compare efficiency estimated from the risk-augmented model (Eq. 10) with efficiency estimated from the risk-unadjusted model (Eq. 9) to guess the potential trade-off between risk and efficiency.

[6] Following Huang et al. (2014), the likelihood ratio (LR) test is used to test the null hypothesis that both bank groups operate under a common cost frontier. The LR statistics for the risk-unadjusted and -adjusted cost frontier models are 511.66 and 718.76, respectively. The LR statistics are significant at the 1% level, suggesting that the two bank groups do not operate under a common cost frontier. This justifies using the cost meta-frontier framework.

The cost inefficiency is modelled as follows:

$$u_{it} = Z_{it}\lambda + \varepsilon_{it,} \tag{11}$$

where u_{it} is the non-negative truncated inefficiency term where the point of truncation is -$Z_{it}\lambda$; Z_{it} is a vector of inefficiency determinants; λ is a vector of unknown parameters; ε_{it} is the random error term representing the effects of unobserved factors on inefficiency. The specific form of Eq. (11) with details concerning inefficiency determinants provided in subsection 5.1.

We estimate the translog cost function and the model of cost inefficiency using Battese and Coelli's (1995) one-step procedure, which is more efficient than a two–step procedure (for details see Kumbhakar, Ghosh & McGuckin, 1991; Wang & Schmidt, 2002). More specifically, the maximum likelihood estimator (MLE) is employed for such simultaneous estimation. The MLE results are obtained with iterative procedures that comprise an estimation of OLS regression and two-phase grid search for gamma, γ (for details, see Coelli, 1996).

4.3 Empirical results on cost efficiency

The parameter estimates for the bank group-specific models indicate that the translog cost frontiers fit both Islamic and conventional bank groups reasonably well, and a majority of the estimated parameters in each bank group frontier are statistically significant at the 5% level or less. The parameter estimates for output quantities and input prices conform to the theoretical properties of a cost function outlined in the last subsection. Furthermore, the effect of interactive terms of outputs on total cost is negative and statistically significant at the 5% level, which suggests that both bank groups achieve cost advantage by producing multiple outputs. The coefficients of risk variables are found to be positive and significant, justifying the argument for including bank risks in cost efficiency estimation. The estimated gamma: $\gamma = {\sigma_u}^2/({\sigma_v}^2 + {\sigma_u}^2)$, which measures the contribution of inefficiency to the total variance term of the model, is significantly different from zero for both bank groups. This supports the significant effects of the inefficiency component in the analysis of the cost efficiency. The log-likelihood ratio (LR) test of the one-sider error (u_i) shows that the test statistic is significant at the 1% level, suggesting that the stochastic frontier model is an adequate representation of our data.[7] The LR test of the null hypothesis that the cost efficient frontier is the same for the two bank groups is rejected at the 1% significance level, providing a rationale for using the cost meta-frontier to compare the bank groups' efficiency.

4.3.1 Distribution of estimated cost efficiency

Table 3 presents summary statistics for estimated cost efficiency scores. Panel A of this table provides cost efficiency (CE) scores estimated from the risk-unadjusted frontier cost models, which do not control for risks. The average group-specific cost efficiency score is 0.852 for Islamic banks and 0.929 for conventional banks. Thus, a typical Islamic (conventional) bank incurs 14.8% (7.1%) additional costs to produce the same output-mix compared to a best-practice Islamic (conventional) bank. The mean cost gap ratios (CGR) are 0.972 and 0.948 for Islamic and conventional banks, respectively. Consequently, Islamic banks' cost frontier is closer to the cost meta-frontier when compared to conventional banks. The CGR reflects the joint effects of the production technology gap and the allocative efficiency (with respect to input prices) gap. Islamic banks may have more control over using an allocatively efficient input-mix (Alqahtani et al., 2017) than adopting modern banking technology. The latter may involve transferring rather than sharing of risks through interest-based transactions, derivative contracts and securitisation contracts, which are not

[7] Detailed results for the stochastic frontier estimates are available from the corresponding author on request.

permissible in Islam. Next, we compare the meta-cost efficiency (MCE) between Islamic and conventional banks, which is the product of CGR and group-specific CE. In the risk-unadjusted model, the average MCE is 0.829 for Islamic banks and 0.881 for conventional banks, indicating that the mean cost inefficiency with respect to the meta-frontier is 17.1% and 11.9% for Islamic and conventional banks, respectively. The difference in MCE between the two bank groups is statistically significant at the 1% level, providing support for hypothesis H_1.

Panel B of Table 3 presents summary statistics of risk-adjusted cost efficiency scores. Unlike the risk-unadjusted model, the risk-adjusted model shows that Islamic banks' meta-cost efficiency is higher than that of conventional banks. It is therefore plausible that the additional cost of risk-taking is higher in conventional banks compared to Islamic banks. The difference in risk-adjusted MCE is statistically significant at the 1% level. Thus, hypothesis H_1 also holds on a risk-adjusted basis.

A comparison of the risk-unadjusted model efficiency scores with those from the risk-adjusted model indicates that all efficiency scores (CE, CGR and MCE) diminish after adjusting for risk. The last column of Table 3 suggests the effect of risk-taking on bank efficiency is statistically significant at the 1% level for all efficiency measures, which supports hypothesis $\mathrm{H}_{2\mathrm{a}}$. However, Islamic banks' MCE declines by 18.8 percentage points and conventional banks' MCE declines by 28.1 percentage points. In this way, risk-taking exerts a stronger effect on conventional banks' efficiency than that of Islamic banks, which favours hypothesis H_{2b}.

[Insert Table 3]

We also compare the distributions of Islamic banks' CGR and MCE with those of conventional banks using the two-sample Kolmogorov-Smirnov test of the equality of the distributions. The results in Table 3 show that the Kolmogorov-Smirnov test statistics are statistically significant at the 1% level, indicating that the distributions of CGR and MCE are different between the two bank groups.

The distribution of cost efficiency scores is further examined using Kernel-based density estimation. The Kernel densities of the distribution of CGR are presented in Figure 3. Conventional banks' CGR spread over a broad range while Islamic banks' CGR scores are more concentrated between 0.95 and 1, indicating that most Islamic banks operate closer to the meta-frontier. After adjusting for risks, the distribution of CGR shifts left but its shape remains unchanged. The distribution of meta-cost efficiency is presented in Figure 4. In the risk-unadjusted model, MCE scores of most conventional banks are concentrated between 0.85 and 1, while most Islamic banks' MCE scores are more or less evenly spread between 0.70 and 1. This reverses when MCE is adjusted for risks with Islamic banks' MCEs being more concentrated to the far right-hand side of the distribution compared to those of conventional banks, confirming higher risk-adjusted efficiency of Islamic banks. Overall, the findings suggest that Islamic banks operate on a cost frontier that is closer to the meta-frontier and they are more cost efficient on a risk-adjusted basis compared to their conventional counterparts.

[Insert Figures 3 and 4]

4.3.2 Time variation in cost efficiency

The cross-sectional average values of CGR and MCE for each year are presented in Figure 5. Figure 5a depicts efficiency scores derived from the risk-unadjusted model that omits the risk effect on efficiency. This figure shows that Islamic banks' average CGR consistently remains above conventional banks' average CGR in all years, but conventional banks outperform Islamic banks in terms of meta-cost efficiency in all years except 2005. The CGR and MCE curves tend to shift downward when cost efficiency is adjusted for risks (see Figure 5b). From 2004 onwards, Islamic banks outperform conventional banks in terms of risk-adjusted CGR and MCE. Interestingly, we observe a sharp decline in conventional banks' risk-adjusted CGR and MCE over the five years preceding the GFC, which may be explained by the conventional banks' appetite for high-risk loans in the pre-GFC period (Erkens et al., 2012). In the post-GFC period, conventional banks' MCE has slightly improved. In general, risk-adjusted efficiency scores show high persistence over the whole sample period for Islamic banks and over the post-GFC period for conventional banks.

[Insert Figure 5]

5. What drives cost inefficiency in Islamic and conventional banks?

5.1 Model of inefficiency determinants

To examine factors driving Islamic banks' cost inefficiency, the following specific form of Eq. (11) together with the translog cost function (Eq. 10) are estimated simultaneously using the MLE:

$$u_{it} = \lambda_0 + \lambda_1 SSBSZ_{it} + \lambda_2 SSBACQ_{it} + \lambda_3 SSBREP_{it} + \lambda_4 BG_{it} + \lambda_5 BSIZE_{it} + \lambda_6 BAGE_{it} + \lambda_7 PUBT_{it} + \lambda_8 BC_t + \lambda_9 GDPPC_t + \lambda_{10} T + \varepsilon_{it} \quad (12)$$

where $SSBSZ_{it}$ is the SSB size, representing the number of members serving on the SSB, $SSBACQ_{it}$ is the academic qualifications of SSB members measured as the percentage of members with a doctorate degree on the SSB, $SSBREP_{it}$ is the percentage of reputed Shariah scholars on the SSB, and BG_{it} is the board governance index. The channels through which SSB attributes affect bank inefficiency are explained in Section 3. The board governance index is included in Eq. (12) to estimate the incremental inefficiency effect of SSB governance. A bank's regular board of directors oversees bank managers and provides them with counselling, knowledge and networking resources so that decisions can be made (Hillman & Dalziel, 2003; Daily, Dalton & Cannella, 2003). Consequently, better board governance can help banks to exploit economies of scale and scope, leading to higher cost efficiency. Furthermore, the shareholder orientation of a bank board can increase cost efficiency as a means to maximise shareholders' wealth. However, better board governance can impede any gains in efficiency if the excessive monitoring of bank managers results in an inadequate support for the inclusion of boards' knowledge resources in decision-making (Adams & Ferreira, 2007). $BSIZE_{it}$ is the bank's size measured as the log of total assets, and $BAGE_{it}$ is the bank's age measured as the difference between the end of study period (2014) and the year of establishment of the bank. The age variable captures the efficiency gain through learning-by-doing. PUBT is a dummy variable, taking a value of 1 if the bank is publicly listed and 0 if otherwise; BC_{it} is the bank concentration ratio, measured by the percentage of total commercial banking assets held by the three largest commercial banks, which is an inverse measure of bank competition. $GDPPC_t$ is the growth rate of per capita GDP, and T is time trend which takes a value of 1 for 2003, 2 for 2004, and so on. The time trend captures the evolving nature of cost inefficiencies. To explain conventional banks' cost inefficiency, we use a restricted version of Eq. (12) that includes all but the attributes of the Shariah supervisory board ($SSBSZ, SSBACQ$ and $SSBREP$) as inefficiency determinants.

5.2 Results on the determinants of cost inefficiency

Table 4 presents the results for the determinants of cost inefficiency. We use two alternative dependent variables: risk-unadjusted inefficiency measures (RUIN) and risk-adjusted inefficiency measures (RAIN). RUIN is derived from Eq. (9) which does not control the cost frontier for risks, while RAIN is derived from Eq. (10) that does control the cost frontier for risks. For Islamic banks, we estimate the models both with and without the SSB attributes ($SSBSZ, SSBACQ$ and $SSBREP$) as determinants, and present the results in Panel A of Table 4. Columns (1) and (2) confirm that a larger SSB increases cost inefficiency of an Islamic bank relative to its group-specific frontier regardless of whether or not inefficiency is adjusted for risks. The effect size is also economically significant since an additional member on SSB is associated with an increase in the Islamic banks' cost inefficiency by 0.7 to 0.9 percentage points. In contrast, cost inefficiency is lower in Islamic banks with a higher percentage of members with a doctorate degree or reputation on the SSB. The coefficients of these variables are statistically significant at the 1% level and economically meaningful. For instance, a 10-percentage point increase in SSB members with higher academic qualifications results in 2 to 4 percentage points decrease in Islamic banks' cost inefficiency. Reputation of SSB members has a quantitatively more pronounced effect on inefficiency. The results consequently support the hypothesis that SSB supervision affects Islamic banks' efficiency (H_3). Regular board governance does not exert any statistically significant effect on Islamic banks' cost inefficiency. Larger Islamic banks are more cost inefficient than smaller ones. This can be attributed to the higher information asymmetry, and the higher horizontal and vertical monitoring costs in large banks (Mohanty et al., 2013; Allen & Rai, 1996).

Older banks are less cost inefficient than younger banks, supporting the notion of efficiency gain through learning-by-doing (Mester, 1996; Ray & Das, 2010). This finding is statistically significant only for risk-adjusted inefficiency. The publicly traded Islamic banks tend to have higher cost inefficiency compared to their non-traded counterparts, reflecting shareholders' inability to exercise market discipline to reduce cost inefficiency. This result is statistically significant only for risk-adjusted inefficiency. The reason for this could be that shareholders are indifferent to cost efficiency and they are more interested in profit efficiency

(Chu & Lim, 1998; Havrylchyk, 2006). The bank concentration ratio wields no significant effect on Islamic banks' cost inefficiency. The growth rate of per capita GDP has a positive and significant effect, implying that cost inefficiency of Islamic banks is higher in a rapidly growing economy. Finally, the coefficient for the time trend is statistically insignificant and suggests that Islamic banks' cost efficiency is time invariant.

We also estimate Islamic banks' cost inefficiency model omitting SSB attributes, so that the results are comparable to those of conventional banks. Columns (3) and (4) of Table 4 present the results. The coefficient of regular board governance remains positive but becomes statistically significant when SSB attributes are omitted. This finding suggests that regular board governance partly subsumes the effect of SSB governance. Results for the remaining determinants of inefficiency remain robust.

Table 4 Panel B presents the results on the determinants of cost inefficiency for conventional banks. Columns (5) and (6) show that better board governance is associated with lower risk-unadjusted cost, but higher risk-adjusted cost inefficiency. Dong, Girardone and Kuo (2017) also find mixed effects of board governance attributes on cost efficiency of Chinese conventional banking. Salim, Arjomandi and Seufert (2016) find a negative effect of board governance on the technical inefficiency of conventional banks in Australia, which is consistent with our results for risk-unadjusted cost inefficiency. This is attributed to the omission of risks in their efficiency modelling or a focus on a single country's conventional banks. The effects of bank size and age on cost inefficiency of conventional banks are similar to those for Islamic banks. The public trading of shares of conventional banks is not relevant in determining their cost inefficiency. Country-specific variables become statistically significant in the model of risk-adjusted cost inefficiency. More specifically, cost inefficiency increases with an increase in the banking industry concentration. This result supports the 'quiet life' hypothesis, i.e. banks in more concentrated markets feel less pressure to achieve higher cost savings (Berger & Mester, 1997). Risk-adjusted cost inefficiency decreases with the growth rate of per capita GDP and the trend variable.

Panel C in Table 4 presents the results for the determinants of the cost gap, estimated from the one-sided error term of the stochastic cost meta-frontier model. Since the direction of the relationship between the cost gap and its determinants is the same for risk-unadjusted and risk-adjusted inefficiencies, we focus on the results for the latter (in column 8) here. The results show that board governance has a significant positive impact on the cost gap, indicating that better governance widens the gap between the group-specific cost frontier and the cost meta-frontier. This is plausible because the presence of a strong board may induce risk-averse managers to favour familiar technology over advanced technology due to the fear of being fired if such technologies perform poorly (Balsmeier, Fleming & Manso, 2017). The cost gap is positively associated with bank size and age. The cost gap is lower in publicly traded banks compared to privately owned banks. The banking industry concentration and the growth rate of per capita GDP have little influence on the cost gap but it decreases with the trend variable.

[Insert Table 4]

6. Profit efficiency of Islamic and conventional banks

6.1 Stochastic profit meta-frontier model

We use the alternative profit function proposed by Berger and Mester (1997), to estimate profit efficiency of Islamic and conventional banks. The alternative profit function expresses profit as a function of outputs and input prices instead of output prices and input prices as in standard profit function. The former is reasonable because it is free from measurement errors in output prices, resulting from the heterogeneity in bank outputs, services quality, and the market power of banks over output prices. The alternative profit frontier model therefore employs the same set of independent variables as in the cost frontier model (Eq. 1) but profit before tax replaces total cost as the dependent variable. The stochastic profit frontier model for jth bank group can be expressed as:

$$In(P_{jit} + \theta) = Inf_t^{\,j}(X_{jit}) + v_{jit} + u_{jit} \quad (13)$$

where $P_{jit} + \theta$ is the profit before tax (P_{jit}) plus a constant, θ. The term θ is the absolute value of the minimum profits in the sample plus 1, that is, $\theta = \left|P_{jit_{min}}\right| + 1$. The term θ is added to P_{jit} to avoid taking log of negative profits. The before tax profit is used to rule out the possibility of efficiency gain resulting from a bank's tax-reduction strategies (Berger & Mester, 1997; Shamsuddin & Xiang, 2012). We modify Eq. (13) to define the stochastic risk–adjusted profit frontier model as:

$$In\ (P_{jit} + \theta) = Inf_t^{\,j}(X_{jit}, r_{jit}) + v_{jit} + u_{jit} \quad (14)$$

where r_{jit} represents the risk measures (liquidity risk, credit risk, operational risk and insolvency risk) of the ith bank in the jth group at the tth period. Huang et al.'s (2014) SMF approach is used to compare the profit efficiency of each bank group in relation to the meta-frontier.[8] Figure 6 presents the profit meta-frontier model. At a given output level Y_{jit}, the gap between a bank's actual profit, P_{jit} and the meta-frontier profit for the risk-unadjusted model, $f_t^{\,M}(X_{jit})$ consists of three components: the profit gap ratio, $PGR_{it}^{j} = \frac{f_t^{\,j}(X_{jit})}{f_t^{\,M}(X_{jit})}$, the group-specific profit efficiency, $PE_{it}^{j} = \frac{f_t^{\,j}(X_{jit})e^{-u_{jit}}}{f_t^{\,j}(X_{jit})} = e^{-u_{jit}}$ and the random noise component, $\frac{P_{jit}}{f_t^{\,j}(X_{jit})e^{-u_{jit}}} = e^{v_{jit}}$. That is, $\frac{P_{jit}}{f_t^{\,M}(X_{jit})} = PGR_{it}^{j} \times PE_{it}^{j} \times e^{v_{jit}}$. By accounting for the random error component, the meta-profit efficiency (MPE_{jit}) can be defined and decomposed as: $MPE_{jit} = \frac{P_{jit}}{f_t^{\,M}(X_{jit})e^{v_{jit}}} = PGR_{it}^{j} \times PE_{it}^{j}$. The PGR captures the deviation of the group-

[8]As before, the LR test serves to verify the suitability of using a profit meta-frontier in our research setting. The LR statistics for the risk-unadjusted and -adjusted profit frontier models are 508.04 and 837.95, respectively. These are significant at the 1% level, rejecting the null hypothesis that both bank groups operate under the same profit frontier and justifying utilisation of the stochastic profit meta-frontier model.

specific frontier from the meta-frontier, arising from the gaps in both production technology and allocative efficiency (with respect to input and output prices).

[Insert Figure 6]

The stochastic profit meta-frontier and the translog functional forms of Eq. (13) and Eq. (14) are estimated in a similar fashion as that for the stochastic cost meta-frontier models in subsections 4.1 and 4.2.

6.2 Distribution of estimated profit efficiency

Panel A in Table 5 reports the results for group-specific profit efficiency, profit gap ratio and meta-profit efficiency, without controlling for risks. Column (1) shows that Islamic banks' mean group-specific profit efficiency score is 0.836, indicating that a typical Islamic bank is 16.4 percentage points less efficient relative to the best-practice bank on the group-specific frontier. Islamic banks have an average PGR of 0.658, suggesting that the Islamic bank group has the scope to expand its group-specific profit frontier by 34.2 percentage points. The mean PGR of conventional banks is much higher at 0.925. Consequently, the mean meta-profit efficiency (MPE) of Islamic banks is 18.9 percentage points lower (0.550 - 0.739 = -0.189) than that of conventional banks. Column (2) shows that this difference is statistically significant with a t-statistic of -12.875. We use the two-sample Kolmogorov-Smirnov test of the equality of the distributions of PGR and MPE between Islamic and conventional banks. The test results shown in column (3) suggest that the distributions of PGR and MPE are not the same across bank groups.

Panel B of Table 5 reports the results for risk-adjusted profit efficiency. Column (4) confirms that conventional banks also outperform Islamic banks in terms of risk-adjusted PGR and MPE. This finding may be attributed to the Shariah constraints on intermediation and risk management activities. Although both bank groups are close to each other in terms of group-frontier profit efficiency (PE), the difference in meta-frontier profit efficiency is large, which essentially results from the large difference in the PGR. Column (5) reveals that the differences in PGR and MPE scores between Islamic and conventional are statistically significant at the 1% level. Also, the distributions of PGR and MPE are not the same between the two bank groups as shown by the Kolmogorov-Smirnov test statistics in column (6).

It is interesting to observe that risk-adjusted meta-profit efficiency is higher than risk-unadjusted meta-profit efficiency in both Islamic and conventional banks (Panel C columns 1 and 4). This finding is consistent with Bitar et al.'s (2017) finding of higher technical efficiency when controlling for risk. However, our results in Table 3 show that meta-cost efficiency is lower after risk-adjustment than before risk-adjustment. A comparison of Bitar et al.'s (2017) finding of higher risk-adjusted technical efficiency with ours concerning lower risk-adjusted cost efficiency implies that risk-taking has a more pronounced effect in reducing allocative efficiency (with respect to input prices) than increasing technical efficiency. Overall, our results for cost and profit efficiency indicate that the revenue-increasing effect of risk outweighs its cost-increasing effect.

[Insert Table 5]

Furthermore, we plot Kernel density estimates for PGRs and MPEs in Figures 7 and 8, respectively. Figure 7 illustrates a relatively flat left tail of the distribution of PGRs for conventional banks, indicating that only a few conventional banks are far from the meta-frontier. In contrast, the distribution of PGRs for Islamic banks is less asymmetric. Figure 8 shows that the distribution of conventional banks' MPEs is more tilted towards large values, suggesting that conventional banks operate closer to the meta-profit frontier compared to their Islamic counterparts.

[Insert Figures 7 and 8]

6.3 Trends in stochastic profit efficiency measures

Figure 9 displays the trends concerning the cross-sectional average of the PGR and MPE for Islamic and conventional banks. In the risk-unadjusted model, the PGR shows very little variation over time from 2004 onwards but MPE reveals a slightly declining trend in the years preceding the GFC and a slightly rising trend in the post-GFC period. The risk-adjusted model shows a substantial decline in MPE in the pre-GFC period for both Islamic and conventional banks. Conventional banks consistently outperform Islamic banks both in terms of the PGR and MPE over the period 2003-2014. This finding is robust to the adjustment of risk.

[Insert Figure 9]

7. What drives profit inefficiency?

To investigate the determinants of profit inefficiency, Eq. (12) is re-estimated by replacing cost inefficiency with profit inefficiency as the dependent variable.[9] Two alternative dependent variables are used: risk-unadjusted inefficiency measures (RUIN) and risk-adjusted inefficiency measures (RAIN). The results are presented in Table 6. Column (1) shows that all three attributes of SSB (size, academic qualifications and reputation) contribute to reducing Islamic banks' profit inefficiency. An additional director on the SSB reduces Islamic banks' profit inefficiency by 2.64%. Moreover, a 1 percentage point increase in SSB members with higher academic qualifications and reputation diminishes Islamic banks' profit inefficiency by 0.8 percentage points and 1.4 percentage points, respectively. Column (2) shows that this finding remains statistically significant for SSB size and reputation in the case of risk-adjusted profit inefficiency.

[9] We use the same set of determinants in both the cost and profit inefficiency models following the prior bank efficiency literature (Berger & Mester, 1997; Maudos et al., 2002). These determinants relate to bank corporate governance, financial characteristics, banking industry and macro-economic conditions. The profit frontier and the corresponding inefficiency model are estimated simultaneously using Battese and Coelli's (1995) one-step procedure.

The effects of academic qualifications and reputation of SSB members on profit inefficiency are similar to those reported for cost inefficiency (Table 4). However, the contrasting results are found with respect to the effect of SSB size on cost and profit inefficiency. Specifically, a larger SSB increases cost inefficiency but decreases profit inefficiency. An Islamic bank with a larger SSB may incur additional costs for SSB members' remuneration. A larger SSB is better placed to modify the product portfolio and internal control system for Shariah compliance, both of which may add to operating costs but also improve the bank's revenue generating capacity. In sum, the differential effects of SSB size on cost and profit efficiency are plausible.

Better regular board governance decreases Islamic banks' profit inefficiency, yet the effect is statistically significant only for risk-unadjusted inefficiency. The effect size is -0.027, indicating that an increase in the board governance index by 1 percentage point decreases Islamic banks' profit inefficiency by 2.7 percentage points. Larger Islamic banks are less profit efficient than their smaller peers but profit efficiency is higher in older banks. This finding agrees with previous studies on conventional banks' profit efficiency (Akhigbe & McNulty, 2003; Silva et al., 2016). Profit inefficiency is lower in publicly traded banks than publicly non-traded banks.

The banking industry concentration ratio is negatively and significantly related to risk-unadjusted profit inefficiency, indicating that the higher the banking industry concentration, the lower is profit inefficiency. That is, Islamic banks can charge higher prices for their services in a less competitive market, and consequently achieve higher profit efficiency. A higher growth rate of per capita GDP leads to lower risk-unadjusted profit inefficiency. Islamic banks' profit efficiency is found to be time invariant. We re-estimate Islamic banks' profit inefficiency model, omitting SSB attributes as determinants to make the results comparable to those of conventional banks. The results in columns (3) and (4) show that better board governance increases Islamic banks' profit inefficiency when measured without adjusting for bank risks but its effect is negative on risk-adjusted profit inefficiency. The results for other determinants of profit inefficiency are similar to those reported in columns (1) and (2).

Panel B of Table 6 presents the results on determinants of profit inefficiency for conventional banks. Only three bank-specific variables (bank size, bank age and publicly traded bank dummy) influence profit inefficiency of conventional banks. Other determinants are statistically irrelevant for both risk-unadjusted and risk-adjusted inefficiencies.

Panel C of Table 6 reports the determinants of profit gap estimated from the one-sided error term of the stochastic profit meta-frontier model, which represents the inefficiency component of the gap between the profit meta-frontier and the group-specific profit frontier. Better board governance is associated with a greater profit gap. The larger and older banks have a lower profit gap but publicly traded banks have a higher profit gap. The more the banking industry is concentrated, the smaller is the profit gap. The coefficient of the growth rate of per capita GDP is negative and significant, which implies that banks operating in a rapidly growing economy use better technology. The negative and significant coefficient of the time trend variable suggests that the profit gap decreases over time.

[Insert Table 6]

We did not include country fixed effects in models presented in Tables 4 and 6 because we controlled those models for country-level banking industry and macro variables. However, these country-level variables may not adequately capture country-specific attributes. To check the robustness of our results we re-estimate the models in Tables 4 and 6, controlling for country fixed effects. Appendix Tables A1 and A2 present the results for the determinants of cost and profit inefficiency with country fixed effects. Our key findings on the effects of SSB composition on cost and profit inefficiency in Islamic banks remain unchanged after including country fixed effects. That is, larger SSB size increases cost inefficiency but decreases profit inefficiency. A higher proportion of either highly educated or reputed members on the SSB leads to lower cost and profit inefficiency in Islamic banks.

8. Additional tests

8.1 Efficiency of Islamic and conventional banks—Excluding Malaysia

Given that 15.91% of bank-year observations are from Malaysia, we re-estimate the models excluding Malaysian banks. Appendix Tables A3 and A4 present estimated cost and profit efficiency scores, respectively. Our findings on risk-adjusted cost and profit efficiency from the full sample remain valid in the sample that excludes the Malaysian banks. That is, on a risk-adjusted basis, Islamic banks have higher meta-cost efficiency but lower meta-profit efficiency compared to their conventional counterparts.

The results on the determinants of cost and profit inefficiency are presented in Tables A5 and A6 in the appendix, respectively. In general, our key findings are consistent with the results for the full sample inclusive of Malaysian banks. Specifically, the results reveal that the larger SSB size increases cost inefficiency but decreases profit inefficiency of Islamic banks. SSB members' academic qualifications and reputation contribute to reducing both cost and profit inefficiency in Islamic banks.

8.2 The role of the Shariah Advisory Council in Malaysia

The Central Bank of Malaysia (Bank Negara Malaysia) operates with advice provided by the Shariah Advisory Council (SAC). This council has the authority to pronounce judgements on Shariah principles pertaining to Islamic banking. The SAC also plays an advisory role by giving advice to Islamic financial institutions on any Shariah issue concerning their business and transactions. Thus, we control our inefficiency determinants model (Eq. 12) for the SAC to investigate whether it has any effect on Islamic banks' cost and profit efficiency. The results are presented in Appendix Table A7. Our initial findings (see Tables 4 and 6) on the effects of SSB composition on both cost and profit efficiency remain robust after controlling for the SAC dummy variable. The coefficients of the SAC dummy variable indicate that the SAC is not associated with cost inefficiency but it reduces profit inefficiency. The results imply that the SAC as an external advisory body may have limited scope in reducing bank-level cost inefficiency. However, its juristic Shariah advice may be conducive to enhancing Islamic banks' customer base, product portfolio, and hence profit efficiency.

8.3 Efficiency of Islamic and conventional banks by geographical regions

We examine whether efficiency levels between bank groups differ by geographical regions. Table 7 summarises the statistics on cost efficiency measures across six geographical regions: GCC, East Asia & Pacific, Europe & Central Asia, Non-GCC Middle East & North Africa, Sub-Saharan Africa, and South Asia. For the GCC region, the risk-unadjusted model results in Panel A show that the average CGR is equal to 0.971 for Islamic banks and 0.945 for conventional banks. The meta-cost efficiency (MCE) and group-specific cost efficiency (CE) scores demonstrate that the Islamic banks have MCE and CE of 0.801 and 0.824 versus MCE and CE of 0.900 and 0.952 for conventional banks, respectively. However, in the risk-adjusted model Islamic banks outperform conventional banks with respect to both CGR and MCE. The higher MCE of Islamic banks is attributable to their higher CGR. Furthermore, Islamic banks' CGR and MCE decrease in smaller amounts in the risk-adjusted model than those of conventional banks. Similar results are found for the Islamic banks in East Asia and the Pacific, Europe and Central Asia regions.

Conversely, the results for non-GCC Middle East and North Africa reveal that Islamic banks are superior in both CGR and MCE in the risk-unadjusted model but they lag behind conventional banks' performance in the risk-adjusted model. Islamic banks in Sub-Saharan Africa emerge as superior in CGR and MCE compared to conventional banks irrespective of the efficiency models chosen. The results also confirm that South Asian Islamic banks' CGR is similar to that of conventional banks, but they underperform their conventional counterparts in terms of MCE due to the lower cost efficiency with respect to their group-specific frontier.

We present the summary statistics of profit efficiency measures for six geographical regions in Table 8. Overall, Islamic banks have lower PGR and MPE compared to conventional banks and this is found to be quite similar in both the risk-unadjusted and risk-adjusted models irrespective of the regions.

[Insert Tables 7 and 8]

Next, we investigate the determinants of inefficiency of Islamic banks across geographical regions. Table 9 presents the detailed results. Here we focus on the SSB effects. The results show that larger SSB: firstly, increases cost inefficiency in GCC and Non-GCC MENA regions; secondly, exerts no effect on cost inefficiency in Europe & Central Asia; and thirdly, decreases cost inefficiency in other regions. SSB members' higher academic qualifications contribute to reducing cost inefficiency in all regions. A higher proportion of reputed Shariah scholars on the SSB reduces cost inefficiency in all but the East Asia & Pacific region. Overall, the findings from the full sample remain robust in all regions for the SSB education effect, in all but the East Asia & Pacific region for the reputation effect, and in the GCC and Non-GCC MENA regions for the SSB size effect.

Table 10 presents the results for the determinants of profit inefficiency of Islamic banks across regions. SSB size reduces profit inefficiency in all but GCC and Sub-Saharan African regions. SSB members' higher academic qualifications reduces profit inefficiency in all but Non-GCC MENA and Sub-Saharan Africa. Finally, SSB members' reputation decreases profit inefficiency in all regions except in Europe & Central Asia, and East Asia & Pacific. Overall, our finding of the inefficiency-reducing effect of better Sharia governance from the full sample (see Table 6) holds in most geographical regions. The effects of other variables are also qualitatively similar to those reported in Tables 4 and 6.

[Insert Tables 9 and 10]

8.4 Efficiency results of common frontier estimation

In the previous sections, efficiency results were obtained from the stochastic cost and profit meta-frontiers. We now use a common frontier, which pool together all the data of both bank groups, assuming that they operate under a single frontier. This analysis is motivated by the widespread use of the common frontier in the literature (Hassan, 2006; Bader et al., 2008; Hassan et al., 2009; Saeed & Izzeldin, 2016; Alqahtani et al., 2017; Bitar et al., 2017). In general, our results in Table 11 show that the use of common frontier overestimates cost and profit efficiency levels. For instance, in the risk-unadjusted model the mean of Islamic banks' cost and profit efficiencies are 0.931 and 0.821, respectively, compared to the mean of 0.829 and 0.550 in the meta-frontier models (see Tables 3 and 5). For conventional banks, the common frontier cost and profit efficiencies are 0.911 and 0.892, respectively, while these are 0.881 and 0.739 as reported for meta-efficiencies (see Tables 3 and 5). Results in the risk-adjusted model also reveal a similar pattern. Overall, our analysis demonstrates that a common frontier overestimates efficiency scores for both bank groups due to its assumption of no technology gap between the bank groups. This finding justifies using a profit meta-frontier model to estimate efficiency of Islamic and conventional banks.

[Insert Table 11]

8.5 Profit efficiency with inverse hyperbolic sinh (IHS) transformation of profit model

In Eq. 13, we define the dependent variable of the profit function by adding a constant (θ) to the profit values (P_{jit}) to facilitate taking natural log of ($P_{jit} + \theta$). This section re-defines the dependent variable of the profit function using the inverse hyperbolic sinh (IHS) transformation as suggested by Burbidge, Magee & Robb (1988) and Carroll, Dynan & Krane (2003). The inverse hyperbolic sinh function is defined as:

$$\sinh^{-}(P_{jit}) = \ln(P_{jit} + ({P_{jit}}^2 + 1)^{1/2}) \tag{15}$$

The IHS function admits positive, zero and negative profit values (P_{jit}) and hence does not require an ad-hoc adjustment to a non-positive profit value. In addition, the IHS transformation addresses the potential heteroskedasticity issue by damping outliers. Building on this, profit function in Eq. (13) is restated as:

$$\ln(P_{jit} + ({P_{jit}}^2 + 1)^{1/2}) = {Inf_t}^j(X_{jit}) + v_{jit} + u_{jit} \tag{16}$$

The IHS transformation is also applied to Eq. (14) and calculated with the stochastic profit meta-frontier approach. Our earlier findings in Table 5 regarding group-specific and meta-profit efficiency scores are robust to this alternative specification of the dependent variable of the profit model. We generally find that Islamic banks are less profit efficient relative to their conventional counterparts.[10]

8.6 Endogeneity in the relationship between corporate governance and bank efficiency

The corporate governance variables such as regular board governance index, SSB size, and academic qualifications and reputation of SSB members may be endogenously determined. For instance, a strong commitment to a bank's efficiency may jointly increase both efficiency and corporate governance. To alleviate the concern about endogeneity, we

[10] More specifically, the IHS transformation of the profit frontier model provides the following results. The average group-specific profit efficiency is 0.576 for Islamic banks and 0.671 for conventional banks. The average PGRs are 0.849 and 0.911 for Islamic and conventional banks, respectively. The average meta-profit efficiency is 0.501 for Islamic banks and 0.657 for conventional banks. The risk-adjusted profit model also depicts lower PGR and MPE for Islamic banks compared to conventional banks. Detailed results are available from the corresponding author on request.

examine the relationship between efficiency and corporate governance by using an instrumental variable (IV) for each corporate governance variable. The year-average of each of the corporate governance variables of other banks in the country is used as an instrument for the pertinent bank. This method is employed by John, Litov and Yeung (2008), Laeven and Levine (2009), Aggarwal et al. (2010) and Anginer et al. (2014). This is a reasonable instrument because a change in the efficiency of one bank is less likely to influence the corporate governance of other banks. The results are reported in Table 12 and they are similar to those reported in Tables 4 and 6. Specifically, Panel A of Table 12 shows that cost and profit inefficiencies in Islamic banks are negatively related to SSB members' academic qualifications and reputation. However, an increase in SSB size and better regular board governance lead to higher cost inefficiency but lower profit inefficiency. Our earlier results for the effect of board governance on conventional banks' efficiency hold when the instrumented board governance variable is used in Panels B and C of Table 12.

[Insert Table 12]

We also use the two-step system GMM estimator as an alternative method to address endogeneity concerning corporate governance. Specifically, we adopt Wintoki, Linck & Netter's (2012) approach to obtain system GMM estimates. The GMM estimator addresses unobserved heterogeneity, simultaneity and dynamic endogeneity (Wintoki et al., 2012). The GMM results presented in Table 13 are consistent with the main results as reported in Tables 4 and 6, and with the 2SLS estimation results in Table 12. In sum, the results from both 2SLS and system GMM estimations suggest that banks' regular board governance and Islamic banks' Shariah supervisory board composition significantly influence cost and profit inefficiency.

[Insert Table 13]

9. Conclusion

The Islamic banking industry has continued to maintain double-digit growth rates over the last decade despite economic and political uncertainty in the world's major economies during this period. Hence, there is considerable interest in comparing the efficiency of Islamic and conventional banks, particularly to benchmark bank performance and to better understand the effects of Islamic banking practices and governance on bank efficiency. Previous studies estimate efficiency using a common frontier by pooling together both Islamic and conventional banks (Mohamad et al., 2008; Srairi, 2010; Saeed & Izzeldin, 2016), which can give biased estimates since the common frontier does not account for underlying differences in mode of operations, institutional and supervisory conditions in which the two bank groups operate. This paper overcomes this issue by estimating cost and profit efficiency of the two bank groups using a newly developed stochastic meta-frontier (SMF) approach devised by Huang et al. (2014). The SMF framework can estimate within-group efficiency and between-group efficiency of firms facing heterogeneous production and market opportunities. We examine the sensitivity of efficiency measures to controlling for risks. More importantly, we examine the effects of Shariah supervisory board governance and regular board governance on Islamic banks' efficiency.

Using a matched sample of Islamic and conventional banks in 28 countries over the period 2003-2014, we observe that Islamic banks have higher risk-adjusted cost efficiency, but lower risk-adjusted profit efficiency relative to conventional banks. Islamic banks' cost efficiency is less sensitive than that of conventional banks to the controlling for risks. For both bank groups, in general risk-adjusted cost efficiency is much lower than risk-unadjusted cost efficiency, but risk-adjusted profit efficiency is slightly higher than risk-unadjusted profit efficiency. This finding implies that risk-taking reduces relative cost performance of a bank but improves its relative revenue performance. This study reveals that SSB attributes are important drivers of cost and profit efficiency in Islamic banks. Islamic banks' profit efficiency increases but cost efficiency decreases with larger SSB. However, SSB members with higher academic qualifications and reputation contribute to improving both cost and profit efficiency in Islamic banks. Stronger regular board governance has mixed effects on cost efficiency of both bank groups. It increases profit efficiency in Islamic banks but does not significantly affect conventional banks' profit efficiency. We present additional tests demonstrating that: firstly, the use of a common frontier overestimates cost and profit efficiency levels; secondly, bank efficiency level varies by geographical regions; and thirdly, our key findings are robust to controlling for potential endogeneity in the governance-efficiency relationship. Finally, this study provides a useful benchmark for measuring inefficiency of two bank groups and identifying the key determinants of inefficiency, which may be of interest to bank managers, regulators and international Shariah standard setting bodies of Islamic banks (e.g., IFSB, AAOIFI).

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Table 1 Previous studies on Islamic banks' cost and profit efficiency and research gaps.
This table summarises the prior literature on Islamic banks' cost and profit efficiency and research gaps. The last row of this table highlights the distinguishing features of our study. SSB is the Shariah supervisory board, IBs denotes Islamic banks and CBs denotes conventional banks. 'No' means not being investigated in the relevant study and 'Yes' implies the opposite. N/A means not applicable.

	Panel A: Prior literature				Panel B: Research gaps in Islamic banking literature		
Authors	Research focus	Inefficiency determinants: bank and country-level variables	Average annual Efficiency score for IBs (CBs)	Key findings	Stochastic meta-frontier model	Efficiency adjusted for risks (liquidity risk, credit risk, operational risk and insolvency risk)	Board governance and Shariah supervision as inefficiency determinant
El-Gamal and Inanoglu (2005)	Cost efficiency (4 IBs, 49 CBs, 1990-2000, Turkey)	Yes	0.889 (0.648)	Turkish Islamic banks are more cost efficient compared to conventional banks.	No	Credit risk	No
Abdul-Majid et al. (2011)	Cost efficiency (10 IBs, 51 CBs, 1996-2002, Malaysia)	Yes	0.665 (0.825)	Malaysian Islamic banks are less cost efficient than conventional banks.	No	Credit risk	No
Johnes et al. (2014)	Technical efficiency (45 IBs, 207CBs, 2004-2009, 18 countries)	Yes	0.789 (0.789) 0.879 (0.797) 0.899 (1.000)	Islamic banks' gross efficiency is indistinguishable from that in conventional banks. Islamic banks have higher net (managerial) but lower type (modus operandi) efficiency.	No	No	No
Srairi (2010)	Cost and profit efficiency (23 IBs, 48 CBs, 1999-2007, 6 GCC countries)	Yes	0.515 (0.627) 0.618 (0.734)	Islamic banks in GCC countries are less cost and profit efficient compared to conventional banks.	No	No	No
Alqahtani et al. (2017)	Cost and profit efficiency (30 IBs, 50 CBs, 1999-2012, 6 GCC countries)		0.498 (0.469) 0.687 (0.717)	Islamic banks in GCC countries are more cost efficient but less profit efficient compared to conventional banks.	No	No	No
Saeed and Izzeldin (2016)	Default risk and efficiency (Publicly-traded 23 IBs, 87 CBs, 2002-2010, 8 countries)	Yes	0.846 (0.913) 0.815 (0.721)	Islamic banks are less cost efficient but more profit efficient than conventional banks.	No	No	No
Al-Jarrah et al. (2016)	Cost efficiency (2007-2013, MENA countries)	Yes	0.77 (0.77)	Cost efficiency of Islamic and conventional banks is similar.	No	No	No
Mohamad et al. (2008)	Cost and profit efficiency (43 IBs, 37 CBs, 1990-2005, 21 countries)	Yes	0.318 (0.293) 0.751 (0.754)	The differences in cost and profit efficiency between Islamic and conventional banks are not statistically significant.	No	No	No
Bader et al. (2008)	Cost and profit efficiency (43 IBs, 37 CBs, 1990-2005, 21 countries)	N/A	0.903 (0.935) 0.879 (0.863)	Both groups have similar efficiency.	No	No	No

Hassan et al. (2009)	Cost and profit efficiency (22 IBs, 18 CBs, 1990-2005, 11 countries)	Yes	0.915 (0.927) 0.843 (0.807)	Both groups have similar efficiency.	No	No	No
This study	Risk-adjusted cost and profit efficiency (94 IBs and 94 CBs, 2003-2014)	Yes			Yes	Yes	Yes

Table 2 Descriptive statistics of variables employed to estimate cost and profit efficiency.
Panels A to D present the descriptive statistics of variables used in estimating cost and profit efficiency frontiers. Panel E provides the descriptive statistics for the determinants cost and profit inefficiency. In column (2), the unit of measurement is indicated for all but r_4, which represents Z– score as explained in sub-section 3.2. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

			Islamic banks		Conventional banks		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable names	Variable notations	Unit of measurement	Mean	Std. Dev.	Mean	Std. Dev.	t-statistic for the difference between two means
Panel A: Dependent							
Total cost	TC	Million	203.92	313.68	542.11	928.354	-9.411[a]
Pre-tax profits	P	Million	89.725	251.77	247.21	424.830	-8.532[a]
Panel B: Output							
Total loans	y_1	Million	3514.7	6714.5	8650.8	12740.8	-10.073[a]
Other earning assets	y_2	Million	1366.4	2441.0	4169.2	5708.21	-12.153[a]
Total non-interest	y_3	Million	73.915	165.16	163.88	262.039	-7.904[a]
Panel C: Input prices							
Price of deposits	w_1	Ratio	0.127	0.436	0.071	0.293	2.887[a]
Price of physical capital	w_2	Ratio	12.723	51.983	2.713	3.323	4.875[a]
Price of labour	w_3	Ratio	0.013	0.018	0.011	0.011	2.273[b]
Panel D: Risk measures							
Credit risk	r_1	%	4.463	7.271	4.999	6.248	-1.085
Liquidity risk	r_2	%	52.270	86.795	33.236	39.554	5.111[a]
Operational risk	r_3	%	1.104	1.981	0.889	2.251	1.839[c]
Insolvency risk	r_4	-	1.480	0.505	1.597	0.569	-4.078[a]
Panel E: Determinants of							
SSB size	SSBSZ	Integer	4.151	2.107			
SSB academic	SSBACQ	%	57.666	34.762			
SSB members'	SSBREP	%	19.253	28.907			
Board governance index	BG	%	58.346	20.678	60.413	19.152	-2.420[b]
Bank size	BSIZE	Log	3.270	0.729	3.608	0.828	-10.659[a]
Bank age	BAGE	Integer	17.079	11.483	32.587	24.138	-15.009[a]
Publicly traded banks	PUBT	Dummy	0.460	0.499	0.535	0.499	3.964[a]
Bank concentration	BC	%	69.633	22.212			
Growth rate of per capita	GDPPC	%	1.670	4.038			

Table 3 Summary statistics of cost efficiency scores.
This table presents the average cost efficiency scores obtained with and without adjusting for risks. Columns (1) and (4) report mean efficiency scores before and after risk adjustments, respectively. Columns (2) and (5) present t-statistics for the equality of average efficiency scores between Islamic and conventional banks. Columns (3) and (6) present the two-sample Kolomogorov-Smirnov test statistics for the equality of the distributions of cost efficiency between Islamic and conventional banks. Column (7) presents t-statistics for the equality of risk-unadjusted and risk-adjusted efficiency scores. The group-specific cost efficiency (CE) and cost gap ratio (CGR) scores are obtained from the group-specific frontier and meta-frontier, respectively. The product of CE and CGR provides a measure of meta-cost efficiency (MCE). Test for the difference in group-specific cost efficiency scores between Islamic and conventional banks is not presented as they are not comparable between groups.

	Panel A: Risk-unadjusted cost efficiency			Panel B: Risk-adjusted cost efficiency			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean	t-test for	Kolmogorov-	Mean	t-test for	Kolmogorov-	t-test for

	efficiency score	IBs vs. CBs	Smirnov test for IBs vs. CBs	efficiency score	IBs vs. CBs	Smirnov test IBs vs. CBs	risk-unadjusted vs. risk-adjusted efficiency
Group-specific cost efficiency (CE)							
Islamic banks	0.852			0.771			13.362 [a]
Conventional banks	0.929			0.864			12.568 [a]
Cost gap ratio (CGR)							
Islamic banks	0.972			0.830			7.8541 [a]
Conventional banks	0.948	12.715 [a]	5.324 [a]	0.691	14.241 [a]	6.769 [a]	7.8768 [a]
All banks	0.960			0.761			6.7661 [a]
Meta-cost efficiency (MCE)							
Islamic banks	0.829			0.641			9.3815 [a]
Conventional banks	0.881	-9.439 [a]	6.290 [a]	0.600	4.180 [a]	4.032 [a]	9.847 [a]
All banks	0.855			0.620			4.5695 [a]

Table 4 Determinants of cost inefficiency of Islamic and conventional banks.

This table presents the results on determinants of group-specific cost inefficiency in Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of the cost gap represented by the one-sided error term in the SMF. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Variables	Panel A: Group-specific cost inefficiency of Islamic banks				Panel B: Group-specific cost inefficiency of conventional banks		Panel C: Cost gap in stochastic cost meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	0.009[c]	0.007[b]						
SSB academic qualifications	-0.002[a]	-0.003[a]						
SSB members' reputation	-0.004[b]	-0.008[a]						
Board governance	0.0003	0.005	0.022	0.0052 [c]	-0.002[a]	0.006[a]	0.002	0.006[a]
Bank and country-level variables								
Bank size	0.192[a]	0.220[a]	0.062 [b]	0.206 [a]	0.176[a]	0.070[a]	0.1246[a]	1.110 [a]
Bank age	-0.002	-0.002[b]	-0.051	-0.0008 [c]	0.001	-0.002[a]	0.006	0.007[a]
Publicly traded bank dummy	0.013	0.062[a]	-0.033	0.054 [a]	0.002	-0.003	-0.064[c]	-0.937[a]
Bank concentration	-0.005	0.004	-0.003	0.0004	-0.006	0.164[a]	-0.007[c]	-0.0001
Growth rate of per capita GDP	0.004	0.005[a]	-0.120	0.008 [a]	0.006	-0.002[a]	0.002	0.0034
Time trend	0.006	0.004	0.012	0.003	-0.002	-0.081[b]	-0.015[c]	-0.044[a]
Constant	-0.438[a]	-0.533[a]	-0.304 [b]	-0.535 [a]	-0.460[a]	-0.161[c]	-0.330 [a]	-4.123[a]
R-squared	0.768	0.773	0.712	0.723	0.772	0.601	0.833	0.580
Observations	635	635	635	635	635	635	1270	1270
$\gamma = \sigma_u{}^2/(\sigma_u{}^2 + \sigma_v{}^2)$	0.126 [b]	0.073 [b]	0.029 [b]	0.051 [c]	0. 041 [a]	0.206 [a]	0.108 [b]	0.675 [a]
LR test of the one-sided error (u)	77.407 [a]	129.787 [b]	71.51 [b]	81.78 [b]	65.884 [a]	71.946 [a]	42.246 [a]	249.00 [a]

Table 5 Summary statistics of profit efficiency scores based on the stochastic meta-frontier model.
This table presents the profit efficiency scores obtained with and without adjusting for risks. Columns (2) and (5) present t-statistics for the equality of average efficiency scores between Islamic and conventional banks. Columns (3) and (6) present the two-sample Kolomogorov-Smirnov test statistics for the equality of the distributions of profit efficiency between Islamic and conventional banks. Column (7) presents t-statistics for the equality of risk-unadjusted and risk-adjusted efficiency scores. PE and PGR are obtained from the group-specific stochastic profit frontier and stochastic profit meta-frontier, respectively. The product of PE and PGR is used to measure MPE. Test for the difference in group-specific profit efficiency scores between Islamic and conventional banks is not presented as they are not comparable between groups.

	Panel A: Risk-unadjusted profit efficiency			Panel B: Risk-adjusted profit efficiency			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	t-test for risk-unadjusted vs. risk-adjusted efficiency
Group-specific Profit efficiency (PE)							
Islamic banks	0.836			0.788			6.127 [a]
Conventional banks	0.799			0.846			-6.272 [a]

Profit gap ratio (PGR)							
Islamic banks	0.658			0.775			-12.183 ^{a}
Conventional banks	0.925	-3.378 ^{a}	13.351 ^{a}	0.917	-7.086^{a}	8.313 ^{a}	1.486
All banks	0.791			0.846			-7.561 ^{a}
Meta-profit efficiency (MPE)							
Islamic banks	0.550			0.603			-6.064 ^{a}
Conventional banks	0.739	-12.875^{a}	8.742 ^{a}	0.775	-20.152 ^{a}	8.187 ^{a}	-4.4197 ^{a}
All banks	0.644			0.689			-6.2229 ^{a}

Table 6 s Determinants of profit inefficiency of Islamic and conventional banks.
This table presents the results on determinants of group-specific profit inefficiency in Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of profit gap (PG) represented by the one-sided error term in SMF. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Variables	Panel A: Group-specific profit inefficiency in Islamic banks				Panel B: Group-specific profit inefficiency in Conventional banks		Panel C: PG in stochastic profit meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	-0.0264^{a}	-0.023^{c}						
SSB academic qualifications	-0.008^{a}	-0.003						
SSB members' reputation	-0.014^{b}	-0.001^{c}						
Board governance	-0.027^{a}	-0.009	1.718 ^{a}	-0.0013 ^{c}	0.0054	0.004	-0.001	0.001^{b}
Bank and country-level variables								
Bank size	1.289^{a}	0.431^{a}	0.323 ^{b}	0.449 ^{a}	0.407^{a}	0.477^{a}	-0.503^{a}	-0.786^{a}
Bank age	-0.050^{a}	-0.002	-0.097	-0.006	-0.715^{a}	0.008	-0.032^{a}	-0.023^{a}
Publicly traded banks dummy	-0.927^{a}	-0.080^{c}	1.680 ^{a}	-0.112 ^{a}	-0.839^{c}	0.072	0.073^{a}	0.039^{c}
Bank concentration	-0.022^{a}	-0.002	-2.992 ^{a}	-0.0006 ^{c}	-0.009	-0.001	-0.005^{a}	-0.005^{a}
Growth rate of per capita GDP	-0.105^{a}	-0.002	1.942 ^{a}	-0.003	-0.002	-0.006	-0.007^{b}	-0.020^{a}
Time trend	0.012	0.008	0.260	0.002	-0.008	-0.011	-0.006^{c}	-0.020^{a}
Constant	-2.679^{b}	-0.920^{a}	-0.597 ^{a}	-0.992 ^{a}	-1.526^{a}	-1.742^{a}	2.338^{a}	2.883^{a}
R-squared	0.908	0.919	0.875	0.864	0.695	0.599	0.863	0.367
Observations	635	635	635	635	635	635	1270	1270
$\gamma = \sigma_u{}^2/(\sigma_u{}^2 + \sigma_v{}^2)$	0.975 ^{a}	0.500 ^{a}	0.919 ^{a}	0.455 ^{a}	0.846 ^{a}	0.628 ^{a}	0.99 ^{a}	0.989 ^{a}
LR test of the one-sided error (u)	178.40 ^{a}	145.26 ^{a}	194.56 ^{a}	134.16 ^{a}	82.283 ^{a}	98.41 ^{a}	481.49 ^{a}	428.47 ^{a}

Table 7 Average cost efficiency by geographical region.
This table presents the average values of cost efficiency measures by geographical region. CE is the bank group-specific cost efficiency estimated from the group-specific stochastic frontier model. CGR is the cost gap ratio and MCE is meta-cost efficiency obtained from the stochastic meta-frontier cost model.

	Islamic banks			Conventional banks		
	CE	CGR	MCE	CE	CGR	MCE
Panel A: Risk-unadjusted efficiency						
GCC	0.824	0.971	0.801	0.952	0.945	0.900
East Asia & Pacific	0.826	0.968	0.799	0.937	0.920	0.863
Europe & Central Asia	0.828	0.967	0.801	0.936	0.930	0.871
Non-GCC Middle East & North Africa	0.929	0.976	0.907	0.841	0.969	0.816
Sub-Saharan Africa	0.945	0.986	0.931	0.948	0.964	0.914
South Asia	0.867	0.984	0.853	0.923	0.982	0.906
Panel B: Risk-adjusted efficiency						
GCC	0.717	0.839	0.602	0.845	0.652	0.549
East Asia & Pacific	0.764	0.791	0.604	0.856	0.532	0.454
Europe & Central Asia	0.751	0.809	0.608	0.793	0.689	0.548
Non-GCC Middle East & North Africa	0.850	0.813	0.692	0.891	0.831	0.740
Sub-Saharan Africa	0.910	0.882	0.803	0.920	0.747	0.690
South Asia	0.800	0.872	0.697	0.918	0.876	0.804

Table 8 Average profit efficiency by geographical region.

This table presents the average values of profit efficiency measures by geographical region. PE is the bank group-specific profit efficiency estimated from the group-specific stochastic frontier model. PGR is the profit gap ratio and MPE is meta-profit efficiency obtained from the stochastic meta-frontier profit model.

	Islamic banks			Conventional banks		
	PE	PGR	MPE	PE	PGR	MPE
Panel A: Risk-unadjusted efficiency						
GCC	0.815	0.734	0.598	0.801	0.918	0.735
East Asia & Pacific	0.843	0.620	0.525	0.806	0.971	0.783
Europe & Central Asia	0.691	0.669	0.469	0.702	0.949	0.667
Non-GCC Middle East & North Africa	0.902	0.620	0.560	0.873	0.899	0.785
Sub-Saharan Africa	0.887	0.575	0.510	0.770	0.889	0.687
South Asia	0.891	0.601	0.537	0.797	0.895	0.713
Panel B: Risk-adjusted efficiency						
GCC	0.714	0.846	0.600	0.778	0.925	0.721
East Asia & Pacific	0.760	0.770	0.584	0.844	0.945	0.798
Europe & Central Asia	0.695	0.785	0.532	0.746	0.924	0.687
Non-GCC Middle East & North Africa	0.899	0.726	0.650	0.937	0.891	0.836
Sub-Saharan Africa	0.931	0.663	0.618	0.958	0.852	0.816
South Asia	0.903	0.705	0.638	0.937	0.899	0.843

Table 9 The effect of Shariah supervisory board on cost inefficiency of Islamic banks across geographical regions.
This table presents the effects of the Shariah supervisory board on group-specific cost inefficiency in Islamic banks across six geographical regions. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: GCC		Panel B: Non-GCC MENA		Panel C: South Asia		Panel D: Europe &		Panel E: Sub-Saharan Africa		Panel F: East Asia &	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	RUIN	RAIN	RUI	RAI	RUI	RAI	RUI	RAI	RUIN	RAIN	RUI	RAI
Corporate governance												
SSB size	0.142	0.015 [c]	0.02	0.02	0.14	-	0.046	-	0.008	-	0.11	-
SSB academic qualifications	-0.047	-0.004	-	-	-	-	-	-	-	-	-	-
SSB members' reputation	-0.710	-0.002	0.02	-	-	0.00	-	0.02	-	-	0.92	-
Board governance	-0.140	0.001 [b]	-	0.00	-	-	-	-	-	0.429	-	0.00
Bank and country-level												
Bank size	-0.011	0.169 [a]	0.03	0.17	0.16	-	0.377	-	0.199	0.009	1.15	0.03
Bank age	-0.192	-0.002	-	0.00	0.03	0.01	0.039	0.00	0.053	-	0.03	0.00
Publicly traded bank dummy	0.247 [a]	0.005	0.17	-	-	0.28	0.002	0.00	-	-	0.22	0.00
Bank concentration	1.052 [a]	-0.005	0.01	-	0.30	0.00	0.179	0.07	0.350	0.077	-	-
Growth rate of per capita	-0.444	0.002	-	0.00	-	-	-	0.08	-	-	-	-
Time trend	-0.209	0.009	0.05	-	-	0.00	-	-	0.356	-	-	0.01
Constant	-0.289	-0.034	0.02	-	0.28	1.08	0.059	-	-	-	2.72	-
R-squared	0.581	0.551	0.27	0.26	0.49	0.47	0.231	0.14	0.212	0.194	0.35	0.28
Observations	221	221	71	71	108	108	59	59	43	43	133	133
Country control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.296 [a]	0.902 [a]	0.65	0.99	0.89	0.70	0.897	0.03	0.989	0.966	0.88	0.85
LR test of the one-sided error	36.79 [a]	74.35 [a]	57.9	36.2	55.3	35.3	16.91	77.5	25.53	111.1	56.8	54.6

Table 10 The effect of Shariah supervisory board on profit inefficiency of Islamic banks across geographical regions.
This table presents the effects of the Shariah supervisory board on group-specific profit inefficiency in Islamic banks across six geographical regions. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: GCC		Panel B: Non-GCC MENA		Panel C: South Asia		Panel D: Europe &		Panel E: Sub-Saharan		Panel F: East Asia &	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Variables	RUIN	RAIN	RUI	RAI	RUI	RAI	RUI	RAIN	RUI	RAI	RUIN	RAI
Corporate governance												
SSB size	0.733	0.115	-	-	0.180	-	0.259	-0.491	0.144	0.004	-0.486	-
SSB academic	-0.343	-0.005	0.297	0.002	-	0.001	0.215	-0.243	-	0.038	-2.596	-
SSB members' reputation	-0.221	-0.002	-	-	-	-	-	-0.243	0.023	0.017	0.274	0.005
Board governance	0.766	0.005	0.777	0.008	0.770	-	-	0.078	0.010	-	2.185	0.002
Bank and country-level												
Bank size	0.211	0.525	-	-	0.030	0.073	0.704	-0.034	0.096	-	-1.207	0.176
Bank age	-0.761	0.014	-	0.003	-	-	-	-0.014	-	0.008	-1.111	-
Publicly traded bank	0.016	-0.452	0.011	-	-	0.073	0.205	0.094	0.152	0.012	0.942 [c]	0.000
Bank concentration	0.042	-0.001	1.764	0.003	0.591	0.002	-	0.128	-	-	-0.591	-
Growth rate of per capita	-0.332	-0.017	0.194	0.002	0.807	-	-	0.147	-	0.020	0.563	0.027

Time trend	0.785	-0.042	0.197	0.013	0.531	0.015	0.007	-0.067	0.051	0.056	-0.480	0.013
Constant	-0.264	-2.852	-	-	-	-	0.578	-0.354	0.012	0.011	-1.660	-
R-squared	0.733	0.755	.0.71	0.684	0.509	0.512	0.594	0.531	0.415	0.394	0.510	0.471
Observations	221	221	71	71	108	108	59	59	43	43	133	133
Country control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = {\sigma_u}^2/({\sigma_u}^2 + {\sigma_v}^2)$	0.863	0.925	0.897	0.996	0.879	0.925	0.913	0.999	0.291	0.110	0.803	0.941
LR test of the one-sided	47.52	195.7	49.83	64.85	58.90	55.96	40.09	152.7	51.77	40.92	115.5	56.89

Table 11 Summary statistics for cost and profit efficiency scores based on the common frontier model.
This table presents the cost and profit efficiency scores estimated from a common frontier in Panel A and B, respectively. The common frontier model assumes that both Islamic and conventional banks operate under a common frontier with no technology gap between them.

	Cost efficiency				Profit efficiency			
	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Panel A: Risk-unadjusted efficiency								
Islamic banks	0.931	0.043	0.649	0.990	0.821	0.110	0.078	0.949
Conventional banks	0.911	0.055	0.656	0.985	0.892	0.056	0.486	0.957
All banks	0.921	0.050	0.649	0.990	0.857	0.094	0.078	0.957
Panel B: Risk-adjusted efficiency								
Islamic banks	0.911	0.047	0.769	0.997	0.875	0.085	0.473	0.975
Conventional banks	0.895	0.049	0.768	0.998	0.876	0.086	0.575	0.976
All banks	0.903	0.048	0.768	0.998	0.870	0.086	0.473	0.976

Table 12 Determinants of cost and profit inefficiency: 2SLS estimation results.
This table presents the 2SLS estimation results for the determinants of cost and profit inefficiency. We use instrumented corporate governance variables. The Kleibergen-Paap F-statistics and the Hansen J test confirm the absence of a weak instruments problem and the validity of our instruments, respectively. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A Group-specific inefficiency in Islamic banks				Panel B Group-specific inefficiency in conventional banks		Panel C Cost/profit gaps in stochastic meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
I. Determinants of cost inefficiency								
Corporate governance variables								
SSB size	0.0022	0.0029 ^{b}						
SSB academic qualifications	-0.0007^{a}	-0.0007^{a}						
SSB members' reputation	-0.0012^{a}	-0.0008^{a}						
Board governance	0.00003	0.0005^{a}	0.009 ^{b}	-0.003	-0.0013^{a}	-0.0019^{a}	0.0005^{a}	0.0037^{a}
Bank and country-level variables								
Bank size	0.1259^{a}	0.1561^{a}	0.1162 ^{a}	0.1475 ^{a}	-0.0217^{a}	0.0922^{a}	0.0141^{a}	0.0443^{a}
Bank age	-0.0012^{a}	-0.0009^{a}	-0.0060 ^{b}	-0.0005 ^{a}	0.0006^{a}	-0.0003^{b}	0.0005^{a}	0.0027^{a}
Publicly traded bank dummy	0.0197^{a}	0.0547^{a}	-0.0080	0.0368 ^{a}	-0.037^{a}	-0.0481^{a}	-0.0128^{a}	-0.0636^{a}
Bank concentration	-0.0005^{a}	0.0000	-0.0007 ^{a}	0.0088	0.0002	-0.0008^{a}	-0.0001^{b}	0.0002
Growth rate of per capita GDP	0.0033^{a}	0.0043^{a}	0.0062 ^{a}	0.0066 ^{a}	-0.0018^{b}	0.0020^{a}	0.0004	-0.0008
Time trend	0.0023^{a}	0.0034^{a}	0.0009 ^{a}	0.0025 ^{a}	0.0012	-0.0039^{a}	-0.0035^{a}	-0.0066^{a}
Constant	-0.2073^{a}	-0.336^{a}	-0.168 ^{a}	-0.294 ^{a}	0.2114^{a}	0.0276^{c}	-0.0073	-0.1324^{a}
Observations	575	575	575	575	575	575	1150	1150
R-squared	0.9095	0.9734	0.668	0.870	0.0554	0.5903	0.2362	0.1385
Kleibergen-Paap F-statistics	83.846	83.846	60.155	60.155	191.864	191.864	223.887	223.887
Hansen J test (P-value)	0.593	0.593	0.71	0.71	0.173	0.173	0.409	0.409
II. Determinants of profit inefficiency								
Corporate governance variables								
SSB size	-0.0313^{a}	-0.0242^{a}						
SSB academic qualifications	-0.0006	-0.0005^{c}						
SSB members' reputation	-0.0017^{a}	-0.0012^{a}						
Board governance	-0.0027^{a}	-0.0016^{b}	-0.0036 ^{a}	-0.0029 ^{a}	0.0001	-0.0004	0.0014^{b}	0.0007
Bank and country-level variables								
Bank size	0.0832^{a}	0.2136^{a}	0.0716 ^{a}	0.2045 ^{a}	0.0251^{a}	0.1240^{a}	-0.0516^{a}	-0.0603^{a}
Bank age	-0.0012^{c}	-0.0009^{b}	-0.0016 ^{a}	-0.0013 ^{a}	-0.0001	0.0003^{c}	-0.0027^{a}	-0.0013^{a}
Publicly traded bank dummy	-0.0023	-0.0321^{a}	-0.0625 ^{a}	-0.0755 ^{a}	0.0140	0.0123	0.0504	0.0313^{a}
Bank concentration	-0.0010^{a}	-0.0010^{a}	-0.0003	-0.0052 ^{a}	-0.0005	-0.0004^{a}	-0.0001	-0.0001
Growth rate of per capita GDP	-0.0034^{b}	-0.0017^{c}	-0.0026 ^{b}	-0.0013	-0.0015	-0.0026^{a}	0.0003	0.0001
Time trend	0.0021	0.0046^{a}	0.0018	0.0045 ^{a}	-0.0023	-0.0021	-0.0023	-0.0025
Constant	0.3212^{a}	-0.1947^{a}	0.2105^{a}	-0.279 ^{a}	0.1225^{a}	-0.2513^{a}	0.3707^{a}	0.3695^{a}
Observations	575	575	575	575	575	575	1150	1150
R-squared	0.0502	0.7486	0.1023	0.7432	0.0507	0.6687	0.1591	0.1383
Kleibergen-Paap F-statistics	83.846	83.846	60.155	60.155	191.864	191.864	223.887	223.887
Hansen J test (P-value)	0.593	0.593	0.71	0.71	0.173	0.173	0.409	0.409

Table 13 Determinants of cost and profit inefficiency: System GMM estimation results.

This table presents the system GMM estimation results for the determinants of cost inefficiency and profit inefficiency. As an alternative to the IV estimator, the two-step system GMM estimator is used to check the robustness of results on the effects of SSB and regular board governance on cost and profit inefficiency. The Hansen test confirms that all instruments used for corporate governance are valid. AR (1) and AR (2) are tests for first-order and second-order serial correlation, respectively. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A Group-specific inefficiency in Islamic banks				Panel B Group-specific inefficiency in conventional banks		Panel C Cost/profit gaps in stochastic meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
I. Determinants of cost inefficiency								
$\text{Inefficiency}_{it-1}$	0.2471 ^{b}	0.0670	0.654 ^{a}	0.389^{a}	0.8569 ^{a}	0.5749 ^{a}	0.505 ^{a}	0.349 ^{a}
Corporate governance variables								
SSB size	0.0060 ^{b}	0.0061 ^{a}						
SSB academic qualifications	-0.0006 ^{a}	-0.0007 ^{a}						
SSB members' reputation	-0.0007 ^{a}	-0.0005 ^{b}						
Board governance	0.0002 ^{a}	0.0004 ^{b}	0.0038 ^{b}	0.002 ^{a}	-0.0005 ^{c}	-0.0003 ^{c}	-0.0043	0.008 ^{b}
Bank and country-level variables								
Bank size	0.0996 ^{a}	0.1492 ^{b}	0.0441 ^{a}	0.0922 ^{a}	-0.0069	0.0377 ^{a}	0.0089 ^{b}	0.032 ^{c}
Bank age	-0.0009 ^{a}	-0.0010 ^{a}	-0.0012	-0.0003 ^{c}	-0.0001	-0.0001	0.00018 ^{b}	0.0021 ^{a}
Publicly traded bank dummy	0.0074 ^{b}	0.0430 ^{c}	0.0019	0.0259 ^{a}	-0.0079	-0.0136	-0.0112 ^{b}	-0.057 ^{b}
Bank concentration	-0.0003 ^{a}	0.0001	-0023 ^{a}	0.0053	-0.0001	-0.0006 ^{a}	-0.005 ^{b}	-0.0004
Growth rate of per capita GDP	0.0030 ^{a}	0.0041 ^{a}	0.0031 ^{a}	0.0043 ^{a}	-0.0012 ^{b}	0.0020 ^{a}	0.0006 ^{a}	0.0006
Time trend	0.0006	0.0028 ^{a}	-0.0018	-0.0004	0.0009	-0.0030 ^{c}	-0.0007	-0.0072 ^{b}
Constant	-0.194 ^{a}	-0.331 ^{a}	-0.089 ^{a}	-0.1942 ^{a}	0.072 ^{b}	-0.0272 ^{b}	0.0185 ^{b}	0.0221 ^{c}
Observations	635	635	635	635	635	635	1270	1270
Model fits:								
F-statistics	450.2 ^{a}	461.08 ^{a}	427.36 ^{a}	296.39 ^{a}	41.47 ^{a}	50.53 ^{a}	33.91 ^{a}	16.91 ^{a}
Hansen J test (P-value)	0.964	0.940	0.880	0.581	0.936	0.455	0.619	0.772
AR (1) test	-1.91 ^{c}	-1.71 ^{c}	-2.85 ^{a}	-2.20 ^{b}	-1.76 ^{c}	-3.7 ^{a}	-2.39 ^{b}	-2.61 ^{b}
AR (2) test	-0.01	-0.15	0.805	0.637	-0.88	-0.56	0.62	0.98
II. Determinants of profit inefficiency								
$\text{Inefficiency}_{it-1}$	0.428 ^{a}	0.3964 ^{a}	0.452 ^{a}	0.529 ^{a}	0.5858 ^{b}	0.4952 ^{a}	0.571 ^{a}	0.4678 ^{a}
Corporate governance variables								
SSB size	-0.0111 ^{b}	-0.0095 ^{b}						
SSB academic qualifications	0.0008	-0.0002 ^{b}						
SSB members' reputation	-0.0011 ^{b}	-0.0006 ^{b}						
Board governance	-0.0004	-0.0005 ^{c}	0.0006	-0.002 ^{b}	0.0004 ^{a}	0.0010	-0.0009	0.0005 ^{a}
Bank and country-level variables								
Bank size	0.0149	0.1250 ^{a}	0.0325 ^{b}	0.0981 ^{a}	0.0106 ^{b}	0.0518 ^{a}	-0.006	-0.0114
Bank age	0.0005	-0.0004	0.0001	-0.0006	0.0000	0.0002	-0.0018 ^{a}	-0.0007 ^{b}
Publicly traded bank dummy	0.0086	-0.0224 ^{c}	-0.0207	-0.0328 ^{b}	0.0119	0.0175	0.0081	0.0111
Bank concentration	-0.0006 ^{a}	-0.0007 ^{a}	-0.0027 ^{b}	-0.0006 ^{a}	0.0001	-0.0003 ^{a}	0.0001	-0.0006
Growth rate of per capita GDP	-0.0017	-0.0008	-0.0015	-0.0007	0.0006	-0.0006	0.0007	0.0014
Time trend	-0.0037	-0.0007	-0.0066	-0.0013	-0.0019	-0.0036 ^{b}	0.0009	-0.0018
Constant	0.1651 ^{a}	-0.1401 ^{b}	0.0353 ^{a}	-0.1252 ^{a}	0.0234 ^{b}	-0.1394 ^{b}	0.1589 ^{b}	0.1668 ^{a}
Observations	635	635	635	635	635	635	1270	1270
Model fits:								
F-statistics	8.76 ^{b}	110.88 ^{a}	9.19 ^{a}	226.97 ^{a}	5.6 ^{a}	34.96 ^{a}	25.90 ^{a}	16.13 ^{a}
Hansen J test (P-value)	0.968	0.959	0.640	0.364	0.999	0.307	0.751	0.913
AR (1) test	-2.97 ^{a}	-2.8 ^{a}	-3.11 ^{a}	-2.98 ^{a}	-3.61 ^{a}	-3.02 ^{a}	-3.26 ^{a}	-3.97 ^{a}
AR (2) test	-0.5	0.12	0.684	0.649	1.15	-1.1	-0.13	0.84

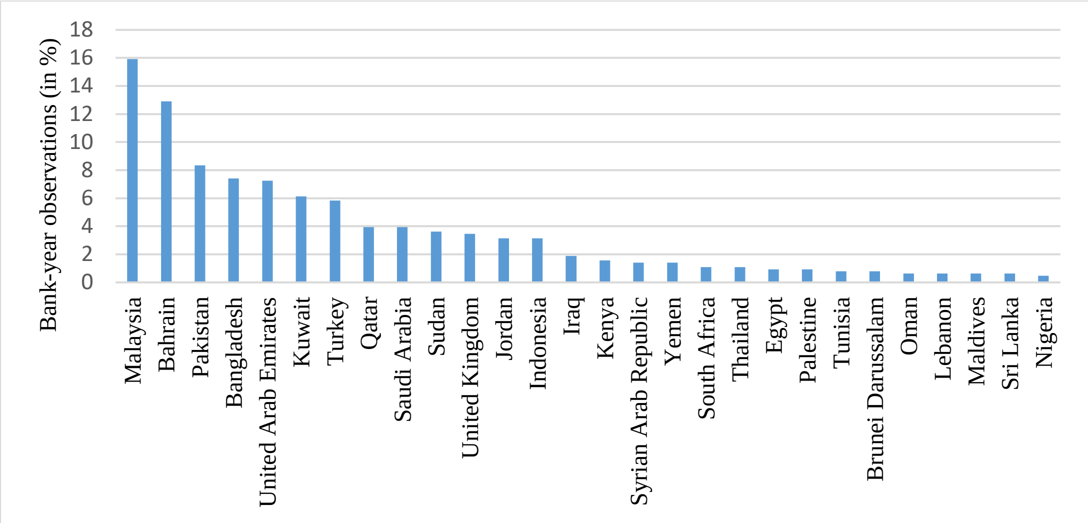

Fig. 1. Distribution of bank-year observations by country, 2003-2014.

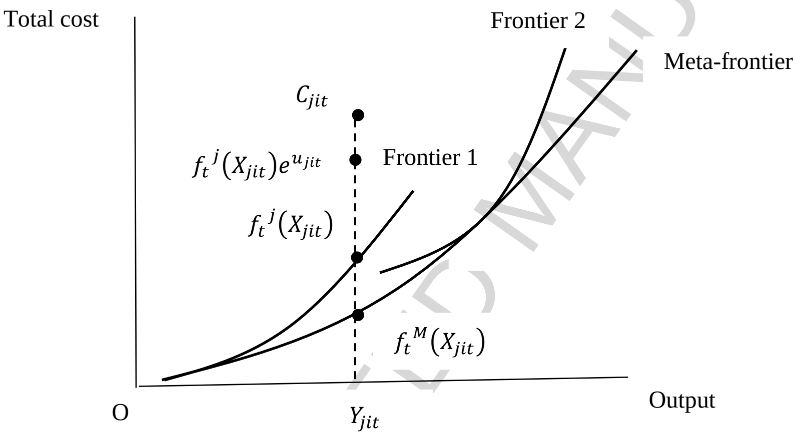

Fig. 2. Stochastic meta-frontier cost model.

Notes: This figure represents the stochastic meta-frontier cost model. The points Y_{jit} and C_{jit} denote the output quantities and actual total cost of a bank *i* in group *j* for the time period *t*. The term X_{jit} is the vector of outputs and input prices. The difference between the cost meta-frontier point, $f_t{}^M(X_{jit})$ and the C_{jit} comprises three components: the cost gap ratio, $CGR_{it}^j = f_t{}^M(X_{jit})/f_t{}^j(X_{jit})$; the group-specific cost efficiency, $CE_{it}^j = \frac{f_t{}^j(X_{jit})}{f_t{}^j(X_{jit})e^{u_{jit}}}$; and the random error component, $\frac{f_t{}^j(X_{jit})e^{u_{jit}}}{C_{jit}}$.

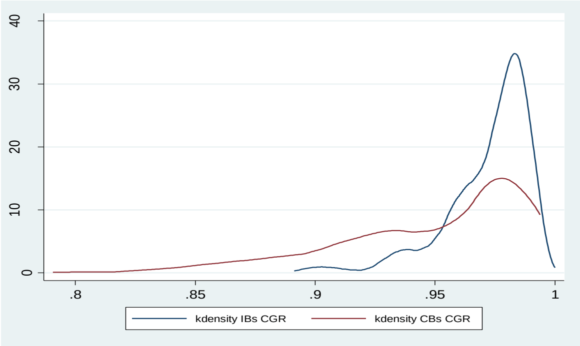

Fig. 3a. CGR in risk-unadjusted model of cost efficiency

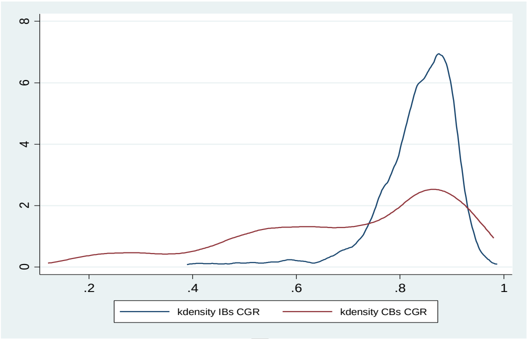

Fig. 3b. CGR in risk-adjusted model of cost efficiency

Fig. 3. Kernel-based density estimation of cost gap ratios (CGR) in cost meta-frontier.
These figures present the Kernel density of TRG scores for Islamic banks (IB) and conventional banks (CB). Fig. 3a presents CGR scores estimated from the stochastic meta-frontier cost function without adjusting for risks. Fig. 3b presents CGR scores estimated from the risk-adjusted stochastic meta-frontier cost function.

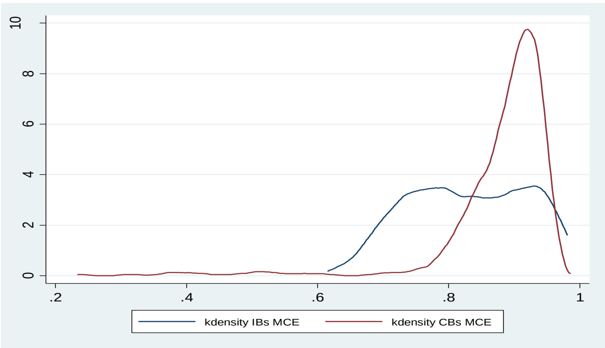

Fig. 4a. MCE in risk-unadjusted model of cost efficiency

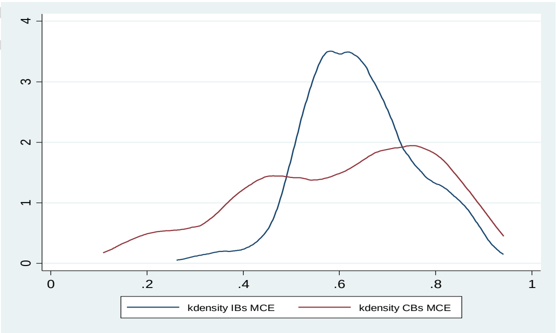

Fig. 4b. MCE in risk-adjusted model of cost efficiency

Fig. 4. Kernel-based density estimation of meta-cost efficiency (MCE) scores.
These figures present the Kernel density of MCE scores for Islamic Banks (IB) and conventional banks (CB). Fig. 4a shows distributions of MCE scores estimated from the stochastic meta-frontier cost function without adjusting for risks. Fig. 4b shows distributions of MCE scores estimated from the risk-adjusted stochastic meta-frontier cost function.

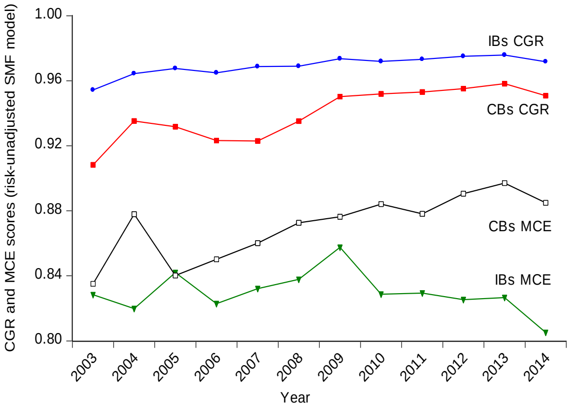

Fig. 5a. Trends of CGR and MCE (risk-unadjusted SMF model)

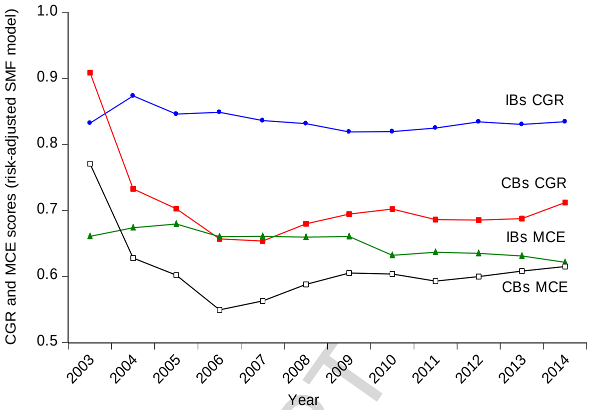

Fig. 5b. Trends of CGR and MCE (risk-adjusted SMF model)

Fig. 5. Time series plots of cost efficiency measures.
Fig. 5a plots average CGR and MCE scores for Islamic banks (IB) and conventional banks (CB) obtained from the stochastic meta-frontier cost function without adjusting for risks. Fig. 5b presents average CGR and MCE scores obtained from the risk-adjusted stochastic meta-frontier cost function.

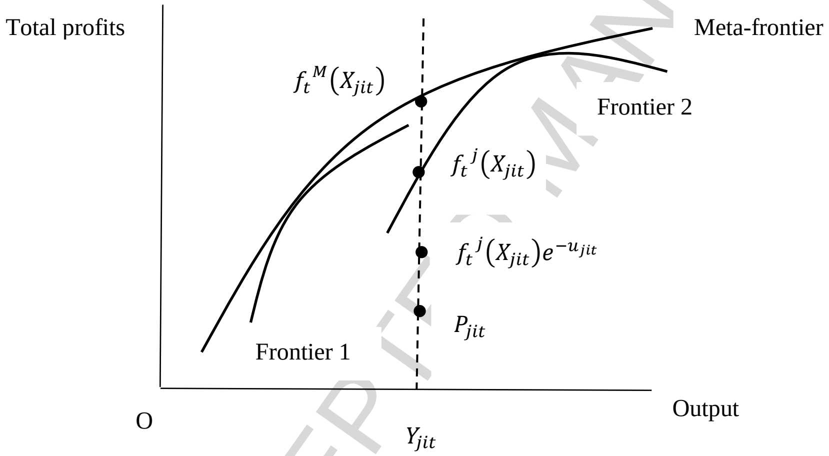

Fig. 6. Stochastic meta-frontier profit model.

Notes: This figure presents the stochastic meta-frontier profit model. The points Y_{jit} and P_{jit} refer to output and observed profit of bank *i* in group *j* for year *t*. The difference between the profit meta-frontier point, $f_t^{M}(X_{jit})$ and the P_{jit} arises from three components: the profit gap ratio, $PGR_{it}^{j} = f_t^{j}(X_{jit})/f_t^{M}(X_{jit})$; the group-specific profit efficiency, $PE_{it}^{j} = f_t^{j}(X_{jit})e^{u_{jit}}/f_t^{j}(X_{jit})$ and the random noise component, $P_{jit}\,/f_t^{j}(X_{jit})e^{u_{jit}}$.

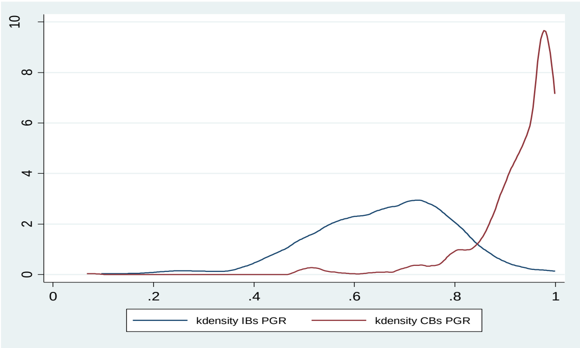

Fig. 7a. PGR in risk-unadjusted model of profit efficiency

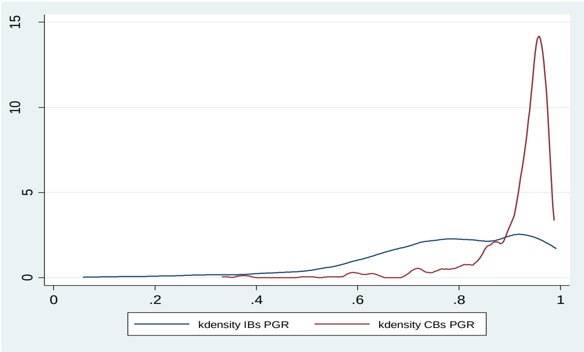

Fig. 7b. PGR in risk-adjusted model of profit efficiency

Figure 7 Kernel-based density estimation of profit gap ratios (PGR) in profit meta-frontier.
These figures present the Kernel density of PGR scores for Islamic banks (IB) and conventional banks (CB). Fig. 7a shows the distribution of PGR scores estimated from the stochastic meta-frontier profit function without adjusting for risks. Fig. 7b shows the distribution of PGR scores estimated from the stochastic meta-frontier profit function controlling for risks.

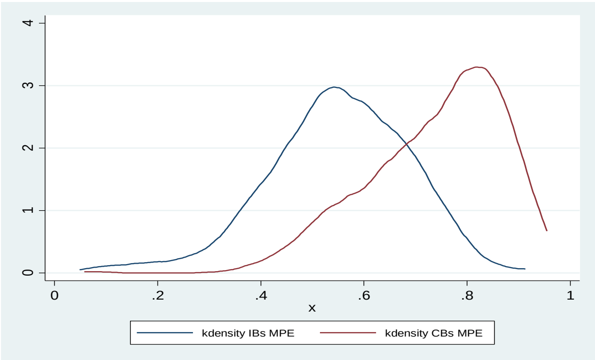

Fig. 8a MPE in risk-unadjusted model of profit efficiency

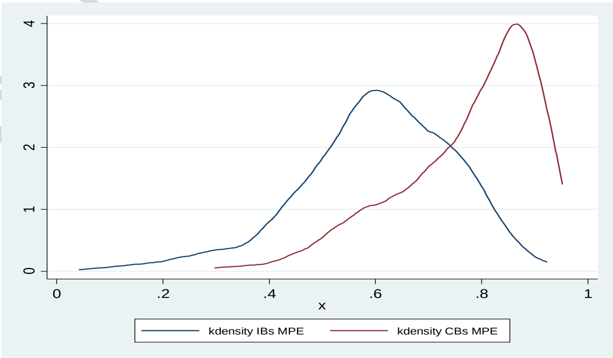

Fig. 8b MPE in risk-adjusted model of profit efficiency

Fig. 8. Kernel-based density estimation of meta-profit efficiency (MPE) scores.
These figures present the Kernel density of MPE scores for Islamic banks (IB) and conventional banks (CB). Fig. 8a shows the distribution of MPE scores estimated from the stochastic meta-frontier profit function without adjusting for risks. Fig. 8b shows the distribution of MPE scores estimated from the stochastic meta-frontier profit function controlling for risks.

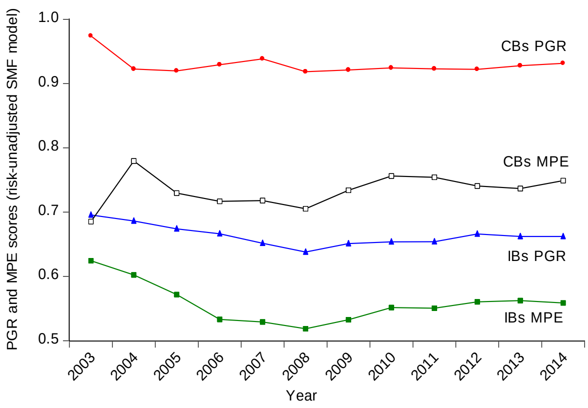

Fig. 9a. Trends of PGR and MPE (SMF risk-unadjusted model)
Fig. 9b. Trends of PGR and MPE (SMF risk-adjusted model)

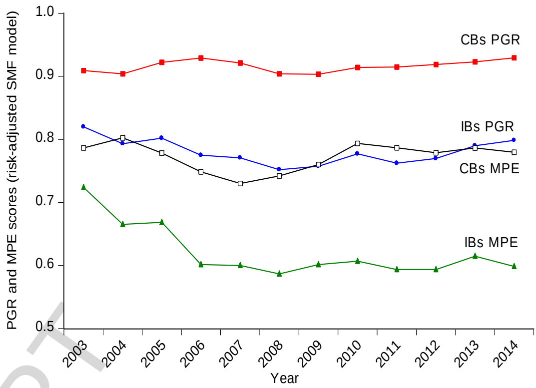

Fig. 9. Time series plots of profit efficiency measures Fig. 9a plots average PGR and MPE scores for Islamic banks (IB) and conventional banks (CB) obtained from the stochastic meta-frontier profit function without adjusting for risks. Fig. 9b plots the same obtained from the risk-adjusted stochastic meta-frontier profit function.

APPENDIX

Table A1 Determinants of cost inefficiency of Islamic and conventional banks.
This table presents the results on determinants of group-specific cost inefficiency of Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of the cost gap represented by the one-sided error term in the SMF framework. The results are obtained using the MLE estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: Group-specific cost inefficiency of Islamic banks				Panel B: Group-specific cost inefficiency of conventional banks		Panel C: Cost gap in stochastic cost meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	0.007[a]	0.005[a]						
SSB academic qualifications	-0.001[a]	-0.001[a]						
SSB members' reputation	-0.001[a]	-0.004[a]						
Board governance	0.002[a]	0.004[a]	0.001	0.003[a]	0.003	-0.001[a]	-0.018[a]	-0.001[c]
Bank and country-level variables								
Bank size	0.111[a]	0.148[a]	0.117[a]	0.155[a]	-0.028[a]	0.090[a]	0.013[a]	0.035[b]
Bank age	-0.001[a]	-0.001[a]	-0.006	-0.009[a]	0.008[a]	0.000	0.004[a]	0.003[a]
Publicly traded bank dummy	0.016[c]	0.053[a]	-0.002	0.0379[a]	0.004	-0.042[a]	-0.002	-0.017
Bank concentration	0.0005	0.0001	-0.002	0.0001	-0.000	-0.001[a]	-0.0002[a]	0.000
Growth rate of per capita GDP	0.003	0.004	0.007	0.0039[a]	0.007	-0.002[a]	-0.003[c]	-0.001
Time trend	0.003	0.004	0.002	0.028	-0.007	-0.005[a]	-0.002[a]	-0.001
Constant	-0.228[a]	-0.323[a]	-0.256	-0.356[a]	-0.124[a]	-0.055[c]	-0.028[b]	-0.130[a]
R-squared	0.689	0.603	0.652	0.623	0.872	0.801	0.792	0.546
Observations	635	635	635	635	635	635	1270	1270
Country control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.831[a]	0.345[a]	0.742[a]	0.529[a]	0.133[a]	0.633[a]	0.162[a]	0.640[a]
LR test of the one-sided error (u)	212.23[a]	185.81[a]	28.673	160.27[a]	70.09[a]	112.54[a]	124.34[a]	138.90[a]

Table A2 Determinants of profit inefficiency of Islamic and conventional banks.
This table presents the results on determinants of group-specific profit inefficiency of Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of the profit gap represented by the one-sided error term in the SMF framework. The results are obtained using the MLE estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: Group-specific profit inefficiency of Islamic banks				Panel B: Group-specific profit inefficiency of conventional banks		Panel C: Profit gap in stochastic profit meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	-0.008	-0.006 [a]						
SSB academic qualifications	-0.007 [a]	-0.004 [a]						
SSB members' reputation	-0.002 [a]	-0.005 [b]						
Board governance	-0.005	-0.002 [b]	-0.005	-0.002 [c]	0.001	0.002	0.007 [c]	0.004
Bank and country-level variables								
Bank size	0.038 [b]	0.175 [a]	0.034 [c]	0.169 [a]	0.057 [a]	0.109 [a]	-0.110 [a]	-0.112 [a]
Bank age	0.004	0.002	-0.002	0.005	-0.005 [b]	-0.002	-0.003 [a]	-0.002 [a]
Publicly traded bank dummy	-0.008	-0.031 [c]	-0.011	-0.032 [b]	-0.036	0.006	0.078 [b]	0.078 [b]
Bank concentration	-0.001	-0.003 [b]	-0.001	-0.003 [b]	0.0004	-0.003 [b]	-0.002	-0.002
Growth rate of per capita GDP	-0.004 [b]	-0.002 [b]	-0.002 [b]	-0.001 [b]	-0.003 [a]	-0.002 [a]	-0.007	-0.007
Time trend	0.002	0.005	0.003	0.004	-0.007	-0.006	-0.005 [a]	-0.006 [a]
Constant	-0.073 [a]	-0.366 [a]	0.108 [b]	-0.359 [a]	-0.002 [a]	-0.240 [a]	0.566 [a]	0.566 [a]
R-squared	0.890	0.819	0.864	0.837	0.678	0.612	0.712	0.591
Observations	635	635	635	635	635	635	1270	1270
Country control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.487 [a]	0.862b	0.846 [a]	0.989 [b]	0.763 [a]	0.987 [a]	0.978 [a]	0.988 [b]
LR test of the one-sided error (u)	32.95 [a]	63.52 [a]	266.02 [a]	365.94 [a]	198.12 [a]	212.97 [a]	81.49 [b]	48.47 [b]

Table A3 Summary statistics of cost efficiency scores, excluding Malaysian banks
This table presents the average cost efficiency scores obtained with and without adjusting for risks. Columns (1) and (4) report mean efficiency scores before and after risk adjustments, respectively. Columns (2) and (5) present t-statistics for the equality of average efficiency scores between Islamic and conventional banks. Columns (3) and (6) present the two-sample Kolomogorov-Smirnov test statistics for the equality of the distributions of cost efficiency between Islamic and conventional banks. Column (7) presents t-statistics for the equality of risk-unadjusted and risk-adjusted efficiency. The group-specific cost efficiency (CE) and cost gap ratio (CGR) scores are obtained from the group-specific frontier and meta-frontier, respectively. The product of CE and CGR provides a measure of meta-cost efficiency (MCE). Test for the difference in group-specific cost efficiency scores between Islamic and conventional banks is not presented, as they are not comparable between groups.

	Panel A: Risk-unadjusted cost efficiency			Panel B: Risk-adjusted cost efficiency			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	t-test for risk-unadjusted vs. risk-adjusted efficiency
Group-specific cost efficiency (CE)							
Islamic banks	0.856			0.768			3.174 [a]
Conventional	0.959			0.891			10.790 [a]
Cost gap ratio (CGR)							
Islamic banks	0.919			0.883			5.609 [a]
Conventional	0.826	13.922 [a]	7.152 [a]	0.725	12.070 [a]	11.630 [a]	3.572 [a]
All banks	0.872			0.873			-0.104
Meta-cost efficiency (MCE)							
Islamic banks	0.786			0.676			4.682 [a]
Conventional	0.791	-0.651	1.466 [b]	0.646	3.700 [a]	1.790 [a]	7.751 [a]
All banks	0.789			0.661			2.920 [a]

Table A4 Summary statistics of profit efficiency scores, excluding Malaysian banks

This table presents the profit efficiency scores obtained with and without adjusting for risks. Columns (1) and (4) report mean efficiency scores before and after risk adjustments, respectively. Columns (2) and (5) present t-statistics for the equality of average efficiency scores between Islamic and conventional banks. Columns (3) and (6) present the two-sample Kolomogorov-Smirnov test statistics for the equality of the distributions of profit efficiency between Islamic and conventional banks. Column (7) presents t-statistics for the equality of risk-unadjusted and risk-adjusted efficiency scores. PE and PGR are obtained from the group-specific stochastic profit frontier and stochastic profit meta-frontier, respectively. The product of PE and PGR is used to measure MPE. Test for the difference in group-specific profit efficiency between Islamic and conventional banks is not presented, as they are not comparable between groups.

	Panel A: Risk-unadjusted profit efficiency			Panel B: Risk-adjusted profit efficiency			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	Mean efficiency score	t-test for IBs vs. CBs	Kolmogorov-Smirnov test for IBs vs. CBs	t-test for risk-unadjusted vs. risk-adjusted efficiency
Group-specific Profit efficiency (PE)							
Islamic banks	0.789			0.750			4.015 [a]
Conventional	0.848			0.866			-2.111 [b]
Profit gap ratio (PGR)							
Islamic banks	0.692			0.806			-11.641 [a]
Conventional	0.882	-9.387 [a]	8.264 [a]	0.909	-8.964 [a]	8.528 [a]	-5.099 [a]
All banks	0.787			0.858			-10.626 [a]
Meta-profit efficiency (MPE)							
Islamic banks	0.545			0.603			-5.509 [a]
Conventional	0.741	-2.831 [a]	8.160 [a]	0.787	-2.978 [a]	8.227 [a]	2.831 [a]
All banks	0.643			0.695			-6.612 [a]

Table A5 Determinants of cost inefficiency of Islamic and conventional banks, excluding Malaysian banks

This table presents the results on determinants of group-specific cost inefficiency in Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of the cost gap represented by the one-sided error term in the SMF. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: Group-specific cost inefficiency of Islamic banks				Panel B: Group-specific cost inefficiency of conventional banks		Panel C: Cost gap in stochastic cost meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	0.011 [c]	0.008 [b]						
SSB academic qualifications	-0.001 [b]	-0.001 [a]						
SSB members' reputation	-0.001 [c]	-0.008 [b]						
Board governance	0.001	0.005 [c]	-0.001	-0.0005	0.000	-0.011 [a]	0.022 [a]	0.005 [b]
Bank and country-level variables								
Bank size	0.193 [a]	0.207 [a]	0.021	0.043 [b]	0.017	-0.116 [a]	0.410 [a]	0.639 [a]
Bank age	-0.003	-0.002 [b]	-0.001 [c]	-0.003 [b]	0.005	-0.001 [c]	0.029 [a]	0.017 [a]
Publicly traded bank dummy	0.063 [b]	0.060 [b]	0.030	0.221 [a]	-0.028	-1.227 [a]	-0.249 [a]	-0.019
Bank concentration	0.001	0.004	0.001	0.004	-0.001 [b]	-0.006 [a]	-0.001 [b]	-0.002
Growth rate of per capita GDP	0.003	0.004 [b]	0.003	0.008 [a]	0.003	-0.012 [c]	-0.055 [a]	0.004
Time trend	0.009	0.004	0.007	-0.002	-0.016 [b]	-0.068 [a]	-0.116 [a]	0.006
Constant	-0.632 [a]	-0.494 [a]	-0.141 [b]	-0.188 [a]	0.020	2.112 [a]	-6.013 [a]	-1.839 [a]
R-squared	0.715	0.721	0.681	0.701	0.853	0.774	0.609	0.683
Observations	534	534	534	534	534	534	1068	1068
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.772 [a]	0.661 [a]	0.598 [a]	0.342 [a]	0.727 [a]	0.884 [a]	0.998 [a]	0.859 [a]
LR test of the one-sided error (u)	64.841 [a]	124.39 [a]	57.773 [a]	41.985 [a]	37.191 [a]	84.815 [a]	163.928 [a]	278.949 [a]

Table A6 Determinants of profit inefficiency of Islamic and conventional banks, excluding Malaysian banks.
This table presents the results on determinants of group-specific profit inefficiency in Islamic and conventional banks in Panels A and B, respectively. Panel C reports the determinants of profit gap (PG) represented by the one-sided error term in SMF. Model parameters are estimated using the maximum likelihood estimator. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A: Group-specific profit inefficiency of Islamic banks				Panel B: Group-specific profit inefficiency of conventional banks		Panel C: Profit gap in stochastic Profit meta-frontier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN	RUIN	RAIN
Corporate governance variables								
SSB size	0.179	-0.010 ^{c}						
SSB academic qualifications	-0.115 ^{a}	-0.001 ^{c}						
SSB members' reputation	-0.488 ^{c}	-0.001						
Board governance	1.400 ^{a}	-0.002 ^{c}	0.002	0.001	0.003 ^{a}	0.004 ^{a}	-0.009 ^{b}	-0.002
Bank and country-level variables								
Bank size	0.253 ^{b}	0.278 ^{b}	-0.024	-0.673 ^{a}	0.361 ^{a}	0.451 ^{a}	-0.387 ^{b}	-0.962 ^{a}
Bank age	-0.159	-0.004	0.001	0.003 ^{a}	0.001	0.002	-0.0307 ^{c}	-0.051 ^{a}
Publicly traded bank dummy	0.255 ^{a}	-0.118 ^{b}	0.071	0.093 ^{a}	-0.009	-0.014	0.135	0.357 ^{a}
Bank concentration	-0.852 ^{b}	0.004	0.001	0.007	0.005	-0.001 ^{c}	0.013	-0.002 ^{b}
Growth rate of per capita GDP	1.178 ^{a}	-0.006	0.002	0.003	-0.005 ^{c}	-0.004	-0.0254	-0.023 ^{a}
Time trend	0.336	0.002	0.003	0.000	-0.016 ^{a}	-0.017 ^{a}	-0.0173	-0.071 ^{a}
Constant	-1.045 ^{b}	-0.336 ^{b}	-0.092 ^{b}	2.714 ^{a}	-1.318 ^{a}	-1.800 ^{a}	0.158 ^{a}	3.074 ^{a}
R-squared	0.908	0.910	0.867	0.872	0.893	0.837	0.909	0.846
Observations	534	534	534	534	534	534	1068	1068
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.864 ^{a}	0.847 ^{b}	0.7501 ^{b}	0.667 ^{a}	0.371 ^{a}	0.655 ^{a}	0.501 ^{a}	0.999 ^{a}
LR test of the one-sided error (u)	190.126 ^{a}	175.081 ^{b}	8.586 ^{b}	196.923 ^{a}	113.349 ^{a}	80.716 ^{a}	194.129 ^{a}	514.971 ^{a}

Table A7 The role of the Shariah Advisory Council (SAC) on cost and profit inefficiency in Islamic banks.

This table presents the results for the effects of the SAC on group-specific cost and profit inefficiency in Islamic banks. Model parameters are obtained using the maximum likelihood estimator. The SAC is unique to Malaysia and represented by a dummy variable that takes a value of 1 for Malaysia and zero if otherwise. The models are run excluding the Malaysian country dummy variable to avoid perfect collinearity. RUIN and RAIN refer to risk-unadjusted and risk-adjusted inefficiency measures, respectively. The inefficiency effect (γ) is positive in all cases and the null hypothesis that a stochastic frontier model is equivalent to the traditional mean response function is rejected by the LR test statistic. Superscripts a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively.

	Panel A:Cost inefficiency		Panel B: Profit inefficiency	
	(1)	(2)	(3)	(4)
	RUIN	RAIN	RUIN	RAIN
Corporate governance variables				
Shariah Advisory Council (SAC)	0.069	-0.040	-0.076 ^{c}	-0.120 ^{b}
SSB size	0.011 ^{b}	0.009 ^{a}	-0.008 ^{b}	-0.009 ^{b}
SSB academic qualifications	-0.001 ^{a}	-0.001 ^{a}	-0.007 ^{b}	-0.001 ^{a}
SSB members' reputation	-0.001 ^{a}	-0.001 ^{b}	-0.001	-0.010 ^{a}
Board governance	0.001	0.001 ^{c}	-0.002 ^{a}	0.001 ^{b}
Bank and country-level variables				
Bank size	0.391 ^{a}	0.213 ^{a}	-0.141 ^{a}	-0.541 ^{a}
Bank age	-0.002 ^{c}	-0.002 ^{b}	0.001 ^{c}	0.002 ^{b}
Publicly traded bank dummy	0.031	0.047 ^{b}	0.082 ^{a}	0.072 ^{b}
Bank concentration	0.001 ^{a}	0.000	0.001 ^{b}	0.001 ^{b}
Growth rate of per capita GDP	0.002	0.005 ^{a}	0.004 ^{b}	0.003
Time trend	0.009	0.003	-0.001	-0.005
Constant	-0.695 ^{a}	0.015	0.190 ^{a}	2.022 ^{a}
R-squared	0.724	0.671	0.872	0.823
Observations	635	635	635	635
Country Control	Yes	Yes	Yes	Yes
$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2)$	0.037 ^{a}	0.379 ^{a}	0.432 ^{a}	0.046 ^{a}
LR test of the one-sided error (u)	168.289 ^{a}	123.156 ^{a}	50.309 ^{a}	165.546 ^{a}

Highlights

- Compared to conventional banks, Islamic banks are more cost efficient but less profit efficient on a risk-adjusted basis.
- Higher bank risk reduces cost efficiency but increases profit efficiency.
- Having a stronger Shariah supervisory board is conducive to improving Islamic banks' profit efficiency.