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Efficiency convergence in Islamic and conventional banks

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ABSTRACT

This paper examines how efficiency dynamics of Islamic and conventional banks compare and how they are converging across different countries. We employ both parametric and non-parametric methods to analyse a panel of Islamic and conventional banks from 23 countries during the period 1999 to 2014. Parametric methods (stochastic frontiers methods) shows that both steady state efficiency and the speed of convergence of Islamic and conventional banks are similar. A non-parametric framework (classification trees) identifies a varying degree of alignment between the Islamic and conventional banking model across countries, which could explain the plurality in conclusions in the Islamic/conventional bank efficiency debate. We find that the alignment between the two bank types is positively related to the country's financial depth, transparency, economic stability and banking concentration. At the bank level, the alignment in the two banking systems is associated with higher income diversification, liquidity, profitability and financial stability.

1. Introduction

Banking efficiency studies have long been of interest to a variety of stakeholders.[1] At a macro level, there is evidence that economic growth is positively related to banking sector efficiency (Abedifar et al., 2016; Berger et al., 2004). At a micro level, efficiency studies provide benchmarking information that will be of interest to bank managers and policy makers in order to improve banks' performance. Banking efficiency and related dynamics are closely linked to bank risk-taking and capitalization (Altunbaş et al., 2001; Kwan and Eisenbeis, 1997), while the ever-increasing competition in the financial services sector makes efficiency a primary consideration for bank managers, regulators and policy makers (Fiordelisi et al., 2011). Banking efficiency has also been widely studied in comparative banking analyses, notably when comparing Islamic and conventional banks; see

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[1] The number of citations to the seminal papers by Aigner et al. (1977) and Charnes et al. (1978) on stochastic frontier analysis (SFA) and data envelopment analysis (DEA) jointly equal around 40,000, while the number of citations to Berger and Humphrey (1997) and Berger and Mester (1997), the two seminal reviews on banking efficiency, are around to 4200 and 2600 respectively.

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Johnes et al. (2014) for a comprehensive review of empirical studies on efficiency of these two bank types. Efficiency dynamics (i.e., the steady states and the convergence rates) of such banking systems are less scrutinized.

Islamic banks have established their presence in the global financial system, with total assets under management of around $1.7 trillion, while maintaining a double-digit annual growth rate even amidst the financial crisis and political turmoil (Ernst & Young, 2016). While practically non-existent in the Western countries, Islamic banking (IB) is an important aspect of several North African, Middle and Far Eastern Asian countries, where it typically accounts for over 20% of the banking system assets. For example, in Saudi Arabia and Malaysia, Islamic banking accounts for 51.2% and 21.3% of the banking system assets, respectively (Ernst & Young, 2016). Although often small in scale, Islamic banks have managed to withstand the competition they face locally from their conventional bank counterparts. Underpinning Islamic banks' success is their unique business model that prohibits debt interest payments, complex derivative products, short-selling, speculation, and investments in particular lines of (largely deemed unethical) businesses. In addition, the financial products of Islamic banks are built on the concept of risk sharing between the providers and users of funds, which appear to inspire responsible behavior that mitigates credit risk (Baele et al., 2014). Requirements that transactions are backed by tangible assets, place Islamic banks closer to the real economy compared to conventional banks, and this has been important in the post-financial crisis era. The choice of Islamic or conventional banking products falls in its entirety to the investor, although it is expected that investors from Muslim countries may show a preference to the former. Yet, the selection *per se* of Islamic or conventional banking may be informative to investors. For example, investors in Saudi Arabia welcome the use of Islamic bank financing by listed firms (Almansour and Ongena, 2018). In addition, firms that issue an Islamic bond can pay a lower coupon compared to the equivalent conventional issue (Shafron, 2019). Overall, investors in Islamic finance may be willing to incur an extra cost for a "psychic dividend" (Bollen, 2007).

A number of studies comparing the efficiency of the Islamic and conventional banking sectors have identified a significant efficiency gap between the two bank types at given points in time and for a variety of countries (Abdul-Majid et al., 2010; Al-Muharrami, 2008; Johnes et al., 2014; Kamarudin et al., 2014; Srairi, 2010). Given the observed differences between the Islamic and conventional banking business models, the variations in efficiency dynamics are perhaps to be expected. However, the underlying dynamics of this efficiency have barely been examined. Examining banking efficiency and related dynamics warrants an investigation due to the close links to bank risk-taking and capitalisation (Altunbaş et al., 2001; Kwan and Eisenbeis, 1997). Furthermore, the ever-increasing competition in the financial services industry places efficiency at the forefront of bank managers, regulators and policy makers' agendas (Fiordelisi et al., 2011). Motivated by the importance of efficiency measurement and related dynamics, this paper addresses three questions regarding the Islamic and conventional banking business models. First, do Islamic and conventional banks have different steady state efficiency levels? Second, do Islamic and conventional banks have different rates/dynamics of efficiency convergence? Third, are Islamic and conventional banks more aligned in certain countries with respect to efficiency dynamics, and if so, what are the drivers of this behaviour?

We address the above questions using various approaches and techniques. First, we use a stochastic frontier output distance function (ODF) to provide estimates of efficiency. Second, a conditional β-convergence model with Islamic bank shift and slope dummies is estimated using pooled OLS, random effects (RE) and system-GMM. A random parameter model (RPM) that allows for both the steady state efficiency and the β-coefficient to vary by bank is also used. These estimation techniques allow for an increasing degree of heterogeneity in the convergence process across years, countries and bank types, while mitigating potential endogeneity concerns.

Third, we utilise a classification trees approach that offers a way to identify whether there are groups of banking systems, which are similar in terms of steady state efficiency and efficiency convergence rate. This approach, novel in this context, is necessary for the following reasons. The fact that the substantial literature on the comparative efficiency of Islamic and conventional banks has reached no consensus on which of the two banking systems is consistently more (or less) efficient provides *prima facie* evidence that the conclusion is largely country and/or year and/or bank specific. The models employed in the earlier step, which are consistent with this relevant literature, are hindered by the vanishing degrees of freedom when trying to control for all such factors at once. Moreover, the small number of Islamic banks in any given country further complicates any attempt to capture heterogeneity. This casts doubts on the standard practice in the literature of sampling across countries.

Fourth, we combine the classification tree results with panel logit models and a wide array of financial structure, regulation and supervision quality, macroeconomic, market structure and bank-level characteristics to explain the drivers of the (mis-)alignment of the two banking systems across countries.

Evidence of differences in both efficiency steady states and convergence rates would support the hypothesis that Islamic banks operate a different banking business model. On the other hand, the absence of a significant difference can be taken as an indicator of mimicking behaviour and would favour the hypothesis that the two banking models differ only theoretically and not in practice. Our main findings are as follows. On average, the traditional β-convergence model finds no significant differences in steady state efficiency and efficiency convergence rates of the two bank types. Thus, Islamic banking practices (at an international level) are not sufficiently different from conventional ones to affect long-run efficiency or convergence, although at various points in time – e.g., episodes of financial distress – short-run efficiency deviations may exist. Examination of differences in convergence rates by country suggests that convergence can be significantly different between the two bank types.

The classification trees analysis further reveals that steady state efficiencies and convergence rates vary both by bank type *and* by country in certain cases. For example, Islamic and conventional banks in Malaysia are indistinguishable in terms of steady state efficiency and convergence rates, whereas differences between the two banking systems are more evident in some of the Middle East countries. The cross-country alignment of the two banking systems is positively related to financial depth, transparency in business, stability in the economic environment and concentration. Aligned banking systems are associated with diversified income sources, higher liquidity, profitability and financial stability.

Our paper offers four main contributions. We provide the first formal approach that goes beyond a simple efficiency analysis by comparing efficiency dynamics (i.e., steady states and convergence rates) between Islamic and conventional banks. Second, we use a random parameter model, which is novel in this context and allows for increased heterogeneity in the efficiency steady states and convergence rates across banks. Third, we provide a country classification of the two bank types by steady state efficiency and efficiency convergence. This is important as it groups the countries where the two banking systems are more aligned. Thereby we provide novel results that bring further insights regarding the differences between the two banking business models and underlying corporate structure. Furthermore, our findings tally with the recent trend in the literature suggesting that the practices of the two bank types are converging (Olson and Zoubi, 2017). Fourth, and to the best of our knowledge, this study is the first to highlight the drivers behind the (mis-)alignment of Islamic and conventional banks from a cross-country perspective.

In summary, our analysis extends the conventional paradigm adopted by most studies, which focuses on explaining the differences between the two banks types based on the business model, and shifts the focus instead on highlighting the role of country specific economic and financial indicators as drivers to such differences. Moreover, we also outline that differences with respect to efficiency and convergence are only significant in the short-run and that the two systems are pretty much aligned in the long-run. Given the current Covid-19 pandemic and its impact on economies around the world (similar to the 2008 Global Financial Crisis), this analysis permits important and timely lessons and implications to be learned. As such, our results are important from both an operational and regulatory perspectives.

The remainder of the paper is organised as follows. Section 2 provides background information, reviews the relevant literature and presents the theoretical framework. The methodological approaches employed to address our stated questions are presented in Section 3, while the data are presented in Section 4. Results and discussion are presented in Section 5. Finally, we draw conclusions and policy implications in Section 6.

2. Background information, related literature and theoretical framework

2.1. Background information

Islamic banking refers to practices that are commensurate with *Shariah*, where commonly acknowledged prohibitions include: debt interest payment, complex derivative products, short-selling, gambling, and dealing with alcohol and tobacco. Islamic finance engages with equity-based services (*Mudarabah*) in which an investor and an entrepreneur enter a joint profit-sharing venture. *Murabahah* is a cost-plus-profit sale. With *Ijarah* a bank leases an asset charging set fee. Among a variety of general features that investigations purport to show, are that Islamic banks: are more profitable (Hasan and Dridi, 2011), feature superior asset quality and capitalisation (Beck et al., 2013b); share a similar risk profile with their conventional counterparts (Abedifar et al., 2013; Baele et al., 2014; Čihák and Hesse, 2010; Pappas et al., 2017); and exhibit higher technical efficiency (Johnes et al., 2014).[2] That is not to say that Islamic banks are not subject to economic shocks, but the claim is that these are more muted (Di et al., 2017; Olson and Zoubi, 2017).

It is argued that the distinct Islamic profile enhances diversification opportunities for investors, see for example Sorwar et al. (2016), Alexakis et al. (2017) and Akhtar et al. (2017). Conversely, some Islamic stocks may be adversely affected by religious restrictions on stock trading (Alhomaidi and Kabir Hassan, 2017). Moreover, Islamic banks are particularly engaged with the development and economic welfare within low income countries (Abedifar et al., 2016). In part, this may be explained by their relatively higher liquidity creation (Berger et al., 2017).[3] In terms of corporate governance, Islamic banks typically maintain a *Shariah* Supervisory Board (SSB) which, working alongside a Board of Directors, is considered the "Supra Authority" (Choudhury and Hoque, 2006). Related research finds that a large SSB is associated with enhanced financial performance (Farag et al., 2017; Mollah and Zaman, 2015) and acts as a protective cushion against risk (Mollah et al., 2017a, 2017b; Pappas et al., 2017; Uddin et al., 2017). However, the dual board structure of Islamic banks is also known to impair their cost efficiency (Uddin et al., 2017).

2.2. Related literature

Studies of banking efficiency fall into two general categories. The first comprises studies which estimate banking sector efficiency at specific points in time, and possibly examine the determinants of efficiency in a second stage analysis. The sec-

[2] We direct you to Abedifar et al. (2015), Alzahrani and Megginson (2017), Hassan and Aliyu (2018), Narayan and Phan (2019) for some interesting surveys of Islamic banking literature.

[3] More research is required in the link between liquidity creation and real economic activity; the limited evidence suggest a positive link between liquidity creation and GDP/capita (Berger and Sedunov, 2017).

ond category contains studies which examine the existence and speed of efficiency convergence, and hence are more focused on the dynamics underlying efficiency convergence. We consider each of these in turn.

A vast literature is devoted to the measurement of banking efficiency with early reviews including Berger and Humphrey (1997), Berger and Mester (1997), Brown and Skully (2002), Casu et al. (2004), while a more recent synthesis can be found in Fethi and Pasiouras (2010). A growing literature that compares the efficiency of Islamic and conventional banks provides only mixed evidence regarding the efficiency of the two bank types. Some of these studies find no significant difference between the two bank types (El-Gamal and Inanoglu, 2005; Grigorian and Manole, 2006; Hassan et al., 2009; Mohamad et al., 2008), while other studies find that Islamic banks are significantly more efficient than conventional banks (Al-Jarrah and Molyneux, 2006; Al-Muharrami, 2008; Olson and Zoubi, 2008). But there is also evidence (including the most recent studies) that Islamic banks are significantly less efficient than conventional ones (Abdul-Majid et al., 2011a, 2011b, 2010; Kamarudin et al., 2014; Mobarek and Kalonov, 2014; Safiullah and Shamsuddin, 2020).[4] These conflicting findings are in part attributed to the sample selection deficiencies that studies in this field suffer from. In particular, to boost the sample size, a customary practice is to feature a number of disparate countries, where banks can be expected to face different economic conditions, banking and accounting regulations, as well as practices.

Banking efficiency studies that undertake a second stage analysis indicate that efficiency *per se* is an important aspect alongside other bank characteristics such as size, composition of assets, risk, liquidity and market structure/macroeconomic variables that affect banking performance (Beck et al., 2013a, 2013b; Berger and Mester, 1997; Dietsch and Lozano-Vivas, 2000; Hasan and Dridi, 2011; Koutsomanoli-Filippaki et al., 2009; Miller and Noulas, 1997; Staikouras et al., 2008; Yudistira, 2004).

Measuring efficiency convergence typically employs two approaches: the β- and σ-convergence models borrowed from the growth literature (Sala-i-Martin, 1996) and the dynamic factor models (Kose et al., 2012; Phillips and Sul, 2009, 2007). A key hypothesis is that increasing global financial integration has led to banking efficiency convergence in a world-wide setting and there is plenty of evidence in support of such convergence across time (Andrieş and Căpraru, 2014; Fung, 2006; Gallizo et al., 2016; Kasman and Kasman, 2013; Mamatzakis et al., 2008; Rughoo and Sarantis, 2014; Weill, 2009; Zhang and Matthews, 2012).

In the context of Islamic and conventional bank efficiency convergence little research has been done, even though this is a well-researched topic within the EU and the US. In particular, little interest has been shown in the steady state values that are derived from efficiency estimation models. One exception highlights that bank efficiency convergence of US bank holding companies is conditional upon their initial differences in X-efficiency (Fung, 2006). The relatively few studies devoted to Islamic banking do not deal with efficiency convergence. Yet, convergence becomes increasingly important as Olson and Zoubi (2017) find that the two banking systems converge in terms of profitability, but not in terms of risk. As Islamic banks work alongside conventional banks there is every reason to expect comparable efficiency convergence dynamics between the two bank types. This is worth investigating as a similar pattern would indicate that the two business models are closely related despite of being argued otherwise elsewhere (Khan, 2010). Different conversion patterns confirm the existence evidence that two entities are indeed different. These are the gaps in the literature that we aim to fill.

2.3. Theoretical framework

The dynamics of efficiency are particularly important in the context of competitive advantage. Based upon resource-based theory (Chen et al., 2015) relative profitability performance correlates with differences in efficiency (Demsetz, 1973; McGahan and Porter, 1999). Such efficiency differences might arise from differences in technology, experience or the business model. If efficient production techniques can be imitated by rivals, efficiency differences should not persist. Where differences do persist, this might indicate an inability to identify (or an unwillingness to copy) the operations of rivals. The terminology is *"uncertain imitability"* (Lippman and Rumelt, 1982).

The pivotal role of efficiency in banking has been well-documented in studies examining the interlinks between capitalisation, bank risk and competition (Altunbaş et al., 2001; Dong et al., 2017; Fiordelisi et al., 2011; Gonzalez, 2009; Kwan and Eisenbeis, 1997; Schaeck and Cihák, 2014). Recent studies show a negative relationship between competition and bank stability (Anginer et al., 2014; Goetz, 2018). Given the association between low values of efficiency and higher bank risk (Berger and DeYoung, 1997; Kwan and Eisenbeis, 1997), competition incites banks to increase efficiency, strengthen performance and survive. Indeed, the role of efficiency may be catalytic (Beck et al., 2013a; Schaeck and Cihák, 2014). The speed of convergence in the presence of efficiency differences could be taken as a signal of competitive advantage; with slow convergence, competitive advantage is maintained for longer. In an ideal world, any bank would optimise its business model to attain long-run efficiency. Several factors (relating to economic conditions, operation and regulatory frameworks) may impede this process, and therefore affect both the convergence rate and the level of long-run efficiency of the bank. Differences in convergence rates (as well as the steady state efficiency levels) might arise because business practices, objectives and underlying principles differ.

[4] We focus on studies investigating technical efficiency, but a similar conclusion is reached across studies investigating cost and profit efficiency – a recent synthesis is found in (Safiullah and Shamsuddin, 2019).

There is no clear theory underlying the similarities/differences between the convergence rates of Islamic banks to their conventional counterparts. But these may be expected between the two bank types for a number of reasons.

First, there may be differences between the theoretically envisaged Islamic banking model and what is observed in practice. For instance, the cornerstone of Islamic banking is equity finance (El-Hawary and Grais, 2003), with profits and losses shared between the contracted parties according to some pre-determined ratio (Usmani, 2004). Yet, equity financing may constitute a small percentage of a typical Islamic bank's asset portfolio (El-Gamal, 2006; Khan, 2010; Zaman and Movassaghi, 2002). Instead, fee-based financial products are the norm, where an "implicit" interest rate is charged that is often highly correlated with the "explicit" interest rate observed in the conventional banking sector (Hussan and Masih, 2014).

Second, the extent of compliance with Islamic principles tends to vary by bank size, product offerings and demographics. Products, such as Islamic microfinance, are more common in the Far East, whereas real estate finance is more dominant in the Gulf Cooperation Council (GCC) region. Therefore, differences in steady state efficiency and efficiency convergence rates might be expected *within* the Islamic banking sector; hence blurring distinctions *between* Islamic and conventional banks.

Third, over time we would expect financial integration to increase worldwide through common regulatory frameworks (such as the Basel Accord),[5] trade and monetary unions (for example the European Union) and an ever-increasing global banking presence (HSBC, for example, has branches in 80 countries). Thereby efficiency is more likely to become prominent on banks' agenda and convergence is expected to take place (Fiordelisi et al., 2011).

Fourth, regulation and supervision of Islamic banking remains challenging at an international level. For example, regulators need to incorporate the peculiarities of Islamic banking, most notably with respect to capitalisation and liquidity management, into their operations, while ensuring a level playing field between Islamic and conventional banking (Song and Oosthuizen, 2014). Some countries document important improvements at this front but Islamic banking expands to new countries, each with unique peculiarities. Hence, cross-country differences with respect to accounting standards, regulatory and supervisory frameworks, licensing requirements and Shariah board authority impedes standardisation further contributing to the efficiency gap.

Fifth, unique aspects of the Islamic business model could affect the efficiency gap and its dynamics. The Islamic banking model allows risk to "pass-through" from the asset to the liability side, thereby limiting the impact of adverse shocks on their solvency (Beck et al., 2013b). Islamic financial products require the management of an inventory of assets (e.g., real estate, commodities), a task of increased complexity, known to impact efficiency (Ariss, 2010; Beck et al., 2013b). Shariah restrictions can increase asset concentration amidst limited hedging and risk management capabilities (Elnahass et al., 2014; Saeed and Izzeldin, 2016). Islamic banks may have limited course of action with regards to late payments and/or default (Baele et al., 2014; Song and Oosthuizen, 2014). The increased loyalty of religious clients may reduce pressure on Islamic banks to perform (Abedifar et al., 2013).

In summary, both efficiency and the ability to swiftly revert to the steady-state (i.e., efficiency convergence), are key to the Islamic banks' growth and long-term survival.

3. Estimation framework – efficiency and convergence

An implicit assumption underlying most efficiency studies is that all the banks under examination are fully synchronized. Yet, banks may face diverse – and react differently to – idiosyncratic and systemic shocks. Hence, they might be at different stages on their convergence path towards equilibrium efficiency. To allow for this we generalize the assumption of homogenous response to shocks by first estimating the efficiency of our alternative and conventional sample of banks and then examining more closely their steady state efficiency and convergence patterns. We utilize three different techniques that we detail below.

3.1. Efficiency estimation

Banking efficiency is typically measured using one of two approaches: a parametric frontier estimation, such as stochastic frontier analysis (SFA) or a non-parametric frontier estimation, such as data envelopment analysis (DEA). Both approaches have been widely adopted within the banking context; see for example Ghroubi and Abaoub (2016) and the literature therein.

In this study, we estimate the output distance function (ODF) using SFA to allow for stochastic shocks in the system, and apply a translog functional form as it is flexible, easy to estimate and permits the imposition of homogeneity (Coelli and Perelman, 2000) which allows the parametric estimation of a multi-input and multi-output ODF. The translog output distance function is defined below for N banks using inputs x_k $(k = 1, ..., K)$ to produce outputs y_m $(m = 1, ..., M)$:

$$\ln D_{it}(x,y) = \alpha_0 + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{M}\sum_{n=1}^{M} \alpha_{mm} \ln y_{mit} \ln y_{nit} + \sum_{k=1}^{K} \beta_k \ln x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M} \delta_{km} \ln x_{kit} \ln y_{mit} \quad i = 1, 2, \cdots, N \tag{1}$$

[5] Delis et al. (2011) highlights the contribution of such international organisations to the financial development of transitional economies.

where the subscript *it* refers to bank *i* at time period *t*. Distance function restrictions require the following conditions to hold:

a) Homogeneity of degree +1 in outputs

$$\sum_{m=1}^{M} \alpha_m = 1 \text{ and} \tag{2a}$$

$$\sum_{n=1}^{M} \alpha_{mn} = 0 m = 1, 2, \cdots, M \text{ and} \tag{2b}$$

$$\sum_{m=1}^{M} \delta_{km} = 0 k = 1, 2, \cdots, K \tag{2c}$$

b) Symmetry

$$\alpha_{mn} = \alpha_{nm} m, n = 1, 2, \cdots, M \text{and} \tag{3a}$$

$$\beta_{kl} = \beta_{lk} k, l = 1, 2, \cdots, K \tag{3b}$$

By the homogeneity restriction, $D(x, \omega y) = \omega D(x, y)$, whereby one output can be chosen arbitrarily, for example the *M*th output, such that $\omega = 1/y_M$. Thus Eq. (1) can be written as:

$$-\ln y_{Mit} = \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln\left(\frac{y_{mit}}{y_{Mit}}\right) + \frac{1}{2}\sum_{m=1}^{M-1}\sum_{n=1}^{M-1} \alpha_{mn} \ln\left(\frac{y_{mit}}{y_{Mit}}\right) \ln\left(\frac{y_{nit}}{y_{Mit}}\right) + \sum_{k=1}^{K} \beta_k \ln x_{kit} + \frac{1}{2}\sum_{k=1}^{K}\sum_{l=1}^{K} \beta_{kl} \ln x_{kit} \ln x_{lit} + \sum_{k=1}^{K}\sum_{m=1}^{M-1} \delta_{km} \ln x_{kit} \ln\left(\frac{y_{mit}}{y_{Mit}}\right) + \varepsilon_{it} i = 1, 2, \cdots, N \tag{4}$$

where $\varepsilon_{it} = -\ln D_{it}(x, y)$

The quantity of interest here is the distance (or efficiency), $\ln D_{it}(x, y)$, as measured by the error term in Eq. (4). We assume this error term can be split into two components i.e., $\varepsilon_{it} = v_{it} - u_{it}$ where v_{it} represents statistical noise, i.e., v_{it} $N(0, \sigma_v^2)$, and u_{it} represents the efficiency of bank *i* in time period *t* and is distributed as half-normal i.e. u_{it} $N^+(\mu, \sigma^2)$, following Aigner et al. (1977).

Thus, the SFA estimation allows for stochastic errors and can be adapted to the panel structure of our data. We estimate the ODF across all observations, i.e., across countries and across time periods as in for example Gallizo et al. (2016) and the literature therein. While it might be argued that different countries observed at different time periods face different production conditions, this is, in fact exactly what the convergence models in the subsequent stage aim to capture. Making allowances for these differences at this stage might conceal variations either in steady state efficiency or convergence rate, which might exist *because of differences in environment or initial conditions*. Moreover, we measure efficiency in such a way so as to ensure a level playing field for both bank types in the respective samples. Therefore, we use a production function approach as in Casu and Girardone (2010) in preference to a cost or profit function because Islamic banks may not focus entirely on cost-minimization or profit-maximization. Given that the similarities between the Islamic and conventional banking practices can be both country and time specific, we opt to measure efficiency using an ODF that makes no specific assumptions with respect to the optimizing behavior.

The selection of variables qualifying for the distance function is guided by the previous literature (Abdul-Majid et al., 2010; Casu et al., 2004; Casu and Girardone, 2004) and data availability. We follow the popular intermediation approach; see for example, Pasiouras (2008). For the choice of inputs and outputs we follow Johnes et al. (2014), using: i) deposits and short term funding (x_1), ii) fixed assets (x_2), iii) general and administration expenses (x_3) and iv) equity (x_4) as inputs to produce: i) total loans (y_1) and ii) other earning assets (y_2). All monetary variables have been converted to real values using the appropriate GDP deflator.

3.2. Steady state efficiency and convergence

We utilise the concepts of β- and σ-convergence models (Young et al., 2008) to explore differences in steady state efficiency and efficiency convergence across the two bank types over the sample period. The convergence models used here and in other studies of banking efficiency convergence, see for example Weill (2009) and Casu and Girardone (2010), are adapted from the growth literature (Sala-i-Martin, 1996). The basic β-convergence model is:

$$\ln(u_{i,t}) - \ln(u_{i,t-1}) = \alpha + \beta \ln(u_{i,t-1}) + \varepsilon_{i,t} \tag{5}$$

where $u_{i,t}$ is the measure of efficiency of bank i in time period t. The value of the parameter β represents convergence (if $\beta < 0$) or divergence (if $\beta > 0$) in banking efficiency. The larger is $|\beta|$ the greater is the speed of convergence or divergence. However the β-coefficient can be negative because of data measurement errors and random shocks rather than because of genuine convergence (Fung, 2006). To ensure that the β-coefficient signifies real convergence (rather than reversion towards the mean) it must coincide with significant σ-convergence (Fung, 2006), which is a measure of convergence based on the dispersion of a bank's efficiency around the sector average in a given time period. We therefore estimate σ-convergence in order to validate our β-convergence measures are valid. The basic σ-convergence model is given by:

$$\Delta w_{i,t} = \gamma + \sigma w_{i,t-1} + \varepsilon_{i,t} \tag{6}$$

where $w_{i,t} = \ln(u_{i,t}) - \ln\left(\bar{u}_t\right)$ and $\Delta w_{i,t} = w_{i,t} - w_{i,t-1}$. Note that the value of the parameter σ can be interpreted in a similar manner to the value of β.

We estimate a conditional β-convergence model whereby specific banks (Islamic or conventional) are permitted to have different steady state efficiency levels and convergence rates. Specifically, the following conditional β-convergence model is estimated:

$$\ln(u_{i,t}) - \ln(u_{i,t-1}) = \alpha + \beta \ln(u_{i,t-1}) + \gamma \mathrm{TYPE}_{i,t} + \delta \mathrm{TYPE} \times \ln(u_{i,t-1}) + \sum \vartheta_c \mathrm{LOCATION}_{c,i,t} + \sum \omega_t \mathrm{YEAR}_{i,t} + \varepsilon_{i,t} \tag{7}$$

where TYPE is a binary variable with 1 denoting bank type (Islamic) and zero otherwise. Country dummies (LOCATION) and year dummies (YEAR) are also included to account for differences in financial regimes and technology across countries and time. If $\gamma \neq 0$ then the banking models are converging on different steady state efficiency levels; if $\delta \neq 0$ then the banking models have different convergence rates. For robustness, we use a variety of estimation methods including OLS, random effects and system-GMM. We implement a two-step system GMM approach, in line with the empirical applications of Mollah and Zaman (2015) and Casu and Girardone (2010), while following the theoretical underpinnings of Arellano and Bover (1995), Blundell and Bond (1998) and Roodman (2006).

The convergence model of Eq. (7) presupposes that differences between banks depend solely on the business model under consideration (i.e. Islamic and conventional). Yet there may be some Islamic banks whose behavior is more typical of conventional banks than of Islamic banks, and *vice versa*. In order to allow for differences between individual banks as revealed by the data the following β-convergence model is estimated using the random parameter model (RPM).

$$\ln(u_{i,t}) - \ln(u_{i,t-1}) = \alpha_i + \beta_i \ln(u_{i,t-1}) + \varepsilon_{i,t} \tag{8}$$

The estimated parameters (α_i, β_i) therefore allow each bank: a) to have a unique steady state efficiency, and b) to react differently to its past efficiency level. In order to see whether there are differences between Islamic and conventional banks, we subsequently examine the α_i and β_i estimates for possible differences between the bank types. While a random parameter stochastic frontier approach has been applied to estimating bank efficiencies in the context of Mexico (Barros and Williams, 2013), the random parameter approach has not been previously applied in the context of banking efficiency convergence. Our estimation methods address the issues of unobserved heterogeneity and endogeneity to differing extents. In particular, the RPM generalizes the efficiency convergence framework by allowing each bank to exhibit unique convergence dynamics. This is particularly relevant for the Islamic banks as there are important differences within their sector with regards to country location, bank size, age, financial product focus and *Shariah* board compliance.

3.3. Classification trees

We employ various approaches to explore further the patterns of efficiency convergence and steady state revealed by the RPM analysis. The Islamic bank sample is taken from many different countries, and within each country there might be only a few Islamic banks, and so an alternative approach is required to tease out further information. A difficulty in the cross-country analysis is to identify precisely the impact of bank type, country specific characteristics and regulation upon the quantity of interest (e.g., efficiency steady state or convergence rate). Traditional estimation methods often pose restrictions, due to limitations in the degrees of freedom, when examining differences in the values of α and β (see Eq. (7)) by country and type. So, for the Islamic banks sample we use a non-parametric classification tree methodology (see Appendix A) to identify groups of banking sectors (by country) with similar steady state (α) or convergence (β) characteristics. Although the classification tree method has been used in a banking efficiency setting by Emrouznejad and Anouze (2010), it has not been applied in the context of steady state efficiency or efficiency convergence.

We apply the classification tree algorithm using the steady state efficiency (α) and convergence rate (β) based on the RPM to examine whether there are groups/clusters of banks that share similarities with respect to efficiency dynamics. Here, we assume that any differences conform to the ex-ante Islamic/conventional split for every country. Classification trees can handle various types of control variables (i.e., continuous, categorical and binary), although the dependent variable must be binary.[6] A β-convergence binary variable is constructed for the full sample and classifies banks into high/low β-convergence estimates according to a median split. In a similar manner, a steady state binary variable based on the RPM estimation is constructed. Our control variables are the bank type (Islamic or conventional) and the country indicator.

4. Data

The data are drawn predominantly from the balance sheets and income statements of the Bureau van Dijk Bankscope database for the period 1999 to 2014 and across 23 countries. The countries are: Bangladesh, Bahrain, Brunei, Egypt, Indonesia, Iran, Jordan, Kuwait, Lebanon, Mauritania, Malaysia, Oman, Philippines, Pakistan, Qatar, Saudi Arabia, Sudan, Singapore, Syria, Tunisia, Turkey, United Arab Emirates and Yemen. A small number of observations for missing periods were obtained from the annual reports of individual banks. We finally derive an unbalanced panel of 4864 bank-year observations for Islamic and conventional banks, with the number of banks ranging from 158 in 1999 to 502 in 2014. Of this total of bank-year observations, 1089 relate to Islamic banks and 3775 relate to conventional banks.[7] There is clearly a large difference between the number of Islamic and conventional banks. While nearly 25% of our observations relate to Islamic banks this is similar or higher than in previous studies (Abdul-Majid et al., 2010; Al-Jarrah and Molyneux, 2005; Beck et al., 2013b; Čihák and Hesse, 2010; Srairi, 2010). In line with Beck et al. (2013a, 2013b), we have winsorized at the 1st and 99th percentiles. Table 1 presents the distribution of bank observations and bank total average assets by operational mode and country. The Islamic banking percentage share column reflects the importance of the Islamic banking in each country over the period of study. Every country has at least one bank of each type over the time period covered.

Table 2 displays the mean values of the inputs and outputs of the ODF by bank type (panel a) and the number of bank observations by type and country (panel b). While Islamic banks are typically smaller than conventional banks in terms of deposits, loans and other earning assets, they are remarkably similar in terms of administrative expenses and are larger in terms of fixed assets. The relatively large mean administrative expenses for Islamic banks is reflective of the extra costs related to the *Shariah* board; while the high value of mean fixed assets follows the collateral requirements of many Islamic banking products; hence banks would typically have tangible assets (e.g., buildings, commodities) at their disposal for such use.

5. Results and discussion

5.1. Parametric estimation of efficiency

Fig. 1 presents the efficiency scores derived from the first stage stochastic ODF,[8] from which it appears that conventional banks have a higher efficiency than Islamic banks (Abdul-Majid et al., 2011a, 2010; Johnes et al., 2014; Srairi, 2010). This difference is significant at the 10% significance level for the sample as a whole and for all individual years apart from 2011. Whether these efficiency differences between Islamic and conventional banks at given points in time represent a difference in long term or steady state efficiency will be investigated in the second stage convergence analysis.

5.2. Steady state efficiency and efficiency convergence

a) OLS, random effects and system-GMM estimation

Table 3 reports parameter estimates of absolute and conditional β-convergence models using, respectively, OLS, random effects (RE) and system-GMM estimation methods.[9] The parameter estimates are similar across all estimation methods. The significance of the σ coefficient in the associated σ-convergence model (see Appendix B for full σ-convergence results) confirms that the estimates of β-convergence in these models can be considered to be genuine, rather than reversion to the mean; see also Casu and Girardone (2010).

A first inspection of the estimated parameters of models in columns I, IV and VII provide interesting reading. The (exponentiated) estimated intercepts suggest that all banks are converging at a steady state efficiency value of around 0.92 to 0.95, depending on estimation method. While there is no obvious link between steady state efficiency and financial development (as proxied by stock market capitalisation), the three countries with the markedly lowest steady state efficiency in the sample (see Fig. 2), namely Syria, Brunei and Mauritania with a 3.85% average percentage point difference to Egypt, do not feature a stock market. The estimated β coefficient ranges between -0.283 and -0.442 and is comparable with estimates reported in previous studies using EU and US banking data, suggesting comparable efficiency convergence dynamics in the banking systems of our sampled countries.[10]

[7] Most of these banks are domestic, with only six banks having operations in another country. For example, Kuwait Finance House is headquartered in Kuwait and has another subsidiary in Bahrain. Our main results remain unchanged to the exclusion of these six banks. We omit this part of the analysis for brevity and is available upon request.

[8] The estimated parameters of this distance function are omitted for brevity and are available upon request.

[9] Note that the system-GMM estimations satisfy the conditions that there is significant AR(1) serial correlation, no AR(2) serial correlation and high Sargan/Hansen test (Casu and Girardone, 2010).

[10] Some countries (Brunei, Oman, Philippines and Tunisia) have limited Islamic bank observations. To make sure our results are robust, we have rerun the analysis after excluding these countries, and the results (available upon request) remain qualitatively similar. We retain the original results due to the relative importance of Islamic banking in these countries (see also Table 1). For example, Brunei has been of growing importance within the Islamic financial markets' universe, with Islamic banks managing above more than half of the total banking assets and the government taking significant steps towards making Brunei an Islamic financial hub (IFSB, 2019). Oman is one of the most recent players in Islamic finance, and since 2011 has two Islamic banks covering around 15% of the total banking assets (IFSB, 2019).

Table 1
Bank observations and total assets by types and country.

	Bank observations				Bank Total Average Assets			
	All	Conventional	Islamic	Islamic %	All	Conventional	Islamic	Islamic %
Bahrain	213	118	95	44.6	11,300	9,334	1,967	17.4
Bangladesh	161	136	25	15.5	4,104	2,023	2,080	50.7
Brunei	18	16	2	11.1	6,941	1,485	5,456	78.6
Egypt	361	325	36	10.0	8,155	5,448	2,707	33.2
Indonesia	854	785	69	8.1	5,132	3,977	1,155	22.5
Iran	156	3	153	98.1	29,163	8,377	20,786	71.3
Jordan	187	151	36	19.3	9,723	8,103	1,619	16.7
Kuwait	145	65	80	55.2	24,090	17,378	6,713	27.9
Lebanon	409	394	15	3.7	3,663	3,543	120	3.3
Malaysia	195	127	68	34.9	26,422	18,954	7,468	28.3
Mauritania	93	76	17	18.3	223	129	94	42.2
Oman	92	88	4	4.3	4,793	4,395	398	8.3
Pakistan	153	99	54	35.3	3,755	3,343	412	11.0
Philippines	230	224	6	2.6	4,670	4,656	14	0.3
Qatar	119	84	35	29.4	20,595	13,336	7,260	35.2
Saudi Arabia	173	128	45	26.0	42,973	27,283	15,690	36.5
Singapore	111	103	8	7.2	49,148	48,667	481	1.0
Sudan	227	66	161	70.9	1,812	1,112	700	38.6
Syria	87	74	13	14.9	2,221	1,487	734	33.0
Tunisia	180	178	2	1.1	2,647	1,895	753	28.4
Turkey	311	282	29	9.3	27,158	19,865	7,293	26.9
United Arab Emirates	314	220	94	29.9	20,538	13,092	7,445	36.3
Yemen	75	33	42	56.0	993	476	517	52.1

Table 2
Descriptive statistics of ODF model variables.

	All banks			Conventional banks			Islamic banks		
Variable	Mean	S.D.	Median	Mean	S.D.	Median	Mean	S.D.	Median
Deposits and Short-Term Funding(x_1)	5,276	11,949	1,209	5,715	13,077	1,280	3,755	6,483	1,025
Fixed Assets(x_2)	92	239	18	75	171	19	151	386	16
General and Administration Expenses (x_3)	128	265	33	129	268	34	127	257	30
Equity(x_4)	732	1,641	170	784	1,787	166	552	954	177
Total Loans(y_1)	4,864	8,975	785	3,923	9,789	795	2,978	5,188	680
Other Earning Assets(y_2)	2,331	5,666	471	2,667	6,295	524	1,168	2,071	344

Note: Source Bankscope. All data have been adjusted to 2005 prices using the appropriate GDP deflator for each country.

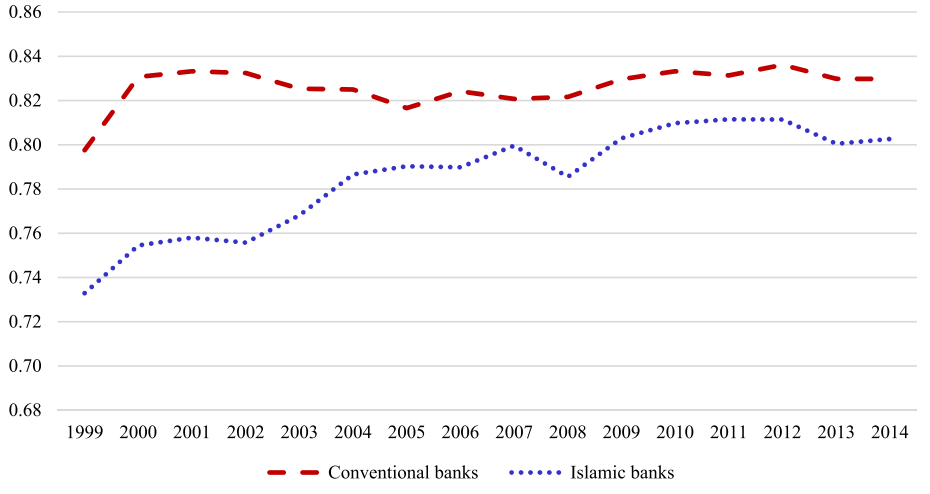

Fig. 1. Evolution of efficiencies over time and by bank types.

The slope and intercept dummies for bank type show no statistical significance across all models (columns II, V and VIII). The same conclusion is reached when country intercept and slope effects and time intercept effects are considered (columns III, VI and IX). This shows that Islamic and conventional banks are not different in terms of long-term (steady state) efficiency

Table 3
β-convergence model estimated using various estimation methods.

Method	Pooled OLS robust			Random Effects robust			System-GMM two-step robust		
Model	(I) Absolute β-convergence	(II) Conditional β-convergence	(III) Conditional β-convergence	(IV) Absolute β-convergence	(V) Conditional β-convergence	(VI) Conditional β-convergence	(VII) Absolute β-convergence	(VIII) Conditional β-convergence	(IX) Conditional β-convergence
βcoefficient	−0.283***	−0.282***	−0.332***	−0.363***	−0.378***	−0.402***	−0.442***	−0.473***	−0.489
	(0.027)	(0.004)	(0.072)	(0.030)	(0.053)	(0.077)	(0.063)	(0.081)	(0.331)
TYPE		−0.014*	−0.016		−0.010	−0.019		−0.006	0.015
		(0.010)	(0.011)		(0.012)	(0.009)		(0.023)	(0.032)
TYPE × $\ln(u_{i,t-1})$		−0.017	−0.018		0.020	−0.014		0.059	0.161
		(0.055)	(0.059)		(0.061)	(0.048)		(0.110)	(0.146)
Constant	−0.053***	−0.051***	−0.059***	−0.071***	−0.070***	−0.070***	−0.082***	−0.086***	−0.088
	(0.005)	(0.006)	(0.014)	(0.005)	(0.009)	(0.014)	(0.012)	(0.015)	(0.061)
Country shift dummies	No	No	Yes	No	No	Yes	No	No	Yes
Year shift dummies	No	No	Yes	No	No	Yes	No	No	Yes
Country slope dummies	No	No	Yes	No	No	Yes	No	No	Yes
Year slope dummies	No	No	No	No	No	No	No	No	No
m_1 p-value							0.000	0.000	0.000
m_2 p-value							0.533	0.507	0.465
Sargan/Hansen p-value							0.092	0.194	0.574
R^2	0.205	0.209	0.259	0.205	0.209	0.256			

Notes: The table reports estimated coefficients and standard errors in parentheses. OLS = ordinary least squares. TYPE takes the value 1 for Islamic banks and zero otherwise. N = 4179 bank year observations for all models, and T = 15 years. Tests for first- and second order autocorrelation in the system-GMM model are denoted by m1 and m2, respectively. Sargan/Hansen is a test of the over-identifying restrictions relevant to the system-GMM model. ***, **, * denote statistical significance at the 1, 5, 10% level respectively.

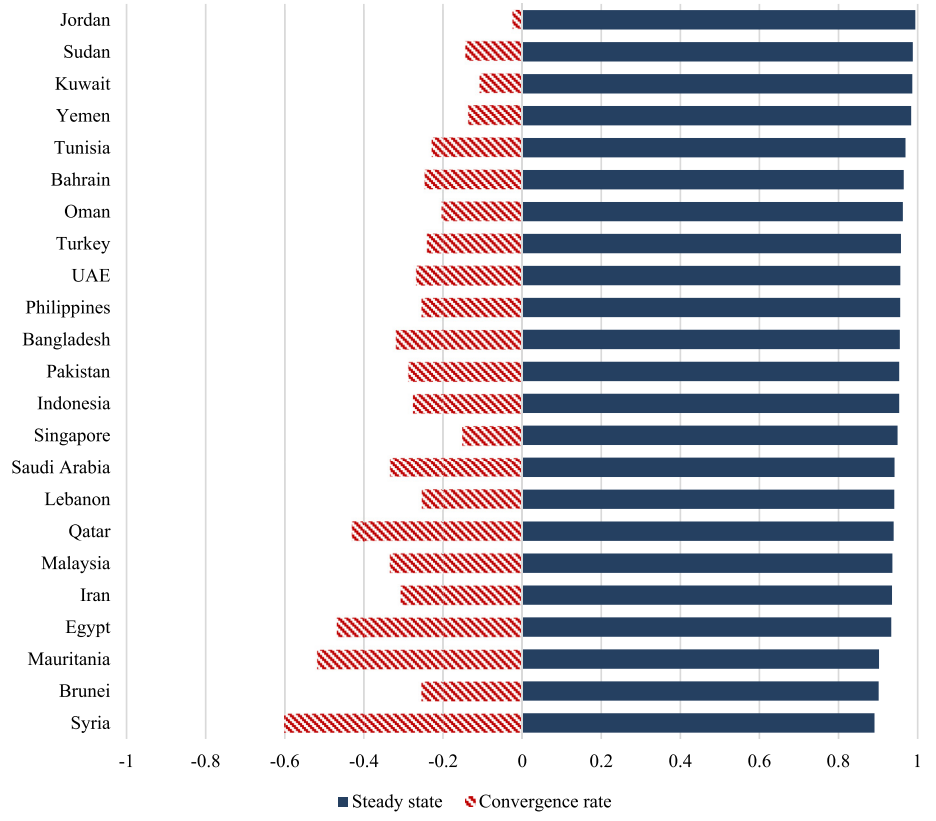

Fig. 2. Steady state efficiencies and convergence rates by country. Notes: The figure is based on the results of column III in Table 3.

and convergence (to the steady state) rates. This suggests a close alignment of the two bank types, which may be in part attributed to Islamic banks offering products that are closely aligned to those of the conventional. In turn this may be driven by similarities in the financial products required by the clientele of either bank type. There is also the need to comply with international accounting standards, banking regulation frameworks and product offering (Martynova and Renneboog, 2011). The finding offers an affirmation to the literature contradicting any differences between the two bank types (see also Section 2). Therefore, any differences in efficiency observed in the first stage (Fig. 1) of the analysis, and which are echoed in a substantial part of the literature, are merely short-term, transitory ones.[11]

Fig. 3 presents the steady state efficiencies over time. The countries in the sample have been through several instances of financial distress and instability, most notably the late 1990 s Far East Crisis, the 2003 Iraq War, the 2005 crash of the Saudi Arabian stock market, and the 2008 global financial crisis. The patterns suggest that such events are negatively associated with steady state efficiency.

b) RPM estimation

Table 4 presents the average estimated coefficients of the RPM model (see Eq. (8)) and Fig. 4 presents their kernel densities by bank type. The average steady state efficiency is 0.90 with no significant difference between Islamic and conventional banks. Likewise, the average convergence rate is −0.554, again with no significant difference between Islamic and conventional banks. These (average) results are in line with those of the alternative estimation methods reported in Table 3. Thus, once the individual circumstances of each bank are accounted for (i.e., each bank is permitted to have its own steady state efficiency and convergence rate) there appears to be no significant difference between Islamic and conventional banks either in terms of their steady state efficiency or the speed with which they converge to it. Our *a priori* clubs (Islamic and conventional) are thus far not confirmed empirically.

However, the kernel densities suggest that the efficiency convergence dynamics of the two bank types may still be different, albeit country factors may be concealing such variations. Here, we want to elaborate on this rather crucial point. Suppose that the average efficiency steady state of conventional banks in our sample is 0.93. All the regression-based techniques

[11] Our results are robust to the inclusion of a third output variable, where we opt for Total income and Non-interest income. These results are omitted for brevity and are available from the authors upon request.

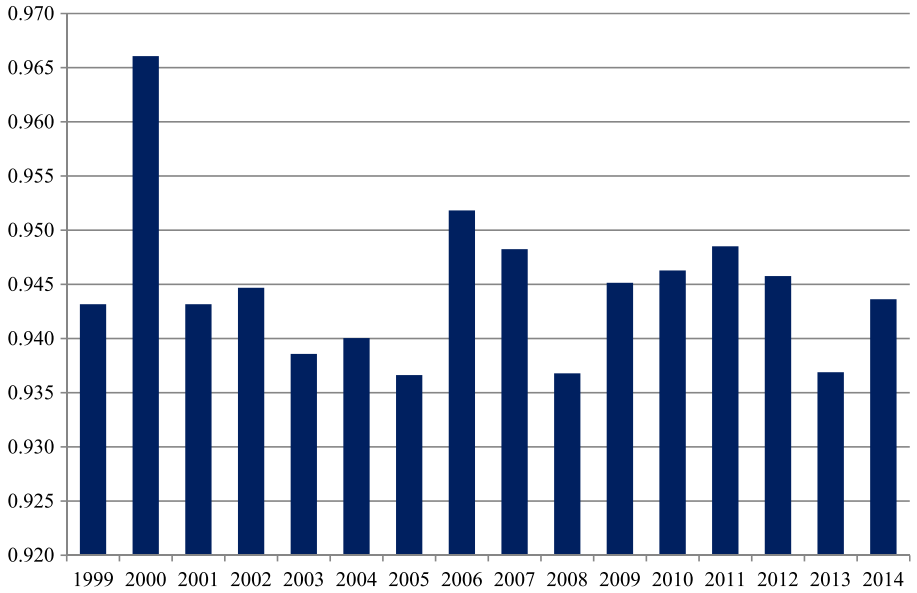

Fig. 3. Steady state efficiencies over time. Notes: The base year is 1999. The figure is based on the results of column III in Table 3.

Table 4
RPM conditional β-convergence.

Model (7)	All	Islamic	Conventional	p-value
β	−0.554	−0.525	−0.564	0.209
	(0.000)			
α	−0.105	−0.112	−0.102	0.175
	(0.000)			
Number of banks	388	84	304	
Chi-sq	315.47			
	(0.000)			

Notes: The table reports the average estimated coefficients for All banks, Islamic banks and Conventional banks, while the p-values are given in parentheses. The p-value column reports the results of the Wald tests for the equality of the convergence rates (β) and steady states (α) between Islamic and conventional banks.

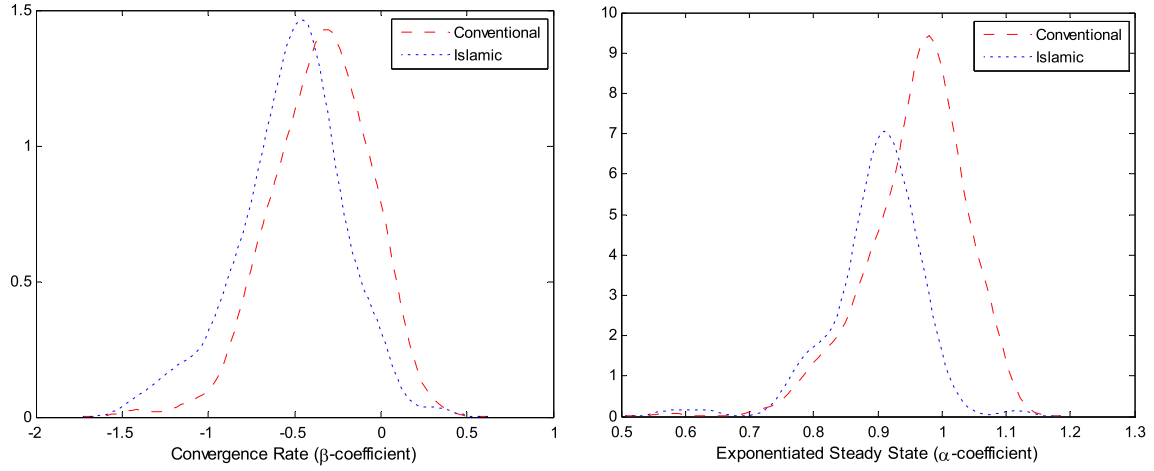

Fig. 4. Kernel density plots for convergence rate (β) and steady state (α). Notes: The figure shows the kernel density plots for the convergence rate (β) and exponentiated steady state (α) estimates from the RPM model for conventional and Islamic banks.

we have deployed up to this point are valid for the *average* efficiency steady state of Islamic banks, while potentially allowing for country and time effects. However, such (parametric) techniques cannot allow for interactions between country, time effects and bank type due to the vanishing degrees of freedom. Therefore, these models are incapable to allow for the fact that in some countries Islamic banks may have a higher efficiency steady state than conventional banks while in others the opposite may be true. The RPM estimation offers a way to take this into account, but when the results are averaged, for reporting purposes as in Table 4 for example, this information is lost. Instead, kernel density plots of the estimated parameters allow for the extraction of such information. Kernel densities by country are even better in this respect and show precisely that the Islamic banks are not always (i.e., in every country) inferior to conventional banks.[12]

Therefore, before concluding that the two banking models are truly similar, we need to explore the possibility that country differences are concealing variations between the two bank types. The section below presents the results of the classification trees approach.

5.3. Classification trees

Table 5 presents goodness-of-fit statistics for the classification trees, in line with those reported in Delen et al. (2013), Irimia-Dieguez et al. (2015), West (2000), namely accuracy, area under curve (AUC), expected misclassification cost (EMC), and pseudo R-squared (see also Appendix C). These goodness-of-fit statistics show that most of the explanatory power comes from country factors, not bank type. However, using both country and banking type information the classification works the best.

Table 6 presents the clubs generated by the classification tree approach based on steady state (Panel A) and β-convergence according to bank type and country. The upper (lower) part of the table represents the high (low) steady state and β-convergence groups, respectively. Each panel lists the Islamic and conventional banking system of each country and the intersection region. It is the intersection region that provides the most interesting conclusion as it identifies those countries for which the two banking systems are similar. Fig. 5 presents a visual illustration of Table 6 contents using Venn diagrams.

The classification tree results of Table 6 show clear evidence as to why the parametric approaches of the previous steps fail to identify any differences in steady state efficiency and convergence rate. Results vary by country, for instance in some countries, the Islamic banks are the ones exhibiting the highest speed of convergence; in other countries, it is the conventional ones. In addition, disparities in the initial conditions of banks in terms of economic and financial development of the country in which they are located, and the implementation of policies and reforms across countries, mean that banks operating therein may have different steady state efficiency levels as observed in panel A. In some countries, the two banking systems are indistinguishable from one another in terms of steady state efficiency and/or convergence speed; these lie in the intersection of areas in panels A and B of Table 6 respectively. A few notable examples are discussed below.

In Malaysia, the two bank types under investigation are indistinguishable in terms of the speed of the steady state efficiency *and* convergence. In contrast, banks in Jordan belong to different classifications, with conventional (Islamic) banks exhibiting low (high) steady state and high (low) convergence rate. This finding is driven by two reasons. First, in Malaysia, it is common practice for Islamic and conventional banks be part of a bank holding company, thereby sharing knowhow, experience and clientele. In contrast, Islamic banks in the Middle-East cannot be part of a bank holding company owing to regulations that prohibits Islamic banks from sharing any ties with conventional financial institutions, hence expertise and other resources cannot be shared (Song and Oosthuizen, 2014). Furthermore, Islamic banks in Malaysia adopt financial instruments, whose *Shariah* conformity has been challenged in the Middle-East and as a consequence these are not valid for use therein.[13] This allows Malaysian banks to enhance their marketability and outreach of their Islamic Finance banks and related outlets. In contrast, the Middle East (and particularly the GCC) comprises a dominant, concentrated, mainly domestic banking sector and traditional loan-taking/deposit-making activities constitute the bulk of operations there. As such, the banking portfolio of these countries features large exposures in real estate, infrastructure and household financing, while securities investments are limited (Al-Hassan et al., 2010).

Pakistani Islamic banks belong to a low steady state/low convergence club, while the high steady state/high convergence club is populated by the conventional banks. This apparent underperformance of Islamic banking in Pakistan may be linked to the relatively small asset size of Islamic banks and the history of the institution, where Pakistan is one of the (very) few countries that had opted in the past for a pure Islamic banking model, and which was subsequently abandoned due to implementation problems.[14] Hence, it may be plausibly expected that besides the high marketing and set-up costs that emerging Islamic banks would face, a "stigma" from the past may still persist.

[12] These kernel densities by country are available upon request.

[13] Certain financial instruments used in Malaysia, quite notably Bai Bithaman Ajil (BBA) that is utilised as a buy-sale property instrument, are not considered Shariah-compliant in the Middle East. Additionally, the Securities Commission of Malaysia (SCM) has higher tolerances on the non-Shariah sources of income for Shariah-compliant firms (Usmani, 2004).

[14] During the 80s and 90s Pakistan was operating on a non-interest, Islamic banking model, which faced several implementation issues and was subsequently used in parallel to the conventional banking since 1999. The other two countries being Sudan and Iran; Iran still operates a pure Islamic banking model, albeit it has recently allowed for conventional foreign bank branches to open in special economic free zones.

Table 5
Classification trees goodness of fit statistics.

Dependent Variable	Steady State			Convergence Rate		
Accuracy (%)	65.10	62.40	51.60	64.90	61.90	52.80
AUROC	0.703	0.681	0.514	0.711	0.654	0.533
EMC	0.840	1.375	0.986	1.050	1.249	1.875
Pseudo-R^2	0.406	0.362	0.028	0.422	0.308	0.066
Explanatory Variables						
Country	Yes	Yes	No	Yes	Yes	No
Islamic Bank	Yes	No	Yes	Yes	No	Yes

Notes: AUROC and EMC denote the Area Under the Receiver Operating Characteristic curve and Expected Misclassification Cost respectively.

Table 6
Beta convergence rate and steady state classifications.

	Panel A: Steady State			Panel B: Convergence Rate		
	Conventional	*Conventional ∩ Islamic*	Islamic	Conventional	*Conventional ∩ Islamic*	Islamic
High	Indonesia Oman Pakistan Philippines Tunisia Turkey	Egypt Lebanon Qatar Sudan	UAE Bangladesh Iran Jordan Kuwait	UAE Brunei Egypt Oman Pakistan Philippines Singapore Turkey	Lebanon Sudan Yemen	UAE Bahrain Bangladesh Brunei Egypt Iran Jordan Kuwait Qatar
Low	Bahrain Bangladesh Brunei Iran* Jordan Kuwait UAE	Malaysia Mauritania Saudi Arabia Singapore Syria Yemen	Bahrain Brunei Indonesia Oman Pakistan Philippines Tunisia Turkey	Bahrain Bangladesh Indonesia Iran* Jordan Kuwait Qatar Syria Tunisia	Malaysia Mauritania Saudi Arabia	Indonesia Oman Pakistan Philippines Singapore Syria Tunisia Turkey

Notes: Notes: Classification based on the steady state as estimated from the random coefficients model. A transformation is applied to convert the continuous beta steady states into a binary variable denoting as 1 the High steady state banking systems (average value = −0.0597; average efficiency = 0.942) and as 0 the Low steady state ones (average value = −0.1506; average efficiency = 0.860). The threshold for this separation is the median value here (−0.090; average efficiency = 0.914). Classification is based on 2 variables, Bank Type and Country Identifier. Classification based on the beta convergence rate as estimated from the random coefficients model. A transformation is applied to convert the continuous beta convergence rates into a binary variable denoting as 1 the Low convergence banking systems (average beta = −0.338) and as 0 the High convergence ones (average beta = −0.770). The threshold for this separation is the median value here (−0.530). Classification is based on 2 variables, Bank Type and Country Identifier. * Iran is typically considered an Islamic-banking country; however conventional banks are allowed to operate within specific free economic zones (Presstv, 2010; Rooz, 2010).

The above results highlight the usefulness of the classification trees in bringing out the differences in a composite financial system, where the efficiency dynamics of multiple banking systems are not always clear-cut.[15] The fact that there is no common equilibrium average efficiency level for Islamic and conventional banks across countries may give evidence of a dual-banking model (Zhang and Matthews, 2012). Conversely the existence of a common equilibrium average efficiency level for the two bank types may give evidence of a single banking model. In the latter case, the country would appear in the intersection of the graph. Drivers of this distinction, albeit latent, may be linked to country-specific characteristics, interpretations of the Islamic banking model and the degree of substitution between the two banking systems on behalf of its clientele.

5.4. Bank type alignment, characteristics and economic indicators

The finding that the two banking systems are more aligned in certain countries is worthy of further investigation for several reasons. From a policy perspective, these banking systems are arguably less challenging as the two bank types may be viewed as sufficiently similar not to warrant different policy actions; one-size-fits-all type of policies should be most effective here. Policies, regulatory and supervisory practices of these systems may act as paradigms to other, particularly newer

[15] Traditional techniques such as regression analysis would require many degrees of freedom. Statistical significance tests are also not useful here given that they are either bivariate or require an *a priori* assumption on the banking system groupings.

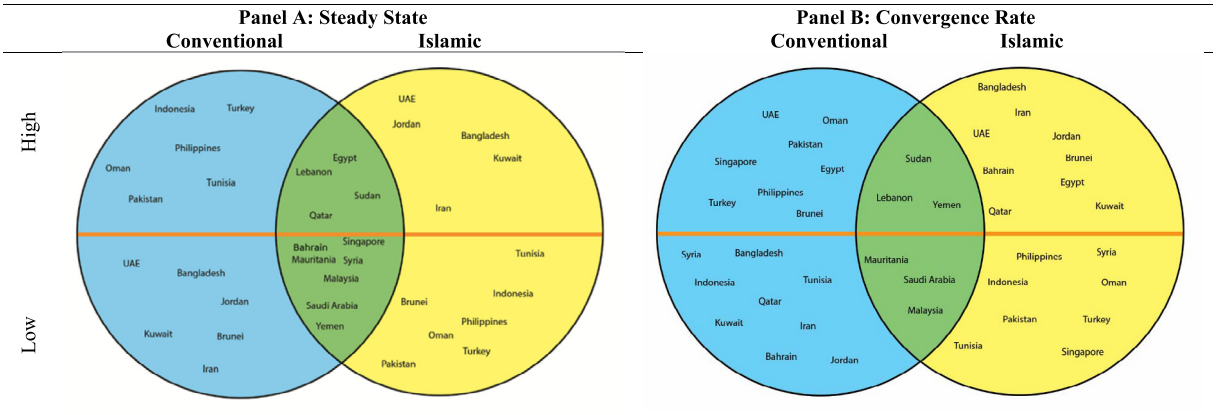

Fig. 5. Steady State and Convergence Rate Classifications. Notes: Classification based on the steady states as estimated from the random coefficients model. A transformation is applied to convert the continuous beta steady states into a binary variable denoting as 1 the High steady state banking systems (average value = −0.0597; average efficiency = 0.942) and as 0 the Low steady state ones (average value = −0.1506; average efficiency = 0.860). The threshold for this separation is the median value here (−0.090; average efficiency = 0.914). Classification is based on 2 variables, Bank Type and Country Identifier. Classification based on the beta convergence rate as estimated from the random coefficients model. A transformation is applied to convert the continuous beta convergence rates into a binary variable denoting as 1 the Low convergence banking systems (average beta = −0.338) and as 0 the High convergence ones (average beta = −0.770). The threshold for this separation is the median value here (-0.530). Classification is based on 2 variables, Bank Type and Country Identifier.

country-adopters of Islamic finance (Mejia et al., 2014; Song and Oosthuizen, 2014); see Gelbard et al. (2014) for Islamic finance in Sub-Saharan Africa challenges. By contrast, such policies in the countries outside of the intersection might contribute to the performance gap between the two bank types. From an investor perspective, it is useful to know how the two banking systems compare in countries that fall within/outside the intersection.

We seek to identify the salient features that characterise the banking systems that lie within the intersection of Table 6 from the rest. Table 7 compares background information on the financial structure, macroeconomic environment, market structure and bank specific information[16] for those banking systems that lie inside the intersections of both graphs of Table 6 (steady state and convergence), and those that lie outside. We refer to the former as *Fully Aligned (FA)* and the latter as *Not-Fully Aligned (NFA)*.

An inspection of Table 7 suggests that there are significant differences between the two groups of banking systems, and these are primarily manifested within the financial structure, macroeconomic and market structure environment. The financial structure variables are suggestive of more pronounced differences with respect to financial depth than financial access. A comparison of the FA banking systems to the NFA ones finds the former to mobilise significantly more domestic credit to private sector, have a more developed insurance industry, while foreign banks are more active in loan generating/deposit taking business. The macroeconomic and market structure environment shows lower inflation rates, higher contribution from trade to GDP and a more concentrated banking system. Higher transparency, less bureaucracy and a more competent legal environment is evidenced in the FA group. The banks in the two groups are comparable in terms of profitability, but the ones in the FA group have higher financial stability (*z-score*), more diversified operations (*Income diversity*), and higher liquidity (*Net Loans/Total Assets*).[17]

To better estimate the drivers of the alignment between alternative banking systems, we invoke the following robust logit model specification.

$$Z_i = \mu_0 + \theta \mathrm{X} + \zeta \mathrm{M} + \varepsilon_i \tag{9}$$

where Z is a binary variable that takes the value 1 for all banks in the FA group; zero otherwise. The explanatory variables include bank-specific information (denoted as *X*) and macroeconomic, supervision and regulation quality, market structure and financial development indicators (denoted as *M*). According to the IFSB (2019) countries that satisfy the criterion of having a more than 15% share of Islamic banking assets are categorised as systemically important. Using this criterion, we construct a SIIB (Systemically Important Islamic banking) variable to denote the countries where Islamic banking is systemically important. We extract information related to i) Capital requirements (CAPR); ii) Market disciplinary power (MDP); iii) Supervisor disciplinary power (SDP) and iv) Activity restrictions (ACTR) from the Bank Regulation and Supervision Survey (BRSS, 2019). We aggregate these four components into a BRSS variable where higher values denote stronger bank supervision and

[16] Similar variables are used in Bertay et al. (2013).

[17] Our analysis covers the key banking risks including insolvency, liquidity and credit risk. Whilst acknowledging the limitation of not covering operational risk, we note that due to its particular nature related research is in a nascent stage and no universally accepted metrics exist, while the simpler approaches based on gross income rely on oversimplistic assumptions (BIS, 2020, 2014).

Table 7
Characteristics of banking systems.

	Not-Fully Aligned	Fully Aligned	t-statistic
Financial Structure: Access			
Account at a formal financial institution (% age 15+)	43.912	44.176	0.098
Account used for business purposes (% age 15+)	7.178	6.621	0.873
Account used to receive government payments (% age 15+)	14.325	5.129	6.472***
Account used to receive remittances (% age 15+)	7.637	5.964	2.800***
Account used to receive wages (% age 15+)	15.241	16.058	0.571
Saved any money in the past year (% age 15+)	42.712	44.595	1.135
Saved at a financial institution in the past year (% age 15+)	17.116	18.967	1.530
Loan in the past year (% age 15+)	45.411	39.644	4.061***
Loan from a financial institution in the past year (% age 15+)	12.407	10.373	3.315***
Loan from a private lender in the past year (% age 15+)	5.177	5.178	0.002
Loan from an employer in the past year (% age 15+)	4.782	5.990	2.842***
Loan through store credit in the past year (% age 15+)	13.645	15.370	1.694*
Loan from family or friends in the past year (% age 15+)	31.180	28.705	2.157**
Financial Structure: Depth			
Domestic credit provided by financial sector (% of GDP)	57.157	98.085	9.933***
Domestic credit to private sector by banks (% of GDP)	40.807	64.958	8.045***
Syndicated loan average maturity (years)	6.998	7.388	1.876*
Credit to government and state-owned enterprises/GDP (%)	17.175	25.666	4.817***
Liquid liabilities/GDP (%)	57.192	109.386	10.929***
Bank deposits/GDP (%)	50.706	99.753	10.346***
Life Insurance Premium Volume/GDP (%)	0.614	1.150	4.759***
Non-Life Insurance Premium Volume/GDP (%)	0.718	0.913	4.532***
Loans from non-Resident Banks/GDP (%)	9.632	28.178	10.148***
Offshore Bank Deposits/Domestic Bank Deposits (%)	15.240	21.767	3.913***
Macroeconomic			
Trade (% of GDP)	86.307	105.008	2.740***
Inflation (%)	8.993	6.614	4.508***
Oil rents (% of GDP)	8.546	9.602	0.819
GDP growth (%)	4.907	4.630	2.161**
Market structure & Bank regulation and supervision quality			
Business extent of disclosure index	6.603	7.095	1.539
Strength of legal rights index	2.543	3.650	5.394***
Hirschman-Herfindahl index	0.191	0.308	8.678***
Hirschman-Herfindahl (Conventional sector)	0.213	0.387	10.586***
Hirschman-Herfindahl (Islamic sector)	0.398	0.436	1.829*
Capital requirements (CAPR)	6.128	7.295	9.810***
Market disciplinary power (MDP)	5.603	5.607	0.049
Supervisor disciplinary power (SDP	12.198	12.169	0.202
Activity restrictions (ACTR)	9.757	10.422	3.194***
BRSS	33.687	35.493	5.316***
Bank-specific			
Total Assets (ln)	9.092	9.131	0.154
Equity/Total Assets	14.771	14.322	0.344
Net Interest Revenue/Total Assets	3.694	2.734	3.197***
Other Operating Income/Total Assets	2.027	2.167	0.637
Net Interest Margin	4.550	3.869	0.733
ROA	1.341	1.261	0.306
ROE	10.101	11.161	0.681
Cost/Income	60.278	60.156	0.038
Net Loans/Total Assets (Liquidity risk)	51.499	39.805	6.152***
Liquid Assets/Customer Deposits and Short-Term Funding	41.597	47.396	1.460
z – score (Insolvency risk)	24.214	41.839	4.487***
Non-Performing Loans/Total Loans (Credit risk)	9.228	8.622	0.420
Loan Loss Reserves/Total Loans (Credit risk)	7.629	7.248	0.354
Income diversity	0.357	0.553	2.583***

Notes: Fully Aligned (FA) refers to the banking systems that lie inside the intersections of both graphs of Fig. 5 (steady state and convergence), while Not-Fully Aligned (NFA) refers to those that lie outside. ***, **, * denote statistical significance at the 1, 5 and 10% level respectively. Sources: Global Financial Development Database, Bank Regulation and Supervision Survey, Bankscope and authors' calculations.

regulatory quality.[18] Several models are estimated that allow for an increasing number of control variables and allow for fewer similarities between the two bank types. In particular, Model I allows for financial structure, macroeconomic and market structure variables, while Model II caters for bank-specific characteristics. Models III and IV capture the distinction between Islamic and conventional banks by allowing for interaction terms. Models V-VI consider the systemic importance of Islamic banking and

[18] More information on the creation of this variable is provided in Appendix 3.

Table 8
Panel logit estimation results.

Models	I	II	III	IV	V	VI	VII	VIII
Business extent of disclosure index	0.193***	0.247***	0.412***	0.570***	0.102*	0.168**	0.103**	0.163**
	(0.052)	(0.067)	(0.119)	(0.133)	(0.055)	(0.080)	(0.041)	(0.069)
Domestic credit to private sector (% of GDP)	0.051***	0.062***	0.122***	0.143***	0.084***	0.102***	0.132***	0.150***
	(0.006)	(0.009)	(0.039)	(0.031)	(0.009)	(0.014)	(0.013)	(0.018)
Inflation, GDP deflator (annual %)	−0.128***	−0.103**	−0.141***	−0.135*	−0.335***	−0.365***	−0.106**	−0.069
	(0.032)	(0.042)	(0.055)	(0.071)	(0.041)	(0.065)	(0.043)	(0.061)
Strength of legal rights index	0.229	−0.002	−0.758**	−1.068***	0.428	0.366	−0.148	−0.464
	(0.270)	(0.256)	(0.385)	(0.314)	(0.280)	(0.242)	(0.251)	(0.288)
Bank credit to bank deposits (%)	0.029***	0.055***	0.0590**	0.099***	0.023**	0.051***	0.066***	0.095***
	(0.008)	(0.008)	(0.020)	(0.018)	(0.009)	(0.009)	(0.009)	(0.012)
Loan through store credit in the past year	0.282***	0.290***	0.528***	0.622***	0.456***	0.511***	0.561***	0.602***
	(0.043)	(0.034)	(0.171)	(0.124)	(0.049)	(0.060)	(0.067)	(0.065)
Income Diversity	1.102**	2.227***	0.859	2.561*	1.290**	1.780***	0.695*	2.186
	(0.450)	(0.635)	(0.725)	(1.335)	(0.543)	(0.574)	(0.391)	(0.648)
Total Assets (ln)		−0.547***		−0.838***		−0.587***		−0.688***
		(0.177)		(0.196)		(0.189)		(0.190)
Equity/Total Assets		−0.071***		−0.143***		−0.074***		−0.076***
		(0.024)		(0.039)		(0.020)		(0.023)
Net Interest Margin		−0.006		0.052		0.040***		0.007
		(0.012)		(0.067)		(0.012)		(0.013)
Return on Equity		0.026***		0.028		0.033***		0.023
		(0.010)		(0.023)		(0.011)		(0.017)
Cost/Income		−0.007		−0.006		−0.002		−0.006
		(0.007)		0.010)		(0.008)		(0.009)
Net Loans/Total Assets (Liquidity risk)		−0.048***		−0.058***		−0.059***		−0.033**
		(0.015)		(0.022)		(0.017)		(0.016)
z – score (Insolvency risk)		0.013***		0.026***		0.015***		0.019***
		(0.004)		(0.008)		(0.004)		(0.005)
Hirschman-Herfindahl Index (CB)	5.977***	6.059***	9.143***	9.150***	1.460*	0.246	5.025***	3.840***
	(0.628)	(0.876)	(2.378)	(1.255)	(0.834)	(1.430)	(0.655)	(0.960)
Hirschman-Herfindahl Index (IB)	11.91***	10.07***	15.48***	14.40***	17.452***	18.366***	16.883***	14.071***
	(3.188)	(2.496)	(4.468)	(2.682)	(3.360)	(3.040)	(3.299)	(2.424)
SIIB					3.918***	5.408***		
					(0.556)	(0.957)		
BRSS (ln)							6.155**	5.398*
							(3.087)	(3.013)
Business extent of disclosure index × IB			−1.129***	−1.254***				
			(0.293)	(0.304)				
Domestic credit to private sector (% of GDP) × IB			0.0159	−0.0356				
			(0.019)	(0.030)				
Inflation, GDP deflator (annual %) × IB			−1.393***	−1.212***				
			(0.513)	(0.398)				
Strength of legal rights index × IB			0.588*	1.408***				
			(0.342)	(0.376)				
Bank credit to bank deposits (%) × IB			0.0714***	0.048*				
			(0.021)	(0.028)				
Loan through store credit in the past year × IB			0.558***	0.292				
			(0.197)	(0.192)				
Income Diversity × IB			1.812	1.988				
			(1.208)	(1.764)				
Total Assets (ln) × IB				0.783***				
				(0.297)				
Equity/Total Assets				0.074				
				(0.077)				
Net Interest Margin × IB				−0.039				
				(0.068)				
Return on Equity × IB				0.046				
				(0.052)				
Cost/Income × IB				0.024				
				(0.016)				
Net Loans/Total Assets × IB				−0.037				
				(0.035)				
z-score × IB				−0.008				
				(0.015)				
Constant	−18.45***	−13.88***	−30.06***	−26.51***	−25.06***	−23.14***	−52.20***	−45.07***

(*continued on next page*)

Table 8 (*continued*)

Models	I	II	III	IV	V	VI	VII	VIII
	(3.314)	(2.677)	(8.403)	(5.338)	(3.339)	(3.420)	(14.341)	(12.631)
F-statistic	421.22	184.51	63.34	158.99	284.51	168.72	347.32	185.45
Pseudo R^2	0.463	0.558	0.560	0.680	0.493	0.602	0.523	0.613
Observations	435	435	435	435	435	435	421	421

Notes: The table reports estimated coefficients and robust standard errors in brackets for the panel robust logit estimation of Section 5.4 (Eq. (3)). ***, **, * denote statistical significance at the 1, 5, 10% level respectively.

Models VII-VIII further control for bank supervision and regulatory quality. We use a stepwise algorithm that maximises the goodness of fit. Table 8 presents these results.

The results show that country level variables (macroeconomic, market structure and financial development) have the largest explanatory power. This is supported by the fact that around 83% of the explanatory power of Model II emanates from country level variables with the remaining proportion attributed to bank-specific factors. The banking systems in the FA group have a significantly higher *business disclosure index*, suggesting that business practices are more transparent therein. Additionally, the financial depth in the FA group is also higher as indicated by the positive and significant *domestic credit to private sector* and *bank credit to bank deposits* variables; thus warranting enhanced opportunities for company financing through higher financial development. On average, lower *inflation* rates characterize the FA group, corroborating further on the importance of a stable economic environment. Concentrated banking systems are more evident in the FA group, as shown by the positive and statistically significant *Hirschman-Herfindahl* index. Bank-level characteristics are also important. In specific, the average bank in the FA group has a well-diversified source of income (*Income Diversity*), is typically smaller (*Total Assets*), more leveraged (*Equity/Assets*), more liquid (*Net Loans/Total Assets*), more profitable (*Return on Equity*) and are more financially stable (*z-score*) than the average bank of the NFA group.

Compared to Models I and II, Models III and IV show that the response of the two banking systems may react differently to similar changes in the underlying metrics. For example, a stable economic environment, proxied by lower inflation rates, tends to align the practices in Islamic and conventional banking systems; which leads to a more homogenous financial system. A similar conclusion is reached for the financial depth. By contrast, alignment in the two banking systems is affected inversely with respect to the *Business Disclosure Index* and the *Legal Rights Index*, potentially highlighting the different requirements of either bank type. Therefore, a country's improvement with reference to these metrics needs to ensure a close alignment between these characteristics. Differentiated responses between the two bank types also exist with respect to bank-specific characteristics, for example, with respect to the average bank size. Large imbalances between banks constitute a challenge for a closely aligned financial system. For instance, large Islamic banks behave similarly to conventional banks (Abedifar et al., 2013), while the smaller banks tend to perform better and bear less risk (Beck et al., 2013b; Čihák and Hesse, 2010).

A higher relative importance of Islamic banking in a country, as reflected by the positive coefficient on the SIIB variable leads to a higher alignment between the banking systems, as is plausibly expected. Likewise, a strong regulatory and supervision framework is likely to bring the banking systems closer together, as evidenced by the positive coefficient on the BRSS variable.

6. Conclusion

Measuring and comparing banking efficiency has received much attention, but few studies focus upon the dynamics of efficiency (steady state and convergence) and none compare conventional and Islamic banks. In this paper, we compare and contrast estimates of steady state efficiencies and efficiency convergence rates of Islamic and conventional banks. With an extended dataset spanning a decade and a half (1999 to 2014) and covering 23 countries, we obtain estimates of bank efficiency scores using stochastic frontier analysis. Our timespan covers well the 2008 Global Financial Crisis and its aftermath, and the analysis permits important and timely lessons to be learned in light of the Covid-19 pandemic and its impact upon the world economy.

To measure steady state efficiency and efficiency convergence, we import the concept of β-convergence from the growth literature. This is a familiar concept in the context of banking in economic unions. We obtain estimates of the convergence rate using OLS, random effects, system-GMM and random parameter model techniques, the last of which is a novel feature of this paper. Using the β-convergence model, our estimates using OLS, random effects and system-GMM finds no significant differences exist between the two bank types in terms of steady state efficiency and convergence efficiency. This result is confirmed when the random parameter estimation method is used.

To identify clubs of countries and banking sectors with similar characteristics, we adopt a classification trees framework: a multi-dimensional separation procedure, which circumvents the vanishing degrees of freedom faced by parametric techniques. Classification trees show that the distinctiveness of Islamic and conventional banking (in terms of efficiency steady state and convergence) varies across countries. For example, in Malaysia we observe similar practice for the two bank types; but in Jordan the distinction is marked.

To examine the drivers behind the alignment of the two banking systems, we use a panel logit estimation and a wide array of bank-specific, macroeconomic, market structure, regulation and supervision, and financial development indicators. We find that the more financially aligned systems are characterised by financial depth, transparency in business, stability in the economic environment and concentrated banking systems. Individual banks operating within aligned banking systems have more diversified sources of income, higher liquidity, profitability and financial stability.

Our research clearly identifies countries where the banking sectors are distinct (in terms of steady state efficiency and the speed with which banks converge to it) and those where they are similar. Thus, our findings inform the debate over the claim that Islamic banks generally mimic conventional banks. Given that similarities exist only in certain countries suggest that behaviour may not be attributable to mimicking but to other factors such as regulatory/corporate, economic as well as bank-specific characteristics. Regulators and judicial authorities might be tasked to devise mechanisms and platforms that account for the identities of the two banking models. Future work should attempt to underpin our findings by looking into other factors such as demographic, educational, cultural, business, governance and financial screening practices.

The approach considered in this paper feeds into the literature on the dynamics of distinctive banking models that co-exist within a single banking sector; yet with marked differences in terms of size, products and objectives. It may also be interesting if future research explores how our findings here tally against other alternative banking models, such as community banks.

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Appendix A. Classification trees

While no asymptotic theory exists, the virtue of the algorithm underpinning the classification trees methodology lies in its ability to reveal multidimensional data splits (Durlauf and Johnson, 1995). Classification trees may be viewed as a type of variable selection procedure. The main difference is that in a stepwise regression the sample remains unchanged and the control variables are selected; in a classification tree the control variables are selected and the sample is allowed to vary. The classification trees procedure may be viewed as a union of piecewise linear functions, where observations are grouped according to the control variables. The splits are chosen with respect to minimising misclassification costs (Breiman et al., 1984). The essence of the algorithm is described here; for a full exposition of the classification tree algorithm we direct you to Breiman et al. (1984) and Durlauf and Johnson (1995).

Assume Y to be the variable of interest and $X_1, \cdots, X_j$ the control variables. The aim is to find a model for predicting Y from $X_1, \cdots, X_j$ through binary recursive splits. Starting from a club equivalent to the entire population of banking systems, say $= \{i_1, i_2, \cdots, i_n\}$ (this can be referred to as step 0) the algorithm searches for the best binary splits in the dataset.

Step 1. For the data under investigation select a binary split, which is of the form $x_j < s$ versus$x_j \geq s$. The choice of the binary split consists of two components, the selected control variable (j) and the realisation of the control variable(s). The binary split creates two nodes that are subsequently tested for *impurity*. *Impurity* of a node is measured by the Gini's Diversity Index (GDI).[19] The GDI of a node is given as $1 - \sum_i p^2(i)$ where the sum is over the clubs i at the node and $p(i)$ is the observed fraction of clubs with club i that populate the node. A pure node has only one club and a GDI equal to zero; otherwise positive values of GDI measure the degree of impurity in the node where more than one clubs are present.

Therefore, at each splitting level the following expression is minimised:

$$\Delta(h) = \min_{js} \left\{ \min_{c_2} \left(1 - \sum_i \left(\frac{c_1}{c_1 + c_2} | x_i \in R_{1,js} \right) \right) + \min_{c_1} \left(1 - \sum_i \left(\frac{c_2}{c_1 + c_2} | x_i \in R_{2,js} \right) \right) \right\}$$

where the parameter h denotes the splitting level with $h = 1$ denoting the first level that two nodes exist. The variables of interest to the algorithm (j, s) split the realisations of the Y variable (c_1, c_2) into two nodes R_1, R_2.[20] The lower the value of the quantity $1 - \frac{c_1}{c_1 + c_2}$ the higher the purity level of the first node.

Step 2. If one of the resulting nodes has zero impurity score then this is classified as a *pure node* and the branch is terminated here. Conversely, if one of the resulting nodes has a positive impurity score, then a further split may be possible.

Step 3. For the impure nodes, continue from step 1.

The algorithm finishes when the resulting nodes are either pure or cannot be broken down any further due to observation requirements.

[19] For a full exposition of impurity metrics used in this context we direct you to Berzal et al. (2003).

[20] For ease of exposition we assume that the predictor variables are categorical variables.

Accuracy is defined as the percentage of banking systems that are correctly predicted by the model as being of high/low convergence rate; see also Delen et al. (2013).

The area under the receiver operating characteristic (AUROC) curve is used to gauge the performance of a binary classifier system, such as classification trees. An AUROC curve that is convex to the diagonal indicates that the proposed model is better in distinguishing positive and negative ranks (or in our case high vs low convergence banking systems) than randomness would imply. Irimia-Dieguez et al. (2015) offer an application of the AUROC curve in classification trees, with Swets (2014) offering a more detailed analysis.

Expected misclassification cost (EMC) is given as:

$$EMC = C_{12}\pi_2 FPR + C_{21}\pi_1 FNR$$

where C_{12} and C_{21} are the relative costs of misclassification with C_{12} representing the case where a low convergence banking system is classified as a high one and C_{21} represents the case where a high convergence banking system is not classified as a high one; π_2, π_1 are prior probabilities of high and low convergence banking systems; FPR and FNR denote the False-Positive-Rate and False-Negative-Rate respectively. In terms of values, C_{12} and C_{21} are assumed equal to 1 and 5 respectively, in line with Irimia-Dieguez et al. (2015) and West (2000); π_2, π_1 are equal to 0.5 by definition of the median-split we imposed, while FPR and FNR are estimated from the data.

Appendix B. Estimated -convergence models

See Table A1.

Appendix C. The BRSS variable

The Bank Regulation and Supervision Survey (BRSS) survey contains information on how banks are regulated and supervised around the world.[21] Although the BRSS dates to the early 2000s it is not available on an annual basis, and five versions currently exist. Version I was released in 2001 (Barth et al., 2001). The second version of the database was issued in 2003, the third in 2007, and the fourth in 2012, the fifth in 2019. The most recent version covers regulations and supervisory practices pertaining to bank (1) entry/licensing, (2) ownership, (3) capital, (4) activities, (5) external auditing, (6) internal management or governance, (7) liquidity and diversification, (8) depositor protection, (9) provisioning, (10) disclosure and information, (11) dealing with problem institutions and exit from the industry, (12) supervisory powers, (13) banking sector characteristics, (14) consumer protection, and (15) Islamic banking for more than 180 countries. Nevertheless, not all countries have participated in all five versions, while the survey becomes increasingly comprehensive through the addition of extra fields.

In our case we use four categories of bank regulation and supervision that are consistently present in all versions of the BRSS, namely i) Capital requirements (CAPR); ii) Market disciplinary power (MDP); iii) Supervisor disciplinary power (SDP) and iv) Activity restrictions (ACTR).

CAPR captures initial and overall capital stringency by reflecting the type and quality of funds that may be used as regulatory capital, and if relevant authorities need to verify their sources. The CAPR variable is computed using the following 8 questions and assigning the value of 1 to positive (negative) answers in questions 1–6 (7–8); zero otherwise. (1) Is the minimum required capital asset ratio risk-weighted in line with Basle guidelines? (2) Does the ratio vary with market risk? (3–5) Before minimum capital adequacy is determined, which of the following are deducted from the book value of capital: (a) market value of loan losses not realized in accounting books? (b) unrealized losses in securities portfolios? (c) unrealized foreign exchange losses? (6) Are the sources of funds to be used as capital verified by the regulatory/supervisory authorities? (7) Can the initial or subsequent injections of capital be done with assets other than cash or government securities? (8) Can initial disbursement of capital be done with borrowed funds? Higher values of CAPR indicate more stringent capital requirements.

MDP captures market disciplinary power by reflecting the quality of disclosure requirements that banks need to fulfil. For example, whether banks need to disclose off-balance sheet items and their risk management procedures to the public and the existence of a deposit insurance protection system. The MDP variable is computed using the following 8 questions and assigning the value of 1 to positive (negative) answers in questions 1–6 (7–8); zero otherwise. (1) Is subordinated debt allowable (or required) as part of capital? (2) Are financial institutions required to produce consolidated accounts covering all bank and any non-bank financial subsidiaries? (3) Are off-balance sheet items disclosed to public? (4) Must banks disclose their risk management procedures to public? (5) Are directors legally liable for erroneous/misleading information? (6) Do regulations require credit ratings for commercial banks? (7) Does accrued, though unpaid interest/principal enter the income statement while loan is non-performing? (8) Is there an explicit deposit insurance protection system?

SDP captures the power of the supervisor to take specific action against a bank, including its management, directors and auditors, such as the bailout and the dissolution of a bank, the change of the organisational structure and the suspension of bonus/dividend pay-outs. The SDP variable is computed using the following 14 questions and assigning the value of 1 to positive answers; zero otherwise. (1) Does the supervisory agency have the right to meet with external auditors to discuss their report without the approval of the bank? (2) Are auditors required by law to communicate directly to the supervisory agency

[21] The dataset is available here: https://www.worldbank.org/en/research/brief/BRSS.

Table A1
σ-convergence model estimated using various estimation methods.

Method	Pooled OLS robust			Random Effects robust			System-GMM two-step robust		
Model	(I) Absolute σ-convergence	(II) Conditional σ-convergence	(III) Conditional σ-convergence	(IV) Absolute σ-convergence	(V) Conditional σ-convergence	(VI) Conditional σ-convergence	(VII) Absolute σ-convergence	(VIII) Conditional σ-convergence	(IX) Conditional σ-convergence
σ coefficient	-0.281^{***}	-0.279^{***}	-0.325^{***}	-0.281^{***}	-0.279^{***}	-0.325^{***}	-0.412^{***}	-0.449^{***}	-0.967^{***}
	(0.027)	(0.038)	(0.068)	(0.035)	(0.049)	(0.093)	(0.053)	(0.075)	(0.506)
TYPE		-0.011^{***}	-0.012^{***}		-0.011^{***}	-0.012^{***}		-0.017^{***}	-0.012
		(0.002)	(0.002)		(0.002)	(0.002)		(0.003)	(0.008)
TYPE $\times \ln(u_{i,t-1})$		-0.019	-0.015		-0.019	-0.015		0.037	0.279
		(0.055)	(0.060)		(0.073)	(0.076)		(0.081)	(0.261)
Constant	0.001^{***}	0.003^{***}	0.007	0.001^{***}	0.003	0.007^{***}	0.003^{***}	0.005^{***}	0.014^{*}
	(0.001)	(0.001)	(0.007)	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.010)
Country shift dummies	No	No	Yes	No	No	Yes	No	No	Yes
Year shift dummies	No	No	Yes	No	No	Yes	No	No	Yes
Country slope dummies	No	No	Yes	No	No	Yes	No	No	Yes
Year slope dummies	No	No	No	No	No	No	No	No	No
m_1 p-value							0.000	0.000	0.000
m_2 p-value							0.553	0.528	0.421
Sargan/Hansen p-value							0.044	0.632	0.743
R^2	0.203	0.203	0.252	0.203	0.203	0.252			

Notes: The table reports estimated coefficients and standard errors in parentheses. OLS = ordinary least squares. TYPE takes the value 1 for Islamic banks and zero otherwise. N = 4179 bank year observations for all models, and T = 15 years. Tests for first- and second order autocorrelation in the system-GMM model are denoted by m1 and m2, respectively. Sargan/Hansen is a test of the over-identifying restrictions relevant to the system-GMM model. ***, **, * denote statistical significance at the 1, 5, 10% level respectively.

any presumed involvement of bank directors or senior managers in illicit activities, fraud, or insider abuse? (3) Can supervisors take legal action against external auditors for negligence? (4) Can the supervisory authorities force a bank to change its internal organizational structure? (5) Are off-balance sheet items disclosed to supervisors? (6) Can the supervisory agency order the bank's directors or management to constitute provisions to cover actual or potential losses? (7) Can the supervisory agency suspend director's decision to distribute dividends? (8) Can the supervisory agency suspend director's decision to distribute bonuses? (9) Can the supervisory agency suspend director's decision to distribute management fees? (10) Can the supervisory agency supersede bank shareholder rights and declare bank insolvent? (11) Does banking law allow supervisory agency or any other government agency (other than court) to suspend some or all ownership rights of a problem bank? (12) Regarding bank restructuring and reorganization, can the supervisory agency or any other government agency (other than court) supersede shareholder rights? (13) Regarding bank restructuring and reorganization, can supervisory agency or any other government agency (other than court) remove and replace management? (14) Regarding bank restructuring and reorganization, can supervisory agency or any other government agency (other than court) remove and replace directors? Higher values of SDP indicate higher market disciplinary power through increased disclosure practices.

ACTR captures the restrictions on banks' activities that are in place by the regulator. In particular it assesses the level of freedom banks enjoy in their operations involving securities, insurance, real estate activities as well as the ownership of non-financial firms. The ACTR variable is computed by assigning values 1–4 on whether each activity is unrestricted, permitted, restricted or prohibited respectively.

Data limitations require specific treatments of the dataset. Timewise we assume that the rankings remain constant during the years covered by a particular version of the BRSS as follows: version I (1999–2000), version II (2001–2003), version III (2004–2007), version IV (2008–2012) and version V (2013–2014). For the countries that do not participate in all versions of the BRSS, we use interpolation techniques for the years they opted out (e.g., Bangladesh, Indonesia, Qatar, Saudi Arabia, Singapore, Sudan, Syria, Tunisia, Turkey, Yemen). Countries that never participated are excluded (e.g., Brunei, Iran). For studies that have also used this dataset and worked under similar assumptions we direct you to Barth et al. (2013), Louhichi et al. (2020), Pasiouras et al. (2009).

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