Investigating similarities between Islamic and conventional banks in GCC countries: a dynamic time warping approach

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Abstract

This paper aims to study the similarities between Islamic and conventional banks in the Gulf Cooperation Council (GCC) countries by assigning them to different clusters. We perform such clustering by employing the k-means algorithm with dynamic time warping barycenter averaging. More specifically, the series of average efficiency scores are used in this clustering. In this regard, for each Islamic or conventional bank, we calculated its series of efficiency scores using the stochastic frontier production functions of Battese and Coelli (1995).

Our empirical study covered 44 Islamic banks and 46 conventional banks in GCC countries during 2006-2015. The results show that Islamic and conventional banks are included in the same cluster for Qatar, Bahrain, and Oman. In contrast, Islamic and conventional banks do not share the same cluster for the Kingdom of Saudi Arabia, Kuwait, and the United Arab Emirates. This is due to setting the interest or profit rate below the social discount rate (a measure of an optimal profit rate for Islamic Banks). In this case, banks are incentivized to take more risks to compensate for interest/profit losses, which increases efficiency and allocates Islamic and conventional banks to different clusters. Accordingly, there is no absolute discrimination due to the initial status between Islamic and conventional banks. However, the overall banks, either Islamic or conventional, are discriminated through the distance of the banking applied interest/profit rate and the social discount rate.

Key words: efficiency scores, dynamic time warping, k-means clustering, Islamic banking, Logit model

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1. Introduction

The dilemma between sharia principles and the practices imposed by Sharia Supervisory Boards has been discussed by many authors, such as Willison (2009) and Hasan and Dridi (2010). They have demonstrated that Islamic banks' superiority is rooted in the practices and laws imposed by Sharia Supervisory Boards. On the other side, other authors such as Hamza and Guermazi-Bouassida (2012) confirmed that the reasons of this superiority are found, in large part, in the ethical sharia principles. The ethical principles regarding finance in Islam are, in brief, respecting the market discipline of information transparency and social justice. The profits/losses accordingly to Islamic ethics are essentially based on money service cost and not on money cost. The money must have a tangible counterparty. Consequently, remuneration rate funds in Islam are the tangible remuneration and not the time wear of money.

According to Chapra (2008), information asymmetry originates from interest remuneration of depositors' funds. Therefore, the depositors provide funds to banks without knowing the nature of their investment and their profit origin. In addition, information transparency requires banking efficiency.

In this paper, we examine the similarities or dissimilarities in terms of banking efficiency, which may exist between Islamic and conventional banks in the Gulf Cooperation Council (GCC) countries. In previous studies, efficiency was frequently used to compare Islamic and conventional banks. (Abdul-Majid et al., 2008); (Johnes et al., 2009); (Abdul-Majid et al.,2010, 2011a, b). To calculate the efficiency scores of the different banks studied in this paper, we opted for the methodology proposed by Battese and Coelli (1995), which consists of establishing a stochastic frontier representing the banking technology and comprising the factors that may affect the banks' efficiency.

More specifically, given the confusing aspects between the two types of banks, we will study their efficiency similarities using a clustering technique based on the k-means algorithm with dynamic time warping barycenter averaging. This method has not been used in previous studies on both banking structures to the best of our knowledge. The main reason for choosing this method, apart from its use for prediction purposes, is that it can highlight dependencies between the two types of banking structures. At this level, the dynamic time warping (DTW) distance can inform as to which structure leads the other. In particular, the DTW distances are calculated

from the efficiency measures of the different banks covered by this study as discussed above. Hence, we use two models to explain the clustering results :

The first model is a linear model related to Battese and Coelli's stochastic frontier efficiency. It aims to test the effect of fundamental factors set on inefficiency for Islamic and conventional banks. To this end, we use the gap (difference) between the discount interest rate as an optimal profit rate of the real financial market of goods and services and the interest/profit rate applied by both banks. Additionally, we include the risk factor as a control variable and use it along the lines of many authors; see, for example, Alam (2012). This model allows comparisons between both Islamic and conventional banks according to their inefficiency/efficiency in terms of the interest/profit gap and credit risk.

The second model is a logit model similar to Ben Khediri et al. (2015). Such a model can help detect the power discrimination between both banks concerning efficiency, the interest/profit gap, and credit risks.

The contribution of this paper, compared to previous studies focusing o this topic, is twofold. First, we use a new approach based on the k-means algorithm with dynamic time warping barycenter averaging to determine the optimal number of clusters and to study the similarities between both banks in the GCC countries. Second, this clustering is carried out with the different banks' efficiency series. We opt for this approach because efficiency is the main parameter explaining banks' transparency of information according to Sharia principles of investment in tangible assets. On the other hand, according to social justice principles, we introduce two main fundamental factors related to the real economic market from the theory of Ramsey (1928) (risk and interest factors) to test their power discrimination using the two models mentioned above.

Our paper proceeds as follows. Section 2 highlights stylized facts about the existing similarities and dissimilarities between Islamic and conventional banks. We reserve Section 3 for a brief literature review on similarities and dissimilarities between both banks. Section 4 describes the methodology used in this paper. The first part of this section gives the details of Battese and Coelli's (1995) model allowing the calculation of the efficiency scores for the different banks, either Islamic or conventional. In the second part of this section, we describe the clustering algorithm allowing the division of the banks studied into groups according to their efficiency scores. Section 5 discusses the empirical results obtained. Finally, the last section concludes.

2. Islamic and conventional banks: similarities or dissimilarities: stylized facts

Islamic banks are widely regarded as financial institutions prohibiting Ribaa and not lending money. Specifically, in theory, Islamic banks sell and buy goods and services with a profit margin different from the profit rate. This definition may lead to confusing Islamic banks with conventional banks (Tayyebi, 2009). Indeed, conventional banks lend money to buy goods and services through the borrower. Consequently, the refund value may be confused with the selling price applied by Islamic banks.

More specifically, Islamic banks apply two contracts. The first is for buying transactions that indicate the initial price of the goods. The second is reserved for selling transactions mentioning the forward selling price that coincides with the capitalized value (the refund value of debt) in terms of discount rates. Conventional banks use the same parameters as Islamic banks (the buying price and selling price). However, the names refer to the debt and not to the counterparties of debt (the current debt value and the debt capitalized value). In addition, conventional banks establish only one contract. In light of the confusion regarding both types of banks, we can quire about the main differences between Islamic and conventional finance.

To answer such a question, we rely on the theoretical concept of the money capital cost and its relation to goods and monetary transactions as well as on the cost of capital discussed in financial theory. According to Keynes, there are three types of demand for money: transactional, precautionary, and speculative. In Islamic economics, the money supply must have a real demand in the form of fixed assets that exist in reality. Such a real demand coincides with the transactional and precautionary demand for money, as Keynes advocated. Furthermore, the speculation money demand is interdicted in Islam because it can generate virtual money that does not have a real asset as a counterpart. Accordingly, conventional banks' lending for demand transactions will be perfectly approximated by the selling and buying of goods and services by Islamic banks.

The interest/profit rate is the price of services and goods rendered by money but not the price of money to render services and goods. In general, there are three different rates, one specific to money transactions (profit rate), one for precautionary purposes (profit rate), and one for money speculation (interest rate). The interest rate is the equilibrium price between the demand and supply for money. Since Islamic banks prohibit speculation, they fix profit rates based only on demand for the transaction, which is the only demand allowed by Islam. In this way, Islamic banks lend money, provided that borrowers place it in a real transaction and not in speculation. In contrast, conventional banks use an interest rate covering all kinds of money demands.

Referring to the financial theory of capital cost, the lending profit rate of transactional demand is the economic discount rate that provides the capital cost of goods and services through time and is also called the social discount rate. On the other hand, the interest rate of all demands, as applied by conventional banks, is the discount rate and is considered as being the cost of capital.

In practice, for concurrence reasons, Islamic banks employ a profit rate from the real market imposed by a Sharia supervisory board, which is adjusted by the interest rate of conventional banks. Therefore, the combination of the two rates contributes to the confusion between Islamic and conventional banks. Many studies have confirmed that divergence between interest rate and profit rate causes different economic shocks, such as the deterioration of economic growth, the accrual of refunding defaults, and the expansion of the gap between social classes. At this level, this divergence has also been observed in other economic phenomena and findings. For example, in the subprime crisis, USA banks' interest rates have been far from the capital costs of goods and services (profit rate). This situation has resulted in distortion between the real and the financial sphere. Consequently, major banks have supported high expenditure costs in terms of interest/profit rate losses and hence, have lost their efficiency.
Hence, we can distinguish between two concepts: the Sharia principles based on the social-ethical value provided mainly from « Quran and Sunna » and the profit rate setting practices provided by Sharia committees that exist in Islamic banks. Profit rates in Islamic banks should converge with Sharia principles. However, we can observe a deviation between them in reality.

On the other hand, conventional banks establish their interest rate based on both capital markets and tangible goods markets. The obtained rate is the interest rate of the money, not of its counterpart. The interest/profit rate-setting in both banks can be quite divergent from Sharia principles.

The Islamic banks apply, at the outset, a profit rate based on profit sharing. In this respect, the provisional gains of credit are financed from deposits, and then the percentages of distribution of profits are allocated between the depositor and the bank. Next, these percentages will be converted into a profit rate reflecting the cost of capital of credit granted. These last "profit rate-setting practices" in Islamic banks comply with the Sharia principle since it responds to the loss/profit sharing, the tangible goods investment, and the information transparency principles. However, there are some countries who apply the money market rate [MMR] (cost of capital of money supply) because of competition. Consequently, the Islamic profit rate decided by the Sharia committee will be adjusted by the MMR. Therefore, if such a profit rate exceeds the MMR, the Islamic bank must lower it by injecting liquidity through reserves. In contrast, if the

profit rate is lower than the MMR, the Islamic bank must increase it to reach the MMR. These practices converge with those followed by conventional banks.

3. Brief literature review on similarities between Islamic and conventional banks

We distinguish two research streams in the literature. The first stream supports the similarity between Islamic and conventional banks in terms of risk-taking. The second stream claims no similarities between the banks with different risk-taking strategies accordingly to their efficiency.

Saifullah (2021) has demonstrated that Islamic banks are more stable in terms of efficiency. Such stability of efficiency comes from the synergy system between all banks of these countries. The Islamic banks are theoretically less risky than the conventional ones because they have many instruments based on risk-sharing such as Moucheraka and Moudharaba. The topic is examined by Alam (2012), who highlighted a significant difference between Islamic and conventional banks. The author showed that risk-taking contributes to raising Islamic banks' efficiency, although they are less efficient than conventional banks in emerging markets countries. On the other side, the dual system between Islamic and conventional banks can enhance banking efficiency. Louati et al. (2016) assessed the relationship between the cost-efficiency variation in risk and capital in the MENA and Asian countries and the results showed that the variations in both banks are not the same. Yet, some authors rejected any differences between both bank types. Ben Khedhiri et al. (2015) have shown that credit risk may not differentiate between Islamic and conventional banks.

The credit risk has a relationship with default banking. Saeed and Izzeldin (2014) showed that an increase in both banks' efficiency gives them more confidence in risk-taking and increases the distance to default. The capital requirement by Basel committee can be a substitution act for risk-taking to maximize banking efficiency. Dulal Miah and Uddin (2017) test this hypothesis in a dual system between conventional and Islamic banks. They found no difference between both banks as far as long-term stability was concerned; furthermore, the best-capitalized banks had the highest inefficiency scores.

Saeed and al (2020) used a three-equation system estimated by seemingly unrelated regression, integrating efficiency, capitalization, and risk-taking. They showed that higher efficiency is related to higher risk-taking in Islamic banks and lower risk-taking in conventional banks.

Saufullah and Shamsuddine (2020) applied a stochastic meta-frontier directional distance function model. They find that a typical Islamic bank is less technically efficient compared to its conventional counterpart. This is due to Islamic banks using less advanced technology compared to conventional ones.

However, there are other approaches to compare both banks, such as classification techniques. Using such techniques aims to discriminate between Islamic and conventional banks and not to compare them. In this regard, Izeldine et al. (2021) applied a non-parametric framework using a classification tree. They showed that the speed of efficiency convergence of Islamic and conventional banks are similar. The alignment between the two bank types is positively related to the country's financial depth, transparency, economic stability, and banking concentration. Olson and Zoubi (2008) have studied a set of Islamic and conventional banks in GCC countries using a logistic regression model, neural network, and k-means-nearest-neighbor methods. They found that discrimination between both banks is nonlinear with about 92% of discrimination.

The third factor that we want to integrate into our study is the interest/profit rate of both banks. This confusion between the two rates has been discussed by Saeed et al. (2022) on Malaysian banks. They demonstrated that the Islamic profit rate is influenced by the conventional interest rate in a dual banking system. However, Malaysian Islamic Banks are obliged to compare their profit rates to conventional interest rates and supposed them as a benchmark. These authors have supposed that Islamic banks take into consideration the profiling between religious and economic fundamentals to satisfy the customer profit desire.

Our contribution in this last field, as discussed in section.2, is to propose a theoretic Islamic rate measured by a social discount rate of Ramsey (1928) and to compare it with the applied interest/profit rate in both Islamic and conventional banks.

4. Methodology

First, we calculated the efficiency series of Islamic and conventional banks for the period extending from 2006-2015 in the GCC countries, i.e., the Kingdom of Saudi Arabia (KSA), Kuwait, the United Arab Emirates (UAE), Bahrain, Qatar, and Oman. Our study involved 46 conventional banks and 44 Islamic banks in GCC countries. The details on these banks are found in Table 10 in the appendices.

4.1. Measurement of efficiency scores of Islamic and conventional banks

Our estimation of the bank efficiency series is based on the methodology of Battese and Coelli (1995). The cost function is a logarithmic quadratic model written as follows:

$$Ln\left[\frac{CT_{it}}{P_2}\right] = \alpha_0 + \alpha_1\, ln(Y_{1,it}) + \alpha_2\, ln(Y_{2,it}) + \alpha_3\, ln(\frac{P_{1,it}}{P_{2,it}}) + \alpha_4 \frac{1}{2} ln\left(Y_{1,it}\right)^2 +$$
$$\alpha_5\, ln(Y_{1,it})\, ln(Y_{2,it}) + \alpha_6 \frac{1}{2} ln\left(Y_{2,it}\right)^2 + \alpha_7 \frac{1}{2}\, ln\left(\frac{P_{1,it}}{P_{2,it}}\right) + \alpha_8\, ln(Y_{1,it})\, ln\left(\frac{P_{1,it}}{P_{2,it}}\right)^2 +$$
$$\alpha_9\, ln(Y_{2,it})\, ln\left(\frac{P_{1,it}}{P_{2,it}}\right) + \alpha_{10}\, ln(Equity_{it}) + \alpha_{11} \frac{1}{2} ln(Equity_{it})^2 +$$
$$\alpha_{12}\, ln(Equity_{it})\, ln(Y_1) + \alpha_{13}\, ln(Equity_{it})\, ln(Y_2) + \alpha_{14}\, ln(Equity_{it})\, ln\left(\frac{P_1}{P_2}\right) + U_{it} +$$
$$V_{it}, \quad (1)$$

where the banking cost $\mathbf{C_{it}}$ in Eq. (1) is the banking cost of bank i during period t corresponding to bank output vector Y_{it} and input price vector P_{it}. This methodology allows efficiency scores and parameters of factors influencing bank inefficiency to be simultaneously determined by using the one-stage econometric model (1). Consequently, Ln C_{it} = C ($Y_{it,}$,P_{it} ,α) is supposed to represent the predicted cost log function that the bank must apply to minimize its total cost given the pair (Y_{it}, P_{it}).

Our choice here is fixed on two output vectors and two input vectors. The formulation of the above equation is derived from Berger and Humphrey (1997). The explanatory variables defining Eq. 1 are as follows: i/Y_1: loans, ii/Y_2: interest income, iii/P_1: the first input variable +designating the cost of principal loanable funds measured by the ratio $\frac{\text{interest/profit expenditure}}{\text{total deposit}}$, iv/$P_2$: the second input variable characterizing the labor cost defined by the ratio $\frac{\text{Personnel expenses}}{\text{total assets}}$, and finally, v/equity is a sort of quasi-fixed input. It is worth noting that equity is always used as a quasi-fixed input in the banking cost and profit functions to distinguish between the different levels of risk preference in the sample.

The error term of the model described by Eq. (1) represents the inefficiency of the banking cost. It is divided into two components: the U_{it}s defined by the truncation (at zero) of the N distribution ($ineff_{it}$, σ_u^2), where $ineff_{it}$ is defined in line with Battese and Coelli (1995), and the V_{it}s are purely error terms assumed to be i.i.d. N (0,σ_v^2) random variables.

Given the specifications of the banking technology function in terms of cost, cost inefficiency is estimated by exp (Uit), where efficiency score takes the value of 1 up to infinity. To render the results comparable, cost efficiency score will be transformed by the measure:

$$\text{Efficiency}_{it} = \frac{1}{\exp(U_{it})}. \quad (2)$$

Thus, for a bank, high scores close to unity indicate that the bank achieves great cost efficiency.

[Insert Table 1 about here]

Table 1 provides some summary descriptive statistics of the explanatory variables used in Eq. (1). As shown by Battese and Coelli (1995), the efficiency score of bank i at time t is given by:

Following Battese and Coelli (1995), we have estimated the coefficients of the cost function (Eq. (2)) using the maximum likelihood method.

[Insert Tables 2, 3, and 11 about here]

To justify our calculus of the efficiency scores calculated for the two types of banks, we tested whether we have an efficiency problem for each type. Table 2 provides the results of this test and does show that inefficiency is rejected at the 1% level for both types of banks. That is why we have introduced Table 3 to provide some descriptive statistics for the efficiency scores for both types of banks during 2006-2015.

We will study the similarities that exist between Islamic and conventional banks in the following sections. Since our study focuses on both the bank nature and their location withal, we have calculated, for each country, two series. The first is obtained by averaging the efficiency scores of conventional banks each year. The second series is calculated using the same approach for Islamic banks.

[Insert Tables 4 and 5 about here]

The results in Tables 4 and 5 justify our approach. We conducted a one-way ANOVA test where we tested the null hypothesis of equality of the means of the efficiency scores of conventional banks in each country (Table 4). The test was also conducted in the same way to test the equality of the means of the efficiency scores of Islamic banks in each country (Table 5). The results of these two tables show that there are no significant differences between the efficiency scores of conventional banks on one hand and Islamic banks on the other hand for each country. At first glance, these results may also testify to the similarities that exist between conventional and Islamic banks. However, the analysis of similarities will be further explored by using a clustering technique described in the following subsection.

4.2. Clustering of both Islamic and conventional banks

The second step in our empirical study is to group the GCC countries first according to the average efficiency of Islamic banks and second to both the average efficiency of conventional and Islamic banks. This shall be done using a clustering method described later. Our goal is to see which countries share common features regarding Islamic banking. It is well known that the distance is a basic notion in each clustering algorithm. In the sequel, we will describe the distance used here. In general, such algorithms use common distances, such as Euclidean and Manhattan distances. Inspired by Franses (2020), we chose the dynamic time warping (DTW) distance as another type of distance that highlights the similarities existing between time series that have equal or different lengths.

The DTW distance minimizes the temporal alignment between the two time series $x = (x_1, x_2, \dots, x_G)$ and $y = (y_1, y_2, \dots, y_H)$. More specifically, let $DTW(i,j)$ be the optimal distance between the first i and first j elements of the two series x et y, respectively. Then, $DTW(i,j)$ can be defined as:

$$DTW(i,j) = d(x_i, y_j) + \min[\mathrm{DTW}(i, j-1), \mathrm{DTW}(i-1, j), \mathrm{DTW}(i, j-1)], \quad (3)$$

where $d(x_i, y_j)$ is a distance measure. Consequently, the DTW distance is accompanied by a path, called the dynamic warping path, that represents the different iterations. The resulting minimal warping cost, $DTW(G,H)$, is a nonparametric measure of similarities between both time series. The minimal warping cost can simply be called the DTW distance.

After exposing the DTW distance, we apply clustering to the series of average efficiencies using the k-means algorithm. This algorithm was introduced by Macqueen (1967) and is designed to group numerical data in which each cluster has a center called the mean. The k-means algorithm is classified as a partitional or nonhierarchical grouping method. The number of clusters k is assumed to be fixed in this algorithm. The choice of a distance is fundamental in this algorithm since it defines its error function. For given k initial clusters, the algorithm proceeds to allocate the remaining data to the nearest clusters, then repeatedly changes the membership of the clusters according to the retained error function until the error function does not change significantly or the memberships in the different clusters no longer change; see Gan et al. (2007).

There are two phases in the k-means algorithm: the initialization phase and the iteration phase. The algorithm starts in the initialization phase by randomly assigning the cases in k clusters.

Next, the algorithm calculates in the second phase (iteration) the distance between each case and each cluster and assigns the case to the nearest cluster. Accordingly, the notion of the mean of a set of time series is a key element of the k-means algorithm. In doing so, we opt for DTW barycenter averaging, which was introduced by Petitjean et al. (2011). Roughly described, this method iteratively calculates the initial means through the minimization of the squares of the distance DTW between a set of series and an already established average resulting from these series; see Petitjean et al. (2011) and Franses (2020).

4.2.1. Clustering of the GCC countries according to the average efficiency of Islamic banks

First, we examine the information obtained from DTW on the leading and lagging relationships between the two time series. More specifically, we observe the average efficiency series of Saudi Arabian Islamic banks (blue) and the equivalent series of Kuwaiti Islamic banks (black) presented in Figure 1. From the tilt of the alignments, we remark that the kingdom of Saudi Arabia (KSA) leads Kuwait in approximately the first two-thirds of the sample. The relationship is then reversed, and Kuwait leads Saudi Arabia in approximately the last third of the sample. Figure 2 illustrates the DTW path between both series, confirms this observation again, and shows that the DTW distance is approximately 0.38.

We then use our DTW DBA-k-means algorithm to assign the GCC countries to their clusters according to the Islamic banks' average efficiency. However, before that, we should appropriately choose the number of clusters. Based on Hubert's second difference statistic, we can see from Figure 3 that there is a peak in the Hubert index, suggesting three clusters. We then apply the DTW DBA-k-means algorithm and find three clusters as follows: the first cluster contains only Oman, while the second is made up of Kuwait and the United Arab Emirates (UAE). The last cluster includes KSA, Bahrain, and Qatar. Figure 4 shows these clustering results on the map of the GCC countries.

4.2.2. Clustering of the GCC countries according to both the average efficiency of Islamic and conventional banks

Before presenting the results of this clustering and discussing them, we start by giving some insight into how similar the two series of the average efficiency Islamic banks and conventional banks in the same country are. We chose KSA as it is a leading country in Islamic banking. Figure 5 displays the alignments between both series. We deduce from the alignments thereof that conventional banks lead the Islamic banks in the whole sample. On the other hand, Figure 6 displays the DTW path between both series and shows that the DTW distance between them

is equal to 0.40. This suggests that the Islamic banking sector has benefited from the existing structure set up by conventional banks.

Next, we opt for clustering the GCC countries regarding the average efficiency of Islamic banks and the same series of conventional banks. To be slightly more specific, we will consider the two series of the average efficiency of Islamic banks and conventional banks for each country. We will subsequently apply the DTW DBA-k-means algorithm to all these series in the GCC countries. However, before presenting the results, it will be convenient to clarify the notations used henceforth. In this respect, we denote the average efficiency of Islamic banks in Oman and the average efficiency of conventional banks in the UAE as Oman_is and UAE_con, respectively. Turning to the clustering results, we deduce from Figure 7 that we have four clusters, as we have a peak in the Hubert index corresponding to four (Figure 7). Table 6 gives the composition of each cluster and Figure 8 shows the graphical representations of the average efficiency scores of Islamic and conventional banks according to their clusters.

4.3. Effect of fundamentals factors on banking inefficiency and clusters

To better understand the causes of discrimination between the different groups of Islamic and conventional banks, which have been revealed by our clustering technique, it would be convenient to return to the literature and see the effects of certain fundamental variables on the (in)effectiveness of both types of banks and compare them. According to Battese and Coelli (1995), we explain inefficiency (efficiency) by a vector of observable explanatory variables. To do this, we will need regressions (4) and (5) defined by:

$$\widehat{\text{Inefficiency}}_i = \hat{a}_0 + \hat{a}_1 X_i, \qquad (4)$$

$$\text{Ln}\left(\frac{\pi_i}{1-\pi_i}\right) = \alpha_0 + \alpha_1 X_i, \qquad (5)$$

where $X_i = (X_{1i}, X_{2i}, \ldots, X_{ji}, \ldots, X_{ki})$ in (4) and (5) designates the vector of fundamental factors affecting bank i and π_i is the probability that bank i is Islamic. We later describe the components of X_i used in our study. Eq. 4 is manifestly a logit model ensuring the knowledge of the most discriminating power of one or more of the fundamental factors between Islamic and conventional banks. Here, to be more precise, the logit model has the same explanatory variables explaining inefficiency in (4). In addition to these variables, efficiency can also be an explanatory variable in (5). Likewise, after estimating the parameters of the logit model (5), we

can measure the relative effect of one specific explanatory variable on the probability of being an Islamic bank.

In this respect, Ben Khediri et al. (2015) used the model to distinguish between Islamic and conventional banks by generating 0 as a prior probability for conventional banks and 1 for Islamic banks. In this model, we are not interested in these coefficients, but rather in the marginal effects of the fundamental factors in terms of the induced variations of the probability π to be an Islamic bank, i.e., $\frac{\partial \pi_i}{\partial X_{ji}}$, thus defining the discriminating power of X.

The first factor we include in our models (4) and (5) is credit risk. Along the lines of Berger and DeYoung (1997), Altunbas et al. (2000), Fiordelisi et al. (2011), Beck et al. (2013), Kabir et al. (2015), Louati et al. (2016), Mohanty et al. (2016), and Mester (1996), the variable is measured by the ratio of nonperforming loans to the total loans.

The second factor, which we chose to include in models (4) et (5), is the gap between the interest/profit rate applied by both banks and the real market discount rate in GCC countries. Islamic banks' financial investments should be oriented to the real market of goods and services and not oriented to speculation and activities off the balance sheet, such as financial derivatives and similar; see, *inter alia*, Ben Khediri et al. (2015).

Theoretically, Islam prohibits Ribaa in regards to interest rates. It assumes that any market cash flow that does not admit a real, tangible counterpart leads to speculation, and is assumed to be Ribaa because it does not contribute to material wealth creation. In practice, Islamic banks employ a profit rate in the real market imposed by the Sharia Board president and that is adjusted by the money's capital cost (money market rate) that is also applied in conventional banks.

However, in principle, the Islamic profit rate shall be the discount rate of goods and services. In contrast, the conventional interest rate is the discount rate of goods and services, as well as that of money speculation.

The greater the gap converges to zero, the more interest-rate setting coincides with Sharia principles. Therefore, if the gap converges to zero, we can conclude that both Islamic and Conventional banks use a remuneration rate based on the real market that is the profit rate,

instead of the monetary market (interest rate). Otherwise, if the gap is different from zero, the remuneration rate is based on the money market.

More specifically, we expect a gap different from zero for conventional banks and one that tends towards zero for Islamic banks. It should be noted that we can find gaps far from zero in Islamic banks and near zero in conventional banks. In this paradoxical situation, we confirm that Sharia principles are more respected in conventional banks' laws of remuneration rate establishment that tend to profit rate than in those of Islamic banks.

The interest/profit rate we will consider here is the global interest/profit rate applied by banks to loan ratings. It is the sum of the depositor's remuneration and that of the bank. We then approximate it by summing the average rates of total interest/profit expenses with total deposits and the interest/profit margin.

The discount rate we consider is the real market's capital cost, as developed by Ramsey (1928), who considered that the discount rate is the price of preference consumption of an economic agent in the present rather than in the future. This discount rate, also called the social interest rate that we will approximate it as an optimal profit rate, can be written as follows:

$$r = \delta + \gamma\, g, \qquad (6)$$

where δ is the time preference, γ is the elasticity of the marginal utility of consumption, and g is the growth rate.

Following Evans (2005) and Lopez (2008), we approximate the preference rate for the present by the annual mortality rate in each country corresponding to our bank sample. The basic argument supporting this asserts that each society member updates their future utility by the probability of not being alive on that date.

The marginal elasticity measures the decrease of utility relative to 1% consumption raising. We consider here the study of Aylward Porras (1998) to measure this factor as follows:

$$\gamma = \frac{\delta - invr}{\frac{S}{Y}(invr - y) + y} \qquad (7)$$

We note that δ is the preferred rate for present expressed by the annual mortality rate for each country containing the corresponding bank. The variable invr in (7) is the investment rate approximated by the ratio of total GDP to investment. In addition, the remaining variables in

(7) are as follows: S is the national savings money, Y is the national income, and y is the growth rate of GDP for the country, including the corresponding bank.

[Insert Tables 7 and 8 about here]

Figures 9 and 10 show the discrepancies between the applied interest rates and social discount rates. The two rates are divergent and never intersect for both banks. However, the applied interest rates always exceed discount rates.

Table 7 reports the descriptive statistics of these variables included in Eqs. (4), (5), (6), and (7), while Table 8 shows the means of the variables used in the estimation of the logit model in (5).

5. Discussion and Main Results

According to Table 6, we observe that there are four clusters obtained. Cluster 1 and cluster 3 each contain only conventional banks relating to the UAE and Kuwait, respectively. On the other hand, the Islamic banks of these two countries are included in the same cluster (cluster 2) in addition to the Islamic and conventional banks of the remaining countries, i.e., Oman, Qatar, and Bahrain. However, the Islamic banks of the KSA are classified alone in cluster 4.

Table 9 shows the results of the logit model (Eq. 5). In view of this table, the efficiency factor is significant only for KSA, Kuwait, and UAE. Islamic and conventional banks can be discriminated by efficiency only in these countries. The composition of Clusters 1, 2, and 4 confirms this finding. On the other side, we remark that both banks cannot be discriminated by efficiency in Bahrein, Qatar, and Oman. Consequently, Islamic and conventional banks are included together in the same cluster (Cluster 2).

Furthermore, the interest/profit rate gap is significantly also only in KSA, Kuwait, UAE, and Qatar. We can deduce that in these countries, conventional and Islamic banks can be discriminated against according to the position of their interest/profit rates in comparison to the theoretical social discount rate. The discrimination effect of the GAP variable is negative in KSA while it is positive in the rest of these countries. This shows that KSA conventional banks establish an interest rate higher than the discount rate more noticeably than Islamic banks. This situation is inversed for Kuwait, UAE, and Qatar. Therefore, the banks that applied an optimal interest rate near to the theoretical rate are Islamic banks of KSA and conventional banks of Kuwait, UAE, and Qatar.

The credit risk has a significant effect on banking discrimination in KSA and a significant effect in the rest of GCC countries, confirming that the credit risk can differentiate between both

banks. Islamic banks in KSA and conventional ones in Kuwait, UAE, Bahrein, Qatar, and Oman adopt the risk taking strategies.

Basing on credit risk and interest/profit GAP, we conclude that Islamic banks of KSA and conventional ones of Kuwait and UAE, have the same characteristics. We show that, credit risk taking and the social interest/profit rate establishment differentiate these banks, confirming the composition of Cluster 1, Cluster 3 and Cluster 4.

Table.8 reports the effect of credit risk and interest/profit GAP on Islamic and conventional banks inefficiency. Through this table, we try to understand the comportment of each cluster. The credit risk has a significant and a negative effect on the inefficiency of Islamic and conventional banks for the KSA, UAE, and Kuwait. An increase in their credit risk leads banks to be more efficient.

The variable gap also has a significant and a positive effect on conventional bank inefficiencies in Kuwait and the United Arab Emirates and on Islamic bank inefficiency of KSA. Consequently, the efficiency of both Islamic banks of the KSA and conventional banks of the UAE and Kuwait depends on the applied interest/profit rate's position compared to the discount rate. When banks establish an interest/profit rate below the discount rate, they become less expensive. Hence, they are attempting to take more risks and increase their efficiencies, albeit sometimes in a way that is not automatic. In our view, this provides an interpretation of why these banks found placement in a single cluster (Cluster 1, Cluster 3, Cluster 4). According to Farooq and Zaheer (2015), we add that Islamic banks in the KSA may be more resistant than conventional banks, given that they establish a profit rate near the capital cost (discount rate).

On the other hand, cluster 2 encompasses the majority of banks. Specifically, conventional and Islamic banks in Oman, Qatar, and Bahrain belong to this cluster, showing that all these banks share the same feature, namely, the positive effect of credit risk on inefficiency. Thus, when these banks take risks, their inefficiency will increase, and their interest/profit rates will be found below or barely above the capital cost.

Furthermore, setting an interest/profit rate close to the discount rate is part of financial justice, which is an objective of Shariah principles. An increase in interest/profit without considering the capital cost of the market may penalize creditors to the detriment of depositors, as discussed by Chapra (2008). In contrast, an interest/profit rate consistent with the discount rate (optimal

profit rate) is an act of social cooperation that reinforces the fairness and transparency regarding market information that is recommended by Shariah principles.

Therefore, when the interest/profit rate converges to the capital cost of tangible assets, banks generate an economic and social rent shown by efficiency in controlling costs. On the other hand, the application of the social profit rate reflects the social opportunity cost of the investment (Baumol, 1968).

In summary, we have found that discrimination in terms of efficiency between Islamic and conventional banks can be observed only in UAE, Kuwait, and KSA. In addition, the other factors that contribute to this discrimination are essentially the GAP between the applied interest/profit rates and the discount rate (the theoretical profit rate that should be applied by Islamic banks) and the credit risk. In this vein, we found that the credit risk-taking and the rapprochement of applied interest/profit rates to the discount rate make banks more efficient and classify them in a single cluster. More specifically, these banks are the conventional banks of UAE, the conventional banks of Kuwait, and Islamic banks of KSA.

6. Conclusion

In this paper, we studied the similarities between conventional and Islamic banks in GCC countries. Our choice of this region is justified by the similarities between these countries at the economic, social, and cultural levels. After calculating the efficiency scores for all the studied banks using the methodology of Battese and Coelli (1995), we averaged the obtained scores for each country and each year. More specifically, we obtained two average scores for each country: the first one is attributed to conventional banks and the other to Islamic banks. Then we have clustered all banks according to these averaged efficiencies and based on the dynamic time warping distances. Second, we have used a logit and an inefficiency model while the gap between the applied interest/profit rates and the theoretical social profit rate-that Islamic banks should apply-and the credit risk factor are displayed in the set of explanatory variables.

The main finding of this study is that there is no absolute discrimination between Islamic and conventional banks in any country. The KSA Islamic banks (cluster 4), the conventional banks of Kuwait (cluster 3), and the UAE conventional banks (cluster 1) are riskier, less expensive in terms of interest/profit rates, and less efficient.

Further, the efficiency of these banks requires taking more risks and maintaining lower levels of interest/profit rates as compared to the discount rate. Hence, the primary strategy that discriminates between banks is mapped out by risk-taking and establishing an interest/profit rate below or near the discount interest rate. Additionally, profit rate-setting practices presented in Islamic banks can deviate from ethical principles, as seen in cluster 2 composed simultaneously by conventional and Islamic banks of Bahrain, Oman, and Qatar.

However, a certain rapprochement between social classes originates the efficiency increase of Islamic banks in KSA and conventional banks in UAE. We can assign such a rapprochement to the fact that these banks do not penalize creditworthy borrowers to the detriment of others. This non-penalization concerns rather the management of their resources intended for the credit granting. To do this, these banks have to focus more on the behavior of investors to reduce the gap between social classes; see Gollier (2011).

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Table 1. Descriptive statistics of the explanatory variables of Eq. (1) for the overall period

	Overall	
Variable	**Conventional**	**Islamic**
Y1	14695.14 (15087.17)	6585.954 (10152.61)
Y2	6183.683 (7035.778)	21193.37 (89504)
P1	0.0229 (0.0211)	0.0336 (0.0744)
P2	0.0238 (0.1034)	0.0184 (0.03657)
Equity	258895 (277901.4)	1512453 (60472)

Notes: The variables included in this table are as follows: Y1 = Loans, Y2 = Other earning assets,P1=$\frac{\text{Interest expenditure}}{\text{Total deposit}}$, P2 = $\frac{\text{Personnel expenses}}{\text{Total assets}}$ and Equity is quasi-fixed inputs. Numbers without parentheses are the means of the variables, while the numbers in parentheses are their standard deviations.

Table 2. Results of specification tests of cost efficiency function estimated

	Conventional Efficiency Cost	**Islamic Efficiency Cost**
Wald Khi-square	9790.14***	6595.58 ***
Log likelihood	193.1573	62.5099

sigma_U	6.487** (3.299)	0.4012*** (0.0554)
sigma_V	0.057*** (0.0075)	0.0984*** (0.0239)
Inefficiency Test		
Inefficiency statistic	113.6954***	4.077221 ***
Critical value	11.748	7.918
Test Result	Reject H0	Reject H0

Notes: sigma_U and sigma_V are the standard deviations of U and V, respectively, defined in Eq. (1). The null hypothesis H_0 is the absence of technical inefficiency effect : $\lambda = 0$ where $\lambda = \frac{\sigma^2\ (U)}{\sigma^2\ (U)+\sigma^2\ (V)}$; see Battese and coelli (1995). *** and ** correspond to the rejection of the null hypothesis at 1% and 5%, respectively.

Table 3. Descriptive statistics of efficiency scores for conventional and Islamic banks

	Conventional banks		**Islamic Banks**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
2006	0.8827	0.11421	0.9030	0.0696
2007	0.8212	0.1922	0.8769	0.0625
2008	0.8210	0.1390	0.8540	0.1340
2009	0.8654	0.1219	0.8199	0.2057
2010	0.8680	0.0907	0.9107	0.0626
2011	0.8540	0.1382	0.9112	0.0425
2012	0.8733	0.1143	0.8796	0.0962
2013	0.8703	0.1120	0.8771	0.0800
2014	0.8621	0.1169	0.8925	0.0634
2015	0.8513	0.1201	0.8813	0.0758
Overall	0.8569	0.1279	0.8818	0.0961

Table 4: Oneway ANOVA test of the equality of the means of the efficiency scores for the conventional banks

Conventional Banks

KSA	**SS**	**df**	**MS**	**F**	**Prob > F**	**chi2(7)**	**Prob>chi2(a)**
Between groups	.036534904	7	.005219272	0.39	0.8982	14.2081	0.048
Within groups	.384306594	29	.013251952				
Total	.420841497	36	.011690042				
KW							
Between groups	.116277195	4	.029069299	0.57	0.6901	20.2138	0.000
Within groups	.871872385	17	.051286611				
Total	.988149579	21	.047054742				
UAE							
Between groups	.245147792	14	.017510557	1.03	0.4315	26.1517	0.025
Within groups	1.18565196	70	.016937885				

Total	1.43079976	84	.01703333				
Bahrain							
Between groups	.267414745	6	.044569124	1.93	0.1021	35.6324	0.000
Within groups	.83048119	36	.023068922				
Total	1.09789594	42	.026140379				
Qatar							
Between groups	.01191318	4	.002978295	0.45	0.7707	7.9299	0.094
Within groups	.198057987	30	.006601933				
Total	.209971167	34	.006175623				
Oman							
Between groups	.035497069	5	.007099414	1.07	0.3954	25.6473	0.000
Within groups	.191792769	29	.006613544				
Total	.227289838	34	.006684995				

Notes: For each country, the null hypothesis of the test is the equality of the means of the efficiency scores of conventional banks.

Table 5: Oneway ANOVA test of the equality of the means of the efficiency scores for the Islamic banks

	Islamic Banks						
Country	**SS**	**df**	**MS**	**F**	**Prob > F**	**chi2(7)**	**Prob>chi2(b)**
KSA							
Between groups	.062990976	4	.015747744	0.64	0.6359	24.1835	0.000
Within groups	.68511075	28	.024468241				
Total	.748101726	32	.023378179				
KW							
Between groups	.028348166	9	.003149796	0.45	0.9001	10.1096	0.342
Within groups	.431196022	62	.006954775				
Total	.459544188	71	.006472453				
UAE							
Between groups	.097819906	8	.012227488	0.82	0.5904	29.1132	0.000
Within groups	.837586505	56	.014956902				
Total	.935406412	64	.014615725				
Bahrain							
Between groups	.141682404	14	.010120172	1.37	0.1846	32.6499	0.003
Within groups	.687839993	93	.007396129				
Total	.829522396	107	.007752546				
Qatar							
Between groups	.087170875	3	.029056958	1.93	0.1534	11.8807	0.008
Within groups	.346816879	23	.015078995				
Total	.433987754	26	.016691837				
Oman							
Between groups	.035497069	5	.007099414	1.07	0.3954	25.6473	0.000
Within groups	.191792769	29	.006613544				
Total	.227289838	34	.006684995				

Notes: For each country, the null hypothesis of the test is the equality of the means of the efficiency scores of Islamic banks.

Table 6. The clustering results of the GCC series of the average efficiency of Islamic banks and the average efficiency of conventional banks

Cluster 1	UAE_conv
Cluster 2	Oman_con;Qatar_con;Bahrain_con;Kuwait_Is;UAE_Is; Bahrain_Is;Qatar_Is;Oman_Is; KSA_con
Cluster 3	Kuwait_con
Cluster 4	KSA_Is

Notes: KSA_Is stands for the average efficiency series for Islamic banks of KSA while KSA_con designates the average efficiency series for conventional banks of KSA

Table 7. Descriptive statistics of the variables needed in the discount rate derivation.

Variable	Bahrain	KSA	Kuwait	Oman	Qatar	UAE
Income	4.89e+10 (0.45879)	9.85e+11 (0.231457)	2.25e+10 (0.639014)	9.85e+10 (0.562314)	5.58e+11 (0.35478)	4.49e+10 (0.83265)
Saving	9.17e+09 (0.17548)	2.54e+11 (0.72458)	7.28e+10 (0.20658)	1.98e+10 (0.59854)	1.04e+11 (0.161478)	5.58e+10 (0.105478)
Mortality arte	2.548 (0.045879)	3.463 (0.0501171)	2.4326 (0.053647)	2.7709 (0.1485119)	1.2421 (0.38607)	1.4221 (0.0638594)
GDP	2.71e+10 (0.47658)	5.83e+11 (0.14587)	1.36e+11 (0.2755)	6.21e+10 (0.14879)	1.40e+11 (0.490358)	3.22e+11 (0.60147)
GDP per person	8347.953 (1.4748)	.1949119 (1.498826	12571.22 (1759.506)	7249.105 (1028.666)	266127 (38607.94)	146581.4 (14314.71)
Growth rate of GDP	4.622199 (1.890059)	3.973198 (2.990297)	2.503725 (4.845178)	4.903045 (2.727543)	12.34775 (7.605722)	3.843192 (3.716993)
Investment rate	0.2833425 (0.0376723)	0.2824857 (0.034033)	0.1723214 (0.0352392)	0.27277 (0.0494174)	0.3561256 (0.066941)	0.2405405 (0.0355786)
Consumption Marginal Utility elasticity	(0.0929242 (0.022664)	0.0744589 (0.1128791)	0.1228474 (0.1860535)	0.0350207 (0.1104041)	0.0749901 (0.0604386)	0.0477995 (0.0515453)
Discount rate	0.0234203 (0.0019838)	0.0343925 (0.0016406)	0.0218128 (0.0083937)	0.0299291 (0.0071886)	0.0117448 (0.002516)	0.0132024 (0.00525)

Applied Interest rate	0.1095592 (0.151824)	0.0408455 (0.0167647)	0.0632066 (0.058679)	0.0587908 (0.0192203)	0.0472408 (0.0216103)	0.0586451 (0.0208076)

Notes: For each cell, the first number is the mean, the number in ( ) is the standard deviation

Table 8. Effect of fundamental factors on inefficiency of Islamic and conventional banks (Eq. (4))

	KSA		Kuwait		UAE		Bahrain		Qatar		Oman	
	Conv	**ISL**	**Conv**	**ISL**	**Conv**	**ISL**	**Conv**	**ISL**	**Conv**	**Isl**	**Conv**	**ISL**
RISK	0.645*	-0.0490*	-0.421*	0.181*	-0.2949*	0.0696*	0.231*	0.395*	0.793*	0.156*	0.204*	0.010*
	(3.4951)	(3.016)	(4.895)	(1.565)	(1.066)	(1.773)	(0.961)	(1.567)	(1.201)	(13.16)	(0.1483)	(14.561)
GAP	291.545	11.28948*	0.2469*	0.248	0.25*	46.453	0.25	189.786	0.25784	0.25235	588.928	13.568
	(1189.566)	(932.025)	(856.65)	(18623.21)	(963.548)	(425.912)	(558.639)	(879.542)	(879.654)	(965.258)	(1587.732)	(489.235)
cons	4.174	0.5848971	0.161	0.234	2.819	-0.781	0.392	-20.105	-3.893	0.256	1.513	0.258
	(26.725)	(39.424)	(70.174)	(15.554)	(13.691)	(19.695)	(0.2596615)	(83.84282)	(75.124)	(44.84057)	(2.269)	(1.204)

Notes: This table reports the effect of fundamental factors on Islamic and conventional banks inefficiency, the stander deviation and the p-value
*Significance at 10% level.

Table 9. Discrimination between conventional and Islamic Banks using Logit model.

	KSA	Kuwait	UAE	Bahreïn	Qatar	Oman
EFF	-0.990694*	.9241125**	0.5419069**	.4839987	-3.736024	-1.925769
	0.56025	0.73167	0.40235	.51364	2.39228	3.542732
	0.077	0.020	0.017	0.346	0.118	0.587
RISK	0.11717*	-0.145034*	-0.0323842**	-0.0068185	-0.5370239***	-0.00784***
	0.06304	0.08739	0.01738	0.01487	0.18464	0.0158
	0.063	0.097	0.062	0.646	0.004	0.001
GAP	-6.433469*	8.473364***	7.14035***	.7447099	54.92665**	29.12873
	5.77155	3.22277	2.2487	1.04157	26.247	19.46285
	0.065	0.009	0.001	0.733	0.036	0.902

Notes: This table reports the discriminatory power between Islamic and conventional banks, the standard deviation and the p-value
*Significance at 10% level.**Significance at 5% level.***Significance at 1% level.

Table 10. List of Islamic and conventional banks used in the study

Number	Conventional banks
1	Abu Dhabi Commercial bank (UAE)
2	Ahli Bank QSC (Qatar)
3	Ahli United Bank BSC (Bahrain)
4	Al Ahli Bank of Kuwait (Kuwait)
5	Al Khalij Commercial Bank (Qatar)
6	Alubaf Arab International Bank (Bahrain)
7	Arab Bank for Investment & Foreign Trade-Al Masraf (UAE)
8	Arab Banking Corporation BSC-Bank ABC (Bahrain)
9	Arab National Bank Public Joint Stock Company (KSA)
10	BBK B,S,C (Bahrain)
11	BMI Bank BSC (Bahrain)
12	Bank Sohar SAOG (Oman)
13	Bank Muscat SAOG (Oman)
14	Bank Sohar SAOG (Oman)
15	Bank of Sharjah (UAE)
16	Banque Saudi Fransi JSC (KSA)
17	Burgan Bank SAK (Kuwait)
18	National Bank of Abu Dhabi (UAE)
19	Commercial Bank International P,S,C (UAE)
20	Commercial Bank of Dubai P,S,C (UAE)
21	Doha Bank (Qatar)
22	Emirates NBD PJSC (UAE)
23	First Gulf Bank (UAE)
24	Gulf Bank KSC (Kuwait)
25	Gulf International Bank BSC (Bahrain)
26	HSBC Bank Oman (Oman)
27	International Bank of Qatar Q,S,C (Qatar)
28	Invest Bank P,S,C (UAE)
29	Mashreqbank PSC (UAE)
30	National Bank of Abu Dhabi (UAE)
31	32National Bank of Bahrain (Bahrain)
32	National Bank of Fujairah PJSC (UAE)
33	National Bank of Kuwait S,A,K, (Kuwait)
34	National Bank of Oman (SAOG) (Oman)
35	National Bank of Ras Al-Khaimah (P,S,C,)-RAKBANK (UAE)
36	National Bank of Umm Al-Qaiwain PSC (UAE)
37	National Commercial Bank (KSA)
38	Oman Arab Bank SAOC (Oman)
39	Riyad Bank (KSA)
40	Samba Financial Group (KSA)
41	Saudi British Bank JSC (KSA)

Table 10. *(Continued)*.

42	Saudi Hollandi Bank (KSA)
44	The Commercial Bank (Qatar)
45	Union National Bank (UAE)
46	United Arab Bank PJSC (UAE)
Number	**Islamic banks**
1	A'Ayan Islamic Leasing & Investment Company (Kuwait)
2	ABC Islamic Bank (E,C,) (Bahrain)
3	Abu Dhabi Islamic Bank - Public Joint Stock Co (UAE)
4	Ajman Islamic Bank
5	Al Hilal Islamic Bank PJSC (UAE)
6	Al Rajhi Islamic Bank Public Joint Stock Company (KSA)
7	Albaraka Banking Islamic Group B,S,C (Bahrain)
8	Albaraka Islamic Bank BSC (Bahrain)
9	Alinma Islamic Bank Public joint stock company (KSA)
10	Alizz Islamic Bank S,A,O,G (Oman)
11	Al-Salam Islamic Bank-Bahrain B,S,C (Bahrain)
12	Arcapita Islamic Bank B,S,C (Bahrain)
13	Aref Investment Islamic Group (Kuwait)
14	Bahrain Islamic Bank B,S,C (Bahrain)
15	Barwa Islamic Bank (Qatar)
16	Boubyan Islamic Bank KSCP (Kuwait)
17	Dubai Islamic Bank PJSC (UAE)
18	Emirates Islamic Bank PJSC (UAE)
19	First energy Islamic bank (Bahrain)
20	First Investment Islamic Company K,S,C,C (Kuwait)
21	GFH Islamic Financial Group B,S,C (Bahrain)
22	Ibdar Islamic Bank BSC (Bahrain)
23	Investment Dar Co Islamic (Kuwait)
24	Islamic Ahli United Bank KSC (Kuwait)
25	Islamic Bank AlBilad (KSA)
26	Islamic Bank AlJazira JSC (KSA)
27	Islamic Bank Alkhair BSC (Bahrain)
28	Islamic Bank Nizwa SAOG (Oman)
29	Islamic Development Bank (KSA)
30	Islamic Kuwait Finance House (Kuwait)
31	Islamic Tamweel PJSC (UAE)
32	Ithmaar Islamic Bank B,S,C (Bahrain)
33	Khaleeji Commercial Islamic Bank (Bahrain)
34	Kuwait International Islamic Bank (Kuwait)
35	Kuwait Islamic Finance House (Bahrain)
36	Masraf Islamic Al Rayan (Q,S,C,) (Qatar)
37	Noor Islamic Bank (UAE)

Table 10. *(Continued).*

38	Qatar International Islamic Bank (Qatar)
40	Rasameel Structured Finance Company K,S,C Islamic (Kuwait)
42	Sharjah Islamic Bank (UAE)
43	Venture Capital Islamic Bank BSC (c)-VCBank (Bahrain)
44	Warba Islamic Bank (Kuwait)

Table 11. Further details on the estimation of Battese and Coelli's (1995) model (Eq. (1)) and the test of technical efficiency effect

	Conventionnal Banks				**Islamic Banks**			
	Coef.	Std. Err.	z	P>z	Coef.	Std. Err.	z	P>z
α_1	1.0155	0.4759	2.13	0.069	0.0494	0.3035	2.16	0.071
α_2	-0.8049	0.3344	-2.41	0.073	-0.8309	0.3251	-2.56	0.011
α_3	1.4974	0.1286	11.64	0.000	1.3052	0.1663	7.85	0.000
α_4	0.0005	0.0002	1.98	0.093	0.0001	0.0003	2.44	0.059
α_5	-0.0945	0.0249	-3.79	0.001	0.1609	0.0523	3.07	0.002
α_6	-0.0009	0.0003	-2.55	0.058	-0.0002	0.0001	-2.34	0.079
α_7	0.00031	0.00004	6.44	0.000	0.00029	0.00006	4.49	0.000
α_8	-0.0390	0.0232	-1.68	0.704	0.0105	0.0085	1.24	0.216
α_9	0.0469	0.0194	2.41	0.060	-0.0430	0.0353	-1.22	0.223
α_{10}	-0.0816	0.2036	-0.40	0.069	1.3546	0.3304	4.10	0.000
α_{11}	-0.00003	0.00002	-1.36	0.605	0.00005	0.00001	3.19	0.001
α_{12}	0.0242	0.0361	3.67	0.000	-0.0950	0.0341	-2.79	0.005
α_{13}	0.1166	0.0323	3.60	0.000	-0.00006	0.0355	-0.00	0.999
α_{14}	-0.0917	0.0091	-10.00	0.002	-0.0558	0.0264	-2.11	0.035
α_0	-2.5571	1.4765	-1.93	0.069	-5.1694	2.2940	-2.25	0.024
Usigma	-3.3914	0.1517	-22.35	0.000	-3.5166	0.24561	-14.32	0.000
Vsigma	-5.5190	0.2914	-18.93	0.003	-4.5459	0.2487	-18.27	0.000
Sigma-u	0.1834	0.0139	13.18	0.065	0.1723	0.0211	8.14	0.000
Sigma-v	0.0633	0.009	6.86	0.000	0.1030	0.0128	8.04	0.000
Lambda	2.8972	0.0207	139.40	0.012	1.6731	0.0293	57.05	0.000

Notes: Test of existence of technical inefficiency effect

H0 : Absence of technical inefficiency effect : Lambda =0 $\left(\lambda = \frac{\sigma^2\ (U)}{\sigma^2\ (U)+\sigma^2\ (V)}\right)$

H1 : existence of technical inefficiency effect : Lambda > 0

The statistic of the test follows a mixed chi-square distribution with critical value from the table of Kodde et Palm (1986). Rejection of (H0) if inefficiency statistic > critical value

Figure 1: Dynamic time warping matching between the average efficiency of Saoudian Islamic banks (vec1) and the average efficiency of Kuwaiti Islamic banks (vec2).

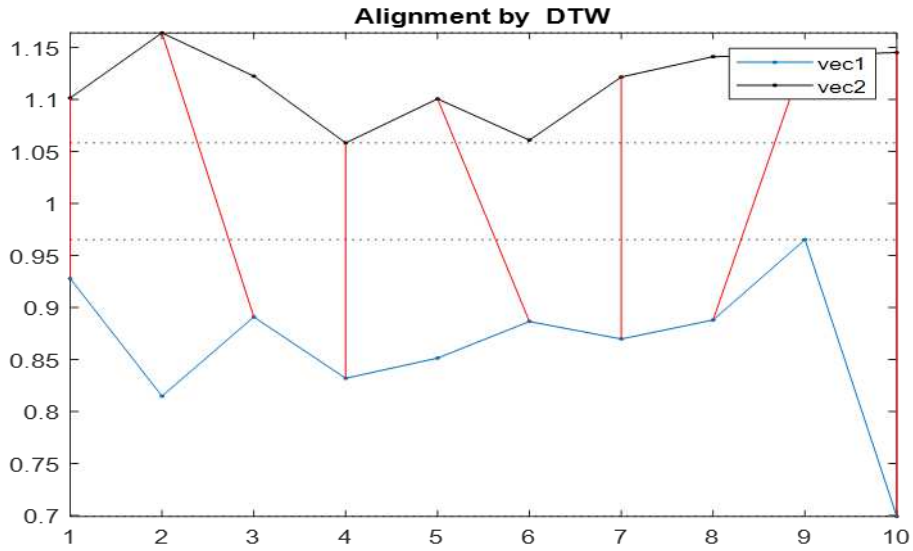

Figure 2: Dynamic time warping path between the average efficiency of Saoudian Islamic banks (vec1) and the average efficiency of Kuwaiti Islamic banks (vec2).

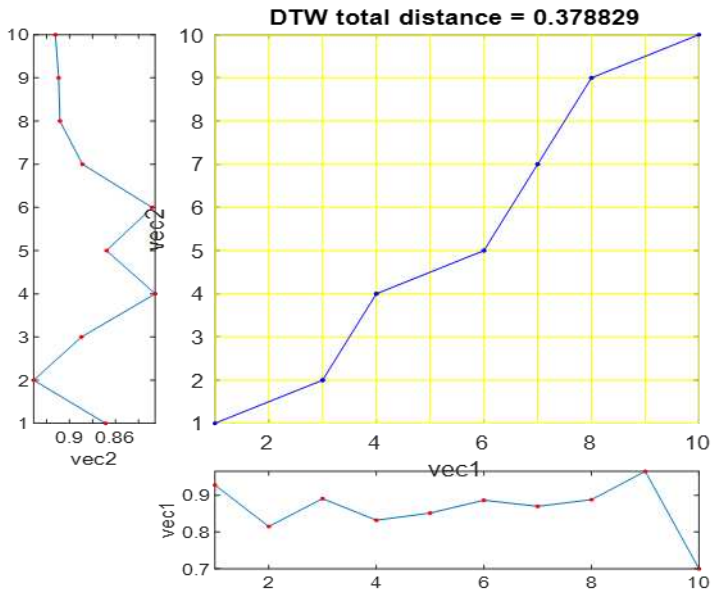

Figure 3: The hubert index plot for clustering the GCC countries according to the average efficiency of Islamic banks

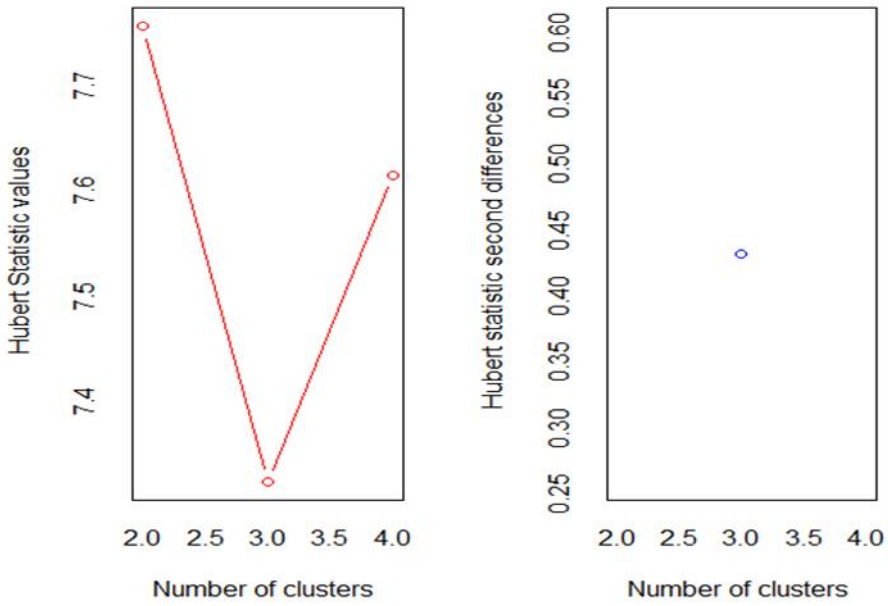

Figure 4: The three clusters of the average efficiency of Islamic banks in the GCC map

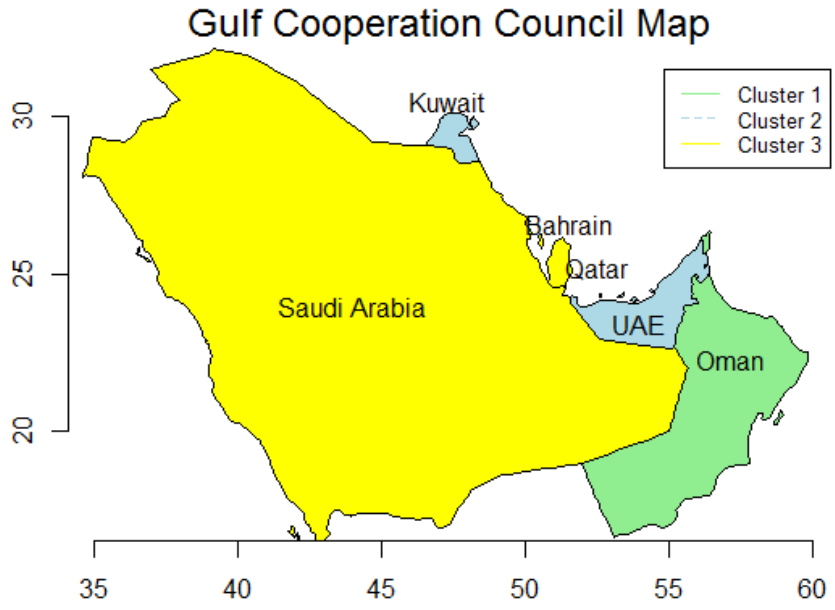

Figure 5: Dynamic time warping matching between the average efficiency of Saoudi Islamic banks (vec1) and the average efficiency of Saoudian conventional banks (vec2).

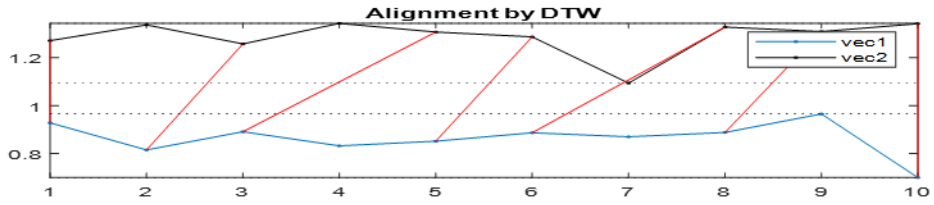

Figure 6: Dynamic time warping path between the average efficiency of Saoudi Islamic banks (vec1) and the average efficiency of Saudi conventional ones (vec2).

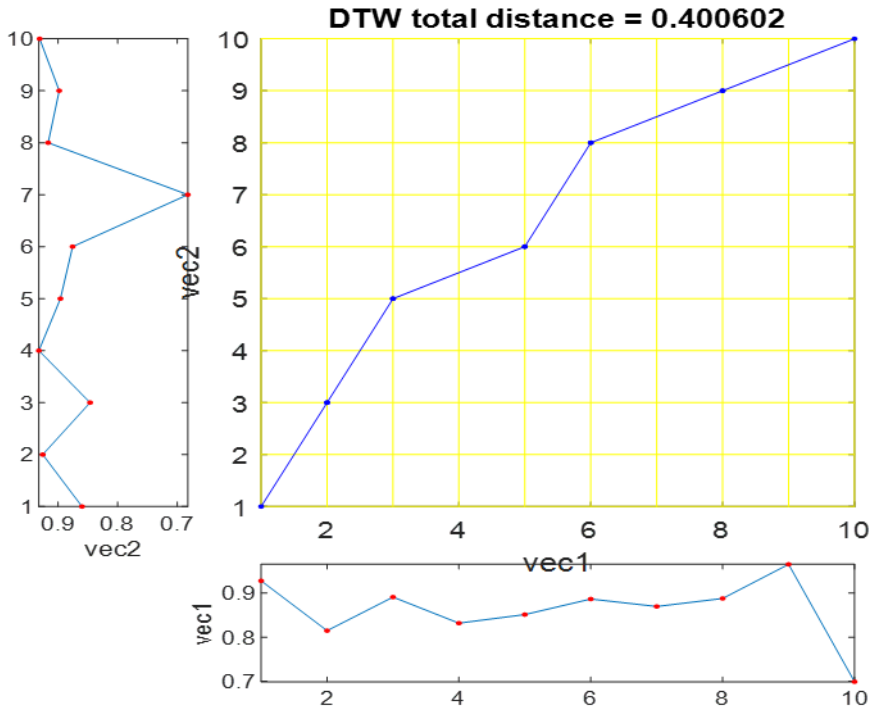

Figure 7: The hubert index plot for clustering the GCC series of the average efficiency of Islamic banks and the average efficiency of conventional banks

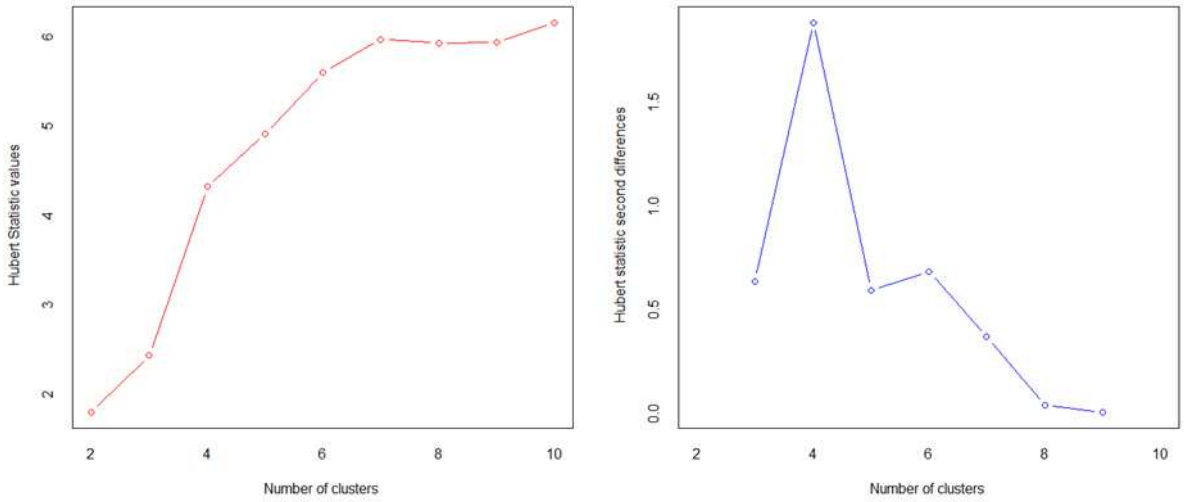

Figure 8: The graphical representation of the average efficiency series of Islamic and Conventional banks according to the clusters

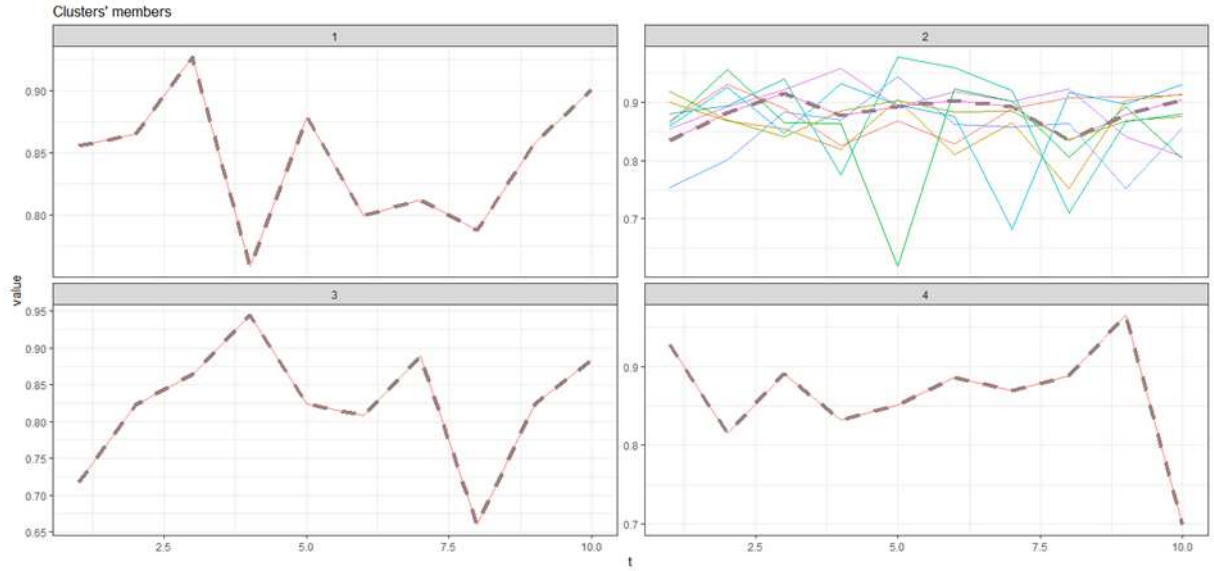

Figure 9: Gap between interest rate and discount rate of conventional banks

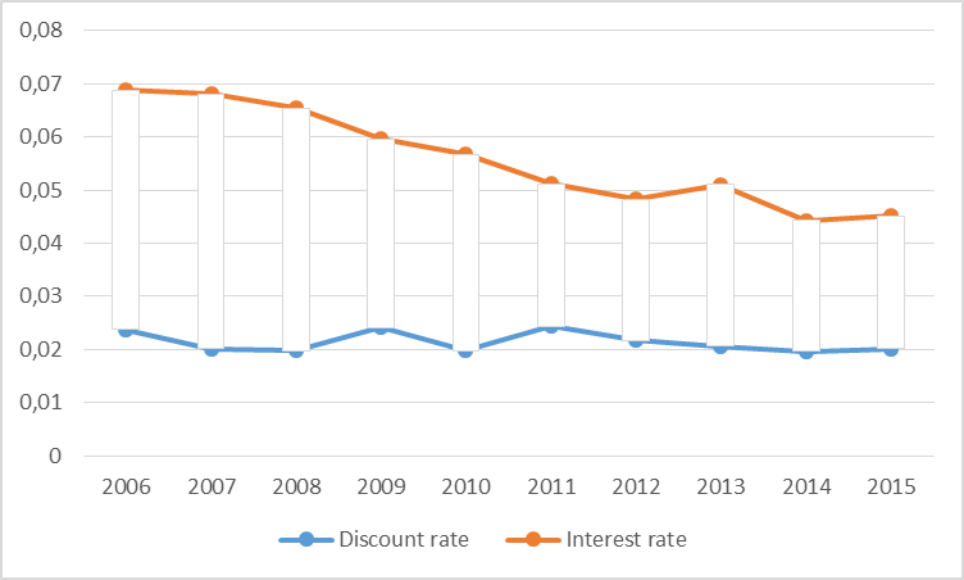

Figure 10: Gap between interest rate and discount rate of Islamic banks