Bank Efficiency and Non-performing Loans: Evidence from Turkey

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Abstract

This study analyses technical and allocative efficiencies in Turkish banks from December 2002 to December 2017, under the assumption of constant returns to scale. We apply a modified version of the Data Envelopment Analysis (DEA) approach introduced by Aparico et al. (2015), which employs a directional distance model to provide estimates of efficiency, with a focus on Non-Performing Loans (NPLs) as an undesirable output. In addition, we examine the determinants of efficiency by applying quantile regressions to panel data. The results obtained support the thesis that NPLs exert a negative impact in terms of technical efficiency, which confirms the "bad management" hypothesis in the banking sector. We also find that the level of efficiency of Turkish banks differs, depending on the ownership structure in place.

Keywords: Quantile regression; Data Envelopment Analysis; Non-performing loans; Efficiency; Turkey

1. Introduction

The Turkish banking sector is the backbone of the financial system in the Turkish economy. Over the past 30 years, a variety of structural and organizational reforms have been implemented, such as the establishment of the Banking Regulation and Supervision Agency (BRSA) and the independence of the Central Bank of the Republic of Turkey from the government in order to enhance the efficiency and stability of the Turkish banking sector. Several studies have examined the profitability and efficiency of Turkish banks across time periods that include differences in political climate, financial liberalization, market sentiment (e.g. global financial crises), and ownership status (e.g. Gunes et al., 2016; Hermes and Meesters, 2015; Assaf et al., 2013; Yilmaz, 2013; Kasman, 2012; Fukuyama and Matousek, 2011; Baum et al., 2010; Bayraktar et al., 2010; Aysan and Ceyhan, 2008; El-Gamal and Inanoglo, 2005; Isik and Hassan, 2002, 2003). A variety of parametric and non-parametric methods were deployed in these studies that confirm the positive impact of financial liberalization on the efficiency of the Turkish banking sector over the past three decades, while studies that have evaluated Turkish banking efficiency during the most recent global financial crisis confirm that it had a strong and negative impact. In addition, the various ownership statuses of Turkish banks and related structural differences are reflected in the efficiency scores (e.g. Assaf et al., 2013; Kasman, 2012). However, there is no consensus in the studies that have investigated efficiency determinants. In particular, following a cross-comparison of studies that have looked at Turkish bank efficiency, we fail to find a consistent relationship between bank size and efficiency level. Moreover, credit risk in the Turkish banking system – the factor to which we gave particular attention during the period we examined – is only considered in one study.

Over the past three decades, the Turkish banking sector has experienced a sharp increase in NPLs that has triggered prolonged instability and an economic downturn. The regulatory response has been to introduce differentiations in loan loss provisions, loan restructuring rules, and the bailing-out of troubled banks (Isik and Hassan, 2003; Athanasoglou et al., 2008). Despite these regulatory reforms, the NPL ratios of Turkish banks have not been reduced, and even after the restructuring plan of 2002 and the subsequent short-lived decrease of NPLs, significant increases were recorded following the 2008 global financial crisis. In particular, the NPLs to total loans ratio increased by approximately 54% during the period 2011-2016, reaching $13.11 million in 2016. In contrast, the average NPLs ratio dropped continuously in all European countries and the US where in 2016, it reached 5.4% and 1.1%, respectively. In addition to NPLs, there was a sharp increase in the restructured credit held by banks from approximately 1% percent to 3% of gross loans, while the low recovery rates on problem loans caused further pressure on the Turkish banking system.

Overall, the credit risk component of Turkish banks, as reflected in the dynamics of NPLs, can be said to be too important to ignore, and therefore the main motivation behind this paper is to evaluate the technical and allocative efficiency of Turkish banks, while accounting for the impact of NPLs. The study by Assaf et al. (2013) is conceptually the closest to ours; however, our study uses a considerably longer time period of quarterly frequency, introduces two novel efficiency determinants, and makes use of quantile regression in the second stage of the analysis. Another notable distinction is that although both Assaf et al. (2013) and our paper consider NPLs as an undesirable output in the production function, Assaf et al. (2013) do so via a Bayesian stochastic frontier approach, while we build on the non-parametric technique of DEA.

This study contributes to empirical research on bank performance in four ways. First, we use an innovative method of estimating technical and allocative efficiency in banks by deploying the DEA approach introduced by Aparicio et al. (2015), which defines a new directional distance function with endogenous directions to accurately measure technical and allocative efficiency. The advantage of this non-parametric approach is that it allows for a simultaneous expansion of desirable outputs and contraction of undesirable outputs (e.g. Barros et al., 2012; Fujii et al., 2004; Fukuyama and Matousek, 2011). Our choice of undesirable output is NPLs, which is consistent with the literature in this field. Second, our second-stage analysis includes more efficiency determinants than previous studies, and in particular, we investigate the impact of two new efficiency determinants – employee education and gender; no previous study has attempted to analyze the impact of these qualitative factors on the efficiency of Turkish banks. An analysis of these two features is worthwhile since it could not only improve management decisions, but also bank performance. Moreover, we examine differences in bank efficiency based on various ownership statuses, based on which investment and development banks were found to be most efficient. Third, we examine the drivers of efficiency in a second-stage regression, using a quantile regression technique. The advantage of quantile regression over the standard regression analysis is that it provides a more accurate representation of the efficiency dispersion across banks and/or time. Here, the use of quantiles is superior to other methods because it allows data to be modeled with heterogeneous conditional distributions (Chen, 2005). To the best of our knowledge, this is the first time that quantile regressions have been applied to evaluate the efficiency determinants of Turkish banks, even though it has been employed to evaluate risk and efficiency in the Central and Eastern European banking industries, based on quantile analysis (Mamatzakis, 2012). Fourth, our study contributes to the Turkish banking literature by examining quarterly data from a long time period, 2002-2017, thereby encompassing a number of currency, financial and economic crises. Quarterly data are known to reduce the problem of the "window dressing" of financial statements that frequently occurs in annual data presentations (Evanoff and Segal, 1997).

As a preview of our findings, we can say that our analysis shows that banks with a high percentage of NPLs tend to be less efficient, meaning that controlling NPLs is of crucial importance to the management of banks. Furthermore, similarly to Fukuyama and Matousek (2011) and Athanasoglou et al. (2008), we find that a far-reaching restructuring program implemented in Turkey led to higher efficiency, while we hope that the fact that employee education has a positive impact on both technical and allocative efficiency scores might lead to increased investment in human capital in Turkish banks.

The remainder of this paper is structured as follows. Section 2 provides an overview of the Turkish banking sector; Section 3 reviews the relevant literature; Section 4 presents the methodology; and Section 5 describes the data and discusses the empirical results. The final section presents a conclusion.

2. The Turkish banking sector: An overview

Both the Turkish financial sector and banking system have undergone continuous legal, structural, and international changes over the last three decades. The country's banking system in particular was prevented from becoming competitive by severe regulations in the 1970s and early 1980s. Before the introduction of the 1980s stabilization program, the government imposed a solid "licensing policy" and "interest rate ceilings" on the banking system by both restricting new entities from operating and regulating interest rates.

Although designed to bring about banking stability, such regulations and policies led to a deterioration in competitiveness, efficiency, and effective credit distribution throughout the Turkish banking sector as a whole.

The introduction of financial reforms in Turkey, which started in the 1980s, had two broad aims: to reduce government intervention, and to widen the role of market forces in the Turkish financial market, including both the financial and banking sectors. The main purpose of these financial policies, exemplified by the 1980s stabilization program, was to improve and enhance the competitiveness, credit allocation, and efficiency of the Turkish banking sector. The initial stages entailed the implementation of liberal regulations and principles such as relaxing interest rates, commissions, and fees, while they also codified the rules for new entries including foreign banks that wished to establish branches in Turkey. The sector response to the program was quick; there was growth in both the number of employees and branches of banks, and the country's banking sector advanced quickly after the implementation of the post-1980s policies and reforms. Furthermore, more flexible interest rates and increases in competition motivated banks to eliminate their total cost of operations to be able to survive in the financial market. Consequently, loss-making and unsuccessful banks were either shut or merged with other banks, while there was also a reduction in the number of employees in Turkish banks.

In the liberalization era, banks began to participate in capital markets by purchasing treasury bonds and government debt securities, operating in foreign exchange markets and providing new products and services to clients such as customer loans and foreign exchange deposit accounts. In addition to enhancing efficiency and fulfilling the aims of the liberalization program, these improvements helped local banks to work more in line with the practices of European Union members, aiding Turkey's wish to eventually become a full member of the Union.

Despite all such efforts, the uncontrolled liberalization policies, combined with steady macroeconomic and microeconomic imbalances, brought about currency and banking crises in 1994 and then in 2001. The economic crises Turkey experienced in 2000 and 2001 indicate a strong correspondence between weak performance and a deregulated banking system, in combination with the unexpected macroeconomic crises. Undeniably, Turkish banks have contributed significantly to the spread of economic crises because they play a crucial role in the Turkish financial market. One of the consequences of these crises was a dramatic decrease in the efficiency level of the banking sector and as a result, in 2001, the Turkish government introduced its Banking Sector Restructuring Program (BSRP). The BSRP was designed to ensure further improvements to the banking regulation, as well as the necessary supervision to develop efficiency in the Turkish banking sector (Bayraktar et al., 2010). Moreover, the government also implemented a policy of full deposit insurance in order to restore confidence in the Turkish banking system. Despite the government expectation that this would stabilize the financial market and banking system, this decision led to concerns that some banks were starting to report declines in the quality of their assets in order to obtain more capital injections from the government, or for bailing-out purposes. The second financial crisis was managed and completed by 2001 because the government, together with the International Monetary Fund (IMF), introduced systemic actions to restructure the Turkish economy through a proposed Rehabilitation Programme. The four most important priorities that this program aimed to address were: (1) firming up private banks; (2) a determination of which banks would be transferred to the Savings Deposit Insurance Fund of Turkey (SDIF) through methods such as mergers, sales, and liquidation; (3) the operational and financial restructuring of state banks, with the end goal of privatization; and (4) the establishment of a legal and institutional framework that would enjoy improved supervisory capacity over the sector in order to increase sector efficiency and competitiveness. The authorities planned their main strategies to ensure regulatory and supervisory improvements, regularize different operational rules, and implement principles to promote sensible behavior by banks.

In 2002, the program was again revised in order to evaluate the financial crisis of 2000-2001 and take its causes and consequences into consideration. The most persistent macroeconomic problem in the country was high inflation rates. To address and control the high rate of inflation, in 2002, the government decided to introduce "inflation accounting" to detect inaccurate financial reporting (Arsoy and Gucenme, 2009). The main purpose of this was to protect the economy against unexpected issues such as external shocks or fluctuations in inflation rates. The implementation of this well-designed and appropriate plan led Turkey to experience a stabilization of its economy during the period 2002-2007. Furthermore, the restructuring of the state and private banks improved both the profitability and stability of the Turkish banking system, since the NPLs on banks' balance sheets were matured against government debt securities (Aysan and Ceyhan, 2008). As a result, the ratio of NPLs to total gross loans declined from 4.3% in 2005 to 3.5% in 2006, and then to 3.4% in 2008. The BRSA played a central role in reorganizing the sector by imposing strict supervision policies, according to which banks were required to make more details and reports available to both sector authorities and other individuals. The ratio of loans to GDP exploded from 15% to 29% during 2003-2006, as Turkish banks offered attractive opportunities to investors with returns on equity of more than 20% annually. Banking regulations were again reconsidered in 2005, this time on the basis of international standards, and as a result, the profitability of the Turkish banking sector increased, while there was also a decline in the rate of inflation, from 54.2% in 2001 to 8.8% in 2007, and a consistent improvement in the government's budget balances (Alper and Anbar, 2011). Like other economies, the recent financial crisis of 2008 had a considerable impact on the Turkish economy and banking sector, but this impact was relatively limited, in comparison to other developing and developed countries (Aras, 2010; Yorukoglu and Atasoy, 2010), which could be due to the post-2001-crisis restructuring program, and the macroeconomic policies of the Central Bank of Republic of Turkey (Yuce, 2009). Although the literature indicates that the actions taken by the Turkish government and the IMF successfully limited the extent of the financial disaster for both banks and the broader Turkish economy, the risk of potential instability and a financial crisis rose when market interest rates decreased from 25% in 2004 to 11% in 2015, competition intensified, and regulation became even stricter, particularly in wholesale banking, which is traditionally the greatest source of Turkish banks' revenue. Concerns about Turkey's economic sustainability have increased since 2012 as its growth has slowed, per capita income has fallen to around $9,000 per year, and the country's unemployment rate has increased. The majority of Turkey's macroeconomic successes have come into question, given the country's instable and volatile circumstances. Furthermore, from 2006 onwards, there has been a constant increase in the size of the assets owned by Turkish banks, while operational efficiency has improved by about 25% from 2006-2013, while it has fluctuated since 2013. The amount of NPLs in Turkish banks' balance sheets fluctuated significantly in the period 2006-2017, which affected their profitability and efficiency. There was a considerable increase from 2007 to late 2010, when the percentage of NPLs to total loans increased from 3.32% to 4.97%, and although banks and managers were able to successfully control the sudden increase in the rate of NPLs, reducing it to 2.5% by 2011, the trend continued, with fluctuations occurring until December 2017, when it reached 2.8%. The ratio of NPLs after provision to total loans during the period 2011-2016 increased by around 54%, reaching $13.11 million in December 2016, dropping in 2017 to about 27%.

3. A brief literature review

Lovell (1993) defined efficiency as an assessment based on the experiential and optimum values of outputs, which can be generated from a given level of inputs. Efficiency can also be defined and explained as the distance between the existence and optimal quality of inputs and achievable outputs (Coelli and Perelman, 1996). Estimating efficiency is relatively easy when there is only one input and one output in a study; however, when there are several inputs and outputs, maintaining the efficiency as a ratio between two scalars that have been aggregated from inputs and outputs is not an easy task. Efficiency can be distinguished from partial efficiency only when a single production factor is concerned, and full efficiency is only achievable when all factors are taken into account. Moreover, efficiency can be studied in many forms, such as technical and allocative efficiency, which is the main focus of this study. Farrell (1957), and later Charnes and Cooper (1978), treated technical efficiency as a concept that is relative to the best detected action. While this is a method of distinguishing efficient units from inefficient ones, it nonetheless fails to clarify the extent of the inefficiencies of the inefficient units, and the efficiency of the efficient vectors. Differently, allocative efficiency is when all produced outputs are not only at their maximum level considering the given inputs, but are produced until their last unit satisfies a marginal utilization need for customers, and at the same time satisfies the marginal cost for producers; in other words, there is no waste on either the production or the consumption side (Grosskopf, 1993).

Initially, we will summarize some studies that have looked at bank efficiencies. Later, this study will provide a brief summary of efficiency studies that have been conducted in Turkey over the last three decades, after which we will explain the gaps in the literature that our study is attempting to fill.

3.1. A brief overview of efficiency studies

Due to the importance of the banking sector in countries all over the world, there are many studies that have looked at various dimensions of bank efficiency, profitability, and productivity, and the scope of these studies is increasing, due to the importance of this topic. Nevertheless, there are many gaps and issues in the literature that have received insufficient attention; furthermore, the rapid growth rate of financial markets and related issues make it difficult to study bank efficiency and productivity, especially for economies in transition and less developed countries.

Many efficiency determinants and types have been investigated via parametric and non-parametric models for different time periods, while studies have also looked at the impact of deregulation, new regulatory frameworks, financial crises, mergers and acquisitions, and the economic environment in which banks are performing. In this study, before focusing on the Turkish banking sector and literature, we will attempt to give a brief summary, which is presented in full in Appendix D, on efficiency studies in both developed and developing countries in order to provide a better understanding of the concept and importance of bank efficiency.

3.2. Efficiency studies: The Turkish banking sector

Empirical research on the efficiency of Turkish banks has been rather limited, in comparison to more developed economies and European countries. Onis (1995) and Ertugrul and Zaim (1999) used the DEA approach to assess the impact of liberalization on the efficiency of Turkish banks, and confirmed that the financial liberalization that took place in the 1980s positively influenced efficiency. This issue has since been evaluated by other researchers (e.g. Bayraktar, 2010; Aysan and Ceylon, 2008; Ertugrul and Zaim, 1999), who came to a similar conclusion. Likewise, other studies such as Ozkan-Gunay and Tektas (2006), Denizer et al. (2007), and Fukuyama and Matousek (2011) analyzed the efficiency of Turkish banks before and after various financial crises; these studies covered different time horizons and used different datasets to evaluate efficiency, and agree that bank efficiency has been negatively influenced by the crises that have occurred over the last three decades. Some studies, such as Denizer et al. (2007), have shown that this negative impact on efficiency is due more to Turkey's unstable macroeconomic environment than to banking activities. Other comparable studies have not only come to the same conclusion, but also evaluated how a selection of outputs can influence efficiency values, in terms of ownership types; they found that a selection of outputs can directly and positively influence foreign banks' efficiency scores, especially during periods of instability.

Another key feature that has been examined in the Turkish banking literature is type of ownership; the main four ownership styles that have been investigated are foreign, private, state-owned, and investment banks. Of scholars who have looked at the relationship between ownership style and banks efficiency, Bonin et al. (2005) studied the efficiency scores of banks on the basis of their ownership during 1996-2000, applying the stochastic frontier method, and found that government-owned banks (which are equivalent to state-owned banks) are not meaningfully less efficient than private banks. They also confirmed that foreign banks offer better services to customers, and have higher efficiency scores. Finally, they suggested that privatization alone would not be enough to boost the efficiency of the banking sector. Another study that has evaluated the impact of ownership on efficiency is that of El-Gamal and Inanoglu (2005), who found that "state-owned banks" were not unusually inefficient; however, they did find a high level of labor inefficiency in the period 1990-2000. Similarly, Isik and Hassan (2002) studied the possible impact of Turkish banks' ownerships structure on efficiency in the period 1988-1996, applying a series of parametric and non-parametric techniques, and found that foreign and private banks were more efficient than other banks in Turkey, a finding that was confirmed by Fukuyama and Matousek (2011). Another study that considered ownership type as a factor that influences the efficiency of Turkish banks is Yilmaz (2013), who looked at 30 commercial banks and applied the DEA approach between the years 2007 and 2010. This study concluded that the efficiency scores of both domestic and foreign banks decreased during 2008 and 2009 due to the global financial crisis, while they rose again in the years after the crisis. Later, Bayraktar et al. (2010) evaluated the efficiency of Turkish banks from 2007-2010, and found that foreign banks are more efficient than domestic banks. The majority of recent studies take ownership style into account, like that of Assaf et al (2013); they did this not as a factor for evaluation, but rather as a determined condition that can lead to a better analysis.

Furthermore, Isik and Hassan (2002 and 2003), El-Gamal and Inanoglo (2005), and Kasman (2012) have investigated some additional determinants of efficiency such as the impact of bank size, capitalization, and the number of branches. The studies that have evaluated the impact of bank size have not reached a consensus on how this factor influences efficiency. For instance, Isik and Hassan (2002) found a negative correlation between bank efficiency and size, whereas according to Kasman (2012), larger banks are more efficient. Similarly to Yaldim (2002), Kasman (2012) applied DEA to assess the technical and scale efficiencies of Turkish commercial banks, and concluded there is a positive relationship between profitability, bank size, and the level of efficiency. This was confirmed later by Assaf et al. (2013), who focused on the impact of NPLs on the technical efficiency of Turkish banks.

Aysan and Ceyhan (2008) evaluated the relationship between the number of branches of a bank, its capitalization, and level of efficiency, and found a positive correlation between capitalization and efficiency; however, they found no meaningful relationship between the number of branches and the level of efficiency. Capitalization was also investigated by Fukuyama and Matousek (2011), who found a positive relationship between capitalization and technical efficiency in Turkish banks.

3.3. Bank efficiency studies: Using non-performing loans

The quality of banks' assets is a significant indicator of bankruptcy signals, and can influence efficiency and stability. The importance of non-performing loans has been discussed by Mester (1996) and Berger and DeYoung (1997), while many studies have found that NPLs negatively affect banks' efficiency and stability because they deteriorate the quality of assets in a bank. In the current literature, non-performing loans have been categorized as either a controlled variable (e.g. Mester, 1997; Berger and DeYoung, 1997; Fries and Taci, 2005; Podpiera and Weill, 2008) or as a bad output (e.g. Park and Weber, 2006; Fukuyama and Weber, 2008; Hajialiakbari et al., 2013; Fukuyama and Weber, 2015; Kumbhakar et al., 2015; Fukuyama, Hirofumi, and Matousek, 2017). The studies all provide evidence that NPLs contribute to bank inefficiency. Berger and DeYoung (1997) argue that the main drawback of studies that consider the impact of NPLs is their assumption that NPLs are a controlled variable, rather than an undesirable output, which directly affects the process of production. This being so, in this study, NPLs will be considered an undesirable output, while measuring efficiency scores.

Assessing non-performing loans is not an easy task, particularly in Turkey, since due to regular restructuring and reforming programs, there is insufficient time for loans to be registered as non-performing loans; although it is crucial to consider NPLs when analyzing the efficiency of banks in Turkey, one study has focused on this issue (Assaf et al., 2013), but have rather looked at macroeconomic activities. In other words, previous studies address the issue from the perspective of financial sophistication.

3.4. Current gaps

As has been illustrated above, a number of studies since the 1980s have examined the issue of bank efficiency and its determinants. They have been done not only to improve our general understanding of the impact of financial liberalization agendas on bank efficiency, but also to provide more information about the impact of various financial crises on the Turkish banking sector. However, despite being rich, the literature discussed above suffers from some considerable gaps. First and foremost, there is only one study in the current Turkish literature that has considered NPLs as an undesirable output while measuring the bank efficiency. Due to the importance of this parameter, the present research accounts for NPLs and its impact on the Turkish banks efficiency. Furthermore, we use a recent and unique dataset, which makes this research different to previous studies because it provides more recent qualitative and quantitative data, and captures a wider picture of the Turkish banking sector. Using these data also enables us, for the first time in Turkish literature, to evaluate the role of employees' education and gender as two novel efficiency determinants. Finally, the methodology in this research is new to the literature on Turkish bank efficiency. In this research, we deploy a modified version of the DEA introduced and applied by Aparicio et al. (2015), in which undesirable output separately can be defined and evaluated. This method is flexible enough to address potential issues related to noise in the dataset, and also distinguishes inefficiency from normal errors, thereby clarifying the sources of inefficiency. It also gives the research a flexible form of function to estimate the distance function. To evaluate the impact of efficiency determinants, this study applies quantile regression to a panel that has been developed recently in the area of banking and finance by scholars such as Behr (2010), and is very new to the Turkish banking literature.

4. Methodology

4.1. Model description

DEA is a non-parametric approach to estimating production frontiers; through this method, there is no need to impose any hypothesis regarding the functional form of the production function, which makes the analysis more flexible. This approach was first introduced by Charnes, Cooper and Rhodes (1979). In this model, inefficiency is defined as any aberration from the defined frontier. DEA can also compute efficiency measures when there are multiple inputs and outputs, without any requirement such as establishing pre-specified weights for each variable.

The efficiency of decision-making units (DMUs) in this model is calculated based on the assumption that all these units are located somewhere below or above the frontier line. Obviously, all the DMUs that are on the frontier line are considered efficient units, and any deviation from the line illustrates inefficiency. The chief beneficial aspect of the application of DEA is that it can identify and illustrate the source and level of inefficiency for each of the inefficient inputs and outputs.

DEA accepts the taken inputs X_i and outputs Y_i, with i= 1,2,…,N as the assumed constants, and determines the weights of these assumed inputs and outputs for a specific DMU i_0, taking into consideration the fact that the efficiency of the unit should be maximized less than for constraints. These constraints confirm that the best selected weights for DMU i_0 do not illustrate efficiency more than the one in the obtained function.

We follow a constant return to scale in our study, in which we assume that if a combination of (X,Y) is a possible function, then for all the positive scalar t ∈ $\mathcal{R}$, the combination of (tX, tY) is also possible. According to this given production function, the above assumption is represented as ray unboundedness (Banker et al., 1984).

To measure the technical and allocative efficiency of every given Turkish bank, we use a modified version of DEA introduced and applied by Aparicio et al. (2015). This version offers a new directional distance function with an endogenous direction to measure efficiency, at the same time as considering the undesirable outputs.

It is difficult but necessary to decide on the technology production function, especially when looking at undesirable variables to estimate the efficiency; the disposability of a chosen technology function is also an important factor. The inputs/outputs disposability can be defined as the possibility of any reduction or exposure of inputs/output during the production process, by any desired amount. Following this definition, technology disposability can be defined as weak or strong, in order to shrink the undesirable output by a given amount of inputs. An ideal production/technology function is then supposed to demonstrate a strong and free disposability regarding undesirable outputs, according to which the amount of these undesirable outputs can be reduced, without any changes to the other desirable outputs or the given inputs. In contrast, weak and not free disposability illustrates a reduction in the undesirable outputs that is more difficult and dependent on a reduction in the other desirable outputs or changes in the proportion of the given inputs (Zofio and Prieto, 2001). We define the variable vectors in our study as follows:

1) $X_{ij} \in \Re_+$: ith input taken by the jth DMU, i=1,2,…,m , j=1,…,n.
2) $Y^g_{rj} \in \Re_+$: rth "desirable" output which produced by the jth DMU, r=1,…,q , j=1,….,n.
3) $Y^b_{kj} \in \Re_+$: kth "Undesirable" output which produced by the jth DMU, k=1,…l, j=1,…,n.

Accordingly, the DEA technology function can be defined as follows:

$$T = \{(x, y^d, y^u): \sum_{K=1}^{K} z_k y_{qk} \geq y_m, \quad q = 1, \ldots, q, \sum_{K=1}^{K} z_k {y^u}_{rk} = {y^u}_{j}, r = 1, \ldots, J, \sum_{K=1}^{K} Z_K x_{nk} \leq x_n, n=1,\ldots,N, Z_K \geq 0, k = 1, \ldots, K\} \quad (1)$$

where Z_K represents the main variables that are used to enlarge or squeeze a particular perceived combination of functions of DMU i_0 in order to create the U-shaped combination from the achieved inputs and outputs.

Based on the defined technology function T, which is indicated in (1) for each DMUi_0,i = 1,…,N, which is the directional distance function, efficiency can be achieved by resolving the following:

$$D(x, y^d, y^u; g) = max\, \rho^{i'}$$

$$\sum_{i=1}^{I} z_i y_{qi} \geq y_m + \rho^i g_{y^d} \qquad q = 1, \ldots, Q \quad (2)$$

$$\sum_{i=1}^{i} z_i y^u_{ri} = y^u_j - \rho^i g_{y^u} \qquad r = 1, \ldots, R \quad (3)$$

$$\sum_{i=1}^{I} Z_i x_{ni} \leq x_{ni} - \rho^i g_{x_n}, \qquad n = 1, \ldots, N \quad (4)$$

$$Z_I \geq 0 \qquad i = 1, \ldots, K \quad (5)$$

In the above formulas, $\rho^{i'}$estimates the maximum possible increase of desirable outputs/inputs from the maximum possible decrease of undesirable outputs/inputs in order to accurately measure technical inefficiency in DMUs. Consequently, $\rho^{i'} = 0$ illustrates that DMU i_0 is operating on the frontier, and is technically efficient. However, when $\rho^{i'} > 0$, then DMU i_0 operates inside the frontier. This makes it possible to distinguish the technical inefficiency associated with both the desirable and undesirable inputs and outputs; i.e. $\rho^k(q = 1, \ldots, Q) \neq \rho^k(n = 1, \ldots, N) \neq \rho^k(r = 1, .., R)$. Indeed, the concern in the current study is only related to technical and allocative inefficiency from the undesirable output (NPLs).

4.2. The directional distance function approach: The use of the undesirable output

In its initial formulation by Fare et al. (2003), the directional output distance function is a substitute technique that can assess efficiency. In this approach, efficiency is assessed as the ability to expand the desirable outputs, while simultaneously reducing undesirable outputs, assuming that the proportion of inputs remains constant or decreases.
Similarly to above, we assume T to be the function:

$$T = [(X, Y^g) : X \text{ can produce } Y^g] \tag{6}$$

The directional technology distance function takes a broad view of both the inputs and outputs in Shephard's distance function, providing a comprehensive illustration of the production technology function. Assuming d= (-d^x, d^g) is a direction vector, then the function can be formulated as:

$$\overrightarrow{D_T} (X, Y^g; d) = \sup [\delta : (X - \delta d^x, Y^g, \delta d^g) \in T] \tag{7}$$

The above equation attempts to maximize attainable growth in the desirable outputs in d^g direction, with the maximum amount of input reduction in d^x directions. Considering the assumptions we make about technology, the above directional technology distance function (7) can be measured for bank i_0 by resolving the following formula:

$$\max_{\delta, \lambda} \delta$$

$$\text{s.t. } \sum_{j=1}^{n} \lambda_j Y_{rj}^g - \delta d_{ri_0}^g \geq Y_{ri_0}^g , \qquad r = 1, \ldots, q \tag{8}$$

$$\sum_{j=1}^{n} \lambda_j X_{ij} + \delta d_{ij_0}^x \leq X_{ij_0} , \qquad i = 1, \ldots, m \tag{9}$$

$$\sum_{j=1}^{Kn} \lambda_j = 1 \qquad j = 1, \ldots, n \tag{10}$$

It is important to note that in the directional distance function approach, δ = 0 represents efficiency, which is the same as θ =1 in the standard DEA formulation.

The direction vector d = (-X,Y^g) helps to analyze technology, bearing in mind the decided targets about expanding desirable outputs and diminishing undesirable outputs and, if possible, inputs.

This approach that encompasses undesirable outputs results in measurements of efficiency by simultaneously increasing desirable outputs, reducing undesirable outputs, and applying a constant amount of inputs (e.g. Fare et al., 2003; Fare and Grosskopf, 2004; Picazo-Tadeo et al., 2005; Mandal and Madheswaran, 2010).

Accordingly, the technology function that encompasses undesirable outputs can be modified and re-defined as:

$$T = [(X, Y^g, Y^b) \text{ X which then can yield: } (Y^g, Y^b)] \tag{11}$$

Let $\rho(X)$ represent all the possible outputs vectors (Y^g, Y^b) for a specified inputs vector:

$$\rho(X) = [(Y^g, Y^b): (x = X, Y^g, Y^b) \in T] \tag{12}$$

The output is then expected to have the following conditions:

(1) $(Y^g, Y^b) \in \rho(X);\ Y^b = 0 \Rightarrow Y^g = 0$ (null-joint-ness);
(2) $(Y^g, Y^b) \in \rho(X)$ and $0 \leq \delta \leq 1$, then $\delta(Y^g, Y^b) \in \rho(X)$ (joint weak disposability);
(3) $(Y^g, Y^b) \in \rho(X)$ and $\tilde{Y}^g \leq Y^g$, then $\widetilde{(Y^g, Y^b)} \in \rho(X)$ (strong disposability of desirable output).

Under the first condition, we try to illustrate that producing desirable outputs may also lead to undesirable outputs. However, under the second condition, the determinants of shrinking the undesirable output must occur along with a proportional decline in desirable outputs, for which weakly disposable criteria are needed.

The directional technology distance function that encompasses the undesirable factor– in our case, undesirable output (NPLs) – is then formally defined as:

$$\overrightarrow{D_T}\ (X, Y^g, Y^b; d) = \sup\ [\ \delta : (Y^g + \delta d^g, Y^b - \delta d^b) \in \rho(X - \delta d^x\ )] \tag{13}$$

where d = $(-d^x, d^g, -d^b)$. Based on the three discussed conditions, the value δ accounts for the technical inefficiency, while the directional technology function (13) follows to gain the maximum achievable increase in the desirable outputs in direction d^g , and the greatest achievable decrease in the undesirable outputs in direction d^b. When a correct technology function is defined, then equation (13) can solve the below optimization formula to measure the level of efficiency.

$$\max_{\delta, \lambda} \delta$$

$$\text{s.t.} \sum_{j=1}^{n} \lambda_j Y_{rj}^g - \delta d_{ri_0}^g \geq Y_{ri_0}^g\ , \qquad r = 1, \dots, q \tag{14}$$

$$\sum_{j=1}^{n} \lambda_j Y_{kj}^b + \delta d_{kj_0}^b \leq Y_{kj_0}^b\ , \qquad k = 1, \dots, l \tag{15}$$

$$\sum_{j=1}^{n} \lambda_j X_{ij} + \delta d_{ij_0}^x \leq X_{ij_0} \qquad i = 1, \dots, m \tag{16}$$

$$\sum_{i=1}^{n} \lambda_i = 1 \tag{17}$$

$$\lambda_j \geq 0 \quad j = 1, \dots, n \tag{18}$$

Similarly to the model described by equations (8) – (10), we adopt a direction vector d = $(0, Y^g, -Y^b)$ that enables us to expand the desirable outputs and reduce the undesirable outputs, without needlessly boosting the amount of inputs. With this specific direction vector, the measured distance functions do not rely on the units and magnitude of the variable alone, so the value of δ will fit the interval [0, 1].

Table1

Descriptive Statistics (Mil US.$)

Variable	Mean	Std. Dev.	Min	Max
Capital	45.523	82.387	3.623	1169.25
Deposit	10550.7	16938.73	0.029	83107.24
Total Loans & Receivable	7461.004	14247.92	0.043	79073.68
Net Securities	3160.268	7029.979	0.672	50050.32
Off-Balance Sheet Activities	108527.3	593430.1	0.439	1.2000
NPLs	266.142	461.196	0.0637	2612.399
Non-Interest Income	136.861	298.916	-70.966	2514.196
Price of Capital	4.512	49.204	-947.955	826.095
Price of Deposit	0.054	0.202	0.056	5.697
Price of Total Loans & Receivable	3.046	57.252	-39.6	2378
Price of Securities	16.104	313.358	-0.0415	1225
Price of NPLs	583.883	9528	-174.466	2614

A number of inputs and outputs will be taken into consideration in this study. Following the current literature (e.g. Fukuyama and Matousek, 2017; Stewart et al., 2016; Fujii et al., 2014), capital and deposits are the two main inputs used to compute both technical and allocative efficiency. Correspondingly, the desirable outputs will be total loans and receivable, total securities, total off-balance sheet activities, and total non-interest income[1]. NPLs is an undesirable output; this includes due loans in arrears for three to six months, and loan debts of longer than six months in length. Since we need to define two different vectors as input and output prices to compute allocative efficiency, this study calculates the price of capital by dividing total operating expenses by total fixed assets (Burger et al., 1997), and the price of deposits by dividing interest expenses on deposit by total deposits (Molyneux et al., 2003). Additionally, following Fukuyama and Matousek (2017), the price of securities is calculated by dividing the other operating expenses by the total securities, while the price of total loans and receivables is calculated by dividing net interest income/expenses by the total loans and receivables. Lastly, the price of NPLs is calculated by dividing net interest income/expenses by the total amount of NPLs. Given the fact that any correlation between an undesirable output and the inputs, or a desirable output, can lead to a misspecification in the distance function (13), there is a correlation coefficient matrix, which is presented in Appendix C[2].

All the financial data are denominated in millions of US dollars. Table 1 presents descriptive statistics of quarterly variables for 44 Turkish commercial banks, from 2002 to 2017.

5. Data and empirical results

[1] Non-interest income represents how well a bank can generate money from its non-deposit activities.

[2] The correlation coefficient matrix presented in Appendix C indicates that correlations among the variables in this paper are mainly negligible, showing that the model applied in this paper is unlikely to suffer from the issue of considerable multicollinearity.

The sample is made up of 44 banks operating in Turkey, from 2002 to 2017. Our data have been collected from the Banks Association of Turkey (BAT), since it enables us to capture data from almost all commercial banks in Turkey over a long period of time. Our sample is very demonstrative and covers a longer period of time than other available studies in Turkey. Table 2 represents and defines the variables included in this study.

The extraordinary inflationary environment in Turkey can misrepresent the data and results, therefore all our inputs and outputs are denominated in US dollars. According to Assaf et al. (2013), Ozkan-Gunay and Tektas (2006), and Isik and Hassan (2002, 2003), the denomination of variables in US dollars instead of the Turkish Lira not only benefits the literature by managing the possible impact of inflation on real magnitudes, but can also allow a direct adjustment of inflation in the variables. Due to the unstable Turkish macroeconomic environment, it is crucial and rational to adjust inflation for variables since the high inflationary environment in Turkey can falsify the potential result(s) of studies (Fukuyama and Matousek, 2011). We also cleaned our dataset because some variables were omitted. Moreover, some outliers and “zero” variables also have been taken out of the sample since in some cases, they did not match an efficiency target.

According to Berger and Humphrey (1997), there are three main approaches to estimating efficiency. The current paper follows the intermediation approach of Berger and Humphrey (1997) and Molyneux et al. (2003) since it is the best way of assessing bank efficiency as a whole, and not only that of individual branches.

Table 2
Define Input and Output

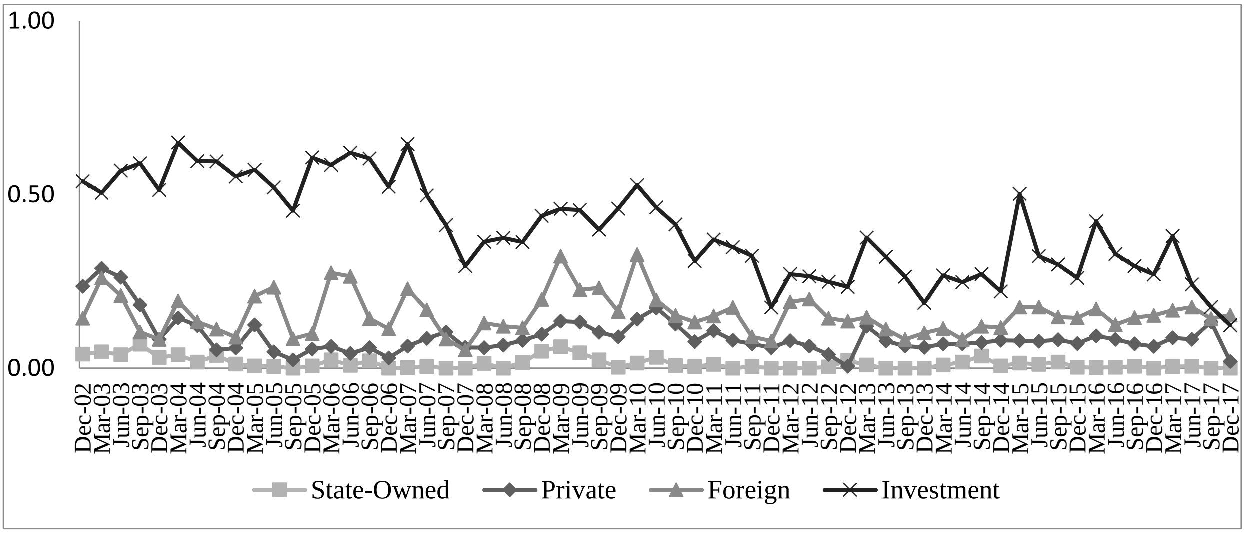
x_1	Capital	Capital
x_2	Deposit	Total Deposit
y_1	Loans and Receivable	Total Loans and Receivable
y_2	Total Securities	"Securities" name was changed as "Financial Assets" at the end of 2002.
y_3	Total Off-balance sheet activities	Off-Balance Sheet Activities
y_4	Non-interest income	The total of "Net Fees and Commissions Income/Expenses", "Dividend Income", "Net Trading Profit and Loss", "Other Operating Income" after 2002.
y_5	Non-performing loans	Non-performing Loans" name was changed to "Loans Under Follow-up".
Px_1	Price of Capital	Total operating expenses/Total fixed assets
Px_2	Price of Deposit	Interested expenses on deposit/ Total deposit
Py_1	Price of Loan and Receivable	Total net income/expenses/Total loan and receivable
Py_2	Price of Securities	Total other operating expenses/Total securities
Py_4	Price of NPLs	Total net income/expenses/Total NPLs

With regard to the elasticities of the inputs and desirable outputs, all the inputs and the off-balance sheet activities from the desired outputs are statistically significant. The magnitude of the coefficient deposit (x_2) (coeff = 0.363) shows a positive relationship between this ratio and technical efficiency. The magnitude of allocative efficiency is also statistically significant and positive (coeff = 0.477). Since efficiency simply means how successful a bank is at transforming its inputs to desirable outputs, the positive relationships between deposits and technical and allocative efficiency illustrate that banks are performing quite well in their decisions regarding their sources of funds. Obviously, these decisions can influence their quality of lending and consequently, their efficiency measures; similarly, this result can be confirmed for capital. A positive result for capital (x_1) (coeff = 0.0145), as can be expected, illustrates managers do have a good control on capital allocation and their costs.

The reported coefficient of the total off-balance sheet activities (y3) (coeff = -0.0029) indicates a decrease in the number of good outputs. Off-balance sheet activities and contracts may be less important in commercial banks, while given the volatile interest rate environment of Turkey, and considering the possible financial risks such as interest-rate risks, it can be beneficial for banks to take advantage of off-balance sheet activities. In terms of undesirable outputs, non-performing loans (coeff = -0.016) were found to have a negative and statistically significant impact on bank performance, in line with the findings of Assaf et al. (2013). This finding suggests that these outputs can directly influence the level of technical efficiency in a bank. Allocative efficiency performs poorly in response to a variation in NPLs, at a level of 0.01%, while non-performing loans react negatively to changes in allocative efficiency in Turkish banks, with a significance level of 10%. This being so, it can, perhaps, be concluded that the source of Turkish banks' inefficiency is related to both allocative and technical inefficiencies. Since the sample and results can be taken to verify the hypotheses of bad management and bad luck, due to the instable financial environment in Turkey, the importance of both outputs[3] should be considered, while neither should be given priority over the other.

Fig. 1 maps the distribution of average technical efficiency scores, organized by bank ownership type[4]. Generally, the technical efficiency scores of all banks fluctuated considerably over the time horizon of this study. This is consistent with our findings of Turkey's economic and banking circumstances.

Fig.1 Technical efficiency by ownership type



Of the four types of bank ownership, there are sharp variations in both upward and downward trends of average technical efficiency; for instance, the scores of foreign banks dropped from September 2007 to early 2008. Surprisingly, all foreign, investment and private banks performed quite well at the beginning of 2008, while declines in technical efficiency can mainly be seen at the end of that year for foreign and investment banks. We find that state-owned banks are the least efficient type of bank, with an average technical efficiency of 4.8%. Investment and development banks seem to be the most efficient in Turkey, with approximately 71% technical efficiency. This could be due their particular structure, which matches their mission and target in the sector, while it could also be due to their unique reactions to the same shocks in the market. Moreover, these banks do not focus on deposits, which makes them very different to other banks; instead, they are dedicated to other activities such as offering corporate finance, mergers and acquisitions,

[3] Both off-balance-sheet activities and NPLs can influence the level of technical and allocative efficiencies in Turkish banks.
[4] TableA.1-2 represents the average technical and allocative efficiency scores per ownership in details in Appendix A.

and foreign exchange to customers, and governmental funds to various sectors of the economy (Etkin et al., 2000).

5.1 The determinants of bank efficiency

There is well-established empirical research that reveals the independent variables that characterize the financial aspects of banks, and are important in determining banks' efficiency (Fethi and Pasiouras, 2010). We investigate two novel determinants of efficiency: bank employees' education and gender; no previous studies have attempted to study the impact of these qualitative factors on Turkish banks' efficiency. This is worth doing, since not only it could lead to improvements in management decisions, but also to bank performance. The current paper investigates the determinants of bank efficiency by applying quantile regressions, which in the case of banking, is a technique that has been applied only recently (e.g. Filippaki et al., 2009). Of the various determinants that have been analyzed in the literature, some have been selected for investigation in the current study. We selected the following regression specification:

NC_O = f (Capital Ratio, NIM, NNIM, ROA, Age, DUMMY1[5], DUMMY2, DUMMY3, DUMMY4, DUMMY5[6], DUMMY6)

In the set of independent variables in our model, in order to control for leverage effect – the fact that the higher the leverage, the more violate the return (Mamatzakis et al., 2012, cited in Saunders et al., 1990) – we use the capital-to-assets ratio, which also accounts for banks' capitalization. Furthermore, we make use of the net interest margin (NIM), which is measured as net interest income compared to total deposits, and the net non-interest income margin (NNIM), which is defined as net non-interest income compared to total assets (Fukuyama and Matousek, 2011). These two variables control for management quality. To account for specific bank characteristics, we chose to use the performance variable, which is represented by return on assets (ROA= net income/total assets). Furthermore, we employed dummy variables to distinguish between employees' gender and level of education. Following Fukuyama and Matousek (2011), we also include the variable of a bank's age to investigate whether any meaningful relationship can be found between banks' efficiency and their years of operation in the market.

Quantile regression can be particularly advantageous in efficiency analysis studies, especially because this method is applicable when there is extensive heterogeneity in the data collected (Behr, 2010). Moreover, the applied conditional quantile is more robust against outliers, and measures means of drawing different slope parameters that describe the production of the most efficient banks, rather than the less efficient ones. Furthermore, as Li et al. (2009) have discussed, although quantile regressions require an assumption about the functional form of the production function – which addresses any possible criticism of the use of DEA in the first part of this paper to estimate efficiency scores – it can be used without imposing a particular form on the distribution of the inefficiency terms. This method also yields the random error, which is another reason why DEA has been criticized.

A quantile regression is particularly useful when the conditional distribution is not standard, and its shape instead illustrates asymmetric, fat-tailed, or truncated distribution, making it suitable for our study. This being so, quantile regression has recently begun to be applied in various strands of the finance and banking literature, including banking risk regulation (Klomp and De Hann, 2012), herding behavior in stock markets (Chiang et al., 2010), capital structure (Fattouh et al., 2005), bankruptcy prediction (Li and Miu, 2010), ownership and profitability (Li et al., 2009), and the relationship between stock price index and exchange rates (Tsai, 2012). In the context of our study, a quantile analysis is an ideal way to examine efficiency

[5] Dummies 1-4 indicate different levels of employees' education, including primary, high school, undergraduate, and graduate degrees.
[6] Dummies 5 and 6 indicate employee's gender: female and male, respectively.

determinants and bank efficiency heterogeneity; it differs from conditional mean models because it enables efficient or almost efficient banks to apply production relations that may vary from average or inefficient banks by providing the most appropriate benchmark within the chosen quantile (Chen, 2005).

We compute technical efficiency scores, considering NPLs as a bad output, for each bank in our sample using the unique DEA model applied by Aparico et al. (2015), and comparing these scores across different quantiles and different types of ownerships. In order to include as wide a range of quantiles as possible, we run regressions for quantiles 0.1, 0.25, 0.5, 0.75, and 0.90.

Fig. 2 reveals technical efficiency scores across quantiles. There are three interesting findings here to be evaluated. First, there is considerable variation across quantiles. Second, technical efficiency estimates across quantiles, and especially in the tail of the distribution, vary noticeably from the conditional mean (OLS) point estimate of efficiency, which is approximated by quantile 0.5, and equals 0.1525. This being so, the quantile regression analysis provides more inclusive results of the fundamental range of inequalities in technical efficiency than the OLS estimation. Third, technical efficiency monotonically increases as it follows a positive trend at the higher order of quantiles.

Fig.2 Technical Efficiency in Different Quantile

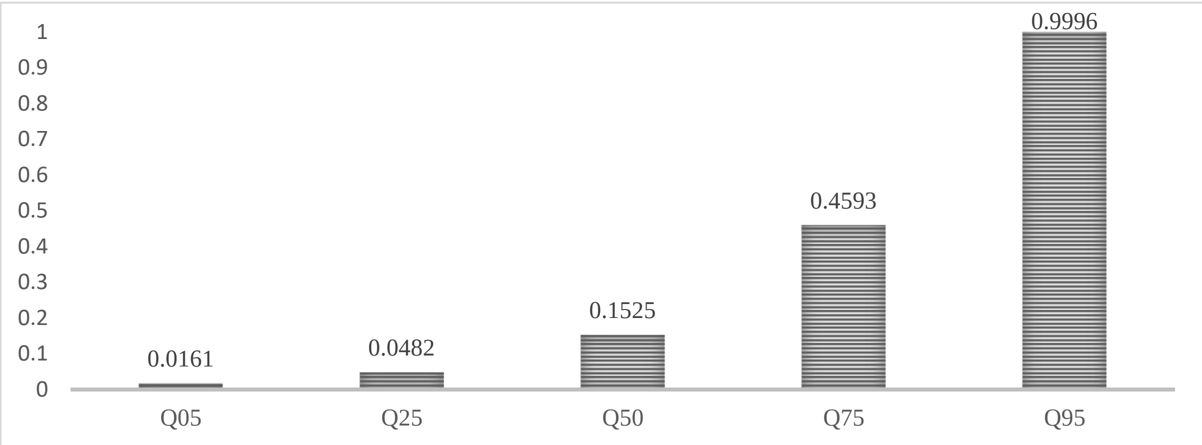
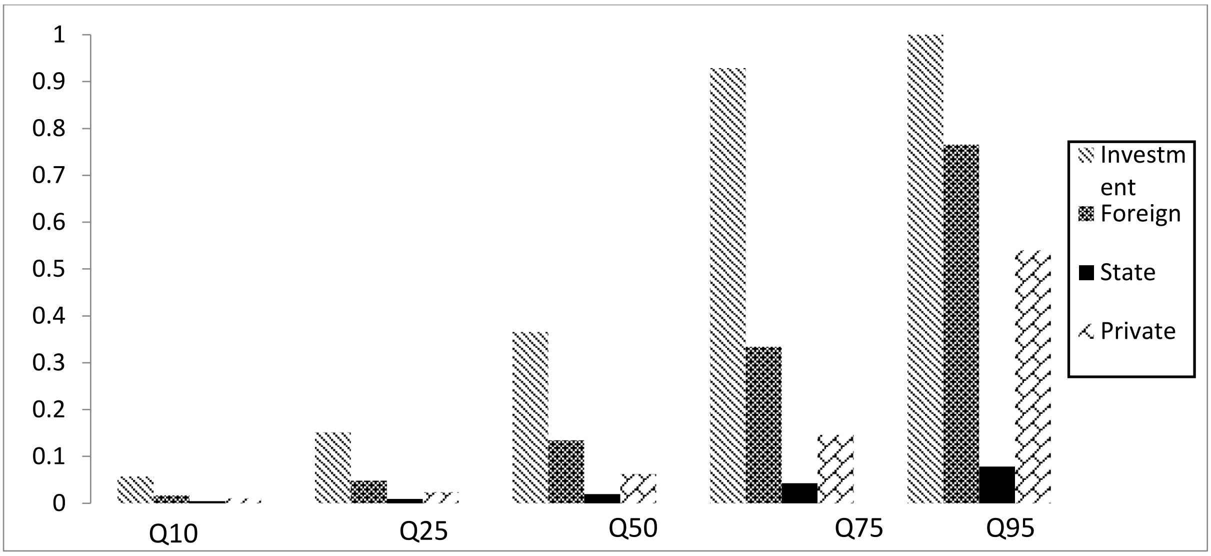


Fig. 3 presents a disaggregation of the estimated technical efficiency in different types of ownerships in Turkish banks. First, this disaggregation confirms the aforementioned trend of technical efficiency in different quantiles, in that it increases in higher quantiles, irrespective of the level of technical efficiencies for each type of ownership and in each quantile. Second, it illustrates some variability in the underlying relationship between ownership types and technical efficiency; in other worlds, the influence of different types of ownership on technical efficiency can also be confirmed by quantile regression. For instance, a higher technical efficiency is generally reported in investment banks, compared to other banks. Moreover, we observe that the largest banks, which are state-owned and private banks, respectively, are less efficient in lower quantiles, and more efficient at higher quantiles. This shows that conducting a simple OLS mean regression analysis would result in a loss of valuable information regarding banks' performance across the world. Finally, the technical efficiency of investment and development banks is always higher than other bank types in various quantiles, and this result is robust. It is worth mentioning that the results obtained for the state-owned and private banks are similar to those of other research, and they show the lowest level of performance in our sample. This suggests that the reforming programs for banks put in place since 2001 in Turkey could have been more advanced and well-designed, and thereby better improve the banks' performance.

Fig.3 Technical Efficiency for each Ownership Style in Different Quantile



Tables B.1-2, which are presented in details in the appendix B, contain estimates of the impact of selected determinants on both technical and allocative efficiency. The coefficient of the capital ratio is positive and statistically significant, which implies a positive relationship between the capital ratio and both technical and allocative efficiency. Moreover, the NIM coefficient is positive and statistically significant, but ignores any misuse of deposits to produce loans and securities in Turkish banks. Unlike NIM, the NNIM coefficient is negative, which may indicate that banks are suffering from bad management systems that are unable to effectively control non-interest income. This coefficient is also statistically significant, in the case of technical efficiency. We also evaluate the Spearman's rank correlation coefficient between the obtained scores for each efficiency type and ROA across different quantiles, while the subsequent positive and statistically significant coefficient corresponds to the findings of other empirical studies (Fukuyama and Matousek, 2011; Isik and Hassan, 2003), indicating that more efficient banks also show a higher level of performance: more efficient banks also perform better. This study finds that older banks are more efficient, which could be due to experience and customer trust, and because they have adjusted to new technologies more effectively than more recently founded banks. Moreover, we find that less educated employees can negatively influence both technical and allocative efficiency, while more educated employees have the opposite effect. One interesting finding of this paper concerns the relationship between employee's gender and efficiency; our results confirm that employees' gender does not influence their level of efficiency. Furthermore, productivity increases when employees are more qualified, which confirms that the type of ownership also has an impact on technical efficiency. This result corroborates with those of Fukuyama and Matousek (2011) and Isik and Hassan (2003), who found that foreign banks were more efficient than state-owned and private Turkish banks. In this way, this paper can be said to support the "quiet life' hypothesis, since the coefficients are statistically significant.

5.2. Robustness check

We ran several robustness tests defining various hypotheses. First, we split the sample into pre and post the 2008 financial crisis and investigated for any changes in the efficiency determinants and performance of Turkish banks. Second, we categorized Turkish banks on the basis of their size[7] in order to analyze any emerging patterns between the size of the banks in different ownerships and the level of efficiency in Turkish banks. Finally, we use an alternative measure of banks' risk which is Z-score[8]. A higher figure of volatility of Z-score indicates lower risks in Turkish banks. TableB.3-8 indicates all the results of robustness check. TableB.3-8 confirms the findings reported in TableB.1 and TableB.2 as follows: 1) more efficient banks represent higher capital ratios 2) approving "bad management" hypothesis in Turkish banks 3) negative sign for NNIM shows managers wasting their non-interest incomes 4) the older banks are the most efficient ones 5) hiring more educated employees enhances both technical and allocative efficiency in banks and finally 6) no relation between employees' gender and the level of efficiency can be confirmed. Moreover, by adding risk measure we found that there is a negative relation between efficiency and Z-score in Turkish banks. Additionally, all of the state-owned banks and majority of private banks, which are the main source of technical inefficiency over the study's time horizon, are categorized in our large banks category.

6. Conclusion

Over the last three decades, many regulators and academics have been interested in the issue of Turkish bank efficiency, and have recognized the country's need for an efficient and well-organized banking system, given that it makes up a majority of the Turkish economy as a whole. Despite the large size of the contemporary literature on Turkish banking efficiency, there is a significant gap in the field, in that there is only one study (Assaf et al., 2013) that has analyzed the impact of NPLs on banks' efficiency and productivity. Consequently, the main aim behind this paper is to assess the technical and allocative efficiency of Turkish banks, while accounting for the impact of NPLs. The current paper also provides an additional direction by modeling banks' production function, focusing on NPLs as an undesirable output. To evaluate the impact of NPLs on technical and allocative efficiencies, we applied a modified DEA model too look at directional measures of efficiency, as done in Aparicio et al. (2015). This model uses an exogenous vector for the undesirable output, while the assumption of the underlying technology is non-homothetic. This model eliminates the inconsistencies of the traditional DEA model (Chung et al., 1997), and thereby allows us to distinguish the vectors for undesirable from desirable variables, and to capture more accurate scores for technical and allocative efficiency. Furthermore, by applying this method, we can distinguish between both sets of desirable and undesirable outputs in order to eliminate any possible bias. We also looked at data over a long period of time, and thereby comprehensively analyzed variations in Turkish banks' efficiency, and their response to local and global financial crises. Although efficiency improved after the financial crisis of 2001, we report that Turkish banks' efficiency remains rather low, with a mean technical efficiency level of 1.21. Furthermore, after the global financial crisis of 2008, there was another slight upward trend in efficiency, indicating that although Turkish banks do not seem to have fully revived, they managed their risks and performed unexpectedly well. However, this upturned performance did not continue for long; many Turkish banks experienced fluctuations in their technical efficiency trend since 2009, although there were fewer fluctuations in allocative efficiency. We further find that since the restructuring and reform program implemented by the Turkish government, foreign banks in Turkey can be said to be performing more efficiently in general, in comparison with their Turkish counterparts. The same result is confirmed in some other studies, such as Fukuyama and Matousek (2011). Our paper reveals that

[7] Following Isik and Hassan (2002 and 2003) we categorized banks size according to their total amount of assets. Small < 100, 100 ≤ Medium <1000, and large ≤1000 ($Million).

[8] Following Fiordelisi and More (2014), Z-score is calculated as the sum of the capital asset ratio (CAR) and the return on assets (ROA) divided by standard deviation return on asset $\sigma(ROA_{c,t})$.

the most stable banks in Turkey, which fluctuate the least, are investment banks. With regard to the impact of undesirable outputs, NPLs have a greater impact on estimations of technical efficiency than allocative efficiency.

NPLs cause more problems in earning assets than in other bank outputs. The model suggests that Turkish banks could increase their good outputs by 17.3%, whilst simultaneously reducing bad outputs by 21%. To boost technical efficiency, Turkish banks could also expand their loans and investment portfolios to achieve the best desirable output combination.

Moreover, investments in technological innovation would be likely to help banks to advance more quickly than their peers and attract customers. Although short-term costs would rise, the benefits for customers and long-term cost savings would generate higher efficiencies in the long term. It is evident that the gap between the target and actual rates of NPLs has significantly increased since December 2011, across the three main ownership structures: foreign, private, and state-owned banks. Our analysis indicates that only development and investment banks have been able to successfully control and reduce the number of their NPLs, while there is further evidence of considerable fluctuations in the trend of securities in Turkish banks. The results indicate that Turkish banks should consider following a specific pattern to stabilize their securities activities. Bank management teams should address this specific issue of underproduction, along with other issues related to the control of NPLs. In terms of the total loans and receivables, which is another output, Turkish banks should take more steps to manage them in the proper manner; an increase in the number of NPLs in the majority of banks could be attributed to a misuse of these loans and receivables, since an increase in the lending of banks corresponds to high levels of uncertainty about the financial stability of potential borrowers, and the country's economy in general.

The applied methodological approach allowed us to compare levels of efficiency and NPLs across different ownership structures of banks. State-owned banks in particular are home to a considerable number of NPLs, and their lending policies do not seem to have been adjusted properly, in the light of financial crises. We explored these results further in our analysis; for instance, we compared the differences between different ownership structures of banks to verify if any substantial differences were to be found. As mentioned previously, state-owned banks are the largest bank type in Turkey, and probably have the greatest impact on the whole economy; for this reason, they generally expect to receive support from the Turkish government during periods of both consolidation and crisis. This being so, they appear less cautious about their management strategies and decisions. We can also confirm that the other types of banks perform better and have larger reserves to cope with potential NPLs.

The other important contribution of this paper is the application of the technique of quantile regression, a flexible method for panel data, to evaluate the impact of efficiency determinants during a particular time horizon. The results obtained from running a quantile regression on the selected determinants confirm that the coefficients of capital ratios are statistically significant for both technical and allocative efficiency, and we may assume that banks with higher capital ratios are also more effective in allocating credit, and in general in the production process; in other words, the more capital to which banks have access, the higher their technical and allocative efficiencies. The NIM coefficient is positive and statistically significant, although it ignores the potential issue of the misuse of deposits in Turkish banks to produce loans and securities. Dissimilarly to NIM, the NNIM coefficient is negative, which may indicate that banks are suffering from bad management systems, and managers are unable to successfully control non-interest incomes. This coefficient is also statistically significant in the case of technical efficiency. Furthermore, the positive and statistically significant coefficient of the ROA corresponds with the findings of other empirical studies (e.g. Assaf et al. 2013; Fukuyama and Matousek, 2011), while a positive and statistically significant relationship between banks' age and both technical and allocative efficiency was found, in addition to between employees' level of education and banks' technical and allocative efficiency. The presence of more employees with higher levels of education in a bank can improve the efficiency level, but surprisingly, this study has not found any meaningful relationship between employees' gender and level of efficiency. This study is also in line with the findings of Isik and Hassan (2003) and Fukuyama and Matousek (2011), that foreign banks operating in Turkey are more efficient than their domestic counterparts.

In order to evaluate the robustness of our results, we ran three sets of tests. Initially, we split the sample to pre and post financial crisis in 2008 and examined the efficiency determinants and performance of Turkish banks in these two time periods to study. Next, we categorized Turkish banks on the basis of their sizes. Lastly, we applied an alternative measure of banks' risk which is Z-score. TableB.3-8, which are represented in the Appendix B, illustrate all the results of the robustness check. TableB.3-8 approve the findings stated in TableB.1 and TableB.2 regarding efficiency determinants. These findings confirm that more efficient banks represent higher capital ratios and state that negative sign for NNIM is a signal of wasting the non-interest incomes. Furthermore, these findings of our robustness check confirm that the older banks are the most efficient ones. Also, a positive and direct impact of hiring more educated employees on both technical and allocative efficiency is confirmed by our robustness checks. Moreover, we did not find any significant relation between employees' gender and the level of efficiency in our robustness check. Running second set robustness test, we found large banks represent the least level of technical efficiency. Investigating more about them, we found that all of the state-owned banks and most of the private banks belong to the large size bank category. Lastly, when we applied risks measure, we found a negative relation between efficiency and the Z-score in Turkish banks.

Our analysis provides suitable directions for regulators and supervisors to evaluate banks' financial stability. The presence of banks with a riskier portfolio involving a higher level of NPLs can diminish the efficiency level of the Turkish banking system as a whole. This being so, regulators need to sensibly supervise and manage the level of risk in commercial banks, as well as their loan issuance process. Alternatively, our findings indicate that drastic regulatory procedures should be implemented to maintain and improve banks' financial stability, reducing their risk of default and improving their performance.

In summary, this paper has shown how NPLs, along with a number of other efficiency determinants (such as ROA, NIM, and ownership) affect levels of efficiency in a banking system, with a specific focus on Turkey, a country whose history has created a unique banking system that makes it particularly useful and interesting to investigate. This study also provides important information for policymakers, given the openness of the Turkish banking system to new banks. Further research that employs different approaches would help to cross-validate the findings of this paper.

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Appendix A: Efficiency scores by Banks' Ownership Type
Table A.1

Technical Efficiency scores by Banks' Ownership Type

Ownership Type	Private Banks		Foreign Banks		Investment & Development Banks	
Year	Mean	Std.	Mean	Std.	Mean	Std.
2002	0.29	0.60	0.58	0.58	0.72	0.36
2003	0.35	0.28	0.30	0.33	0.68	0.34
2004	0.13	0.14	0.23	0.30	0.67	0.35
2005	0.10	0.09	0.21	0.22	0.59	0.42
2006	0.10	0.06	0.29	0.31	0.72	0.37
2007	0.15	0.18	0.29	0.29	0.57	0.31
2008	0.10	0.10	0.26	0.36	0.45	0.39
2009	0.17	0.22	0.28	0.26	0.47	0.36
2010	0.24	0.27	0.28	0.32	0.45	0.34
2011	0.13	0.15	0.22	0.19	0.36	0.37
2012	0.07	0.15	0.25	0.24	0.32	0.33
2013	0.22	0.10	0.23	0.30	0.37	0.35
2014	0.16	0.23	0.17	0.21	0.31	0.32
2015	0.13	0.20	0.25	0.30	0.39	0.35
2016	0.11	0.19	0.28	0.35	0.43	0.35
2017	0.12	0.20	0.27	0.36	0.31	0.28

Note1. The average of Mean and Std. for each year on the basis of quarterly data have been calculated in order to provide a legible table which is presenting technical efficiency measures per ownership.
Note2. Since only three banks out of forty four commercial banks are reported state-owned banks, we removed these banks from the table. However, the results are available on demand.

Table A.2

Allocative Efficiency Scores by Banks' Ownership Type

Ownership Type	Private Banks		Foreign Banks		Investment& Development Banks	
Year	Mean	Std.	Mean	Std.	Mean	Std.
2002	0.82	0.46	0.74	0.29	0.98	0.03
2003	0.82	0.31	0.67	0.34	0.99	0.03
2004	0.83	0.23	0.63	0.32	0.98	0.03
2005	0.87	0.17	0.71	0.29	0.99	0.02
2006	0.87	0.20	0.74	0.26	0.99	0.01
2007	0.91	0.13	0.82	0.23	0.99	0.01
2008	0.92	0.17	0.88	0.18	0.98	0.05
2009	0.89	0.24	0.88	0.15	0.98	0.04
2010	0.88	0.24	0.94	0.10	0.99	0.02
2011	0.86	0.26	0.95	0.10	0.99	0.02
2012	0.89	0.20	0.93	0.14	0.97	0.08
2013	0.93	0.15	0.90	0.17	0.99	0.02
2014	0.92	0.17	0.89	0.16	0.99	0.01
2015	0.92	0.20	0.87	0.19	0.98	0.04
2016	0.92	0.21	0.88	0.22	1.00	0.09
2017	0.94	0.12	0.85	0.29	0.98	0.03

Note1. The average of Mean and Std. for each year on the basis of quarterly data have been calculated in order to provide a legible table which is presenting allocative efficiency measures per ownership.

Note2. Since only three banks out of forty four commercial banks are reported state-owned banks, we removed these banks from the table. However, the results are available on demand.

Appendix B: Efficiency Determinants Analysis

Table B.1

Impact of Efficiency Determinants on Performance -Quantile Regression

Model	OLS	Q.10	Q.25	Q.50	Q.75	Q.90
Dependent Variable	TE	TE	TE	TE	TE	TE
Capital Ratio	0.0282**	0.0060***	0.0060***	0.0448**	0.0561**	0.0673**
	(0.0038)	(0.0017)	(0.0017)	(0.0021)	(0.0061)	(0.0121)
NIM	0.0206**	0.0199**	0.1308	0.1558	0.0103**	0.0310**
	(0.0041)	(0.0116)	(0.0573)	(0.0069)	(0.0019)	(0.0039)
NNIM	-0.6499***	-0.1863	-0.1264	-0.1459***	0.4880	0.3340
	(0.2642)	(0.2315)	(0.0106)	(0.1292)	(0.3686)	(0.7308)
ROA	0.0078***	0.0060***	0.0110***	0.0055***	0.0041***	0.0096***
	(0.0086)	(0.0013)	(0.0106)	(0.0046)	(0.0013)	(0.0026)
Age	0.0015	0.00009	0.0116	0.0019	0.0097	0.0032
	(0.0002)	(0.000167)	(0.0009)	(0.0001)	(0.0003)	(0.0006)
Dummy1	-0.0013	-0.0023	-0.0021	-0.0020	-0.0032	-0.0034
	(0.0005)	(0.0007)	(0.0087)	(0.0001)	(0.0004)	(0.0014)
Dummy2	-0.0001	-0.0013	-0.0056	-0.0002	-0.0003	-0.0041
	(0.0001)	(0.0043)	(0.0006)	(0.0010)	(0.0012)	(0.0013)
Dummy3	0.00009	0.0011	0.0040	0.0005	0.0008	0.0077
	(0.0001)	(0.0003)	(0.0009)	(0.0009)	(0.0011)	(0.0001)
Dummy4	0.00003	0.0051	0.0056	0.0102	0.0009	0.0051
	(0.0001)	(0.0084)	(0.0016)	(0.0003)	(0.0001)	(0.0013)
Dummy5	0.0009	0.0036	0.0088	0.00002	0.00007	0.0099
	(0.0001)	(0.0003)	(0.0004)	(0.0051)	(0.0021)	(0.00013)
Dummy6	0.0005	0.0094	0.0031	0.0061	0.0214	0.00002
	(0.0001)	(0.0023)	(0.0004)	(0.0087)	(0.0211)	(0.00003)
Constant	0.3522	0.0536**	0.1205	0.2308	0.1904	0.8756
	(0.0095)	(0.0038)	(0.0101)	(0.0107)	(0.0031)	(0.0096)
R-sg	0.1837	0.0112	0.0435	0.1047	0.1849	0.1842
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on technical efficiency. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1

Table B.2

Impact of Efficiency Determinants on Performance -Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	Al	Al	Al	Al	Al	Al
Capital Ratio	0.0413***	0.0127**	0.0459**	0.0558**	0.0408***	0.0178***
	(0.0033)	(0.0109)	(0.0106)	(0.0020)	(0.0003)	(0.0006)
NIM	0.0038***	0.0404**	0.0035***	0.0040***	0.0041***	0.0017***
	(0.0010)	(0.0035)	(0.0034)	(0.0006)	(0.0001)	(0.0002)
NNIM	-1.1219***	- 0.7897***	- 1.7072***	- 1.1408***	-0.0077***	-0.0016***
	(0.1998)	(0.6566)	(0.6370)	(0.1225)	(0.0218)	(0.0373)
ROA	0.0015	0.0097	0.0023	0.0004	0.0008	0.0003
	(0.0007)	(0.0024)	(0.0023)	(0.0004)	(0.00008)	(0.00001)
Age	0.0012	0.0042	0.0017	0.0001	0.0003	0.0003
	(0.0001)	(0.0005)	(0.0005)	(0.0001)	(0.000001)	(0.0003)
Dummy1	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
	(0.00008)	(0.0001)	(0.0001)	(0.00002)	(0.000001)	(0.000001)
Dummy2	-0.00003	-0.0001	-0.00004	-0.0001	-0.0001	-0.00002
	(0.00003)	(0.00002)	(0.00002)	(0.00001)	(0.000001)	(0.000001)
Dummy3	0.00004	0.0003	0.00001	0.00001	0.00001	0.00002
	(0.00004)	(0.00009)	(0.0001)	(0.00001)	(0.000003)	(0.00001)
Dummy4	0.00002	0.0007	0.0001	0.0002	0.00002	0.00003
	(0.00001)	(0.0002)	(0.00001)	(0.00003)	(0.00003)	(0.00001)
Dummy5	0.00004	0.0007	0.0002	0.00001	0.00005	0.00005
	(0.00004)	(0.00002)	(0.00002)	(0.0003)	(0.000001)	(0.000001)
Dummy6	0.00005	0.0006	0.00001	0.0005	0.000002	0.00003
	(0.00004)	(0.00001)	(0.00001)	(0.0003)	(0.000001)	(0.000001)
Constant	0.8117	0.2681	0.7270	0.9799	1.0002	1
	(0.0001)	(0.0391)	(0.0379)	(0.0073)	(0.0013)	(0.0022)
R-sg	0.1561	0.1172	0.1245	0.1038	0.059	0.0134
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on allocative efficiency. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.3

Impact of Efficiency Determinants on Performance Before Financial Crisis in 2008- Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	TE	TE	TE	TE	TE	TE
Capital Ratio	0.0210**	0.0001***	0.0067**	0. 0248**	0. 0365**	0.0878**
	(0.0052)	(0.0017)	(0.0029)	(0.0052)	(0.0127)	(0.0122)
NIM	0.0908**	0.0691**	0.0797**	0.1327	0.1013	0.0922**
	(0.0192)	(0.0063)	(0.0107)	(0.0194)	(0.0469)	(0.0453)
NNIM	-1.1381***	-0.3358***	- 0.8431***	- 0.9057***	-1.4205***	-1.9034***
	(0.3055)	(0.1007)	(0.1695)	(0.3075)	(0.7417)	(0.7158)
ROA	0.0078	0.0015	0.0045	0.0051	0.0065	0.0092
	(0.0010)	(0.0003)	(0.0005)	(0.0009)	(0.0023)	(0.0022)
Age	0.0003	0.0005	0.0003	0.0007	0.0012	0.0027
	(0.0006)	(0.0001)	(0.0002)	(0.0004)	(0.0011)	(0.0010)
Dummy1	-0.6718	-0.7750	-0.7735	-0.7685	-0.7758	-0.7566
	(0.0007)	(0.0029)	(0.0039)	(0.0095)	(0.0193)	(0.0019)
Dummy2	-0.0012	-0.7762	-0.7736	-0.7690	-0.7602	-0.7563
	(0.0003)	(0.0023)	(0.0039)	(0.0091)	(0.0195)	(0.0013)
Dummy3	0.0011	0.7723	0.7736	0.7696	0.7601	0.7564
	(0.0003)	(0.0027)	(0.0037)	(0.0092)	(0.0194)	(0.0018)
Dummy4	0.0013	0.7751	0.7737	0.7691	0.7601	0.7564
	(0.0004)	(0.0029)	(0.0034)	(0.0095)	(0.0196)	(0.0019)
Dummy5	0.0012	0.7785	0.7737	0.7690	0.7607	0.7562
	(0.0003)	(0.0025)	(0.0031)	(0.0095)	(0.0192)	(0.0016)
Dummy6	0.0011	0.7764	0.7736	0.7686	0.7602	0.7565
	(0.0003)	(0.0029)	(0.0034)	(0.0092)	(0.0193)	(0.0013)
Constant	0.1964	0.0012	0.0291	0.1050	0.2992	0.5400
	(0.0315)	(0.0090)	(0.0152)	(0.0275)	(0.0665)	(0.06421)
R-sg	0.3651	0.0371	0.0763	0.1248	0.1922	0.3051
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on technical efficiency before financial crisis 2008. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.4

Impact of Efficiency Determinants on Performance Before Financial Crisis in 2008- Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	Al	Al	Al	Al	Al	Al
Capital Ratio	0.0137**	0.0082***	0.0051***	0.0205**	0.0338**	0.0341**
	(0.0048)	(0.0085)	(0.0082)	(0.0084)	(0.01026)	(0.0015)
NIM	0.0672**	0.0375**	0.0487**	0.1027	0.0330**	0.0007***
	(0.0164)	(0.0287)	(0.0277)	(0.0283)	(0.0090)	(0.0053)
NNIM	-0.2420***	-0.2953***	- 0.1928***	- 0.4029***	-0.1966***	-0.0069***
	(0.2462)	(0.4303)	(0.4146)	(0.4248)	(0.1347)	(0.0801)
ROA	0.0069	0.0113	0. 0090	0.0034	0.0008	0.0001
	(0.0010)	(0.0017)	(0. 0017)	(0.0017)	(0.0005)	(0.0003)
Age	0.0007	0.0011	0. 0014	0.0003	0.0007	0.0002
	(0.0004)	(0.0008)	(0. 0008)	(0.0008)	(0.0002)	(0.0001)
Dummy1	-0.0003	-0.0012	-0.0008	-0.0022	-0.0001	-0.0002
	(0.0002)	(0.0004)	(0.0004)	(0.0004)	(0.0001)	(0.0008)
Dummy2	-0.0008	-0.0026	-0.0007	-0.0026	-0.0002	-0.0006
	(0.0002)	(0.0004)	(0.0004)	(0.0004)	(0.0001)	(0.0008)
Dummy3	0.0003	0.0059	0.0005	0.0022	0.0003	0.0004
	(0.0002)	(0.0013)	(0.0003)	(0.0001)	(0.0004)	(0.0002)
Dummy4	0.0003	0.0088	0.0002	0.0096	0.00002	0.0002
	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.00005)	(0.0002)
Dummy5	0.0005	0.0066	0.0001	0.0003	0.00002	0.0009
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.00001)	(0.0003)
Dummy6	0.0007	0.0059	0.0001	00001	0.00001	0.0007
	(0.0006)	(0.0007)	(0.0002)	(0.0001)	(0.00001)	(0.0006)
Constant	0.6277	0.1890	0. 3690	0. 7708	0.9932	0.5400
	(0.0266)	(0.04656)	(0.04487)	(0.0459)	(0.01458)	(0.06421)
R-sg	0.3673	0.3597	0.3450	0.2088	0.0847	0.3051
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on allocative efficiency before financial crisis 2008. Dummy 1-4 represent the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.5

Impact of Efficiency Determinants on Performance After Financial Crisis in 2008- Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	TE	TE	TE	TE	TE	TE
Capital Ratio	0.0270**	0.0017**	0.0345**	0.04170**	0.0300**	0.0007***
	(0.0049)	(0.0007)	(0.0029)	(0.0040)	(0.0092)	(0.0198)
NIM	0.05898**	0.0325**	0.0483**	0.0650**	0.1908	0.1843
	(0.0052)	(0.0052)	(0.0191)	(0.0264)	(0.0608)	(0.1305)
NNIM	-0.1856***	-0.5232***	- 0.0913***	- 0.0383***	-0.8384***	-0.7163***
	(0.0842)	(0.0842)	(0.3077)	(0.4258)	(0.9798)	(0.1009)
ROA	0.0094	0.0001	0.0009	0.0034	0.0100	0.0140
	(0.0016)	(0.0002)	(0.0009)	(0.0013)	(0.0030)	(0.0064)
Age	0.0003	0.00007	0.0001	0.0001	0.0006	0.0039
	(0.0004)	(0.0007)	(0.0002)	(0.0003)	(0.00008)	(0.0018)
Dummy1	-0.00005	-0.00001	-0.00006	-0.00009	-0.00006	-0.0001
	(0.0001)	(0.00001)	(0.00006)	(0.00009)	(0.0002)	(0.0004)
Dummy2	-0.00009	-0.00005	-0.00001	-0.00002	-0.00006	-0.0001
	(0.00009)	(0.0003)	(0.0001)	(0.00004)	(0.00004)	(0.00008)
Dummy3	0.0001	0.00002	0.00006	0.00005	0.00001	0.00004
	(0.0001)	(0.00005)	(0.00004)	(0.00006)	(0.000001)	(0.00003)
Dummy4	0.0001	0.0001	0.00003	0.00004	0.0001	0.0003
	(0.00002)	(0.00001)	(0.00006)	(0.00008)	(0.0001)	(0.0004)
Dummy5	0.00001	0.00006	0.00007	0.00001	0.00003	0.0003
	(0.00007)	(0.00009)	(0.00001)	(0.00008)	(0.00003)	(0.00007)
Dummy6	0.00006	0.00001	0.00002	0.00003	0.00004	0.00004
	(0.00008)	(0.00006)	(0.00001)	(0.00005)	(0.00007)	(0.00002)
Constant	0.2238	0.0186	0. 0301	0.0927	0.2467	07118
	(0.0234)	(0.0037)	(0.0137)	(0.0190)	(0.0438)	(0.0940)
R-sg	0.2232	0.0135	0.0469	0.1248	0.2431	0.2977
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on technical efficiency after financial crisis 2008. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.6

Impact of Efficiency Determinants on Performance After Financial Crisis in 2008- Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	Al	Al	Al	Al	Al	Al
Capital Ratio	0.0438**	0.0343**	0.0492**	0.0598**	0.0541**	0.0180**
	(0.0033)	(0.0099)	(0.0071)	(0.0018)	(0.0008)	(0.0003)
NIM	0.0102**	0.0584**	0.0439**	0.0059***	0.0136**	0.0045***
	(0.0027)	(0.0082)	(0.0058)	(0.0015)	(0.0006)	(0.0003)
NNIM	-0.8335***	-0.9209***	- 1.0560***	- 0.1065***	-0.0089***	-0.0001***
	(0.3325)	(0.0047)	(0.7162)	(0.1897)	(0.0810)	(0.0386)
ROA	0.0020	0.0030	0.0024	0.0004	0.00003	0.00006
	(0.0010)	(0.0032)	(0.0023)	(0.0006)	(0.0002)	(0.0001)
Age	0.0006	0.0023	0.0001	0.0007	0.00002	0.00003
	(0.0002)	(0.0008)	(0.0006)	(0.0001)	(0.00006)	(0.00003)
Dummy1	-0.00007	-0.00006	-0.00003	-0.00004	-0.00006	-0.00005
	(0.00006)	(0.0001)	(0.00001)	(0.00003)	(0.000001)	(0.00006)
Dummy2	-0.00001	-0.0001	-0.00003	-0.00003	-0.00007	-0.00003
	(0.00003)	(0.00003)	(0.00002)	(0.00006)	(0.000002)	(0.00001)
Dummy3	0.00001	0.00003	0.00009	0.00001	0.00007	0.00003
	(0.00006)	(0.00001)	(0.000008)	(0.00002)	(0.00009)	(0.00004)
Dummy4	0.00008	0.0002	0.00008	0.00004	0.00001	0.00001
	(0.00005)	(0.0001)	(0.0001)	(0.00002)	(0.00001)	(0.00006)
Dummy5	0.00008	0.00009	0.00002	0.00005	0.00004	0.00007
	(0.00052)	(0.00003)	(0.00002)	(0.00005)	(0.00002)	(0.00001)
Dummy6	0.0001	0.00005	0.00003	0.00001	0.00001	0.00004
	(0.00005)	(0.00001)	(0.00001)	(0.00005)	(0.00002)	(0.00008)
Constant	0.8525	0.5445	0.8828	0.9860	0.9995	1.002
	(0.0140)	(0.0423)	(0.0301)	(0.0079)	(0.0034)	(0.0016)
R-sg	0.1591	0.3061	0.2692	0.666	0.0811	0.0271
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on allocative efficiency after financial crisis 2008. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.7

Impact of Efficiency Determinants on Performance Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	TE	TE	TE	TE	TE	TE
Z-score	-0.00009	-0.00002	-0.00004	-0.00001	-0.00005	-0.0001
	(0.0001)	(0.00003)	(0.00006)	(0.0001)	(0.0002)	(0.0005)
Capital Ratio	0.0218**	0.0022***	0.0100**	0.0331**	0.0312**	0.0283**
	(0.0038)	(0.0010)	(0.0019)	(0.0031)	(0.0071)	(0.0164)
NIM	0.0799**	0.0094***	0.0636**	0.1040	0.0991**	0.08461**
	(0.0168)	(0.0044)	(0.0084)	(0.0137)	(0.0315)	(0.0722)
NNIM	-0.7952***	-0.1161***	- 0.6777***	- 0.8253***	-1.378***	-0.4893***
	(0.2581)	(0.0681)	(0.1295)	(0.2118)	(0.4842)	(0.1102)
ROA	0.0074	0.0008	0.0026	0.0048	0.0064	0.0072
	(0.0008)	(0.0002)	(0.0004)	(0.0007)	(0.0016)	(0.0036)
Age	0.0004	0.00006	0.00004	0.0002	0.0002	0.0022
	(0.0003)	(0.0001)	(0.00001)	(0.0003)	(0.0007)	(0.0016)
Dummy1	-0.0001	-0.00002	-0.00007	-0.00004	-0.0001	-0.0001
	(0.0001)	(0.00002)	(0.00005)	(0.00009)	(0.0002)	(0.0004)
Dummy2	-0.0001	-0.00002	-0.00007	-0.00001	-0.00004	-0.0001
	(0.0002)	(0.00004)	(0.00008)	(0.00001)	(0.00003)	(0.00007)
Dummy3	0.0001	0.00008	0.00001	0.00005	0.00001	0.00002
	(0.0001)	(0.00001)	(0.00003)	(0.00003)	(0.00001)	(0.00002)
Dummy4	0.0001	0.00004	0.00006	0.00003	0.00001	0.0003
	(0.0001)	(0.00002)	(0.00003)	(0.00006)	(0.0001)	(0.0003)
Dummy5	0.00008	0.00008	0.00002	0.00006	0.00002	0.00008
	(0.0001)	(0.00003)	(0.00007)	(0.00005)	(0.00002)	(0.00006)
Dummy6	0.0002	0.00007	0.00008	0.00005	0.00007	0.00006
	(0.0001)	(0.00001)	(0.00006)	(0.00002)	(0.00003)	(0.00004)
Constant	0.2204	0.01691	0. 0284	0. 0941	0.2746	0.6749
	(0.0190)	(0.0050)	(0.0095)	(0.0156)	(0.0357)	(0.0818)
R-sg	0.2853	0.0166	0.0539	0.1370	0.2224	0.2490
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on technical efficiency with considering Z-score as a proxy of risk. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.8

Impact of Efficiency Determinants on Performance After Financial Crisis in 2008- Quantile Regression

Model	OLS	10	25	50	75	90
Dependent Variable	Al	Al	Al	Al	Al	Al
Z-score	-0.00005	-0.00001	-0.00001	-0.00006	-0.00001	-0.00003
	(0.0001)	(0.0003)	(0.0002)	(0.00008)	(0.00003)	(0.00002)
Capital Ratio	0.0313**	0.0063***	0.0294**	0.0484**	0.0398**	0.0191**
	(0.0031)	(0.0084)	(0.0067)	(0.0023)	(0.0006)	(0.0007)
NIM	0.0758**	0.0752**	0.1076	0.1237	0.0286**	0.0004***
	(0.0114)	(0.0311)	(0.0250)	(0.0086)	(0.0025)	(0.0026)
NNIM	-1.0690***	-0.7139***	- 1.5239***	- 1.2164***	-0.1189***	-0.0001***
	(0.1833)	(0.4973)	(0.4001)	(0.1376)	(0.0400)	(0.0421)
ROA	0.0035	0.0091	0.0039	0.0005	0.0002	0.00004
	(0.0007)	(0.0019)	(0.0015)	(0.0005)	(0.0001)	(0.0001)
Age	0.0008	0.0029	0.0012	0.0002	0.00002	0.00003
	(0.0002)	(0.0007)	(0.0005)	(0.0002)	(0.00005)	(0.00006)
Dummy1	-0.0001	-0.0001	-0.0001	-0.00001	-0.00002	-0.00009
	(0.00007)	(0.0001)	(0.0001)	(0.00005)	(0.00001)	(0.00001)
Dummy2	-0.00003	-0.0001	-0.00007	-0.00005	-0.00003	-0.00006
	(0.0002)	(0.00003)	(0.00002)	(0.00008)	(0.00002)	(0.00002)
Dummy3	0.0001	0.00004	0.00002	0.00003	0.00004	0.00001
	(0.00006)	(0.00001)	(0.000008)	(0.00002)	(0.00008)	(0.00008)
Dummy4	0.0001	0.0002	0.00001	0.00002	0.00001	0.00002
	(0.00008)	(0.0001)	(0.0001)	(0.00003)	(0.00001)	(0.00001)
Dummy5	0.0001	0.0001	0.00006	0.00002	0.00002	0.00004
	(0.00006)	(0.00002)	(0.00002)	(0.00007)	(0.00002)	(0.00002)
Dummy6	0.0001	0.0008	0.00001	0.00001	0.00005	0.00008
	(0.00006)	(0.00008)	(0.00001)	(0.00006)	(0.00002)	(0.00003)
Constant	0.7835	0.2991	0. 6727	0.9835	1.0019	1.0006
	(0.0141)	(0.0384)	(0.0309)	(0.0106)	(0.0031)	(0.0032)
R-sg	0.3013	0.2762	0.2753	0.1680	0.0777	0.0184
p value	0	0	0	0	0	0

Note: This table reports the results of quantile model examining the impact of efficiency determinants on allocative efficiency with considering Z-score as a proxy of risk. Dummy 1-4 represents the employees' education while Dummy 5 and 6 represents number of male and female employees respectively. NIM presents net interest margin, NNIM represents net non-interest margin and age is the number of banks operation. Standard errors in parentheses, ***p<0.001, **p<0.05, *p<0.1.

Table B.9

Average Efficiency by Bank Size

Bank Size	Technical Efficiency			Allocative of Efficiency		
	Average Efficiency	**No.Banks**	**Obs.**	**Average Efficiency**	**No.Banks**	**Obs.**
Small	0. 5239	4	202	0. 7489	4	200
Medium	0. 3815	11	464	0. 8012	11	526
Large	0. 2230	29	1039	0. 9223	29	1576

Note: Following Isik and Hassan (2002 and 2003) we categorized banks size according to their total amount of assets. Small < 100, 100 ≤ Medium <1000, and large ≤1000 ($Million).

Appendix C: Correlation Coefficient Matrix

Table C.1

Correlation Coefficient Matrix

	Deposit	Capital	Total loans & receivable	Net securities	Off-balance sheet activities	Non-interest income	(NPLs)	Price of deposit	Price of capital	Price of loans &receivable	Price of securities	Price of NPLs
Deposit	1.0000											
Capital	-0.1959	1.0000										
Total loans & receivable	0.9370	-0.2302	1.0000									
Net securities	0.9197	-0.1114	0.7439	1.0000								
Off-balance sheet activities	0.7616	-0.2170	0.8496	0.5512	1.0000							
Non-interest income	0.7679	-0.1551	0.7550	0.6959	0.5933	1.0000						
Non-performing loans (NPLs)	0.8108	-0.1822	0.8408	0.6379	0.7553	0.7208	1.0000					
Price of deposit	-0.0339	0.2215	-0.0587	-0.0039	-0.0634	0.0399	-0.0142	1.0000				
Price of capital	0.0571	-0.0698	0.0559	0.0446	0.0607	0.0690	0.0626	0.0662	1.0000			
Price of loans &receivable	-0.0686	0.4600	-0.0678	-0.0548	-0.0621	-0.0532	-0.0679	0.6293	0.0333	1.0000		
Price of securities	-0.0717	0.0878	-0.0643	-0.0700	-0.0562	-0.0551	-0.0674	0.0248	0.0012	0.0373	1.0000	
Price of NPLs	-0.0392	0.0628	-0.0396	-0.0333	-0.0303	-0.0356	-0.0460	-0.0076	0.0537	0.0343	-0.0003	1.0000

Appendix D: Summary of global literature on the Bank efficiency

Table D.1

Summary of literature on the bank efficiency

Authors and Year	Theme	Method	Country	Main Findings
Fukuyama and Matousek (2018)	Banks' network revenue performance	DEA	Japan(2007-2015)	They confirm that the gap between optimal and actual NPLs level significantly deceased. They also state the main source of the Japanese banks inefficiency is from allocative efficiency.
Chen et al. (2018)	Bank efficiency	DEA under stochastic environment	China(2008-2011)	They conclude that different policy should design in terms of high-low efficiency banks. Also, more focused monitoring on the loans and impairment risks in the Chinese banks needed to be taken.
Tan and Floros (2018)	Testing the interrelationships among risk, competition, and efficiency	The efficiency-adjusted Lerner index	China(2003-2013)	They report that higher efficiency leads to higher credit risk and insolvency risk, but lower liquidity risk and capital risk in Chinese banks. They also confirm that the commercial banks take higher credit risk. According to authors competitiveness can increase efficiency in Chinese banks
Tan and Anchor (2017)	Impacts of competition and risk on Chinese bank efficiency	DEA	China(2003-2013)	They find higher competition result in less technical and pure technical efficiency in Chinese commercial banks.
Peng et al. (2017)	Technical, allocative and cost efficiency	DEA	Taiwan(2004-2-12)	Both efficiency and profitability increased. They confirm the positive impact of shareholder value.
Sarmiento and Galan (2017)	Cost and profit efficiency	SFA with random inefficiency parameters	Colombia(2002-2012)	They state that the impact of risk taking differs considering the affiliation and size of bank. They confirm that the foreign and large banks are more efficient.
Delis et al. (2017)	Profit and return efficiency	Risk based SFA	United States(1976-2014)	They claim taking risk in evaluation for efficiency is crucial otherwise results are biased. They also report a tradeoff between risk and efficiency levels.
Simper et al. (2017)	Profit efficiency	Modified DEA to include good and bad output	Korea (2007-2011)	They investigated the preferred method to computing bank efficiency while considering for risk measures
Huang et al. (2017)	Technical efficiency	Stochastic network model	China	They report that Chinese state-owned banks are the least efficient and Chinese joint shock banks are the most efficient banks during 2002-2015.

Feng et al. (2017)	Productivity growth, efficiency change, technical change, and scale effect	SDF method with time varying heterogeneity	United States (2004-2013)	They state there is an unobserved heterogeneity. There is an increase in return to scale and in efficiency and productivity of banks.
Restrepo-Tobon and Kumbhakar (2017)	Revenue, cost, and profit efficiency	Nonstandard profit function approach of Humphrey and Pulley (1997) from applying translog functional forms with standard SFA	United States (2001-2010)	They analyse the impact of cost and revenue efficiency on profit efficiency.
Tan (2016)	Efficiency and risk taking behaviour	Different econometrics methods	China (since 1978)	The author with providing relevant efficiency theories attempt to investigate on efficiency issue with considering the risk taking behaviour in Chinese banks,
Matousek and Tzeremes (2016)	Technical efficiency	Probabilistic DEA	United States(2003-2012)	They confirm nonlinear relation between CEO compensation and bank efficiency. Higher compensation does not lead to higher technical efficiency.
Kao and Liu (2016)	Productivity, efficiency and technical change	Parallel frontier to measure MPI	Taiwan (2008-2013)	They confirm an improvement of productivity in Taiwanese banks from 2008-2013 due to technological improvement.
Silvia et al. (2016)	Risk taking efficiency, cost and profit efficiency	SFA	Brazil(2008-2014)	Investing on periphery structure is beneficial and cost efficient for bank while its risk taking inefficient.
Mamatzakis et al. (2016)	Technical efficiency	Translo enhanced hyperbolic output distance function	Japan (2000-2012)	They report positive relation between bankrupt loans and technical efficiency, which supports moral hazard and skimping hypothesis. Bank luck hypothesis is confirmed in case of restructuring loans.
Asmild and Zhu (2016)	Unrestricted efficiency weighted restricted efficiency	Weighted restricted DEA	European Union (20 countries)(2006-2009)	According to them using the preferred method reduces the overestimated efficiency scores for risky banks. Thus, more accurate results are reported by them.
Zha et al.(2016)	Revenue, cost, and profit efficiency	Dynamic two-stage slacks-based DEA	China (2008-2012)	They believe inefficiency in Chinese banks are due to inefficiency in productivity and in profitability issues. Also, they confirm the impact of ownership on efficiency.
An et al. (2015)	Slack based input/ouput efficiency, deposit generation efficiency, deposit utilization efficiency	Two-stage DEA	China(2008-2012)	They report that Chinese banks performance improved due to deposit utilization efficiency. However, there is still a low efficiency in the context of deposit generation stage

Fu et al. (2014)	Cost and profit efficiency	SFA	Multicounty (Asia Pacific) (2003-2010)	They confirm a positive relation between stock price movement and efficiency. They also state the bank performance is related to market risk, credit losses and bank size.
Hou et al. (2014)	Technical efficiency	Two-stage semi-parametric DEA	China(2007-2011)	They confirm a positive relation between bank efficiency and risk taking.
Tan and Floros (2013)	The relationship between bank efficiency, risk and capital	Three stage least square	China(2003-2009)	They conclude that there is a significant and negative relationship between risk and capitalization, while the relationship between risk and technical/pure technical efficiency of Chinese banks is significant and positive. Also, the positive relation of bank size and efficiency level is confirmed by the authors.
Barros et al. (2012)	Technical efficiency	Non-radial directional performance measurement based on Russel directional distance function	Japan(2000-2007)	They state that non-performing loans have significant impact on bank performance. According to them in Japanese banks labour and premises are underutilized.
Sun and Chang (2011)	Cost efficiency	Heteroscedastic SFA	India, Indonesia, Korea, Malaysia, Philippines, Taiwan, Thailand(1998-2008)	They find a significant impact of risk on the bank efficiency and its degree of influence differs over time and across countries.
Feng and Serletis (2010)	Technical efficiency, return to scale, technical change, total factor productivity	Bayesian translog output distance function	United States(2000-2005)	They state that the regulatory conditions should be imposed while calculating productivity growth to get the most accurate results.
Bos et al. (2009)	Cost and profit efficiency	SFA	Germany(1993-2005)	They claim that heterogeneity should be counted while measuring bank efficiency since their findings show the bank size, location, and type influence on efficiency.
Torrosa-Ausina et al. (2008)	Productivity growth and technical efficiency	DEA, Malmquist productivity index and boostrapping techniques	Spain(2992-1998)	They find a decline in both efficiency and productivity in Spanish banks.