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RESEARCH ARTICLE

Assessing the efficiency and total factor productivity growth of the banking industry: do environmental concerns matters?

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Abstract

This paper investigates the efficiency and total factor productivity (TFP) growth of the Pakistani banking industry and determines the impact of risk and competition on the efficiency and TFP growth. The data envelopment analysis (DEA)–based Malmquist productivity index is used to measure efficiency and TFP growth of the Pakistani banking industry. The generalized method of moments (GMM) model is applied to observe the impact of risk and competition on efficiency and TFP growth. The motivation behind the use of GMM model is its ability to overcome unobserved heterogeneity, autocorrelation, and endogeneity issues. The results of the study show that the credit and liquidity risks have positive while insolvency risk has negative effect on the efficiency and TFP growth. The competition leads to improve technological efficiency but declines the technical efficiency growth. Among other explanatory variables, operational cost management, banking sector development, GDP growth rate, and infrastructure development show significant relationships with various efficiencies and TFP growth. The banks also facilitate for the purchase of carbon-intensive products in order to reduce carbon emissions. Strong banking development successfully allocate their financial resources for the development of energy-efficient technology while banking sector development is found to be negatively related with environmental sustainability. The strong banking sector possesses a significant negative influence on carbon reduction and environmental degradation.

Keywords Competition · Data envelopment analysis · Generalized method of moments · Malmquist productivity index · Risk

JEL classification G21 · D24 · C23 · E44

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Introduction

Nowadays, banks are playing a key role for the sustainable development of the countries. Environmental sustainability has become one of the significant trends. Though the core function of the banks is to boost economic growth and prosperity, but the civil societies in advanced countries have become more concerned about how they fulfill this purpose. The need of "moral capitalism" has emerged which is tune with social and environmental concerns. Banks have been criticized by civil societies regarding their involvement in aiding for various businesses that immensely harm the environment and connected to severe adverse impact on local communities. Although banks do not directly affect the environment and society, they have the ability to do so indirectly via influencing the business organizations they finance. The performance of banks can be better observed by analyzing their productivity and efficiency, as their consequences affect not only the financial institutions and regulatory authorities but also the society as well (Berger et al. 1993). Various scholars used the Malmquist productivity index method (part of the data envelopment analysis (DEA)) for measuring the efficiency and productivity of banks (Berger and Humphrey 1992; Bhattacharyya et al. 1997; Dell'Atti et al. 2015; Kumar et al. 2010; Mansour and El Moussawi 2019; Sufian 2007; Tanna et al. 2017). The growth in technical and technological efficiencies can be better observed through the Malmquist productivity index. Both aforementioned efficiencies are considered extremely important because these are helpful to access the capabilities of banks for minimizing their inputs for a specific amount of output or the extent to which banks can enhance their output by utilizing a certain level of inputs. The pure efficiency and scale efficiency are further extracted from technical efficiency. Pure efficiency identifies the ability and skills of managers to utilize their given resources in an optimum way where the higher value of pure efficiency represents higher managerial skills, whereas lower value represents lower managerial skills and abilities. The scale efficiency of banks denotes the manipulating scale economies by working at a point where the production frontier exhibits constant return to scale.

If the scale efficiency score is less than 1, it means there is room for banks to readjust their scale operations to get their optimum production level while an increase in its value shows improvements in it. Technological efficiency represents how banks are utilizing modern technologies which not only speed up their financial transaction but also improve customer facilitation process through fast human interaction. When both technical and technological efficiencies are multiplied, they give total factor productivity which shows factors partaking in the overall production process.

The impact of risk on the efficiency of banks got considerable attention from scholars after the financial crises of 2007–2008 in all over the world. However, most of the studies which focused risk and efficiency nexus are conducted in advanced countries (Boussemart et al. 2019; Dong et al. 2017; Fiordelisi et al. 2011; Mosko and Bozdo 2016; Tan and Floros 2018; Zhu et al. 2019). In Pakistan, some studies (Bashir and Hassan 2017; Khan et al. 2018) also observed the risk-efficiency nexus in Pakistan by considering various risk-taking behaviors. Their findings suggested the Pakistani government and regulatory authorities to mitigate risk-taking behavior in order to enhance the performance of banks.

Competition is another important factor that can influence banks' performance. The phenomenon of efficiency and competition relationship is elaborated in many banking studies. Some of those studies are consistent with competition-efficiency hypothesis while the others are supportive to the competition-inefficiency hypothesis. In Chinese, American, and European banking sectors, the above-mentioned premises are already tested by different scholars, like Ariss (2010), Brissimis et al. (2008), Casu and Girardone (2009), and Tan and Anchor (2017). However, these hypotheses are still to be experienced in the Pakistani banking industry. The findings of testing these hypotheses will help the Pakistani government, State bank of Pakistan, and banking authorities to make different policies for improving the performance of the Pakistani banks.

This paper is designed to measure the impact of risk and competition on the volatility of efficiency and total factor productivity of Pakistani banks. The credit, liquidity, and insolvency risks are used as risk indicators, while the Lerner index and the Boone indicator are used as competition measures. In addition, unlike others, we measured the impact of competition and risk on the productivity and efficiency growth of banks by using generalized method of movements (GMM) that has ability to overcome heterogeneity endogeneity and autocorrelation problems. Finally, the Pakistani banking industry is a fertile laboratory and worth interesting to study as the banking theories developed in advanced economies may not be same in Pakistan because of different geographical, political, and economic environment (Shair et al. 2019)

The rest of the article is organized as follows: the "Literature review" section contains literature review, the "Materials and methods" section explains the materials and methods, the "Results and discussion" section justifies the results and discussion, while the "Conclusion and policy implication" section concludes.

Literature review

This main section has three subsections; the first section identifies the relevant literature on the impact of risk on banks' efficiency, the second section reviews the impact of competition on banks' efficiency, and the last section shows the

empirical literature that measured the efficiency of the Pakistani banking industry.

Impact of risk on banking efficiency

Banks regularly engaged in various risk-taking activities to get better results. These activities usually assert serious consequences on the banks' performance, so the impact of risk-taking behaviors on the performance of banks has become an important concern in recent literature. The prior studies are mostly observed risk-efficiency nexus by focusing on credit risk and ignored other important types of risks such as liquidity and insolvency risks, which may affect banking efficiency as well. During the financial crises (2007–2008), the banks took excessive risks which led to fire sales, banking run, increased financial fragility, and decreased lending activities (Beltratti and Stulz 2012; Brunnermeier and Pedersen 2008; Shleifer and Vishny 2010). In response to the excessive risk-taking behaviors, the regulatory authorities imposed several restrictions through Basel III standards by imposing higher capital and liquidity requirements among other regulatory measures. In this regard, Tan and Anchor (2017) used several risk measures including liquidity, capital, credit, and insolvency risks to observe their effect on the Chinese banking efficiency. Several studies consider risk as an endogenous variable and observed its impact on the banking efficiency (Altunbas et al. 2007; Berger and DeYoung 1997; Fiordelisi et al. 2011; Zhang et al. 2013). On the other hand, some studies consider as exogenous variables (Chang and Chiu 2006; Chiu et al. 2011; Hughes et al. 2001). All those studies came up with different findings depending on the different methodologies used, conducted in various countries with different banking regulations, geographical, and political environment.

Competition-efficiency nexus in banks

The studies which observed the relationship between competition and efficiency came up with two hypotheses. The first hypothesis argues that in high competition, the relationship of customer and bank is less stable and there is probability that customer can move to another competitor. This can cause information asymmetry and banks have to use more resources for borrowers' screening and monitoring which assert negative effect on banks' efficiency. This is known as competition-inefficiency hypothesis and supported by many researchers like Boot and Schmeits (2005), Chan et al. (1986), DeYoung et al. (1998), Evanoff and Ors (2002), Kumbhakar et al. (2001).

On the other hand, another group of scholars supports competition-efficiency hypothesis by arguing that competition motivates banks to enhance lending technologies and borrowers screening which ultimately improves banks' efficiency. To support this hypothesis, Zarutskie (2013) argued "that more competition prompts banks to specialize and focus on specific types of loans and targeting a particular group of borrowers." It encourages management to adjust their lending technologies which result in better borrowers screening and reduce lending cost. The competition-efficiency hypothesis is also supported by Chen (2007) and Dick and Lehnert (2010).

Investigating efficiency in the Pakistani banking industry

There are some studies published in Pakistan that measured the efficiency of the Pakistani banking industry (Afza and Yusuf 2012; Akhtar et al. 2005; Ansari 2006; Bashir and Hassan 2017; Khan et al. 2018). Even though existing studies shows a quantitative contribution in this line of research, still they have partially viewed the efficiency and ignoring the certain aspects like how the efficiency of banks changes with respect to the level of risk and competition in the banking sector. However, this study will also fill the gap in the existing literature by observing the impact of competition and risk-taking behavior on the efficiency and total factor productivity growth of the Pakistani banks. For econometric estimation, two-step GMM model is used to overcome autocorrelation, unobserved heterogeneity, and endogeneity problems.

Materials and methods

Estimating volatility of technical efficiency, technological change, and total factor productivity in the Pakistani banking industry

Ever since, so far, two methods have been used by scholars to measure efficiency: (1) non-parametric DEA (Konara et al. 2019; Sufian and Habibullah 2009; Tan and Anchor 2017; Triki et al. 2017), (2) parametric stochastic frontier approach (SFA) (Fries and Taci 2005; Phan et al. 2016; Sun and Chang 2011). Seiford and Thrall (1990) claimed that more robust results could be achieved by using DEA for estimating efficient frontier. The use of DEA is more realistic and we preferable because it does not require any additional knowledge for the functional form of frontier and also capable of handling multiple inputs and outputs in various measurement units (Charnes et al. 2013). While selecting inputs and outputs for this study, we adopt the intermediation approach rather than the production approach because banks borrowed funds and invest it into lending and other security investments (Öncü and Aktaş 2007). For measuring efficiency and total factor productivity growth of Pakistani banks, we used deposits and interest expenses as inputs, while loans and interest income are selected as outputs during the study period (2007–2017).

We used the Malmquist productivity index based on the DEA method.

$$M_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1},y_t,x_t\right) = \sqrt{\frac{D_t^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_t^{\text{icrs}}\left(y_t,x_t\right)} \times \frac{D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_{t+1}^{\text{icrs}}\left(y_t,x_t\right)}} \tag{1}$$

We can formulize Eq. (2) as

$$M_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1},y_t,x_t\right) = \frac{D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_t^{\text{icrs}}\left(y_t,x_t\right)} \times \sqrt{\frac{D_t^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)} \times \frac{D_t^{\text{icrs}}\left(y_t,x_t\right)}{D_{t+1}^{\text{icrs}}\left(y_t,x_t\right)}} \tag{2}$$

In Eq. (3), the first part of the right-hand side represents a relative change of technical efficiency (catching-up effect) in the year $(t + 1)$ with respect to the previous year (t), while the geometric mean of these two ratios represents technological change (innovation effect). So by following (Fare et al. 1994), we can decompose the Malmquist productivity index in Eq. (4) into efficiency change and technological change respectively as

$$\text{Efficiency change} = \frac{D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_t^{\text{icrs}}\left(y_t,x_t\right)} \tag{3}$$

$$\text{TECH change} = \sqrt{\frac{D_t^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)}{D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)} \times \frac{D_t^{\text{icrs}}\left(y_t,x_t\right)}{D_{t+1}^{\text{icrs}}\left(y_t,x_t\right)}} \tag{4}$$

Multiplication of efficiency change and technological shift provide change in total factor productivity. While developing the Malmquist productivity index, a range of linear programming problems (LLP) needs to be measured. We measure the Malmquist productivity index by using the input-oriented constant return to scale hypothesis by following the Worthington (2000). Coelli (1996) argued that while using Malmquist productivity index, it does not make any difference whether we use variable return to scale or constant return to scale because both are used to calculate various distances to construct Malmquist indices.

$$\begin{aligned} &\min_{\theta,\lambda}\theta = \left[D_t^{\text{icrs}}\left(y_t,x_t\right)\right]^{-1} \\ &\text{subject to} \\ &-y_{\text{it}} + Y_t\lambda \geq 0 \\ &\theta x_{\text{it}} - X_t\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{5}$$

$$\begin{aligned} &\min_{\theta,\lambda}\theta = \left[D_{t+1}^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)\right]^{-1} \\ &\text{subject to} \\ &-y_{\text{i, t+1}} + Y_{t+1}\lambda \geq 0 \\ &\theta x_{\text{i,t+1}} - X_{t+1}\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{6}$$

$$\begin{aligned} &\min_{\theta,\lambda}\theta = \left[D_{t+1}^{\text{icrs}}\left(y_t,x_t\right)\right]^{-1} \\ &\text{subject to} \\ &-y_{\text{it}} + Y_{t+1}\lambda \geq 0 \\ &\theta x_{\text{it}} - X_{t+1}\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{7}$$

$$\begin{aligned} &\min_{\theta,\lambda}\theta = \left[D_t^{\text{icrs}}\left(y_{t+1},x_{t+1}\right)\right]^{-1} \\ &\text{subject to} \\ &-y_{\text{i,t+1}} + Y_t\lambda \geq 0 \\ &\theta x_{\text{i,t+1}} - X_t\lambda \geq 0 \\ &\lambda \geq 0 \end{aligned} \tag{8}$$

Linear programming models in Eqs. (5) and (6) are calculated by taking the efficient limit of the given period as a base while model (7) relates the data of period (t) with an efficient limit of $(t + 1)$ period. The model represented in Eq. (8) relates the datum of $(t + 1)$ period with period (t) efficient limit. To measure the Malmquist productivity, index of all four linear programming models must be solved for each observation in every period. Thus, given the number of observations (N) and the number of periods (T), $N \times (3\ T-2)$, problems are needed to be solved.

Estimating various types of risks for the Pakistani banking industry

The liquid assets to total assets ratio is used as liquidity risk; Shair et al. (2019) and Tan and Anchor (2017) argued that a lower ratio indicates higher liquidity risk of banks and their inability to meet short-term obligations. The loan loss provisions to total loans ratio is used as credit risk where a higher ratio directs higher credit risk (Athanasoglou et al. 2008; Menicucci and Paolucci 2016; Shair et al. 2019; Staikouras and Wood 2004). The last type of risk is insolvency risk which is measured by Z-score and frequently used in the empirical literature (Berger et al. 2009; Konara et al. 2019; Noman et al. 2017). Z-score is considered an inverse proxy for insolvency risk and measured as

$$Z\text{–score}_{\text{it}} = \frac{\text{Average return on assets}_{\text{it}} + \frac{\text{Average equity}_{\text{it}}}{\text{Total assets}_{\text{it}}}}{\delta\text{ROA}_{\text{it}}} \tag{9}$$

where $\delta\text{ROA}_{\text{it}}$ indicates Sstandard deviation in return on assets of each bank "i" in a specific period "t."

Measuring competition in the Pakistani banking industry

Lerner index This method is a non-structural approach of measuring competition which was developed by Lerner (1934) and is used in recent studies to measure market power of banks in recent studies (Noman et al. 2017; Shair et al. 2019; Tan 2016). The Lerner index represents the banks' ability to set market price above marginal cost, and the deviation of price from marginal cost shows the market power of banks. The value of the Lerner index lies between 0 and 1, where higher value is considered as a markup of price over marginal cost, and deviation of price from marginal cost represents the market power of banks. The value of the Lerner index ranges between 0 and 1, where a lower value represents more competition. The Lerner index can be measured as

$$\text{Lerner index}_{it} = \frac{\text{PTA}_{it} - \text{MCTA}_{it}}{\text{PTA}_{it}} \tag{10}$$

where PTA is the total assets price that is measured by the ratio of total revenue to total assets, where total revenue is equal to the sum of banks' interest and non-interest income, whereas the marginal cost is represented by MC, which is calculated by the translog cost function by following the methodology of Noman et al. (2017) and Shair et al. (2019).

$$\begin{aligned}\ln\text{TC}_{it} = {} & \delta + \nu 1(\ln y_{it}) + \tau 1(\ln w 1_{it}) + \tau 2(\ln w 2_{it}) \\ & + \tau 3(\ln w 3_{it}) + \nu 2(\ln y_{it})^2 + \nu 3(\ln y_{it})(\ln w 1_{it}) \\ & + \nu 4(\ln y_{it})(\ln w 2_{it}) + \nu 5(\ln y_{it})(\ln w 3_{it}) \\ & + \tau 4(\ln w 1_{it})^2 + \tau 5(\ln w 2_{it})^2 + \tau 6(\ln w 3_{it})^2 \\ & + \tau 7(\ln w 1_{it})(\ln w 2_{it}) + \tau 8(\ln w 2_{it})(\ln w 3_{it}) \\ & + \tau 9(\ln w 1_{it})(\ln w 3_{it}) + e_{it}\end{aligned} \tag{11}$$

In Eq. (11), lnTC represents the natural logarithm of the total cost and is calculated by the summation of total non-interest, interest, administrative, and other operating expenses. Y_{it} represents total assets that represent output quality of banks. Three input prices $w1_{it}$, $w2_{it}$, $w3_{it}$ are used for the price of the fund, price of labor, and price of fixed capital, respectively. To ensure symmetry and homogeneity in input prices, we imposed the following restrictions:

$$\tau 1 + \tau 2 + \tau 3 = 1$$
$$\gamma 3 + \gamma 4 + \gamma 5 = 0$$
$$\tau 4 + \tau 7 + \tau 8 = 0$$
$$\tau 5 + \tau 7 + \tau 9 = 0$$
$$\tau 6 + \tau 8 + \tau 9 = 0$$

Estimated coefficients of Eq. (11) are used to compute marginal cost (MCTA_{it}).

$$\begin{aligned}\text{MCTA}_{it} = \frac{\text{TC}_{it}}{Y_{it}} \Big(& \nu 1 + \nu 2 \ln(Y_{it}) + \nu 3 \ln(w 1_{it}) \\ & + \nu 4 \ln(w 2_{it}) + \nu 5 \ln(w 3_{it})\end{aligned} \tag{12}$$

After computing the price of output and estimation of the marginal cost of total assets, we can measure the Lerner index for each bank in every year through Eq. (10). Table 1 shows a summary of all the variables that we used for the estimation of the Lerner index.

The Boone indicator This is a non-structural measure of competition that is used as profit elasticity. It supports competition-efficiency hypothesis by arguing efficient banks perform better with the increase of competition; it is used to estimate the percentage loss when marginal cost is increased by 1%. The Boone indicator can be expressed mathematically by the following equation:

$$\text{Profit}_{it} = \alpha + \beta \ln \text{MC}_{it} + e_{it} \tag{13}$$

Estimation model and data

The GMM model used to determine the impact of risk and competition on the volatility of efficiency and TFP is estimated by the model, expressed as:

$$\begin{aligned}G_{it} = {} & C + \delta G_{i,t-1} + \sum_{j=1}^{j} \beta_j X^j{}_{it} + \sum_{l=1}^{l} \beta_l X^l{}_{it} \\ & + \sum_{m=1}^{m} \beta_m X^m{}_{it} + \gamma DUM + e_{it} + \mu_{it}\end{aligned} \tag{14}$$

where the lower value of δ represents a strong competition and faster adjustment to the equilibrium. G_{it} represents the growth of efficiency and total factor productivity. $X^j{}_{it}$, $X^l{}_{it}$, and $X^m{}_{it}$ represent the bank-specific, industry-specific, and macroeconomic variables, respectively, and is our dummy variable which is used to capture the impact of financial crises (2008–2009) on the efficiency and total factor productivity growth. All 26 banks that operated in Pakistan during the study period (2007–2017) are used as sample. Data is retrieved from banks' annual published reports, the ministry of finance Pakistan and World Bank. For econometric estimation, we used two-step GMM model of Arellano and Bover (1995) and Blundell and Bond (1998) with collapse command to get better estimates. The collapsing method was introduced by Holtz-Eakin et al. (1988) to limit the number of instruments because an important issue with the GMM model is "too many instruments" as the number of instruments exceed from the

Table 1 Measurement of variables used for estimation of Lerner index

Variable	Notation		Measurement
Input prices	$w1_{it}$, $w2_{it}$, $w3_{it}$, respectively	$w1$ = price of funds	Total interest expenses/total deposits
		$w2$ = price of labor	Total personnel expenses/total assets
		$w3$ = price of fixed capital	Sum of administrative and other operating expenses/total assets
Output price	Y_{it}		Total assets
Total cost	TC_{it}		Sum of non-interest and interest expenses
Marginal cost	$MCTA_{it}$		Estimated using Eqs. (11) and (12)

number of cross-sections (Roodman 2009). All risk indicators are used as endogenous variables. The Win4DEAP2 software is used to measure the efficiency and TFP growth while STATA 15 is used for measuring competition, descriptive statistics, correlation analysis, and GMM estimation.

Explanatory variables and their expected impact

The study controls various macroeconomic, industry-specific, and bank-specific variables to examine their impact on the growth of efficiency, technological progress, and total factor productivity of Pakistani banks. Bank size, capitalization, operational cost management, and taxation are used as bank-specific variables. Macroeconomic variables include GDP growth rate and infrastructure development, while banking sector development is used as industry-specific variable. To capture the impact of financial crises on the growth of efficiency, technological progress, and total factor productivity of banks, we also used financial crises as a dummy variable. Natural logarithm of total assets is used as bank size that is frequently used in the empirical literature (Shair et al. 2019; Tan 2016). Generally, the effect of bank size on the performance of the bank has been proved to be positive because larger banks are capable of reducing their cost through the economies of scale and scope. However, the larger banks can enjoy such luxury to a certain extent, because when the banks' size becomes extremely large, their efficiency and total factor productivity growth could reduce because of bureaucratic and other reasons. So, we do not have any prior expectations about the impact of size on efficiency and total factor productivity growth of Pakistani banks.

Bank capital is calculated by the ratio of shareholders' equity to total assets; this ratio has been widely used as a proxy of capitalization in recent literature like Dietrich and Wanzenried (2011), Shair et al. (2019), and Tan (2016). Banks with higher capital are usually in a better position to utilize their capital more productively, so the higher ratio of this variable can lead to more efficiency and total factor productivity in banks. On the other hand, a higher level of capital can harm the efficiency and total factor productivity because accumulated capital is also an expense source of financing. These contradictory opinions leave the door open for us to expect its impact on the efficiency and total factor productivity growth of the Pakistani banks.

Operational cost is another important determinant that can influence banks' performance. Many recent studies observed its impact on banks' performance like Dietrich and Wanzenried (2011), Kosmidou (2008), Liu and Wilson (2010), Shair et al. (2019), and Tan (2016). Usually, banks with highly skilled and competent workers have more productivity but such workers are also paid higher salaries which increase banks' operational cost. So, we expect that the banks with higher operational cost will perform better.

The higher taxation increases the cost of banks, which may lead to a decrease in efficiency and total factor productivity growth. So, we expect the negative influence of this variable on banks' efficiency and total factor productivity growth. The liquidity, credit, and insolvency risks are used in this study to observe their impact on the efficiency and total factor productivity of Pakistani banks. By following the bad luck hypothesis proposed by Berger and DeYoung (1997), we expect a negative effect of risk indicators on the performance of banks.

Competition in the Pakistani banking industry is estimated by using the Lerner index and the Boone indicator. Following the efficient-structure hypothesis and competition-efficiency hypothesis, there exist two contradictory opinions among scholars regarding the impact of competition on the performance of banks. So, we cannot expect the impact of competition on the efficiency and total factor productivity growth in the Pakistani banking industry.

Banking sector development is calculated by the ratio of overall assets of the banking sector to the GDP of the country. The banking sector development is expected to assert a negative impact on the efficiency of banks because it identifies more demand for banking services in the economy which may lead to an increase in the prices of banking services. The resulting increases in the banks' profits encourage managers to be less careful about controlling costs which may lead to reduce efficiency.

GDP growth rate is used as a macroeconomic indicator to observe the impact of monetary stable conditions of the country on banking performance. In economics, with favorable macroeconomic and stable monetary conditions, the efficiency and total factor productivity growth of financial institutions would be higher. So, a positive association of GDP growth rate with banks' efficiency and total factor productivity is expected. Another macroeconomic variable used in this study is infrastructure development that is calculated by the number of mobile subscribers per 100 persons in Pakistan each year. We expect a positive impact of this variable on banks' performance because the higher ratio of this indicator shows that country has better telecommunication infrastructure. The description of the explanatory variables and their expected impact on efficiency and total factor productivity growth is given in Table 2.

Results and discussion

The development of banking sector leads to reduce the financing costs and helps in increasing investments in new projects which are not necessarily environment-friendly. The banks also facilitate credit access to customers for the purchase of high-value and carbon-intensive products such as cars and air cooling systems that enhance carbon emissions. These carbon emissions act as most important source of potential global warming. Therefore, it has become extremely important for banks to carefully assess the projects while financing. The banking sector in developing economies has achieved maturity level because it successfully allocated their financial resources to the environmentally friendly projects. It shows that the loan facilities improved with strong banking development and banks successfully allocate their financial resources for the development of energy-efficient technology. On the other hand, in N-11 countries, the banking sector development is found to be negatively related with environmental sustainability. Table 3 shows the descriptive summary of explanatory variables used during the study period. Table 4 shows the annual summary statistics for efficiency and total factor productivity growth in Pakistani banks from 2007 to 2017. We took one-year additional data (2006) for input and outputs because the Malmquist productivity index provides the results from the second year. The highest total factor productivity growth of the Pakistani banking industry was observed in 2007, while the lowest total factor productivity growth in 2013. Both best and worst growth in total factor productivity was mainly caused by innovation effect (technological growth). The growth in technical efficiency was highest in 2008 but it became worst in the very next year because of the financial crises (2008–2009).

Table 5 shows the efficiency and total factor productivity growth of individual banks during the study period. The average total factor productivity of the Islamic banks was found higher than the private, state-owned, and foreign banks. This higher total factor productivity resulted from higher technological progress in the Islamic banks. The private banks showed better performance through technical efficiency growth while the foreign banks showed the lowest efficiency and total factor productivity growth among all banks.

Figure 1 shows the trend of growth for the pure, scale, and overall technical efficiency in the private, state-owned, Islamic, and foreign banks. The Islamic banks showed better growth during this period, as they had the lowest growth for

Table 2 Measurement of variables, their data sources, and expected impact on the efficiency and total factor productivity of the Pakistani banks

Variables	Description	Data sources	Expected impact
Banks' size	Natural logarithm of total assets	Bank scope	+/−
Banks' capital	Total shareholder equity/total assets	Bank scope	+/−
Annual Taxation	Tax/operating profit before tax payment	Bank scope	−
Operational cost	Operational cost/total assets	Bank scope	+
Z-score (insolvency risk)	See the portion for measurement of the risk	Bank scope	−
Credit risk	Loan loss provisions/gross loans	Bank scope	−
Liquidity risk	Liquid assets/total assets	Bank scope	+
The Lerner index (competition measure)	See portion measurement of the Lerner index	Bank scope	+/−
The Boone indicator (competition measure)	See portion measurement of the Boone indicator	Bank scope	+/−
Banking sector development	Total banking assets/GDP	Finance ministry of Pakistan and bank scope	−
GDP growth	The annual GDP growth rate	The finance ministry of Pakistan	+
Infrastructure development	No. of mobile subscribers per 100 persons	World bank	+

Table 3 Descriptive statistics of explanatory variables

Variables	Observations	Mean	Standard Dev	Min	Max
Bank size	286	12.185	1.242	9.098	14.803
Bank capital	286	0.103	0.064	− 0.025	0.349
Annual taxation	286	0.326	0.096	0.152	0.524
Operational cost	286	0.028	0.010	0.004	0.060
Z-score (insolvency risk)	286	117.738	186.501	− 288.041	529.431
Credit risk	286	0.085	0.055	0.001	0.232
Liquidity risk	286	0.092	0.036	0.034	0.186
Banking sector development	286	0.509	0.036	0.454	0.580
Lerner index	286	0.073	0.218	− 0.445	0.989
Boone indicator	286	− 1.628	1.944	− 5.263	1.022
GDP growth rate	286	0.039	0.014	0.004	0.058
Infrastructure development	286	62.874	9.891	39.204	73.357

all three efficiencies in 2007 but end up with second best for the pure and scale efficiencies in 2017. The overall technical efficiency of the Islamic banks also increased from 0.876 to 0.997 from 2007 to 2017, on the other hand for the same efficiency, the private, state-owned, and foreign banks showed a decreasing trend during the same period. Figure 2 also ascertains that for the technological progress and TFP growth, the Islamic banks performed better by achieving from lowest to highest efficiency scores during the study period.

Table 6 identifies that there is no serial correlation among variables that can affect our results because multicollinearity exists if the coefficient is greater than 0.70 (Wooldridge 2015).

Table 7 shows that the Lerner index is significantly positively related to changes in scale efficiency and overall technical efficiency, which means that higher competition leads to lower the growth of scale efficiency and technical efficiency. These findings are consistent with the competition-inefficiency hypothesis (Boot and Schmeits 2005; Chan et al. 1986). However, we find that the higher level of competition leads to positive growth in technological efficiency in Pakistani banks. This means that higher competition led to reducing lending costs through better borrowers screening and adjusting lending technologies, which helped to improve technological efficiency growth in Pakistani banks. This is in line with the studies of Chen (2007), Schaeck and Čihák (2008), and Zarutskie (2013) supporting competition-efficiency hypothesis.

Moving towards the risk indicators, we find that there is a positive coefficient of credit risk with changes in scale efficiency. This identifies that banks having more loan loss reserves are in a better position to achieve the optimal scale of operations which in turn improves their scale efficiency. The significant negative coefficients of liquidity risk identify that the liquidity risk tends to improve technical, technological, and total factor productivity growth positively because a lower

Table 4 Annual efficiency and total factor productivity growth (overall banks)

Year	Efficiency change	Technological change	Pure efficiency change	Scale efficiency change	Total factor productivity change
2007	1.067	1.295	1.048	1.018	1.382
2008	1.084	0.990	1.043	1.039	1.074
2009	0.924	0.991	0.922	1.003	0.916
2010	1.031	0.957	1.072	0.962	0.987
2011	0.986	0.950	0.992	0.994	0.937
2012	0.999	0.945	0.999	1.001	0.944
2013	1.055	0.865	1.015	1.039	0.912
2014	0.965	1.090	0.999	0.966	1.052
2015	1.006	1.054	1.018	0.988	1.060
2016	1.048	0.901	1.000	1.048	0.945
2017	1.000	1.004	0.998	1.002	1.004

Table 5 Efficiency and total factor productivity growth of individual banks

Banks	Efficiency change	Technological change	Pure efficiency change	Scale efficiency change	Total factor productivity change
Private banks					
Askari Bank Ltd.	1.008	0.985	1.004	1.004	0.993
Bank Alfalah Ltd.	1.038	0.995	1.016	1.022	1.033
Faysal Bank Ltd.	1.001	1.010	1.006	0.996	1.011
Habib Bank Ltd.	1.004	0.982	1.000	1.004	0.986
MCB Bank Ltd.	1.000	0.951	1.000	1.000	0.951
Soneri Bank Ltd.	1.013	1.012	1.014	0.998	1.025
Standard Chartered Bank Ltd.	1.014	1.005	1.014	1.000	1.019
United Bank Ltd.	1.006	1.000	1.000	1.006	1.006
Bank AL-Habib Ltd.	1.014	0.99	1.007	1.007	1.004
Summit Bank Ltd.	0.974	0.993	0.974	1.000	0.967
JS Bank Ltd.	1.059	0.988	0.977	1.084	1.046
Bank AL-Habib Ltd.	1.020	0.988	1.021	0.999	1.008
Habib Metropolitan Bank Ltd.	1.022	0.986	1.022	1.000	1.008
NIB Bank Limited	1.021	1.018	1.019	1.002	1.039
Samba Bank Ltd.	1.047	1.020	1.029	1.017	1.068
Silkbank Limited	1.059	1.019	1.058	1.001	1.079
Average	*1.019*	*0.996*	*1.010*	*1.009*	*1.015*
State-owned banks					
National Bank of Pakistan	0.999	0.988	1.000	0.999	0.987
First Women Bank Ltd.	1.002	0.998	1.007	0.996	1.000
The Bank of Khyber	1.015	0.993	1.014	1.000	1.008
The Bank of Punjab	1.019	1.033	1.027	0.993	1.053
Average	*1.009*	*1.003*	*1.012*	*0.997*	*1.012*
Islamic banks					
Bankislami Pakistan Ltd.	1.001	0.998	0.990	1.011	0.999
Dubai Islamic Bank Pakistan Ltd.	1.016	1.006	1.015	1.001	1.022
Meezan Bank Ltd.	1.039	1.025	1.04	0.998	1.065
Albaraka Bank (Census of Pakistan 1998) Ltd.	0.992	0.997	0.993	0.998	0.989
Average	*1.012*	*1.007*	*1.010*	*1.002*	*1.019*
Foreign banks					
Citi Bank N.A.	0.985	1.000	0.987	0.998	0.986
Deutsche Bank AG	1.001	0.985	1.000	1.001	0.986
Average	*0.993*	*0.993*	*0.994*	*0.9995*	*0.986*

amount of this ratio indicates higher liquidity risk. Our results suggest that the insolvency risk is negatively related to pure efficiency growth which is in line with the bad luck hypothesis (Berger and DeYoung 1997), who claimed that an increase in risk level mainly results from exogenous factors rather than managerial skill. This specifies that the Pakistani banks with higher insolvency risk have more encouragements to reduce and better manage inputs in banking operations, which leads to improve the pure technical efficiency growth.

We find that management of operational cost is positively related to change in pure efficiency, technical efficiency, and total factor productivity. This suggests that operational cost management leads to improve managerial skills which further positively contribute to improving total factor productivity growth of banks. The banking sector development is found to be positively related to growth in technological progress. It shows that technological efficiency in the Pakistani banking sector is greater in a more developed banking sector. More developed banking sector identifies that there is more demand for banking services which helps the banks to reduce their costs via economies of scale. This cost reduction drives to a positive influence on technological efficiency growth. The

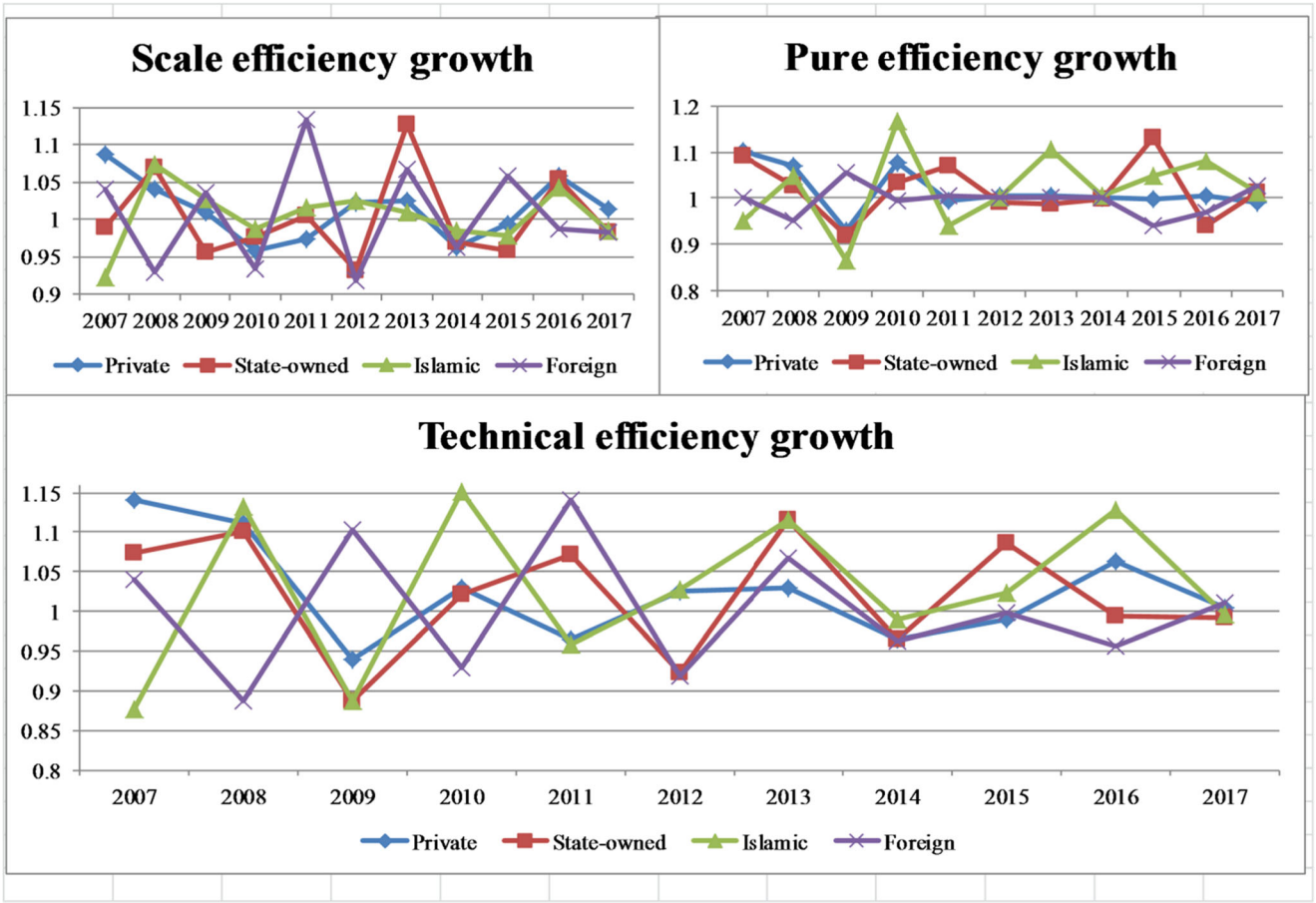

Fig. 1 Growth for the scale, pure and technical efficiency

results identify that coefficients of GDP growth rate are significantly and positively related to the growth in pure efficiency, scale efficiency, technical efficiency, and total factor productivity in the Pakistani banking industry. This shows that during the period of economic boom, the Pakistani banks have higher pure efficiency, scale efficiency, technical efficiency, and total factor productivity growth. This indicates that stable macroeconomic conditions not only increase the demand for banking services increases but also enhance the quality of borrowing. This caused the reduction of cost for monitoring of loan risk and reduction of cost from the economies of scale and scope, which further improved the efficiency and total factor productivity growth of the Pakistani banks. The infrastructure development negatively affects the pure, overall technical, and total factor productivity growth but contributes positively to the change of scale efficiency. The positive impact of infrastructure development (measured by the number of mobile subscribers in the country) on scale efficiency and negative impact on pure efficiency is consistent with the findings of Konara et al. (2019). Finally, the scale efficiency and technological efficiency growth of the Pakistani bank remained positive during the financial crises of 2008–2009.

To check the robustness of our results, we used various methods to measure competition and risks in the Pakistani banks in order to observe their impact on the efficiency and total factor productivity growth. We measured competition with the Boone indicator, credit risk with the ratio of nonperforming loans to total loans, and liquidity risk with the total loans to total deposits ratio. Table 8 shows the results of robustness check that confirms the results of Table 7 as follows: (1) higher competition leads to decrease the growth in the scale and overall technical efficiencies, but improves the growth of technological efficiency; (2) operational cost management contributes positively in the growth of the pure, scale, overall technical efficiencies, and total factor productivity of the Pakistani banking industry; (3) the liquidity risk plays an important role to improve technical, technological, and total factor productivity growth; (4) the pure efficiency growth is negatively influenced by the insolvency risk (*Z*-score); (5) banking sector development positively contributes to the progress of the technological efficiency; (6) GDP growth rate positively affects the pure, overall technical, and total factor productivity growth; (7) infrastructure development negatively affects the pure, overall technical, and total

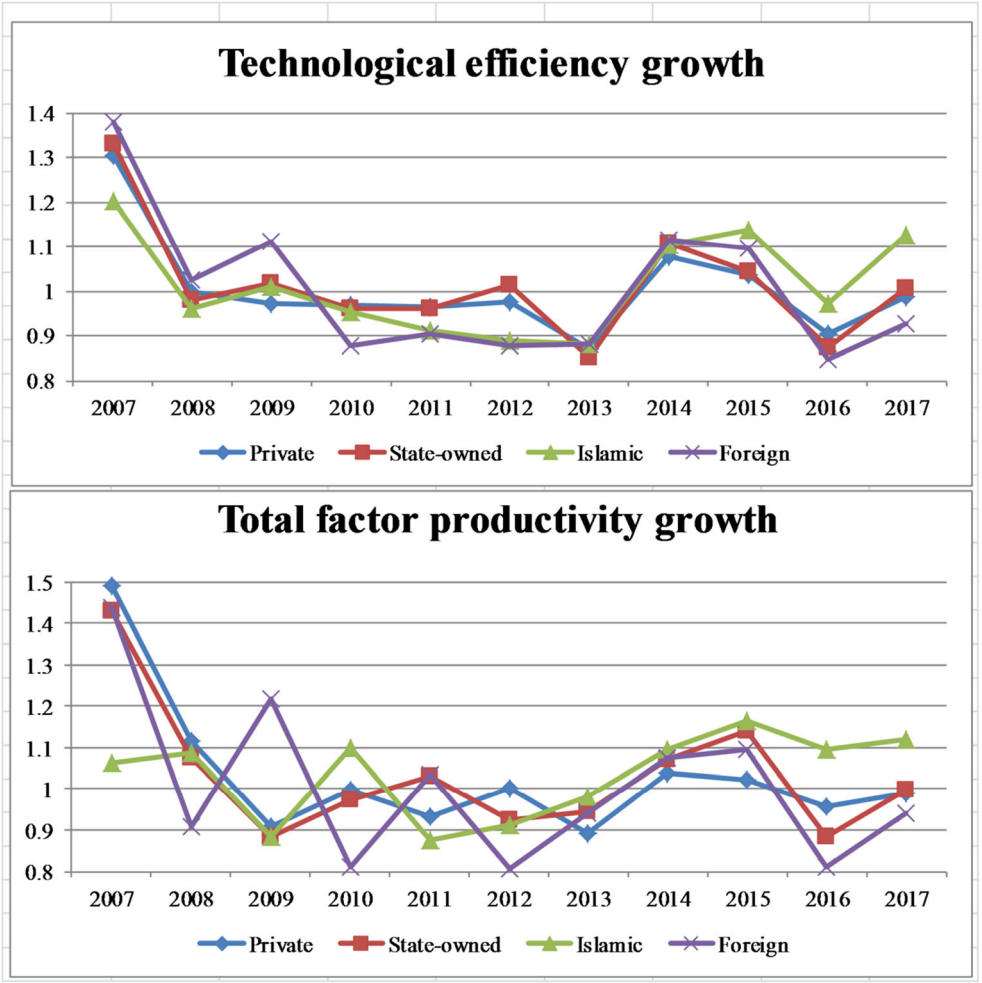

Fig. 2 Growth for technological efficiency and total factor productivity

factor productivity growth but contributes positively in the change of scale efficiency.

t statistics in parenthesis, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$ where *,**,*** indicates that coefficients are significant at 5%,1% and 0.1%, respectively.

t statistics in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$ where *,**,*** indicates that coefficients are significant at 5%,1% and 0.1% respectively.

Conclusion and policy implication

This study was conducted to examine the impacts of competition among Pakistani banks and their risk-taking behaviors on the volatility of their efficiency and total factor productivity. For this purpose, two non-structural approaches, the Lerner index and the Boone indicator, were used for the measurement of competition. Three types of risks including liquidity, insolvency, and credit risks were used to observe their impact on efficiency and TFP growth of banks. In addition to the risk and competition, other control variables were also used, including macroeconomic, industry-specific, and bank-specific variables. The strong banking sector possesses a significant negative influence on carbon emissions and other GHG emission. The Malmquist productivity index was used to measure efficiency and TFP growth during the study period while the two-step GMM model was used for observing the impact of explanatory variables on the efficiency and total factor productivity growth. The findings of the study revealed that the Lerner index has positive relationship with growth of the scale and technical efficiency. It means that growth in scale and technical efficiency is negatively affected by banking competition because higher value of the Lerner index means less competition. It also showed that the Pakistani banking industry is consistent with competition-inefficiency hypothesis regarding technical efficiency. But our both competition indicators showed that technological efficiency improved with the increase in competition. About risk, our study confirms that more liquidity risk tends to improve technical, technological, and total factor productivity growth, while insolvency risk deteriorates the pure efficiency growth. Moreover, the banking sector development improves technological efficiency but deteriorates scale efficiency growth. Infrastructure development influenced positively to the scale

Table 6 Correlation matrix

	(1) Bank size	Bank capital	Annual taxation	Operational cost	Credit risk	Liquidity risk	*Z*-score (insolvency risk)	Banking sector development	GDP growth rate	Infrastructure development	Lerner index	Boone indicator
Bank size	1											
Bank capital	− 0.550***	1										
Annual taxation	0.122*	− 0.0287	1									
Operational cost	− 0.494***	0.468***	0.0201	1								
Credit risk	0.0231	0.0968	− 0.134*	0.0474	1							
Liquidity risk	− 0.178**	0.126*	− 0.0230	0.212***	− 0.237***	1						
Z-score (insolvency risk)	0.0618	− 0.119	0.000807	− 0.167**	− 0.268***	− 0.0334	1					
Banking sector development	0.135*	− 0.0225	0.0873	− 0.132*	− 0.139*	− 0.109	− 0.0273	1				
GDP growth rate	0.196**	− 0.0398	0.106	− 0.124*	− 0.0851	− 0.165**	0.0238	0.559***	1			
Infrastructure development	0.328***	− 0.173***	0.0394	− 0.209***	0.0301	− 0.291***	− 0.00841	0.200**	0.512***	1		
Lerner index	0.378***	− 0.0349	0.210***	− 0.139*	− 0.182**	0.209***	0.385***	0.0683	0.0476	− 0.00768	1	
Boone indicator	0.0881	0.000408	0.162**	− 0.0678	0.0283	0.0248	0.0387	0.241***	0.360***	− 0.0404	0.00605	1

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Table 7 GMM model for the impact of risk and competition (Lerner index) on the efficiency and TFP growth

Independent variables	(1) Pure efficiency change		(2) Scale efficiency change		(3) Efficiency change		(4) Technological change		(5) Total factor productivity change	
L.	− 0.255**	(− 3.33)	− 0.126*	(− 2.77)	− 0.221***	(− 5.94)	− 0.0932*	(− 2.57)	− 0.0595	(− 1.00)
Lerner index	0.0251	(0.63)	0.138**	(3.19)	0.171**	(2.61)	− 0.0859*	(− 7.18)	− 0.0177	(− 1.62)
Bank size	− 0.00542	(− 0.85)	0.00132	(0.38)	− 0.00423	(− 0.82)	0.00142	(0.42)	0.00288	(0.50)
Bank capital	− 0.0266	(− 0.44)	0.00503	(0.09)	0.0218	(0.24)	0.00918	(0.10)	0.0707	(0.57)
Annual taxation	0.0379	(0.78)	− 0.0208	(− 0.94)	0.0186	(0.31)	− 0.0211	(− 0.66)	0.00516	(0.11)
Operational cost	1.912*	(2.79)	0.321	(1.50)	2.073***	(3.75)	0.326	(0.76)	2.662***	(4.51)
Credit risk	− 0.0102	(− 0.04)	0.137*	(2.74)	0.189	(1.63)	− 0.116	(− 0.78)	− 0.0607	(− 0.29)
Liquidity risk	− 0.715***	(− 3.76)	0.250	(1.66)	− 0.352	(− 1.68)	− 0.933***	(− 4.18)	− 1.228***	(− 5.54)
Insolvency risk(*Z*-score)	0.000293***	(5.41)	− 0.0000124	(− 0.80)	0.0000220	(0.62)	− 0.0000116	(− 0.53)	− 0.0000138	(− 0.34)
Banking sector development	− 0.184	(− 1.33)	− 0.122	(− 1.11)	− 0.221	(− 1.12)	0.542***	(8.16)	0.180	(1.07)
GDP growth rate	1.510**	(3.05)	0.971**	(2.80)	3.294***	(5.16)	− 0.284	(− 1.28)	2.605**	(3.14)
Infrastructure development	− 0.00429***	(− 3.84)	0.00210***	(5.05)	− 0.00317**	(− 3.23)	− 0.000395	(− 0.49)	− 0.00338*	(− 2.07)
Financial crises	− 0.0428	(− 1.73)	0.0583***	(4.99)	0.0311	(1.41)	0.0342*	(2.57)	0.0401	(1.81)
Constant	1.661***	(8.96)	0.956***	(13.55)	1.428***	(13.11)	0.908***	(7.95)	1.076***	(6.83)
Observations	260		260		260		260		260	
No. of instruments	26		26		26		26		26	
F test	38.20		59.48		60.24		529.4		23.43	
AR1 (*p* value)	0.00498		0.00355		0.000185		0.0323		0.0120	
AR2 (*p* value)	0.713		0.226		0.115		0.435		0.398	
Hansen-J (*p* value)	0.197		0.0929		0.226		0.317		0.200	

Table 8 GMM model for the impact of risk and competition (Boone indicator) on the efficiency and TFP growth

Independent variables	Pure efficiency change		Scale efficiency change		Efficiency change		Technological change		Total factor productivity change	
L.	− 0.263**	(− 3.44)	− 0.0979**	(9.17)	− 0.186***	(2.22)	− 0.0181	(− 4.44)	− 0.0466	(− 0.69)
Boone indicator	− 0.00298	(− 0.97)	0.00979***	(0.20)	0.00856*	(− 0.26)	− 0.0113***	(0.13)	− 0.00319	(0.37)
Bank size	− 0.00293	(− 0.61)	0.000425	(0.07)	− 0.00113	(0.36)	0.000410	(0.32)	0.00243	(0.62)
Bank Capital	0.000750	(0.01)	0.00321	(− 3.16)	0.0284	(− 0.56)	0.0268	(− 0.27)	0.0833	(0.40)
Annual taxation	0.0502	(1.03)	− 0.0621**	(2.61)	− 0.0363	(4.59)	− 0.0103	(− 0.18)	0.0245	(4.36)
Operational cost	1.904*	(2.67)	0.550*	(1.23)	3.024***	(0.77)	− − 0.0748	(0.56)	2.623***	(0.17)
Credit risk	− 0.0128	(− 0.05)	0.0669	(1.12)	0.106	(− 2.75)	0.0826	(− 4.11)	0.0368	(− 4.24)
Liquidity risk	− 0.688***	(− 3.75)	0.146	(− 0.82)	− 0.606*	(0.19)	− 0.892***	(− 0.31)	− 1.116***	(− 0.18)
Insolvency risk(*Z*-score)	0.000344**	(4.82)	− 0.0000122	(− 3.66)	0.00000619	(− 1.78)	− 0.0000073	(6.83)	− 0.0000072	(1.64)
Banking sector development	− 0.112	(− 0.91)	− 0.355**	(1.89)	− 0.347	(4.42)	0.766***	(− 0.78)	0.325	(3.11)
GDP growth rate	1.589**	(3.09)	0.664	(8.28)	2.769***	(− 1.08)	− 0.239	(− 2.35)	2.700**	(− 2.22)
Infrastructure development	− 0.00504***	(− 3.77)	0.00435***	(8.18)	− 0.00102	(2.72)	− 0.00251*	(− 1.00)	− 0.00431*	(0.74)
Financial crises	− 0.0531	(− 1.95)	0.0942***	(15.22)	0.0626*	(12.02)	− 0.0206	(6.16)	0.0260	(6.07)
Constant	1.637***	(9.48)	0.953***	(15.22)	1.332***	(12.02)	0.840***	(6.16)	1.025***	(6.07)
Observations	260		260		260		260		260	
No. of instruments	26		26		26		26		26	
F test	41.28		50.26		46.82		104.9		23.00	
AR1 (*p* value)	0.00442		0.00530		0.000120		0.0330		0.0103	
AR2 (*p* value)	0.681		0.578		0.391		0.990		0.343	
Hansen-J (*p* value)	0.195		0.144		0.359		0.169		0.142	

efficiency but negatively to the pure, technological, and total factor productivity growth. The pure, technical efficiency, and total factor productivity improve with the strong macroeconomic condition of the country.

Together with energy consumption, financial development also significantly roleplay to environmental degradation. The banks also facilitate credit access to customers for the purchase of high-value and carbon-intensive products such as cars and air cooling systems that enhance carbon emissions. These carbon emissions act as most important source of potential global warming.

The contribution of banking sector in the quality of the environment has been found at greater level. The banking industry is considered as a backbone of the financial system, so to improve the efficiency of the Pakistani banks remained the center of focus for concerned regulatory authority and the government of Pakistan. For this purpose, several banking sector reforms were initiated since last couple of decades. The results of our study are helpful for the Pakistani government and regulatory authorities to improve the efficiency and total factor productivity of the Pakistani banks, as follows:

- The regulatory authorities should make some policies to control competition, as the higher competition tends to deteriorate the technical efficiency of the Pakistani banks, but the regulatory authorities must ensure the growth in technological while making such policies.
- Managerial skills should be improved managers in Pakistan for the better allocation of inputs and outputs; these improved managerial skills will also help to manage operational cost-efficiently, which is a major source of improving technical efficiency.
- The regulatory authority needs to improve its policies regarding the insolvency risk of banks, as insolvency risk asserted negative influence on pure efficiency.
- Holding more liquid assets negatively affected the efficiency and total factor productivity growth, so regulatory authorities should encourage banks to be involved in lending activities with effective borrowers screening, it will also help to enhance investment opportunities in the economy by providing timely loans to entrepreneurs.
- Islamic banking should be encouraged more as it is contributing efficiently to the growth of total factor productivity of the Pakistani banking industry.

There are several limitations based on which future research can extend the current study in several directions.

- Future research can focus on the revenue, profit, and cost-efficiency of the Pakistani banks.
- To get better picture for efficiency of Pakistani banks, some other variables, like mergers and acquisitions and fluctuations in exchange rates, could also be included.
- Risk indicators can be measured with different techniques, like liquidity risk with the volatility ratio of cash to total customer deposits from its trend and credit risk with bank loans to total banks' assets.
- The parametric approach SFA to evaluate the efficiency of banks depending on the sample size can be another direction for further investigation.

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Author contribution Faluk Shair: conceptualization, data curation, methodology, writing original draft. Sun Shaorong: supervision; Hafiz Waqas Kamran: visualization, data curation, editing. Muhammed Sajjad Hussain: review and editing. Muhammad Atif Nawaz: writing, review, and editing. Van Chien Nguyen: methodology, data curation, visualization, software

Data availability The data that support the findings of this study are openly available and attached in this submission.

Compliance with ethical standards

Competing interests The authors declare that they have no competing interests.

Ethical approval and consent to participate We declare that we have no human participants, human data, or human tissues.

Consent for publication We do not have any individual person's data in any form.

References

Afza T, Yusuf MU (2012) The impact of mergers on efficiency of banks in Pakistan. Elixir Int J: Finance Management 48:9158–9163

Akhtar MH, Bokhari H, Director JJ (2005) X-efficiency analysis of commercial banks in Pakistan: a preliminary investigation. Eur J Sci Res 10(2):78–91

Altunbas Y, Carbo S, Gardener EP, Molyneux P (2007) Examining the relationships between capital, risk and efficiency in European banking. Eur Financ Manag 13(1):49–70

Ansari MS (2006). An empirical investigation of cost efficiency in the banking sector of Pakistan: State Bank of Pakistan.

Arellano M, Bover O (1995) Another look at the instrumental variable estimation of error-components models. J Econ 68(1):29–51

Ariss RT (2010) On the implications of market power in banking: evidence from developing countries. J Bank Financ 34(4):765–775

Athanasoglou PP, Brissimis SN, Delis MD (2008) Bank-specific, industry-specific and macroeconomic determinants of bank profitability. J Int Financ Mark Inst Money 18:121–136

Bashir A, Hassan A (2017) Interrelationship among basel capital regulation, risk, and efficiency in Pakistani commercial banks. Bus Econ Rev 9(2):165–186

Beltratti A, Stulz RM (2012) The credit crisis around the globe: why did some banks perform better? J Financ Econ 105(1):1–17

Berger A, DeYoung R (1997) Problem loans and cost efficiency in commercial banks. J Bank Financ 21(6):849–870

Berger A, & Humphrey DB (1992). Measurement and efficiency issues in commercial banking. In Output measurement in the service sectors (pp. 245-300): University of Chicago Press.

Berger A, Hunter W, Timme S (1993) The efficiency of financial institutions: a review and preview of research past, present and future. J Bank Financ 17(2-3):221–249

Berger A, Klapper L, Turk-Ariss R (2009) Bank competition and financial stability. J Financ Serv Res 35(2):99–118

Bhattacharyya A, Lovell CK, Sahay P (1997) The impact of liberalization on the productive efficiency of Indian commercial banks. Eur J Oper Res 98(2):332–345

Blundell R, Bond S (1998) Initial conditions and moment restrictions in dynamic panel data models. J Econ 87(1):115–143

Boot A, & Schmeits A (2005). The competitive challenge in banking. tAmsterdam Center for Law & Economics Working Paper(2005), 08.

Boussemart J-P, Leleu H, Shen Z, Vardanyan M, Zhu N (2019) Decomposing banking performance into economic and credit risk efficiencies. Eur J Oper Res 277:719–726

Brissimis SN, Delis MD, Papanikolaou NI (2008) Exploring the nexus between banking sector reform and performance: evidence from newly acceded EU countries. J Bank Financ 32(12):2674–2683

Brunnermeier MK, Pedersen LH (2008) Market liquidity and funding liquidity. Rev Financ Stud 22(6):2201–2238

Casu B, Girardone C (2009) Testing the relationship between competition and efficiency in banking: a panel data analysis. Econ Lett 105(1): 134–137

Census of Pakistan. (1998).

Chan Y-S, Greenbaum SI, Thakor AV (1986) Information reusability, competition and bank asset quality. J Bank Financ 10(2):243–253

Chang TC, Chiu YH (2006) Affecting factors on risk-adjusted efficiency in Taiwan's banking industry. Contemp Econ Policy 24(4):634–648

Charnes A, Cooper WW, Lewin AY, & Seiford LM (2013). Data envelopment analysis: theory, methodology, and applications. Springer Science & Business Media.

Chen X (2007) Banking deregulation and credit risk: evidence from the EU. J Financ Stab 2(4):356–390

Chiu Y-H, Chen Y-C, Bai X-J (2011) Efficiency and risk in Taiwan banking: SBM super-DEA estimation. Appl Econ 43(5):587–602

Coelli T (1996) A guide to DEAP version 2.1: a data envelopment analysis (computer) program. In: Centre for Efficiency and Productivity Analysis. University of New England, Australia

Dell'Atti S, Pacelli V, Mazzarelli G (2015) The efficiency of the European banking groups and its determinants. Manag Financ 41(7):734–751

DeYoung R, Hasan I, Kirchhoff B (1998) The impact of out-of-state entry on the cost efficiency of local commercial banks. J Econ Bus 50(2): 191–203

Dick AA, Lehnert A (2010) Personal bankruptcy and credit market competition. J Financ 65(2):655–686

Dietrich A, Wanzenried G (2011) Determinants of bank profitability before and during the crisis: Evidence from Switzerland. J Int Financ Mark Inst Money 21(3):307–327

Dong Y, Girardone C, Kuo J-M (2017) Governance, efficiency and risk taking in Chinese banking. Br Account Rev 49(2):211–229

Evanoff DD, & Ors E (2002). Local market consolidation and bank productive efficiency.

Fare R, Grosskopf S, Norris M, Zhang Z (1994) Productivity growth, technical progress, and efficiency change in industrialized countries. Am Econ Rev 84(1):66–83

Fiordelisi F, Marques-Ibanez D, Molyneux P (2011) Efficiency and risk in European banking. J Bank Financ 35(5):1315–1326

Fries S, Taci A (2005) Cost efficiency of banks in transition: evidence from 289 banks in 15 post-communist countries. J Bank Financ 29(1):55–81

Holtz-Eakin D, Newey W, Rosen HS (1988) Estimating vector autoregressions with panel data. Econometrica: Journal of the Econometric Society 56:1371–1395

Hughes JP, Mester LJ, Moon C-G (2001) Are scale economies in banking elusive or illusive?: evidence obtained by incorporating capital structure and risk-taking into models of bank production. J Bank Financ 25(12):2169–2208

Khan IU, Ali S, Khan HN (2018) Market concentration, risk-taking, and efficiency of commercial banks in Pakistan: an application of the two-stage double bootstrap DEA. Bus Econ Rev 10(2):65–95

Konara P, Tan Y, Johnes J (2019) FDI and heterogeneity in bank efficiency: evidence from emerging markets. Res Int Bus Financ 49: 100–113

Kosmidou K (2008) The determinants of banks' profits in Greece during the period of EU financial integration. Manag Financ 34(3):146–159

Kumar L, Malathy D, Ganesh L (2010) Productivity growth and efficiency change in Indian banking: technology effect vs catch-up effect. J Adv Manag Res 7(2):194–218

Kumbhakar SC, Lozano-Vivas A, Lovell CK, Hasan I (2001) The effects of deregulation on the performance of financial institutions: the case of Spanish savings banks. J Money Credit Bank 33:101–120

Lerner A (1934) The concept of monopoly and the measurement ofmonopoly power. Rev Econ Stud 1:157–175

Liu H, Wilson JO (2010) The profitability of banks in Japan. Appl Financ Econ 20(24):1851–1866

Mansour R, El Moussawi C (2019) Efficiency, technical progress and productivity of Arab banks: a non-parametric approach. Q Rev Econ Finance 75:191–208

Menicucci E, Paolucci G (2016) The determinants of bank profitability: empirical evidence from European banking sector. J Financ Rep Account 14(1):86–115

Mosko A, Bozdo A (2016) Modeling the relationship between bank efficiency, capital and risk in Albanian banking system. Procedia Econ Finance 39:319–327

Noman AHM, Gee CS, Isa CR (2017) Does competition improve financial stability of the banking sector in ASEAN countries? An empirical analysis. PLoS One 12(5):e0176546

Öncü S, Aktaş R (2007) Productivity change in Turkish banking sector restructuring period, Celal Bayar University. J Yönetim ve Ekonomi 14:247–266

Phan HTM, Daly K, Akhter S (2016) Bank efficiency in emerging Asian countries. Res Int Bus Financ 38:517–530

Roodman D (2009) A note on the theme of too many instruments. Oxf Bull Econ Stat 71(1):135–158

Schaeck K, & Čihák M (2008). How does competition affect efficiency and soundness in banking? New empirical evidence.

Seiford LM, Thrall RM (1990) Recent developments in DEA: the mathematical programming approach to frontier analysis. J Econ 46(1-2): 7–38

Shair F, Sun N, Shaorong S, Atta F, Hussain M (2019) Impacts of risk and competition on the profitability of banks: empirical evidence from Pakistan. PLoS One 14(11):e0224378

Shleifer A, Vishny RW (2010) Unstable banking. J Financ Econ 97(3): 306–318

Staikouras C, Wood G (2004) The determinants of European bank profitability. Int Bus Econ Res J 3:57–68

Sufian F (2007) Trends in the efficiency of Singapore's commercial banking groups: a non-stochastic frontier DEA window analysis approach. Int J Product Perform Manag 56(2):99–136

Sufian F, Habibullah MS (2009) Bank specific and macroeconomic determinants of bank profitability: empirical evidence from the China banking sector. Front Econ China 4(2):274–291

Sun L, Chang T-P (2011) A comprehensive analysis of the effects of risk measures on bank efficiency: evidence from emerging Asian countries. J Bank Financ 35(7):1727–1735

Tan Y (2016) The impacts of risk and competition on bank profitability in China. J Int Financ Mark Inst Money 40:85–110

Tan Y, Anchor J (2017) The impacts of risk-taking behaviour and competition on technical efficiency: evidence from the Chinese banking industry. Res Int Bus Financ 41:90–104

Tan Y, Floros C (2018) Risk, competition and efficiency in banking: evidence from China. Glob Financ J 35:223–236

Tanna S, Luo Y, De Vita G (2017) What is the net effect of financial liberalization on bank productivity? A decomposition analysis of bank total factor productivity growth. J Financ Stab 30:67–78

Triki T, Kouki I, Dhaou MB, Calice P (2017) Bank regulation and efficiency: what works for Africa? Res Int Bus Financ 39:183–205

Wooldridge JM (2015). Introductory econometrics: a modern approach. Nelson Education.

Worthington AC (2000) Technical efficiency and technological change in Australian building societies. Abacus 36(2):189–197

Zarutskie R (2013) Competition, financial innovation and commercial bank loan portfolios. J Financ Intermed 22(3):373–396

Zhang J, Jiang C, Qu B, Wang P (2013) Market concentration, risk-taking, and bank performance: evidence from emerging economies. Int Rev Financ Anal 30:149–157

Zhu N, Wu Y, Wang B, Yu Z (2019) Risk preference and efficiency in Chinese banking. China Econ Rev 53:324–341