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THEORETICAL ARTICLE

A review of bank efficiency and productivity

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Abstract The objective of this study is to present a systematic literature review in the context of bank efficiency and productivity. It focuses on the recent developments related to empirical methodological advances and new dimensions added to the ever-growing field of bank performance analysis. Selected research papers were coded in terms of their key objectives and were segregated into 11 themes—Branch, Comparison, Consolidation and Expansion, Deregulation and Regulation, Environment, Input–output, Methodological advances, Non-traditional activities, Risk, Stock performance and Others. The 103 selected studies were further analysed based on efficiency measures, input–output approaches and methodology. While summarising the extant literature on bank efficiency and productivity, the ongoing debate regarding the optimal input output approaches and ideal frontier techniques for bank performance analysis has also been dealt with. The current study also highlights the possible future research avenues in this area.

Keywords Banking · Performance · Efficiency · Productivity · Literature review · Survey

JEL Classification G21 · D24 · N20

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1 Introduction

1.1 Background

Modern banking system has grown to a level where it is regarded as one of the most important indicators of macroeconomic stability. There are at least three vital roles that distinguish banks from other financial or non-financial institutions. As described by Corrigan [1], banks provide, (1) transaction accounts, (2) source of liquidity for other institutions; and (3) act as a channel of transmission for monetary policy. Besides, commercial banks reduce information asymmetry between lenders and borrowers by monitoring and screening of debtors and as a result can help in minimizing the adverse selection and moral hazard problems [2]. In addition, banks form a part of payment system and therefore banking activities directly or indirectly impact the economic stability and any bank failure can result into systemic crisis [3]. Tarashev et al. [4] argue that there are several factors that contribute to financial institutions' system wide risk, e.g. bank size, institutions' specific probability of default and various risk factors that interact in non-linear fashion. Contrary to other sectors, banks are funded by demand deposits and this motivates several mechanisms of regulatory and legal environments that influence the bank's incentive for efficiency and risk-taking.

Among the wide spectrum of studies related to banking sector, bank performance analysis emphasises on several aspects. First, evaluating the impact of various policy measures like mergers of banks and the impact of deregulation or changes in market structure on bank performance. Second, identifying the causes of operating inefficiency, improving managerial performance of the banks by identifying and encouraging the best practices and reasons for ineffective resource allocation. Third, ability of banks to align with changes in business environment [5, 6]. Bank performance is usually evaluated with the help of frontier efficiency analysis, which compares efficiency of banks with the best performing banks in the industry and then results can be used to encourage best practices.

1.2 Objective and motivation of the study

The objective of this study is to review the advances in bank productivity and efficiency[1] literature since the earlier work of Berger and Humphrey [5]. The study by Berger and Humphrey [5] is almost 20 years old and there have been numerous advances in efficiency literatures in the last two decades. Earlier studies focused on the application of frontier efficiency techniques to banking sector, however, in recent past there has been several advances in bank efficiency literature both in terms of methodological advances and factors considered to investigate their influence on bank efficiency. Therefore, in this study we focus on advances in bank efficiency studies both in terms of efficiency techniques and new dimensions added

[1] Productivity in simple terms can be defined as the ratio of output to input. Efficiency in simple terms can be defined as the comparison between actual and optimal or achievable values of outputs and inputs. For standard definitions, please refer to Coelli et al. [7].

to the bank efficiency literature. With respect to methodological advances we limited the scope of present study to their empirical application. For example, marketability efficiency dimension to bank efficiency analysis was introduced by Seiford and Zhu [8], capacity utilisation and bank efficiency was considered by [9], Halkos and Salamouris [10] deviated from traditional efficiency analysis and considered some ratios to be used as outputs with no inputs in their model. Schure et al. [11] applied the Recursive Thick Frontier Approach to analyse the cost efficiency of banks in European Union. Berger et al. [12] suggested a new approach to investigate the impact of ownership change by the way of analysing static, selection and dynamic effects. Portela, Thanassoulis [13] investigated the relationship between service quality and branch efficiency. Kumbhakar et al. [14] proposed a new estimation techniques in the case of semiparametric stochastic frontier methodology and applied the same to US banking data. Avkiran [15] applied the network data envelopment analysis to banking data, where this technique can reveal the inefficiencies in profit centres. Holod, Lewis [16] proposed a new way to treat deposits in their study and suggested a two stage DEA model where deposits are treated as output in stage one, which then acts as an input for stage two. Duygun et al. [17] investigated the impact of new product launch on economic efficiency. Matousek, Tzeremes [18] analysed the relationship between CEO compensation and bank efficiency. Thus, there is now ample literature that focuses on the methodological improvement of efficiency techniques and their application on bank efficiency and productivity.

Berger and Humphrey [5] in their literature review analysed 130 research papers that focused on the frontier efficiency techniques and their application to financial institutions. Besides, Berger and Humphrey [5], there are some other reviews that focused on bank performance analysis. Berger [19] did a study titled, "International Comparisons of Bank Efficiency". Fethi and Pasiouras [3] analysed the literature based on operational research (data envelopment analysis) and artificial intelligence techniques. Paradi and Zhu [6] did, "A survey on bank branch efficiency and performance research with data envelopment analysis". Therefore, there is a need for a study which provides a holistic picture regarding the developments in bank efficiency and productivity literature.

1.3 Main contributions of the paper

This paper builds on the earlier work of Berger and Humphrey [5] by extending the review in several important ways. This paper has the broadest objective in comparison to the above literature. We analyse both efficiency and productivity dimension of bank efficiency literature. Due to advances in several dimensions in bank performance literature (methodological advances, input–output approaches and inclusion of new variables and their impact on bank performance), this review provides a holistic view of the recent developments. Finally, we highlight the research gaps in the literature with several future research directions.

1.4 Organization of paper

Rest of the paper is organized as follows: Sect. 2 describes the research methodology. Section 3 focuses on various themes identified based on the objectives of the selected literature. Section 4 highlights the methodological variation in bank efficiency and productivity literature. Section 5 deals with input–output approaches followed by findings and future research in Sect. 6. Section 7 concludes the paper.

2 Research methodology

In this study, the literature is reviewed using a systematic and rigorous method to summarize and analytically criticize the existing literature on banking productivity and efficiency. A preliminary pool of studies was built by conducting a search in electronic databases such as Elsevier's Science Direct, Oxford journals, Springer journals, Emerald journals, JSTOR, Sage Journals, Taylor and Francis journals and Wiley Journals which resulted in 15,192 studies. The various key words used for this purpose were: efficiency; bank efficiency; productivity; bank productivity; parametric and bank efficiency; productivity and banks; parametric and bank productivity; non-parametric and bank efficiency and productivity; semi parametric; bank efficiency and productivity; SFA and banking; and DEA and banking. Studies published in peer-reviewed academic journals were screened for further deliberation and those published in languages other than English were discarded. Studies related to Islamic banking were kept out of the scope of the study. Any duplicate records were also eliminated. This reduced the number of studies to 1,898. These studies were subjected to further screening based on their "title" and resulted in 328 studies. These selected studies were further screened by analysing the "abstract" and "keywords" in line with the scope of this study and finally 103 studies were shortlisted for the review. Final sample comprised of 25 nations and 29 multi-country studies over the time span of almost 20 years (1998–2017).

3 Thematic classification

Various themes were identified based on the primary objectives of the selected research papers. We recognise that any given paper can be classified under multiple themes and our classification may not reflect all the objectives of a research paper. Figure 1 shows the thematic classification of the reviewed literature. Themes were further divided into subthemes wherever separate classification was needed. A total of 11 themes were identified: Branch, Comparison, Consolidation and Expansion, Deregulation and Regulation, Environment, Input–output, Methodological advances, Non-traditional activities, Risk, Stock performance. The studies which could not be identified according to these themes were assigned to the theme "others". Themes which required further segregation into sub themes are as follows: Comparison was subdivided into multiple criteria, cross country and

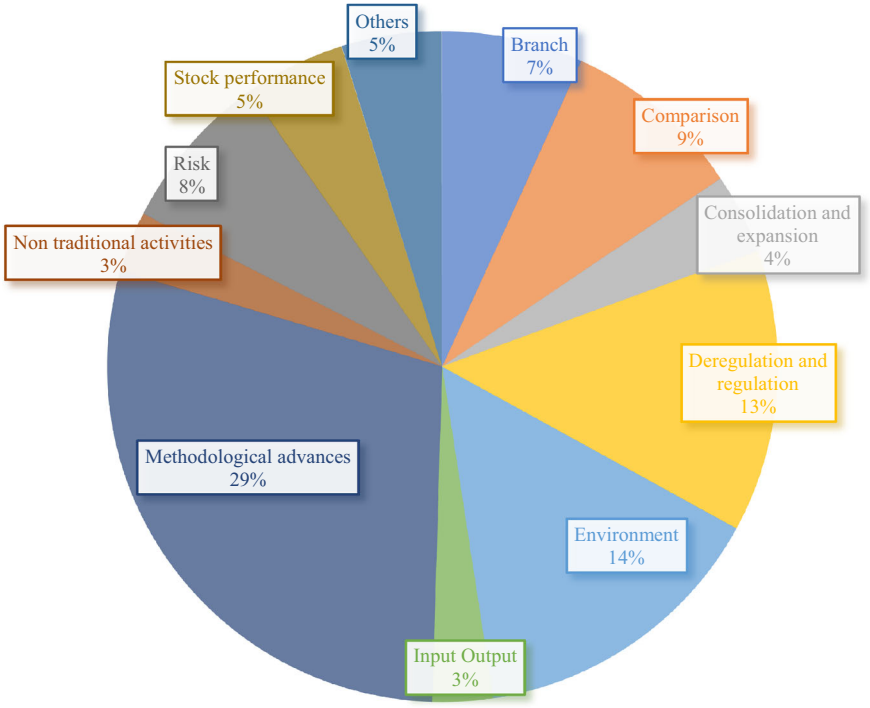

Fig. 1 Thematic classification. Note: Themes were identified based on the primary objective of the study

ownership; Consolidation and Expansion was segregated into consolidation and, expansion; Deregulation and regulation was divided into two sub themes, i.e. deregulation and, regulation. Although impact of economic crisis on bank efficiency can be considered under main theme, i.e. Environment, but due to the significant implication of any economic crisis on banking industry, a sub-theme 'crisis' is defined under the heading Environment. "Appendix" provide details in terms of themes, measure of efficiency, country of study, input–output techniques, type of methodology used and main findings.

3.1 Branch

Branches are the main outlet of bank services and serves as an interaction mechanism with the consumers of banking services. Ignoring the branch efficiency could result in several issues related to efficiency, product mix and economies of scale [20]. We found 7 research papers exploring different aspects of bank branch efficiencies. For example, Paradi et al. [21] investigated the bank branch performance based on different criteria and Aggelopoulos, Georgopoulos [22] studied the branch efficiency while considering the external environment.

3.2 Comparison

A number of studies have compared the bank performance based on various criteria. These factors were categorised as sub-themes in our analysis. First subtheme was comparison based on performance of the banks between different countries or same bank having multi-country operations. These studies compare the efficiency and productivity of banks, based on the number of criteria and also tries to take care of exogenous factors specific to the respective country. For example, Bonin et al. [23] did a cross country comparison across 11 transition economies. Second subtheme was, comparison of ownership type, based on the majority shareholding pattern that is between government banks, private banks and foreign banks. For example, Berger et al. [12] did comparison between different ownership types (state, domestic and foreign ownership). Last subtheme was comparison based on multiple criteria, e.g., Isik and Hasan [24] carried out a comparison on multiple efficiency estimates.

3.3 Consolidation and expansion

Third theme defined was based on impact of consolidation and expansion on the bank efficiency and productivity. Sub-theme consolidation incorporates all those studies which were dealing with the impact of mergers and acquisitions on bank efficiency. Three papers were identified under the sub-theme consolidation, e.g. Halkos and Tzeremes [25]. Only 1 paper was classified under the sub-theme expansion i.e. Berger and DeYoung [26], which investigated the impact of geographical expansion on bank efficiency.

3.4 Deregulation and regulation

Although regulation and regulation are a part of the external environment but due to numerous studies focusing on these aspects a separate theme was justified. This theme was further subdivided in two subthemes: deregulation and regulation. Sub-theme deregulation in simple terms means the opening up of the banking sector for private players, i.e. removal of the restriction on the entry of private ownership. Deregulation can also be in terms of increase in the range of permissible activities. It also includes the liberalization of interest rates on lending and deposits. For example, Tecles and Tabak [27] investigated the impact of privatisation on bank efficiency in the case of Brazilian banks. Sub-theme regulation includes the studies that investigated the impact of regulation on bank efficiency. Regulations are norms issued by central banks from time to time for a healthy financial system. Broadly, regulations can be related to norms for asset classification, income recognition, provisions for NPA, sector specific lending, off balance sheet exposures and other restrictions. This sub-theme also includes the impact of Basel norms on bank efficiency, which refers to the broad supervisory standards agreed upon by a group of central banks. These are mainly for capital requirements and related to bank risks and monitoring. For example, Barth et al. [28] investigated the impact of bank monitoring, regulation and supervision on bank operating efficiency across 72 countries.

3.5 Environment and efficiency

Environmental factors play an important role in determining the performance of the banks. Environmental factors are an important component while analysing the performance of banking industry to account for the exogenous factors. Macro-economic environment varies with the country of operations of banks. Literature use several variables to control for external environment, e.g., population density measures the population per square kilometre. Per capita income measures the income per head for the country and calculated by national income divided by the total population of the country under study. Density of the demand deposit measured by the total deposit per square kilometre. Herfinhal index measures the size of the bank in relation to the banking industry and also indicates the amount of competition among the players. Bank reach is a number of branches per square kilometre. The ratio of equity to total assets measures the average capital. The ratio of loans to deposits measures the level of intermediation. The urbanization factor is the number of people residing in a city town or village. The annual rate of inflation is the yearly rise in prices. The real rate of GDP is the inflation-adjusted measure of the value of all goods and services produced in a given year. Market capitalization measures the size of the stock market. Financial intermediation is calculated as the ratio of credit to the private sector and GDP. We have also classified the papers investigating the impact of economic crisis on bank efficiency under the theme environment and sub-theme crisis. Fifteen research papers were identified under the theme environment e.g. Drake et al. [29] and out of these, 7 research papers were classified under the sub-theme crisis, e.g. Gulati and Kumar [30].

3.6 Input–output

Bank efficiency and productivity studies are usually based on the input output definition of activites. Although, input–output approaches are dealt separately in Sect. 5, but due to some studies exclusively focusing on the definition or new approaches to define input and output for bank effeiciency and productivity analysis, this theme was justified. Three studies were segregated under the theme Input–output e.g. Holod and Lewis [16], which treated deposits as an intermediate product, rather than segregated as input or ouput.

3.7 Methodological advances

Bank efficiency and productivity investigations are usually methodologically driven. As a result, numerous studies modified the existing methodologies or proposed new versions of the earlier approaches. Because of the importance of type of methodology in bank efficiency and productivity, Sect. 4 deals with type of methodologies employed in bank performance analysis. There were 30 papers that were identified out of 103 under this theme and therfore represent a major resarech area in bank efficiency and productivity, e.g. Kumbhakar and Tsionas [14] and Restrepo-Tobón and Kumbhakar [31].

3.8 Nontraditional activities

In recent years, banks have started to expand to non traditional bank activities to generate income. These activites are also called as offbalance sheet activities. Off balance sheet activities are those assets or liabilities that are not kept on the books of a bank. For example, loans are kept on the books of banks but if loans were securitised and sold off as an investment, then onwards are not kept on the books of bank. Other off-balance sheet activites include: sales, servicing, standby letters of credit, loan orinination and derivative securites to name a few. We found 3 papers under the theme Non traditional activities e.g. Lozano-Vivas and Pasiouras [32].

3.9 Risk

Risk and uncertainty is another theme that has started emerging recently. Due to the nature of banking services, modern economies have developed high reliance on banking sector. Any impediment in bank's functioning or activities can result into system wide implications, as was seen in the recent US banking crisis. Several studies investigated the interplay of risk and bank efficiency. Eight papers were identified under the theme Risk, e.g., Rossi et al. [33] investigated the impact of diversification on bank efficiency. L. Sun and Chang [34] highlighted the impact of various risk types (Credit risk, Market risk, and Operational risk) on bank efficiency. Delis et al. [35] developed a new approach to incorporate bank risk based on variance of returns (or profits), within frontier efficiency framework.

3.10 Stock performance

Stock performance is also considered as an indicator of the bank performance. It is considered that more efficient the bank is, better would be the stock performance. As a result, literature has started to focus on the relationship between bank performance and share prices. Five papers were classified under this theme, e.g. Beccalli et al. [36] and Liadaki and Gaganis [37].

3.11 Others

Papers which could not be segregated into any theme were classified under the theme Others. For example, Matousek and Tzeremes [18], investigated the impact of CEO compensation on bank efficiency and Mamatzakis et al. [38] investigated the relationship between problem loans and bank efficiency in the case of Japanese banking system, which provides a distinctive platform for the examination of the long-lasting effect of problem loans on efficiency.

4 Methodological variations: non-parametric, parametric and semi-parametric

Frontier efficiency is an advanced methodology to study the performance and it overcomes the shortcoming of the ratio and regression analysis. These methods take care of multiple inputs and multiple outputs issue of ratio and regression analysis. These benchmarking techniques compare the performance with the peers on cost, scale, profit, revenue and technology [39]. All these methods have one thing in common that the efficiency is measured in comparison to the best performers in the industry. However, there is no consensus regarding the best frontier efficiency method, but all these methods compute a single statistic for efficiency [5].

The frontier efficiency methodology includes Non-parametric and Parametric approaches. Non-parametric approach includes Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH). Parametric techniques include Stochastic Frontier Approach (SFA), Distribution Free Approach (DFA) and Thick frontier approach (TFA). These two approaches differ in the underlying assumption for frontier efficiency. First, they differ in terms of functional form specification for the frontier estimation. Parametric approaches need specific functional form to proceed with, while non-parametric approaches are not restrictive in terms of functional form specification. Second, the two approaches differ in terms of the treatment of the random error. If the random error is taken into consideration then the distribution of random error must be specified to get information regarding inefficiencies and random error. This need to assume the distribution of the random error can be overcome by using non-parametric methods. The results obtained from efficiency techniques can help management to improve upon the areas where the firm is not performing well in comparison to its competitors and can also set future directions. Further, environmental factors can also be taken into consideration to understand the overall picture and then to get the deeper insight into performance issues [6]. Figure 2 shows the methodological variations in our literature review.

4.1 Non-parametric

Data envelopment analysis was operationalised by Charnes et al. [40]. This technique focuses on decision-making units (DMUs), which convert a given amount of inputs to specific output. Sherman, Gold [41] were the first to apply the DEA framework in bank settings. It is worth mentioning that these DMUs don't assume anything about the conversion process of inputs to outputs, hence also named as black boxes. DEA because of very nature envelops the observations under a frontier and therefore named as "Data Envelopment Analysis". DEA is flexible enough by allowing for various assumptions in terms of returns to scale (decreasing return to scale, increasing return to scale, or constant return to scale). Further DEA can be input oriented, output oriented or unoriented model. DEA can also work with a small number of observations but it does not allow for random error, which means any deviation from the frontier would be treated as inefficiency. This shortcoming can possibly result into overstatement of relative efficiency results [42]. Another

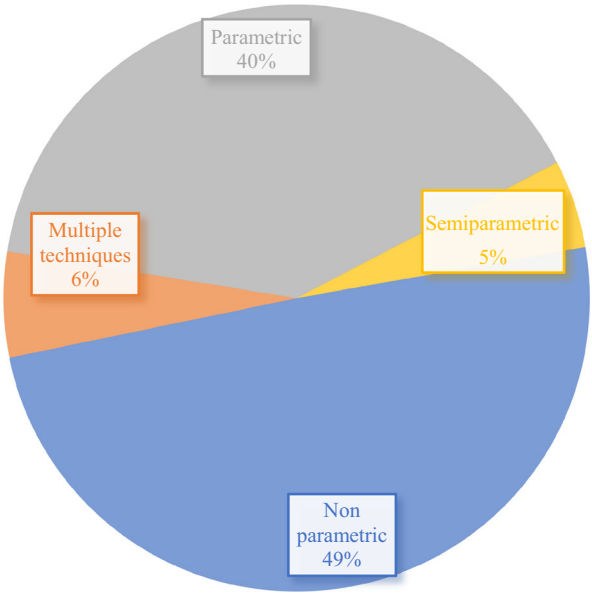

Fig. 2 Methodological variations

drawback of nonparametric methodology is that it is sensitive to extreme values and doesn't allow for noisy data [43].

There have been various extensions to the basic DEA technique. Based on the work of Luenberger [44]; Chambers et al. [45] and Chambers et al. [46], introduced directional distance functions and provided generalization of conventional distance functions. These functions allow for a simultaneous increase in output and along with reduction in input while measuring for technical efficiency. One of the latest variation is the work by Sahoo et al. [47], who proposed a DEA based directional distance approach. Deprins et al. [48] introduced a modified version of DEA, which was termed as Free disposal Hull (FDH) estimator. This estimator relaxes the convexity assumption of DEA. The other variation of DEA model was to include uncertainty and risk into the efficiency analysis Chambers, Quiggin [49], Chambers [50] and O'Donnell et al. [51].

In our review, we found 51 papers exclusively used non parametric techniques for the analysis. A number of papers have relied on traditional measure of DEA, e.g. Barth et al. [28] and Ray [52]. Several authors have also modified the existing non parametric techniques, e.g., Halkos and Tzeremes [25] proposed a bootstrapped DEA to evaluate the impact of merger or acquisition on bank efficiency in a short-run. An et al. [53] proposed a new two stage DEA approach to measure the slack based efficiency. In their procedure, authors divided the bank operating process into deposit generation and deposit utilization stages.

4.2 Parametric

Stochastic frontier approach (SFA) was proposed by three independent groups of researchers [54–56]. All the three original models were developed in the context of production frontier and similar error structure. During the initial development Ferrier, Lovell [57] applied econometric frontier approach to the bank performance analysis. Further, SFA has a very strict requirement regarding the distribution of inefficiencies. Inefficiencies are assumed to follow half normal (asymmetric) and random errors are assumed to follow standard normal (symmetric) distribution. Various researchers have proposed different distribution of inefficiency term. Greene [58]; Stevenson [59] and Lee [60] proposed a Gamma distribution, Gamma and truncated normal distribution, and Pearson family of distributions respectively, for the distribution of inefficiencies. Li [61] suggested the uniform distribution; Gagnepain and Ivaldi [62] proposed the beta distributed; and more recently Almanidis et al. [63] suggested the doubly truncated normal distribution.

Schmidt, Sickles [64] provided another dimension to the efficiency measurement by applying fixed and random effects in the models. Cornwell et al. [65] worked on the time-series and cross-sectional variation. Kumbhakar [66] worked with time varying technical inefficiency and panel data. Battese and Coelli [67] worked on panel data and technical efficiency.

Distribution Free Approach is another parametric frontier technique like SFA but differs in terms of distributional assumptions. DFA relaxes distributional assumptions in the sense that it treats inefficiencies to be stable over time, while on the other hand it assumes expected value of random error to be zero, over a period of time.

We found 41 studies solely employing the parametric techniques for bank efficiency and productivity investigation. For example, Dietsch and Lozano-Vivas [68] and Berger and DeYoung [26] used DFA, Rossi et al. [33] and Uchida and Satake [69] used SFA and Schure et al. [11] used Recursive TFA. Recently, several authors proposed the modification to the existing parametric techniques, e.g. Tabak et al. employed geographical weights in SFA while calculating the bank efficiency scores and M. Delis et al. [35] employed a risk based SFA to investigate bank performance.

4.3 Semi-parametric techniques

Parametric techniques require assumption regarding the distribution of inefficiencies, which can sometime be problematic in empirical settings. Stochastic frontier models are fully parameterized models and about all the models use Translog or Cobb–Douglas functional form [70]. Classical or Bayesian approaches have been used in literature to predict the distribution of error terms. To do away with this requirement semi parametric techniques were developed to keep the essence of parametric techniques, but at the same time they relaxed the distributional or technology assumptions.

Olley and Pakes [71] developed a semi-parametric algorithm, which was further extended by Levinsohn and Petrin [72] and used in efficiency and productivity

studies. Ackerberg et al. [73] extended the work of Olley and Pakes to solve the multi-collinearity issue. Wooldridge [74] extended the earlier work by using GMM (Generalized Method of Moments) estimators for performance analysis.

Bayesian approaches were also developed to relax the parametric assumptions [70]. There has been a rapid development in Bayesian estimators since the earlier work of Van den Broeck et al. [75]; Koop et al. [76] and Koop et al. [77]. The approach was also extended by Kumbhakar [78] and then by Kumbhakar, Tsionas [79]. Sun et al. [80] proposed a stochastic cost frontier estimation by following the semi-parametric approach. Even after continuous development, semi-parametric approaches are not widely used in production function estimation because are difficult to apply [81]. We found 5 papers that exclusively use semi parametric techniques to measure bank performance, e.g. Nakane and Weintraub [82] and Buch et al. [83].

Parametric and non-parametric techniques have their own advantages and disadvantages. As a result, some authors employ multiple approaches to get comparative estimates e.g. [36, 84]. Over the years, a focus on methodological improvement can be noticed in the literature. With very few exceptions, in the early 2000′s the methodology used were DEA [85, 86] or SFA [87–89]. However, recent literature attempts to improve upon the existing methodology, e.g. [34, 90–92]. Furthermore, in our sample, 30 papers out of 103 exclusively deal with methodological improvement and its application to banking sector.

5 Input output approaches

There are numerous variables, which are of interest while analysing the efficiency and productivity of banks. Some of these variables include employees, physical facilities, deposits, loans and advances, interest income, non-interest income, interest expenses and other operating expenses. Due to complexity of the financial transactions, there are different school of thoughts to define the input and output for bank efficiency and productivity studies. Figure 3 highlights the main approaches used in bank efficiency and productivity analysis.

Intermediation approach treats banks as an intermediary of services. It was first proposed by Sealey and Lindley [93] and was termed as an assets approach. In assets approach a bank is considered to be an intermediary of financial services; utilizing deposits, fixed assets and employees, to produce loans and other earning assets. Another version of intermediation approach is a value added approach, which was suggested by Berger and Humphrey [94] and Berger and Humphrey [95]. In value added approach whatever adds value to the bank is considered as an output (can be assets or liabilities) and employees, the premises and fixed assets are considered as inputs. The third and last variation of intermediation approach is a user cost approach, which was proposed by Hancock [96] and Fixler and Zieschang [97]. In this approach output is revenue generating activity (assets or liabilities) and the cost of production is considered as an input (labor, assets and liabilities).

A production approach on the other hand considers banks as a producer of services [98]. In this approach inputs are physical capital and number of employees

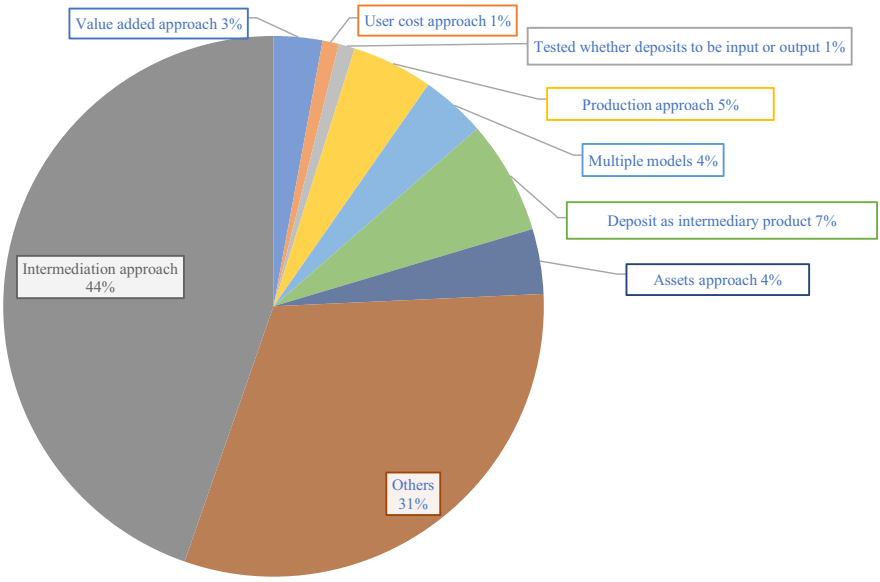

Fig. 3 Input output approaches. Note: 'Intermediation approach' or 'assets approach' are two names of the approach proposed by Sealey, Lindley [93]. We have retained the names as they were used by the authors

and output is deposits, loans, and other earning assets. An income based approach (or operating approach) was suggested by Leightner and Lovell [99]. In this approach firm is treated as a revenue generating unit, where input is costs that are incurred to get revenue. A loan based approach assumes loans, advances and investments as output while all the costs incurred as input. This approach is very similar to an intermediation approach.

The issue of non-performing loans/assets has been the interest of researchers lately. Non-performing loans are those where debtor either default on interest repayment, principal or both. Some studies have included non-performing loans as an undesirable output are Park and Weber [100]; Fujii et al. [101]; Wang et al. [102]; while those have excluded non-performing loans from output are Zhao et al. [103]; Sun and Chang [34]; Barros et al. [104].

To overcome the input output specification issues, researchers have used more than one input output models in the same study. Many studies modify input output specification as per the requirements that do not fit into any above-mentioned classification so they are classified as other approaches in this study.

In literature, the intermediation approach is more popular among researchers and they agree that banks are intermediary of financial services. Banks use deposits for revenue generating activities (loans and advances) and pay interest to depositors, hence it seems more logical to consider deposits as inputs rather than outputs. However, in recent literature deposits are also treated as an intermediary product,

where, deposits are the output of stage one process and then are used as an input for stage two process [16, 53, 105, 106].

6 Findings and future research

6.1 Findings

Owing to the importance of banking sector, the extant literature has highlighted different dimensions of bank efficiency and productivity. The scope of bank efficiency studies continues to grow with every passing year. Nevertheless, the existing literature aims to provide answers to the issues faced by banks and therefore improves our understanding regarding working of banking sector. For example, Anthanassopoulos [107] argued that bank branch networks play an important role in sales performance. Later on, Prior [9] suggested a positive relationship between the size of branch network and inefficiency. However, the performance of branches also depends on their market size and geographical region [21]. Bigger branches can also have scale inefficiencies. Recessionary phases found to have negative impact on branch network efficiencies [22].

Bank efficiency literature highlights the influence of ownership types on bank performance. Mixed ownership banks are found to be better performers than state owned banks [12, 82, 105, 108, 109]. Similarly, privatization is expected to have positive impact on managerial efficiency [105]. In some cases, foreign banks and public banks were found to be cost and technical efficient in comparison to private banks [23, 24, 101, 110, 111]. Similarly, some studies found evidence that state owned banks perform better than other bank types [112]. On the other hand, Tecles and Tabak [27] argued that large banks tend to be cost and profit efficient and big commercial banks are also efficient in comparison to small commercial banks [11, 14]. Furthermore, large banks enjoy market power even though they charge high prices on advances [113]. Higher market power is found to have a positive relationship with profitability [113]. However, Isik and Hassan [24] reported a weak relationship between size and efficiency. Productive banks are usually inclined to enter foreign markets and they also hold considerable volumes of foreign assets [83].

Economic environment is also expected to have an influence on bank efficiency and productivity. On the other hand, efficient financial sector is also expected to be a driver of economic growth. We found substantial evidence suggesting that environmental factors have a significant impact on efficiency estimates [29, 68, 111, 114–116]. Efficient banks (better performers) also have a positive and significant impact on regional growth [117, 118]. Likewise, efficient banks also reported to have higher market power than inefficient counterparts [119].

We found a mixed evidence about the impact of Merger and Acquisition (M&A) on bank efficiency and productivity. Cuesta and Orea [120] reported a mild relationship between mergers and bank efficiency. Besides, M&A between efficient banks does not always result in increase in efficiency [25]. Merger among big banks can have negative impact on overall efficiency and it may result in an anti-

competitive behaviour but merger among small banks can enhance efficiency [121]. Size and profitability have a positive relationship with cross border M&A and efficient banks tend to get into cross border deals [122].

Banking sector is one of the highest regulated sector across nations and therefore any change in regulations or regulatory environment could have significant implications on this sector. Deregulation is found to have a positive impact on bank performance [110, 123–125]. Due to deregulation, banks can come up with innovative products or trademark activities and as a result can attract more customers to open deposit accounts and to avail other services. The banks with more outstanding deposits were found to be more efficient [69]. Similarly, increase in trademark efficiency was found to have positive impact on efficiency and productivity of commercial banks [17, 126, 127]. Even in case of deregulation, big banks are the biggest beneficiaries of deregulation and technology advances and grow at the expense of small banks [128]. Deregulation can also prompt banks to enter into activities that may or may not be closely related to traditional scope of banking activities. However, diversification has a positive impact on profit efficiency and capitalization, and, has a negative impact on bank's realized risk and cost efficiency [33].

Regulatory supervision and capital restrictions were also found to have positive influence on bank efficiency [32] and this relationship is stronger in countries with quality institutions [28, 90, 129]. However, private sector monitoring and restriction on bank activities appear to have a negative impact on bank efficiency [28, 90]. Banks are found to be less efficient when supervisors have to supervise large number of financial sectors [130].

Financial crisis of recent past has also motivated the researcher to investigate its impact on bank efficiency. For example, Park and Weber [100] reported that banks became inefficient before the advent of Asian financial crisis. Furthermore, we found several studies highlighting the impact of recent global financial crisis (GFC). GFC had a negative impact on bank efficiency in Australia [121]. There was a mild negative influence of GFC on efficiency but Indian banks recovered soon after the crisis was over [30]. GFC had an impact on the extent of interest rate pass through [84]. The impact of GFC on banks increases with increase in distance from financial centres [131]. However, impact of subprime crisis was reported to be heterogeneous for countries and ownership types [132].

Banking efficiency analysis is usually based on defining the input–output variables under various assumptions. Researchers have proposed various approaches, however, there is no consensus regarding the optimal input–output approaches. Technical efficiency measures are not robust to input output approaches [133]. Different input–output approaches produce different results in mean efficiency, across sample, across time (temporal variation) and also for cross sectoral rankings [134].

Risk measures have significant impact on the bank efficiency and the degree of influence varies over time and across countries [34]. Moreover, not including risk in efficiency models may result in biased and lower efficiency estimates [35]. However, the impact of risk taking on efficiency varies with affiliation and size of bank [135]. Interestingly, Hou et al. [136] reported a positive relationship between

technical efficiency and risk taking. With regard to non-performing loans, Barros et al. [104] found a significant impact of such loans on bank performance. Besides, Assaf et al. [137] highlighted the importance to include non-performing loans in frontier models.

Literature also highlights the importance of non-traditional activities and the impact of such activities on bank efficiency and productivity. However, excluding these from efficiency models underestimates the efficiency [32, 138, 139].

With regard to the relationship between bank efficiency and marketability Seiford and Zhu [8] reported that maximum banks were inefficient in terms of profitability and marketability. Similarly, Luo [140] showed that marketability inefficiency is of a concern for US banks rather than profitability inefficiency. On the other hand, Beccalli et al. [36] reported that stocks of efficient banks outperform the inefficient banks. Similarly, Liadaki and Gaganis [37] and Fu et al. [141] highlighted the relationship between efficiency and stock price movements.

There are several interesting findings that does not fall under any particular thematic classification followed in this review, for example, recently literature has advocated to account for heterogeneity while analysing bank efficiency [142, 143]. Matousek and Tzeremes [18] reported a nonlinear relationship between CEO compensation and bank efficiency. Silva et al. [144] suggested that investments in core periphery structures are beneficial and at the same time are cost efficient for banks. Mamatzakis et al. [13] reported interesting findings regarding the relationship of bankrupt and restructured loan with efficiency. Peng et al. [145] showed that Bancassurnace business of banks results in improved efficiency levels as well as increase in profitability.

6.2 Future research

Several prospective future research directions could be identified from the literature. Table 1 reports the gaps identified in the bank efficiency and productivity literature review and correspondingly suggests the possible future research avenues.

7 Conclusion

The aim of this paper was to review the developments in bank efficiency and productivity literature since the early work of Berger and Humphrey [5]. Specifically, we focused on the advances in efficiency techniques and the new dimensions added to the bank efficiency and productivity literature. With regard to advances in efficiency techniques, we limited the scope to their empirical applications. As a result, we reviewed 103 studies comprised of 25 nations and 29 multi-country studies over the time span of almost 20 years (1998–2017). We segregated the research papers according to their objectives and could identify 11 broad themes, which were further divided into subthemes wherever necessary. The findings of individual research papers were analyzed to present a comprehensive view of bank efficiency literature. The information was presented according to the

Table 1 Research gap and future research avenues

Theme	Research gap	Possible future research
Branch	There is a need to assess the branch level efficiency at different levels [21]	Future research could focus on the branch level performance evaluation at regional and national levels
	Branch efficiency could be impacted due to several factors that are beyond the management control [146]	Future research could investigate or identify an approach which can control for external factors. Further, the multidimensional approach proposed by Quaranta et al. [146] can be used for comparative analysis, both at branch and bank level
Comparison	While investigating the efficiency heterogeneity between ownership types, it is critical to differentiate between private banks (which also includes foreign banks), new private banks (because of ownership transfer from government to private) and foreign greenfield banks [23]	Separating the ownership type could reveal interesting insights how transition of ownership effects bank efficiency over time. Besides, separating foreign private banks from greenfield banks can uncover the impact of foreign ownership on bank efficiency
	Literature usually relies on single indicator while measuring banking market competition and then results are generalized to the entire bank, which raises the question about generalizability of findings [147]	Future work could use multiple or several indicators to measure banking market competition
	Fu et al. [112] measured meta profit efficiency along with risk effects using a static decomposition but did not control for time dimension	Future research can measure the meta profit efficiency across time horizons and then dividing the measure into various efficiency components
	What is the impact of business model (assets, funding or income dimensions) of foreign banks on the host country while diversifying their business [148]?	Future studies could investigate the sustainability of business models with respect to the host country
Consolidation and expansion	M&A can result in short-run efficiency gains but studies can also investigate the long run implications of M&A [25]	Future research can investigate the long-run or strategic implications on efficiency of M&A

Table 1 continued

Theme	Research gap	Possible future research
Deregulation and Regulation	Trademarking can have an impact on profit efficiency of commercial banks, but even then, some banks avoid trademarking [126]	Future research could focus on finding out the reasons that why some banks don't prefer trademarking
	Literature usually identifies the influence of crisis on bank efficiency by introducing the dummy variables into the model [124]	Future research can focus on more sophisticated techniques to investigate the influence of recent financial crisis on bank efficiency by identifying the momentary and/or lasting shocks. How financial freedom influences the risk and how this risk influences the efficiency can also be an area which can be studied in the context of recent financial crisis
	Due to recent financial crisis the existing approaches to identify the impact of regulation and supervision on bank efficiency may not be useful [149]	Future research can focus on the specific aspects of regulation and supervision rules or guidelines and their impact on bank performance with respect to broader institutional framework
	How does excessive financial freedom impacts the bank performance [125]?	Future research can investigate the impact of excessive financial freedom on the risk-taking tendency of financial institutions and which in turn may impact bank performance
Environment and efficiency	What is the impact of quality of financial markets on bank performance [117]?	Future investigation can focus on the impact of quality of financial markets on bank performance. Furthermore, besides quality, other factors like competition between financial institutions, regional interdependence and regional growth can be included in the model while examining bank performance
	Both supply and demand side of bank intermediation role should be considered to examine bank efficiency [129]	Lensink, Meesters [129] investigated the impact of supply side of intermediation role on bank efficiency. Future studies can investigate the role of demand side of intermediation role on bank efficiency
	The approach used by Diallo [150], was employed only for one year (2009)	In future, the approach can be used to investigate the impact of other economic crisis on bank performance (1990-1992 and 2001-2003). Studies can also investigate the country level bank performance by including bank size or market share in the model

Table 1 continued

Theme	Research gap	Possible future research
Input–Output	The modified version proposed by Holod, Lewis [16] considers deposits as an intermediate product	Future research can disaggregate the inputs for each stage, which can provide interesting insights regarding bank efficiency
Methodology	Traditional DEA measures the efficiency of units and segregate them into efficient and inefficient units. The stochastic DEA approach of Kao, Liu [151] provides the possibility of segregating inefficient units into efficient ones	Future research can focus on ranking of decision making units based on efficiency distributions
	An et al. [53] proposed a new approach to measure the bank efficiency based on deposit generation and deposit utilization stages. However, more work is required to understand the source of inefficiency	Future work can investigate and identify the factors that impact bank efficiency. For example, what are the factors that play a role in input output efficiency or factors that influence the divisional efficiencies
	It is not plausible to assume that non-performing loans get completely offset in a year [152]	While investigating the relationship of bank efficiency and non-performing loans, researchers can incorporate the possible repayment of non-performing loans beyond a year
Risk	Risk can be introduced to the modelling within stochastic DEA framework [35]	Future research can include risk in muti-stage setting as per the non-parametric stochastic frontier approach of Delis et al. [35]
Other	What is the impact of time and CEO remuneration on bank efficiency [18]?	Future research can investigate the impact of time and CEO remuneration on bank efficiency with respect to different geographical locations in a probabilistic framework
	What is the impact of risk-monitored (bankrupt and restricted) loans on bank productivity [38]?	Future work can segregate the total factor productivity growth into various components to investigate the impact of bankrupt and restructured loans

themes, efficiency measure, input output approaches, methodologies, main findings and possible future research avenues.

The literature review has identified and highlighted several general and specific research areas within the specific themes identified in bank performance analysis. The literature review highlights the recent trends, issues and advances in bank performance analysis that could be useful to academicians and policy makers in identifying the best practices and areas of concern in banking industry. With the understanding of various aspects of bank performance analysis, researchers in the area of bank performance analysis can create an opportunity for governments and regulatory institutions to identify the best practices and promote them to the rest of the banking industry.

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Appendix

See Table 2.

Table 2 Identified themes

Author	Measure	Country	Input–output	Method	Main findings
THEME: Branch					
Anthanassopoulos [107]	Market efficiency, cost efficiency	United Kingdom	Other	Modified DEA	Highlighted the significance of branch network for sales performance. Also, reported inefficiencies at branch level
Portela and Thanassoulis [13]	Profit efficiency, transactional efficiency, operational efficiency	Portugal	Other (Multiple models)	Modified DEA	Reported a positive relationship between transactional and operational efficiency. Similarly, found a positive relationship between operational and profit efficiency. Suggested a positive impact of profit and operational efficiencies on service quality
Paradi et al. [21]	Production efficiency, intermediation efficiency, profitability efficiency	Canada	Production model, intermediary model, profitability model	Modified Slacks Based two-stage DEA	Found a difference in performance of branches based on their market size and geographical region. Also, reported a positive relationship between branch size and scale inefficiencies
Yang and Liu [105]	Productivity efficiency, profitability efficiency	Taiwan	Deposit as an output in stage-one, then as an input for stage-two	Fuzzy multi-objective network DEA	Stated that mixed ownership banks are better performers than state owned banks; and privatization reduces managerial inefficiencies. Exhibited that their approach can be employed to identify weakness, efficiency and possibility for improvement
Ray [52]	Cost efficiency	India	Other	DEA	Reported over branching and suggested reduction in their number for some areas
Quaranta et al. [146]	Multiple measures (based on ratio, efficiency analysis and others)	Italy	Other (defining intermediation or the production approach is a part of overall model)	Multidimensional approach	Provided multidimensional measurement of efficiency and suggested that it could be of help when individual methods provide contradictory results
Aggelopoulos and Georgopoulos [22]	Branch management efficiency, technical efficiency, profit efficiency	Greece	Other (profit based approach)	Bootstrap input oriented profit DEA	Asserted that recessionary phases have negative impact on branch network efficiency; Capital controls take time to show results; The proposed improvement in methodology could help in identifying efficiency drivers

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
THEME: Comparison						
Multiple criteria	Isik and Hassan [24]	Cost efficiency, allocative efficiency, technical efficiency, Pure technical efficiency, scale efficiency	Turkey	Intermediation approach	DEA	Results show that foreign and public banks are cost and technical efficient in comparison to private banks. Banks, whose shares are publically traded are found to be more efficient. Found weak relationship between size and efficiency
Cross country	Bonin et al. [23]	Profit efficiency, cost efficiency	Czech Republic, Hungary, Poland, Slovakia,Bulgaria, Croatia, Romania, Slovenia, Estonia, Latvia, Lithuania	Other	SFA	Foreign ownership was found to be associated with efficiency, while strategic foreign ownership improves only cost efficiency. Asserted that international institutional investor have positive influence on profit efficiency
Cross country	Bolt and Humphrey [147]	Competition efficiency	UK, Spain,France, Netherlands, Norway, Denmark Finland, Italy, Belgium, Germany, Sweden	Other	DFA	Found that competition efficiency apparently had very small role in explaining cross country variations in revenues
Cross country	Huang and Fu [114]	Cost efficiency, cost gap ratio	Taiwan and China	Intermediation approach	Stochastic metafrontier approach	Results show the difference between Chinese and Taiwanese banks in terms of cost efficiency and cost frontier of production. Chinese banks are oversized compared to Taiwanese banks. Environmental factors play a significant role in explaining the difference in the cost frontiers of banks in both countries
Cross country	Buch et al. [83]	Productivity	Germany	Other	Semiparametric - Levinsohn and Petrin [72]	Found that productive banks tend to enter foreign markets and they also hold considerable volumes of foreign assets

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
Cross country	Fu et al. [112]	Nerlovian profit inefficiency	Taiwan and China	Intermediation approach	Risk-adjusted metafrontier DEA technology	Found that Chinese state owned banks perform better than other bank types. Taiwan private banks exhibit higher profit and technical efficiencies in comparison to Chinese city banks
Ownership	Berger et al. [12]	Profit efficiency Rank, ROE, cost efficiency rank, costs/assets and NPL	Argentina	Other	Translog function, Ratios	Results show that state owned banks are worst performers in comparison to other ownership type. Privatization results in performance improvements
Ownership	Fujii et al. [101]	Technical efficiency, productivity growth	India	Intermediation approach	Weighted Russell directional distance model	Indicated that efficiency varies with ownership type. Foreign banks were found to be most efficient
Ownership	Curi et al. [148]	Technical efficiency	Luxembourg	Intermediation approach (modified)	Group based DEA	Indicated that efficiency varies with ownership type. Branches were preferred than subsidiaries before the crisis but subsidiaries emerged as winners during financial crisis. Efficient banks appeared to be focused on assets, income strategy and funding
THEME: Consolidation and expansion						
Consolidation	Cuesta and Orea [120]	Technical efficiency	Spain	Assets approach	Stochastic distance function	Results show that there is mild relationship between mergers and bank efficiency in Spain
Consolidation	Halkos and Tzeremes [25]	Operating efficiency	Greece	Intermediation approach	Bootstrapped DEA	Indicated that M&A before and after Greek fiscal crisis did not result in short run efficiency gains. M&A between efficient banks not always result in increase in efficiency
Consolidation	Caiazza et al. [122]	Cost efficiency	Multicountry (34)	Other	Parametric and semi-parametric SFA,	Asserted that banks having high cost to income ratio are expected to get into domestic M&A deals. On the other hand, efficient banks tend to get into cross border deals. Furthermore, size and profitability has a positive relationship with cross border M&A

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
Expansion	Berger and DeYoung [26]	Profit efficiency, cost efficiency	United States	Intermediation approach	DFA	Reported both negative and positive relationship between geographical scope and bank efficiency
THEME: Deregulation and regulation						
Deregulation	Isik and Hassan [123]	Technical efficiency, pure technical efficiency, scale efficiency	Turkey	Intermediation approach	DEA-type Malmquist Index	Found that deregulation had a positive impact on bank performance. Productivity growth in Turkish banking industry was mainly attributed to efficiency increases or in other words bank's effort to match best practices
Deregulation	Park and Weber [100]	Technical efficiency, productivity growth	Korea	Multiple models	Directional distance function	Reported that banks became inefficient before the advent of Asian financial crisis. However, the productivity growth in banking industry was due to technical progress
Deregulation	Tecles and Tabak [27]	Cost efficiency, profit efficiency	Brazil	Intermediation approach	Bayesian SFA	Asserted that large banks tend to be cost and profit efficient. Public banks have improved in terms of cost efficiency but largely remains profit inefficient. Also, capitalization has positive impact on efficiency
Deregulation	Duygun et al. [17]	Cost efficiency, profit efficiency	United Kingdom	Other	SFA	Increase in trademark efficiency was found to have positive impact on cost and profit efficiency of commercial banks in UK
Deregulation	Duygun et al. [126]	Cost efficiency, profit efficiency	United Kingdom	Other	True Fixed Effects SFA	Found that banks who are participating in trademarking appears to be profit efficient than the banks who don't. However, same is not the case for cost efficiency
Deregulation	Luo et al. [124]	Profit efficiency	Multicountry (140)	Intermediation approach	SFA	Results indicate that deregulation has a negative impact on profit efficiency. On the other hand, financial openness has a positive impact on bank risk
Deregulation	Das and Kumbhakar [113]	Technical efficiency	India	Assets approach	Cost and input distance function	Large banks enjoy market power even though they charge high prices on advances. Private and foreign banks are scale inefficient and should increase their size of operations. Higher market power is found to have positive relationship with profit

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
Deregulation	Duygun et al. [127]	Total Factor Productivity	United Kingdom	Intermediation approach (modified)	Non-parametric Metafrontier Malmquist index	Trademarking is found to have positive impact on productivity of participating banks but recent crisis appears to have altered this phenomenon. The impact of financial crisis has not subsided till date (2016)
Regulation	Uchida and Satake [69]	Cost inefficiency	Japan	Intermediation approach	SFA	Banks with more outstanding deposits were found to be more efficient. Therefore, it appears that depositors have significant role to play in disciplining bank management
Regulation	Chortareas et al. [90]	Productive efficiency	European Union	Intermediation approach	DEA	Found that supervision and capital restriction have positive influence on bank efficiency and this relationship is stronger in countries with quality institutions. However, private sector monitoring and restriction on bank activities appears to have negative impact on bank efficiency
Regulation	Barth et al. [28]	Overall bank efficiency	Multicountry (72)	Intermediation approach	DEA	Stated that very high restrictions on bank activity appears to have negative impact on bank efficiency. On the other hand higher capital regulation has positive influence on bank efficiency. Independent and experienced supervisory authority as well as market based monitoring have a positive impact on bank efficiency
Regulation	Chortareas et al. [125]	Overall bank efficiency	European Union	Intermediation approach	Bootstrapped DEA	Deregulation was founded to have a positive impact on efficiency and cost advantages. This relationship is stronger in the countries with superior external environment for business
Regulation	Gaganis and Pasiouras [130]	Profit efficiency	Multicountry (80)	Intermediation approach	SFA	Banks are found to be less efficient when supervisors have to supervise large number of financial sectors. However, there is a negative relationship between central bank independence and bank profit efficiency
Regulation	Jaffry et al. [153]	Overall bank efficiency	India and Pakistan	Other	Bootstrapped DEA	Asserted that banks tend to have lower efficiency at the beginning of reforms but it improves after the adjustment phase is over

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
THEME: Environment and efficiency					
Dietsch and Lozano-Vivas [68]	Cost efficiency	France, Spain	Value added approach	Modified DFA	Found that including environmental variables in common frontier, results in significant reduction in efficiency estimates
Lozano-Vivas et al. [115]	Technical efficiency	Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom	Value added approach	Modified DEA to include environmental variables	Efficiency scores were found to change with the inclusion of environmental variables in the model and magnitude of change depends on the quality of environmental conditions
Drake et al. [29]	Profit approach efficiency	Hong Kong	Other	Modified DEA	Indicated that banks in Hong Kong are affected by the external environment and it is beyond the control of bank's management.
Hasan et al. [117]	Profit efficiency, cost efficiency	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Spain, Sweden	Intermediation approach	SFA, GMM	Efficient banks (better performers) were found to have positive and significant impact on regional growth
Tabak et al. [116]	Technical efficiency	United States	Other	Geographical weights in SFA	Asserted that local environment and constraints have an influence on bank performance.
Curi et al. [154]	Overall bank efficiency	Luxembourg	Intermediation approach	Bootstrapped DEA	Found that home and host country regulations are not an important factor in explaining bank efficiency rather bank size, asset diversification and capitalization are
Sun et al. [155]	Profit efficiency	China	Other	SFA	Reported that strategic investors have positive influence on bank efficiency and it is negatively related to regional development
Lensink and Meesters [129]	Cost efficiency	Multicountry (136)	Intermediation approach	SFA	Results show that well-developed institutions have positive influence on bank efficiency

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
THEME: Environment and efficiency; SUB-THEME: Crisis					
Moradi-Motlagh and Babacan [121]	Pure technical efficiency, scale efficiency	Australia	Other	Bootstrapped DEA	Global financial crisis had a negative impact on bank efficiency in Australia. It was found that merger among small banks can enhance efficiency; Merger among big banks can have negative impact on overall efficiency and it may result in anti-competitive behavior
Gulati and Kumar [30]	Profit efficiency	India	Intermediation approach (modified)	DEA based meta profit frontier framework	There was a mild negative influence of global financial crisis on efficiency but Indian banks recovered soon after the crisis was over. It was found that level of impact was not same for different ownership types. Foreign banks employ best production technology among banks in India
Havranek et al. [84]	Cost efficiency	Czech Republic	Intermediation approach	SFA, DEA	Indicated that global financial crisis had an impact on the extant of interest rate pass through. Banks offering high deposit rates also charge high interest rates on loans
Degl'Innocenti et al. [106]	Overall bank efficiency	EU members in Central and Eastern European (CEE) countries	Deposit as an output in stage-one, then as an input for stage-two	Weight assurance region two-stage DEA	Eastern European and Balkan countries exhibited lower efficiency in comparison to Central European countries over the study period
Belke et al. [118]	Profit efficiency, cost efficiency	Europe (12)	Other	Dynamic panel model and SFA	Reported that efficient bank have a positive influence on regional growth. Moreover, such link holds during both normal and bad times

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Degl'Innocenti et al. [131]	Technical efficiency	Multicountry (80)	Intermediation approach	Probabilistic DEA	Found that there is an inverse relationship between the distance of bank headquarters from financial centers (London and New York) and bank efficiency. The impact of global financial crisis on banks increased with increase in distance from financial centers
Diallo [150]	Overall bank efficiency	Multicountry (38)	Other	DEA	Indicated that bank efficiency lowered the constraints to lend to financially dependent industries during the crisis
THEME: Input–output					
Adams et al. [133]	Technical efficiency	United States	Tested whether deposits to be considered as input or output	Semiparametric stochastic distance frontier, Semiparametric panel estimator	Reported that technical efficiency results are upward biased when deposits are considered as an input. Technical efficiency measures are not robust to input output approaches
Drake et al. [134]	Pure technical efficiency	Japan	Compared intermediation, production and profit/ revenue based approaches	Slack based DEA	Found that different input output approaches produce different results in mean efficiency, across sample, across time (temporal variation) and also for cross sectorial rankings
Holod and Lewis [16]	Overall bank efficiency	United States	Deposit as an output in stage-one, then as an input for stage-two	Modified DEA	The model proposed here, treats deposits as an output for stage one and an input for stage two, therefore provided a new dimension for input output debate
THEME: Methodological advances					
Fukuyama and Weber [156]	Output allocative efficiency	Japan	Assets approach	Non radial DEA	Found that Farrell's measure exhibit higher efficiency in comparison to non-radial Russell's measure. Japanese banks showed decline in productivity over the study period

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Prior [9]	Capacity efficiency	Spain	Production approach	Proposed Non parametric estimation	Reported a positive relationship between size of branch network and inefficiency
Halkos and Salamouris [10]	Technical efficiency	Greece	No input, various ratios were used as outputs	Modified DEA	Indicated that Ratio and DEA analysis can be used as complements but frontier efficiency estimation is superior to ratio analysis
Schure et al. [11]	Cost efficiency	European Union	Value added approach	Recursive TFA	Results show that big commercial banks are efficient in comparison to small commercial banks
Nakane and Weintraub [82]	Total factor productivity	Brazil	Intermediation approach	Semiparametric -Levinsohn and Petrin [72]	Bank privatization was found to have a positive impact on productivity; State ownership is associated with low productivity
Kumbhakar and Tsionas [14]	Cost efficiency	United States	Intermediation approach	Semiparametric SFA	Asserted that big banks are efficient in comparison to small banks
Tortosa-Ausina et al. [157]	Productivity growth, technical efficiency	Spain	Assets approach	DEA, Malmquist productivity index and bootstrapping techniques	Decline in efficiency was reported as the main factor that results in productivity regress
Bos et al. [142]	Cost efficiency, profit efficiency	Germany	Intermediation approach	SFA	Suggested that heterogeneity should be accounted for while analyzing bank efficiency, since location, size and bank type have an influence on efficiency
Avkiran [15]	Profit efficiency	UAE	Other	Network DEA	Showcased that this approach helps in identifying the profit centers that could not be identified with traditional measures
Wheelock and Wilson [128]	Technical efficiency	United States	Intermediation approach	Hyperbolic Malmquist index	Reported that big banks grow at the expense of small banks and are the biggest beneficiaries of deregulation and technology advances

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Kao and Liu [151]	Efficiency distribution	Taiwan	Other	Stochastic DEA, Simulation	Showed that simulation technique yields better results in comparison to stochastic output/ input data
Delis and Tsionas [119]	Cost efficiency	European Economic and Monetary Union (EMU)	Other	SFA with local maximum likelihood technique	Efficient banks were reported to exhibit higher market power
Feng and Serletis [158]	Technical efficiency, returns to scale, technical change, total factor productivity	United States	Intermediation approach	Bayesian translog output distance function	Theoretical regularity conditions should be imposed while measuring productivity growth. Showed empirical application in case of US banks
Behr [159]	Cost efficiency, value added efficiency	Germany	Intermediation approach, value added approach	SFA, Quantile regression	Reported that elasticities obtained from stochastic frontier function and conditional mean function is different from cost and production elasticities of efficient banks
Avkiran [160]	Technical efficiency, profit efficiency	China	Intermediation approach	DEA super efficiency	The combination of slack based DEA with a profitability efficiency model found to be better than other eight combinations to explain the variation in industry ratios (return on average equity, post tax profit to average total assets)
Huang et al. [110]	Technical efficiency, allocative efficiency	Croatia, Czech Republic, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, FYR Macedonia, Poland, Romania, Russia, Slovak Republic, Slovenia Ukraine	Intermediation approach	Fourier flexible shadow cost function	Foreign banks were found to be most efficient. Deregulation results in improvement in efficiency. Over capitalization and excess funds result into allocative inefficiency
Rangkakulnuwat and Wang [161]	Total factor productivity growth, technical inefficiency change, technical progress change, scale effect, allocative effects	Thailand	Other	Fixed Effect model with Instrumental Variables	Results show improvement in technical inefficiency change, output price effects and scale effects

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Asmild and Matthews [108]	Overall bank efficiency	China	Other	Multi-directional efficiency analysis	Reported mixed ownership banks to be efficient in comparison to state owned banks. Furthermore, new methodology allows to test on multiple dimensions
Barros et al. [104]	Technical efficiency	Japan	Intermediation approach	Non-radial directional performance measurement based on Russell directional distance function	Non-performing loans have significant impact on bank performance. Labour and premises were found to be underutilized
Assaf et al. [137]	Technical efficiency, efficiency change, technical change, productivity change	Turkey	Intermediation approach	Bayesian SFA	Technology improvement has driven the productivity growth in Turkish banks. Highlighted the importance to include non-performing loans in frontier models
Goddard et al. [132]	Cost efficiency	Argentina, Brazil, Chile and Mexico	Intermediation approach	Random parameters SFA	This model is able to differentiate between parameter heterogeneity and inefficiency, therefore the mean efficiencies scores of random parameters model tend to be on higher side. In empirical analysis authors reported the impact of subprime crisis was heterogeneous for countries and ownership types
Kao and Liu [92]	Overall bank efficiency	Taiwan	Intermediation approach	Relational network model	Proposed model was found to be more discriminative. Empirical examination of Taiwanese banks revealed that their performance improved over the study period
An et al. [53]	Slacks based input output efficiency, deposit generation efficiency, deposit utilization efficiency	China	Deposit as an output in stage-one, then as an input for stage-two	Two stage DEA	Suggested that performance improvement in sample banks was due to deposit utilization efficiency. Also, there is low efficiency in the context of deposit generation stage

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Kao and Liu [162]	Productivity, efficiency changes, and technical change	Taiwan	User cost approach	Parallel frontier to measure MPI	Found this model to be always feasible. This model can be used for intertemporal analysis. In case of empirical application, Taiwanese banks increased their productivity from 2008 to 2013 due to technology improvements
Wanke et al. [163]	Overall bank efficiency	Mozambique	Production approach	Fuzzy-DEA α-level models	Fuzziness was found to be better than randomness in analyzing the estimated results. Besides, fuzziness can identify missing variables. In case of empirical estimation, labour, capital and market share were found to be important variables while investigating bank efficiency
Asmild and Zhu [164]	Unrestricted efficiency, weighted restricted efficiency	European Union (20)	Intermediation approach	Weight restricted DEA	Traditional DEA apply extreme weights to risky banks, the proposed weight-restricted DEA employ balanced weights that reduces the otherwise overestimated efficiency scores for risky banks
Zha et al. [152]	Technical efficiency, scale efficiency, pure technical efficiency	China	Deposit as an output in stage one, then acting as input for stage-two, a non-performing loan as an undesirable output of stage two	Dynamic two-stage slacks-based DEA	Results show that inefficiencies in Chinese banks are a result of inefficiencies at productivity stage as well as inefficiencies at profitability stage. Technical efficiencies and pure technical efficiencies were found to vary with ownership type
Restrepo-Tobón and Kumbhakar [31]	Revenue efficiency, cost efficiency, profit efficiency	United States	Other	Estimated Nonstandard Profit Function (NSPF) approach of Humphrey and Pulley [168] using translog functional forms with standard SFA	Model allows to investigate the influence of cost and revenue efficiency on profit efficiency. Also, the relative influence of cost and revenue efficiency on profit efficiency can be calculated

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Huang et al. [109]	Technical efficiency	China	Deposit as an output in stage-one, then as an input for stage-two	Stochastic network model	Results show that Chinese joint shock banks are most efficient and big state owned banks are least efficient
Feng et al. [143]	Productivity growth, efficiency change, technical change, scale effect	United States	Intermediation approach	Translog stochastic distance frontier (SDF) model with time varying heterogeneity.	Found evidence for the presence of unobserved heterogeneity. Also, large banking holding companies show increasing return to scale. On an average, banking holding companies exhibit mild productivity growth and technical change, if any
THEME: Nontraditional activities					
Rogers [138]	Cost efficiency, revenue efficiency, profit efficiency	United States	Other	DFA	Nontraditional activities have significant impact on cost and profit efficiency, therefore excluding these from the model underestimates the efficiency
Clark and Siems [139]	Cost efficiency, profit efficiency	United States	Other	SFA, DFA	Advocated for including off balance sheet activities while estimating efficiency
Lozano-Vivas and Pasiouras [32]	Cost efficiency, profit efficiency	Multicountry (87)	Intermediation approach	SFA	On an average, including the off balance sheet activities while calculating the efficiency increases the efficiency estimates. Also, regulation and supervision were found to have positive impact on cost and profit efficiencies
THEME: Risk					
Rossi et al. [33]	Cost efficiency, profit efficiency	Austria	Production approach (modified)	SFA	Found that diversification has a negative impact on bank's realized risk and cost efficiency. However, diversification has a positive impact on profit efficiency and capitalization

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Chiu and Chen [111]	Technical efficiency, super efficiency	Taiwan	Other	Slack based DEA, SFA	Reported that public sector banks are efficient in comparison to other ownership types; External environment has an impact on efficiency and is largest in case of private banks
Sun and Chang [34]	Cost efficiency	India, Indonesia, Korea, Malaysia, Philippines, Taiwan, Thailand	Intermediation approach	Heteroscedastic SFA	Asserted that there is significant impact of risk measures on the bank efficiency and degree of influence varies over time and across countries
Matthews [165]	Income efficiency	China	Deposit as an output in stage-one, then as an input for stage-two	Network DEA	Author found no significant relationship between the risk measures and bank performance indicators like ROA
Hou et al. [136]	Technical efficiency	China	Intermediation approach	Two-stage semi-parametric DEA	Reported a positive relationship between technical efficiency and risk taking
Delis et al. [35],	Profit efficiency, return efficiency	United States	Intermediation approach	Risk based SFA	Not including risk in efficiency model may result in biased and lower efficiency estimates. Also, there exists a tradeoff between risk and efficiency levels
Simper et al. [166]	Profit efficiency	Korea	Other	Modified DEA to include good input and bad output	Investigated the preferred measure of risk while analyzing the bank efficiency. Reported that optimal approach could include two out of three risk control variables

Table 2 continued

Author	Measure	Country	Input–output	Method	Main findings
Sarmiento and Galán [135]	Cost efficiency, profit efficiency	Colombia	Intermediation approach	SFA with random inefficiency parameters	Reported that the impact of risk taking on efficiency varies with affiliation and size of bank. Interestingly large and foreign banks gain from higher market and credit risk. On the other hand small banks benefit from capitalization
THEME: Stock performance					
Seiford and Zhu [8]	Profitability efficiency, Marketability efficiency	United States	Production approach (modified)	Modified DEA	Reported that maximum banks were inefficient in terms of profitability and marketability. Also, banks size appeared to have negative relationship with marketability
Luo [140]	Profitability efficiency, Marketability efficiency	United States	Production approach (modified)	Modified DEA	Showed that marketability inefficiency is of concern for US banks rather than profitability inefficiency. Nevertheless, geographical location is unrelated with the type of efficiency
Beccalli et al. [36]	Cost efficiency	France, Germany, Italy, Spain, UK	Intermediation approach (modified)	SFA, DEA	Reported that change in cost efficiency score results in change in stock prices. Therefore, stocks of efficient banks outperform the inefficient banks
Liadaki and Gaganis [37]	Cost efficiency, profit efficiency	European Union	Intermediation approach	SFA	Changes in profit efficiency score results in change in stock prices. However, that is not the case with cost efficiency
Fu et al. [141]	Cost efficiency, profit efficiency	Multicountry (Asia Pacific)	Intermediation approach	SFA	Suggested a positive relationship between efficiency and stock price movement. Bank performance also found to be related to market risk, credit losses and bank size

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
THEME: Others						
IT	Berger [167]	Cost productivity	United States	Other	Cost function	IT advances found to have a positive influence on bank productivity and scale economies
CEO compensation	Matousek and Tzeremes [18]	Technical efficiency	United States	Intermediation approach	Probabilistic DEA	Reported a nonlinear relationship between CEO compensation and bank efficiency. Higher compensation may not end in higher technical efficiency. CEOs should be paid above a certain threshold level to have a positive impact on bank performance
Financial networks	Silva et al. [144]	Risk taking efficiency, cost efficiency and profit efficiency	Brazil	Other	SFA	Investments in core periphery structures are beneficial and at the same time are cost efficient for banks. However, investment in core periphery structure are risk taking inefficient
Restructured loan	Mamatzakis et al. [38]	Technical efficiency	Japan	Intermediation approach	Translog enhanced hyperbolic output distance function	Reported a positive relationship between bankrupt loans and efficiency (technical efficiency), that indicates support for moral hazard and skimping hypothesis. However, found evidence for the support of bad luck hypothesis in the case of restructured loan and efficiency. Therefore, regulator should identify and control such problems

Table 2 continued

Sub-theme	Author	Measure	Country	Input–output	Method	Main findings
Bancassurance	Peng et al. [145]	Technical efficiency, allocative efficiency, cost efficiency, pure technical efficiency, other profitability measures	Taiwan	Intermediation approach	DEA	Reported that bancassurnace results in improved efficiency levels as well as increase in profitability. Also, bancassurance has a positive impact on shareholder value

DEA is Data Envelopment Analysis; SFA is Stochastic Frontier Approach; DFA is Distribution Free Approach; MPI is Malmquist productivity index; TFA is Thick Frontier Approach; GMM is Generalized Method of Moments

'Intermediation approach' or 'assets approach' are two names of the approach proposed by Sealey and Lindley [93]. We have retained the names as they were used by the authors

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