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Article

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Cogent Economics & Finance

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Suggested Citation: Rezvanian, Rasoul; Mehdian, Seyed; Teclezion, Mussie (2024) : The cost efficiency of the U.S. small banks after the 2008 global financial crisis, Cogent Economics & Finance, ISSN 2332-2039, Taylor & Francis, Abingdon, Vol. 12, Iss. 1, pp. 1-14, https://doi.org/10.1080/23322039.2024.2402558

This Version is available at:
https://hdl.handle.net/10419/321605

Cogent Economics & Finance

ISSN: 2332-2039 (Online) Journal homepage: www.tandfonline.com/journals/oaef20

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To cite this article: Rasoul Rezvanian, Seyed Mehdian & Mussie Teclezion (2024) The cost efficiency of the U.S. small banks after the 2008 global financial crisis, Cogent Economics & Finance, 12:1, 2402558, DOI: 10.1080/23322039.2024.2402558

To link to this article: https://doi.org/10.1080/23322039.2024.2402558

Published online: 16 Sep 2024.

COGENT ECONOMICS & FINANCE
2024, VOL. 12, NO. 1, 2402558
https://doi.org/10.1080/23322039.2024.2402558

GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

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The cost efficiency of the U.S. small banks after the 2008 global financial crisis

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ABSTRACT

This paper examines the relative cost efficiency of U.S. small banks after the 2008 Global Financial Crisis (2008 GFC). Using financial information from 10,495 of the same small banks operating from 2010 to 2021, we examine the after-effects of the recent global financial crises on the U.S. small banks. The study uses Data Envelopment Analysis (DEA) to calculate the overall efficiency using yearly and pooled data. The overall efficiency measure is then decomposed into allocative, technical, pure-technical, and scale efficiency to better understand the sources of small banks' inefficiencies. The results indicate that the overall efficiency of small banks operating in the U.S. after the 2008 GFC has been continuously low until 2021. The source of the low level of overall efficiency has been the low level of technical efficiency rather than allocative efficiency. In turn, the basis of the low level of technical efficiency has been pure technical and scale efficiency. Understanding the origins of cost inefficiencies in small banks has implications for micro and macro policymaking. Examining the underlying causes of cost inefficiencies in small banks after the financial crisis can inform policymakers in devising strategies to improve banks' cost efficiency.

IMPACT STATEMENT

This paper delves into the impact of the 2008 global financial crisis on the efficiency of small banks in the U.S. using Data Envelopment Analysis (DEA). Understanding the reasons for cost inefficiencies in small banks has implications for both micro and macro policy-making. By investigating the root causes of cost inefficiencies in small banks following the 2008 financial crisis, policymakers can develop strategies to improve small banks' cost efficiency.

ARTICLE HISTORY
Received 28 September 2023
Revised 25 July 2024
Accepted 3 September 2024

KEYWORDS
U.S. small banks; efficiency; financial crisis

JEL CLASSIFICATION
G21; G29; C61

SUBJECTS
Economics; Finance; Business, Management and Accounting

1. Introduction

The financial system of any developed country is a cornerstone of its economic growth. Among the key players in this system, depository financial institutions, particularly commercial banking organizations, stand out due to their size and number. These banks serve as financial intermediaries, converting deposits into productive investments that fuel economic development. Given their pivotal role in macroeconomics, it's imperative for policymakers to safeguard the stability and health of the banking system. Despite concerted efforts to bolster its safety, the banking industry has weathered several crises in recent decades, including the 1997 Southeast Asia Financial Crisis and the 2008 Global Financial Crisis (2008 GFC). The increasing interconnectedness of financial markets and the evolution of international payment systems have made any financial crisis a global threat. While all financial crises take a toll, the 2008 GFC is widely regarded as the most destructive, particularly for the global banking system.

The 2008 GFC originated in the United States in 2007, swiftly spreading worldwide and enduring for over two years. Some analysts attribute the crisis to increased household borrowing, particularly for home purchases. It had a far-reaching impact on all sectors of the economy, especially the banking sector, which

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had significantly heightened borrowing and loaded their asset portfolios with risky loans based on subprime lending. The bank management justified the increased borrowing by citing corporate finance theory, aiming to magnify the return on equity and benefit from tax advantages. However, a combination of falling real estate prices, highly leveraged balance sheets, and regulatory oversights laid the groundwork for the arrival of the 2008 GFC. The financial fallout significantly influenced the behavior of commercial banks' management, as many grappled with mortgage defaults and suffered losses due to high foreclosure rates.

During the crisis, policymakers from several developed economies responsible for the stability of the financial systems implemented a series of bold fiscal and monetary policies. They provided support to both depository and non-depository financial institutions. On the monetary policy side, they pursued an aggressive monetary expansion strategy by reducing interest rates to stimulate the economy.[1] On the fiscal policy side, policymakers implemented initiatives such as TARP in the USA. Additionally, banking sector managers undertook strategic changes to restructure and realign their portfolio holdings to reduce potential risks and enhance their banks' performance. The 2008 GFC ended in 2009, leaving significant financial disruptions.

Although all commercial banks perform similar functions, their activities may vary depending on their size.[2] Small banks generally concentrate on the retail side of the business by attracting deposits from individuals and small businesses and making consumer and business loans to individuals and small businesses operating in their communities.[3] Small businesses are critical to the U.S. economy, representing most economic activities and more than half of the private sector workforce. Berger et al. (2004) argue that healthy community banks improve Small and Medium Enterprises (SMEs) financing. De Young et al. (2012) find that SMEs rely on community banks for financing. They also argue that small banks exacerbate economic downturns during the recession due to low diversification and limited access to the government safety net. Hendrik et al. (2015) also show theoretically and empirically that small regional banks are necessary funding providers in regions with low access to financing. Therefore, the soundness and effectiveness of the overall banking system and small banks are essential to policymakers responsible for the proper functioning of the economy.

It is important to assess the strength and effectiveness of banks by analyzing their profit and cost efficiency. More cost-efficient banks tend to be more productive, profitable, and less susceptible to economic downturns. Therefore, it is essential to understand the primary factors influencing banking efficiency before, during, and after financial crises. Assaf et al. (2019) studied the performance of U.S. banks prior to and during, but not after, the 2008 GFC and concluded that cost efficiency is a better indicator of managerial quality. Our research contributes to the existing literature by examining the determinants of cost efficiency in small US banks after the 2008 GFC. This is significant because the findings offer valuable insights to banking management and policymakers in promoting safety and stability within the banking sector.

2. Review of literature

In the past 35 years, a significant body of finance literature has emerged focusing on measuring the efficiency of banking firms. The first study on the banking efficiency frontier was conducted by Sherman and Gold (1985), and since then, numerous studies using different methodologies and input and output definitions have been carried out to address efficiency in the banking industry.[4] Berger and Humphrey (1997) comprehensively reviewed 130 papers on banking efficiency frontier techniques up to 1995. However, since then, there have been significant advances in banking efficiency literature in terms of the development of efficient frontier techniques and consideration of essential factors affecting banking efficiency. These developments have spurred researchers to continue their study of banking efficiency. Recent studies on this topic can be found in Ashton and Hardwick (2000), Casu and Molyneux (2001), Berger (2007), Fethi and Pasiouras (2010), Paradi and Zhu (2013), and Bhatia et al. (2018).

The recent financial crisis has spurred researchers to explore its impact on the financial system and macroeconomics. Caprio and Honohan (2002) have highlighted that a crisis in the financial system, specifically within the banking industry, can lead to a widespread economic recession. Consequently, there has been a growing emphasis on examining the effects of the financial crisis on banking efficiency before and after the crisis. While most studies on the impact of the financial crisis on banking have focused on the 1997 Asian financial crisis, it's essential to recognize that the nature and causes of the 1997 Asian financial crisis differ from those of the 2008 GFC.[5]

There have been several published papers on the impact of the 2008 GFC on the banking industry. However, very few have focused on the effect of the crisis on small banks in the United States. In a study by Moradi-Motlagh and Babacan (2015), it was reported that the 2008 GFC negatively affected the efficiency of banks in Australia, with small banks experiencing a more severe impact. On the other hand, Gulati and Kumar (2016) found that the impact of the 2008 GFC on Indian banks was relatively mild and that the recovery was swift. Additionally, Mehdian et al. (2019) reported a negative impact of the 2008 GFC on the efficiency of large U.S. banks.

This study aims to contribute to the existing literature by investigating the impact of the 2008 GFC on the efficiency of U.S. small banks. While numerous studies have examined banking efficiency, few have focused on the post-crisis efficiency of small banks. This study seeks to fill this gap by analyzing the factors influencing the cost efficiency of small banks following the 2008 GFC. The remainder of the paper is divided as follows: Section 3 describes the data and methodology, Section 4 discusses the empirical results, Section 5 presents the conclusions, and Section 6 addresses the limitations and outlines the future direction of the study.

3. Data and methodology

3.1. Data

This study investigates the efficiency of small banks operating in the United States after the 2008 GFC. The data was collected from the consolidated Report of Condition (balance sheet) and Report of Income (income statement) published by the Federal Deposit Insurance Corporation (FDIC) website.

The nature of financial transactions introduces complexity in defining input and output in bank efficiency and productivity studies. Two main definitions of input and output variables are commonly used in these studies: the intermediation and production approaches. The intermediation approach, introduced by Sealey and Lindley (1977), views banks as intermediaries of services, using inputs such as deposits, fixed assets, and employees to produce earning assets like loans and investments. The production approach, introduced by Benston (1965), considers banks as utilizing inputs such as fixed assets and employees to produce services like deposits and earning assets such as loans and investments.[6]

For this study, we applied the intermediation approach, assuming that small banks provide intermediation services by collecting deposits from savers (both interest- and non-interest-paying deposits and other liabilities) and then channeling these funds to deficit units of the economy through providing loans (such as Real Estate Loans, Commercial and Industrial Loans, and other loans) and investing in various investment securities. Under this approach, we define input and output variables as follows:

Y1 = Commercial and industrial loans.
Y2 = Real estate loans.
Y3 = Other loans.
Y4 = Total investment securities.
X1 = Total Liabilities.
X2 = Number of full-time equivalent employees.
X3 = Premises and fixed assets.
P1 = Unit price of interest = Total interest expenses/Total interest-bearing liabilities.
P2 = Unit price of labor = Wages & benefits expenses/# of full-time equivalent employees.
P3 = Unit price of fixed assets = Total expenses of fixed assets/Total fixed assets.
TC = Total cost, the sum of total interest and non-interest expenses.
TA = Total assets, as a measure of bank size, as included in the bank's balance sheet.

The measures of banking efficiency can vary significantly depending on the sample, input-output specifications, and methodology used. Ferrier and Lovell (1990) observed substantial differences in efficiency among different specifications. Bauer et al. (1998) found varying efficiency scores using five different methodologies. Mester (1997) argues that U.S. banks are too diverse for comparison with a common benchmark and rejects the hypothesis of a common cost function for all banks. We also posit that

Table 1. Summary statistics of outputs, inputs, price of inputs, and total costs for the pooled sample; year 2010–2021 ($N = 10{,}495$).

2010–2021	Y1	Y2	Y3	Y4	X1	X2	X3	P1	P2	P3	TC
Mean	21020	4166	2556	2056	50136	14.33	783	0.0064	66.17	0.6975	1424
Min	0	0	0	0	5090	2	0	0.0001	0.042	0	0.687
Max	311477	85441	120616	64299	281681	157	8993	0.0704	834.2	108	26852
STD	14544	4214	3550	5682	21921	7.54	903	0.0044	21.09	2.346	788

Y1 = Real Estate Loan, Y2 = Commercial and Industrial Loan, Y3 = Consumer Laon, 4 = Securities, X1 = Deposits, X2 = Labor, X3 = Premises and fixed assets, P1 = interest cost, P2 = Labor cost, P3 = Cost of premises and fixed assets, and TC = Total costs.

assuming all banks of all sizes have the same production technology is overly simplistic when measuring their cost efficiency using a single cost-efficient frontier. In this article, we utilize a large, high-quality sample of similar small banks that share the same objective and production model, allowing us to expect a common production technology.

We utilized data from the FDIC Call Report to identify a selection of small FDIC-insured banks spanning from 2010 to 2021. Although there is no standard definition of "small banks," we classified them as banks with total assets below $172,000,000.[7] Our focus on small banks stemmed from two key reasons: firstly, the unique composition of assets and liabilities of small banks sets them apart from medium and large banks, and secondly, we hypothesized that small banks might respond differently to financial crises compared to their larger counterparts. Additionally, we excluded very small banks with total assets below $73,000,000, as we believe they are situated in remote rural areas and possess distinct asset and liability profiles, making them less susceptible to global financial crises. We did not consider the structural aspects of the banking corporations or their geographic locations.

Our analysis covers a 12-year period from 2010 to 2021. To maintain consistency, we only included small banks that were operational throughout this entire period, resulting in a total of 10,495 small banks. This translates to an average of approximately 875 small banks per year. Table 1 presents summary statistics for the outputs and inputs of these 10,495 small banks operating between 2010 and 2021.[8] The number of banks varied yearly, from 829 in 2021 to 895 in 2018. While yearly summary statistics for outputs and inputs are available, they are not included here for brevity but can be provided upon request.[9]

4. Methodology

In simple terms, efficiency is the comparison between the actual outputs produced by a set of inputs and the optimal outputs that could be produced by the same inputs (Coelli et al., 2005). The frontier efficiency methodology is used to compare actual output/input values with the optimal output/input values. In this study, we employ the frontier efficiency methodology to assess the efficiency of U.S. small banks post the 2008 GFC. This methodology encompasses both parametric and non-parametric techniques, both of which establish an efficient frontier from which individual bank efficiency is calculated. The parametric approach constructs the efficient frontier based on a specific production or cost function and allows for random error, whereas the non-parametric techniques do not assume a specific functional form and do not allow for random error.[10] Additionally, both methods can be input or output-oriented and are adaptable to analyze scale efficiency.

In our analysis, we utilize a non-parametric approach originally introduced by Farrell (1957), further developed by Charnes et al. (1978), and extended by Färe et al. (1985). This method involves creating input-oriented efficient frontiers through the solution of multiple Linear Programming (LP) problems, which allows us to calculate the efficiency of each bank. The solutions to these LPs yield five efficiency measures: Overall Efficiency (OE), Overall Technical Efficiency (TE), Allocative Efficiency (AE), Pure Technical Efficiency (PTE), and Scale Efficiency (SE).

To determine a bank's efficiency, we first solve a linear programming model to find the potential minimum total cost and then compute the OE for each bank i each year as follows:

$$\begin{aligned} C_i^* &= \min\ p \times x \\ y_i &\leq zY \\ x_i &\geq zX \\ z &\geq 0 \end{aligned} \tag{1}$$

where C_i^* is the potential minimum total cost of production of bank i, P is a vector of input prices, y_i is a vector of outputs produced by bank i of dimension (1, m), x_i is a vector of inputs utilized by bank i of dimension (1, n), Y is a matrix of observed outputs of all companies in the sample of dimension (m, N), X is a matrix of observed inputs of all companies in the sample of dimension (n, N), z is an intensity vector, N is the number of firms in the sample.

Having the potential minimum total cost of production of bank i calculated (C_i^*), we then, the OE of bank i as:

$$OE = C_i^*/C_i$$

To gain insights into the sources of inefficiency, the OE can be broken down into Overall TE and AE. To determine the TE of bank i in a given year (t = 2010 … 2021), the following linear programming problem is solved for each bank, for each year in the sample:

$$\begin{aligned} &min\ \lambda_i \\ &y_i \leq zY \\ &\lambda_i x_i \geq zX \\ &z \geq 0 \\ &i = 1, \ldots\ldots, N \end{aligned} \tag{2}$$

where all variables are as defined earlier.

λ_i is the measure of efficiency (overall technical efficiency, TE), estimated for bank i relative to a frontier that exhibits constant returns to scale (CRS).

We have broken down this measure into two more efficiency measures to better understand the sources of overall technical inefficiency. The first measure is Pure Technical Efficiency (PTE), which assesses the bank's efficiency relative to a frontier that demonstrates constant and variable returns to scale. The other efficiency measure, the SE measure, offers insights into whether the bank operates at constant returns to scale (optimal scale) or at increasing or decreasing returns to scale (sub-optimal scale). Formally, the TE of bank i can be expressed as:

$$TE_i = PTE_i \times SE_i,\ \text{Where } SE_i \text{ is ratio of } TE_i \text{ to } PTE_i.$$

To compute PTE, denoted by ψ_i, for bank i, Eq. (2) is solved with an additional constraint that is $\sum_{i=1}^{N} z_i = 1$, then we have $SE_i = \lambda_i/\psi_i$. Bank i is called scale efficient if $SE_i = 1$. If $0 \leq SE_i < 1$, bank i is called scale inefficient.

To sort the source of scale inefficiency of bank i, we resolve Eq. (2) after replacing $\sum_{i=1}^{N} z_i = 1$, by $\sum_{i=1}^{N} z_i \leq 1$, and obtaining an efficiency measure denoted by ω. Following Färe et al. (1985) and Turk Ariss et al. (2007), if bank i is not scale-efficient and $\omega = \psi$, the source of scale inefficiency bank i is decreasing returns to scale (DRS). On the other hand, if bank i is not scale-efficient and $\omega \neq \psi$, the source of scale inefficiency of this bank is because of increasing returns to scale (IRS).

Finally, we compute AE, which is an indication of the deviation of the operation from the optimal input mix of resources as: $AE_i = OE_i/TE_i$. We summarize the efficiency measures defined above as follows:

$$OE_i = TE_i \times AE_i, TE_i = PTE_i \times SE_i,\ \text{and then } OE_i = PTE_i \times SE_i \times AE_i$$

To proceed with the methodology mentioned above, we have two approaches for measuring efficiency scores for individual banks: year-specific and pooled sample measures. First, we calculate each bank's efficiency measures relative to each year's frontier using the banks' inputs, outputs, and total cost for that particular year (2010 to 2021). These efficiency measures are referred to as "year-specific measures" because they are calculated relative to the corresponding year's frontier. The efficient frontiers for each year are determined using the data for that specific year. The underlying assumption is that the yearly frontiers represent the available technology for all banks in the sample for that year. Isik and Hassan (2003) outlined two advantages of this approach. Firstly, it is more flexible and, therefore, more appropriate than estimating a single multiyear frontier for the banks in the sample. Secondly, it partially mitigates the problems related to the lack of random error in DEA by allowing an efficient bank in one

year to be inefficient in another year based on the assumption that errors due to luck or data problems are not consistent over time in a given year.

Next, we recalculate the efficiency measures of each bank by pooling the data for all years. We call these "pooled sample efficiency measures," calculated relative to the common frontiers from 2010 to 2021. The underlying assumption is that over the 12 years under study, all banks could have access to the best available technology, that is, they are facing common frontiers. Chen et al. (2015) raise concerns about using a single frontier that envelops all banks for all years. Using a single frontier for all years may underestimate the efficiency measures because banks are compared with the most efficient banks operating under the best available technology during the study. In this study, we will use both approaches.

5. Empirical results

Table 1 provides the Summary Statistics of outputs, inputs, price of inputs, and total assets for 10,495 small banks from 2010-2021. After the 2008 GFC, earning assets (the sum of loans and investments) accounted for 56.1% of total assets. Among earning assets, real estate loans (Y1) represented the largest portion at 68.56% of earning assets and 35.20% of total assets, followed by commercial and industrial loans (Y2) at 13.43% of earning assets and 6.71% of total assets.

The total cost per dollar of earning assets was $0.0481, with labor cost (P2*X2) being the highest input cost at $0.0315 per dollar of earning assets, followed by the interest cost at $0.011 per dollar of earning assets.

Based on the methodology and data outlined in section 3, we initially calculated the efficiency measures of small banks for each year from 2010 to 2021 using the annual efficient frontier. The summary statistics of efficiency measures are presented in Table 2, while Table 3 provides the same information for each year. It's worth noting that the annual efficiency measures, as indicated by Tables 2 and 3, have consistently remained low. The average OE of the 10,495 small banks operating between 2010 and 2021 was 32.93%. Notably, the main contributor to this inefficiency has been low TE at 48.14%, rather than AE at 68.85%. A breakdown of TE into PTE and SE further reveals that the principal cause of the low TE has been both low PTE at 56.955% and SE at 57.77%. In summary, the primary factor contributing to the overall low efficiency of small banks has been the combination of higher pure technical and scale inefficiencies.

The information in Table 3 shows the yearly statistics of efficiency measures for small banks from 2010 to 2021. Figure 1 provides a graphical representation of the same information. According to Table 3 and Figure 1, the operational efficiency (OE) measure of small banks has remained low for all 12 years after the 2008 GFC, ranging from a maximum of 36.29% in 2010 to a minimum of 29.98% in 2015. The primary cause of the low OE has been the low TE, which is, in turn, caused by a low level of PTE and SE.

Next, in our analysis, we established a common efficiency frontier by consolidating data from the 12 years spanning 2010 to 2021, post the 2008 GFC. The summary statistics of efficiency measures are presented in Table 4, while Table 5 provides the same information for each year. As far as we know, there has not been a comparable study using a non-parametric technique to investigate the cost efficiency of U.S. small banks post-2008 GFC. However, Elyasiani and Mehdian (1995) researched the efficiency of small banks before and after the 1980s deregulation. They found that the efficiency of small banks declined during the post-deregulation era compared to the pre-deregulation era. Akhigbe and

Table 2. Summary statistics of efficiency measures of the pooled sample (2010–2021, TN = 10,495).

	OE	AE	TE	PTE	SE
Mean	0.3293	0.6885	0.4814	0.5695	0.5777
Min	0.0881	0.1770	0.0960	0.1740	0.0901
Max	1	1	1	1	1
STD	0.1148	0.1582	0.1480	0.1536	0.1522

OE = Overall Efficiency, AE = Allocative Efficiency, TE = Overall Technical Efficiency, PTE = Pure Technical Efficiency, SE = Scale Efficiency, TN = Total Number of observations.

Table 3. Summary statistics of yearly efficiency measures relative to yearly efficient frontier.

	OE	AE	TE	PTE	SE
2010 ($N = 878$)					
Mean	0.3629	0.6901	0.5270	0.6151	0.5887
Min	0.0960	0.2870	0.1120	0.2280	0.1125
Max	1	1	1	1	1
STD	0.1512	0.1423	0.1770	0.1692	0.1551
2011 ($N = 877$)					
Mean	0.3353	0.6947	0.4838	0.5801	0.5786
Min	0.0955	0.2830	0.1120	0.2150	0.1056
Max	1	1	1	1	1
STD	0.1471	0.14289	0.1744	0.1744	0.1581
2012 ($N = 875$)					
Mean	0.3085	0.6539	0.4769	0.5713	0.5412
Min	0.0900	0.2320	0.1150	0.2050	0.1004
Max	1	1	1	1	1
STD	0.1409	0.1583	0.1751	0.1743	0.1537
2013 ($N = 879$)					
Mean	0.3409	0.7162	0.4827	0.5765	0.5985
Min	0.089095	0.265	0.134	0.206	0.1169562
Max	1	1	1	1	1
STD	0.1429	0.1582	0.1757	0.1785	0.1631
2014 ($N = 878$)					
Mean	0.3578	0.7480	0.4831	0.5883	0.6138
Min	0.0987	0.2490	0.1440	0.2240	0.0987
Max	1	1	1	1	1
STD	0.1501	0.1583	0.1723	0.1757	0.1686
2015 ($N = 867$)					
Mean	0.2988	0.5156	0.5745	0.5805	0.5115
Min	0.0888	0.1140	0.1400	0.1400	0.1140
Max	1	1	1	1	1
STD	0.1488	0.1450	0.1820	0.1885	0.1433
2016 ($N = 878$)					
Mean	0.3352	0.6901	0.4897	0.5823	0.5779
Min	0.0887	0.1900	0.1280	0.2200	0.1182
Max	1	1	1	1	1
STD	0.1504	0.1643	0.1737	0.1740	0.1680
2017 ($N = 879$)					
Mean	0.3377	0.7167	0.4769	0.5619	0.6041
Min	0.0929	0.2010	0.1180	0.2140	0.1236
Max	1	1	1	1	1
STD	0.1502	0.1684	0.1718	0.1741	0.1686
2018 ($N = 895$)					
Mean	0.3344	0.7560	0.4464	0.5408	0.6214
Min	0.0914	0.1830	0.1140	0.1910	0.1086
Max	1	1	1	1	1
STD	0.1518	0.1570	0.1744	0.1813	0.1665
2019 ($N = 895$)					
Mean	0.3173	0.7239	0.4383	0.5463	0.5846
Min	0.0891	0.1780	0.0048	0.2110	0.1064
Max	1	1	1	1	1
STD	0.1462	0.1551	0.261	0.1813	0.1672
2020 ($N = 865$)					
Mean	0.3105	0.7510	0.4190	0.5255	0.5955
Min	0.0884	0.1980	0.1020	0.2070	0.1106
Max	1	1	1	1	1
STD	0.1458	0.1541	0.1796	0.1854	0.1660
2021 ($N = 829$)					
Mean	0.2895	0.5991	0.4810	0.5654	0.5125
Min	0.0914	0.1880	0.1070	0.2030	0.1203
Max	1	1	1	1	1
STD	0.1485	0.1676	0.1922	0.1946	0.1590

OE = Overall Efficiency, AE = Allocative Efficiency, TE = Overall Technical Efficiency, PTE = Pure Technical Efficiency, SE = Scale Efficiency, N = Number of Observations per year.

McNulty (2003) examined the comparative profit efficiency of small banks from 1990 to 1996 and concluded that small banks are more profit-efficient than larger banks.

Based on Table 4, the average OE for the 10,495 small banks operating within the common efficient frontier from 2010 to 2021 was 25.52%. The primary contributors to this OE inefficiency were low TE (38.56%) rather than AE (67.23%) efficiency. Breaking down the TE into its components of PTE and SE reveals that the main reason for low TE is low PTE (47.75%) and SE (53.78%). When considering these

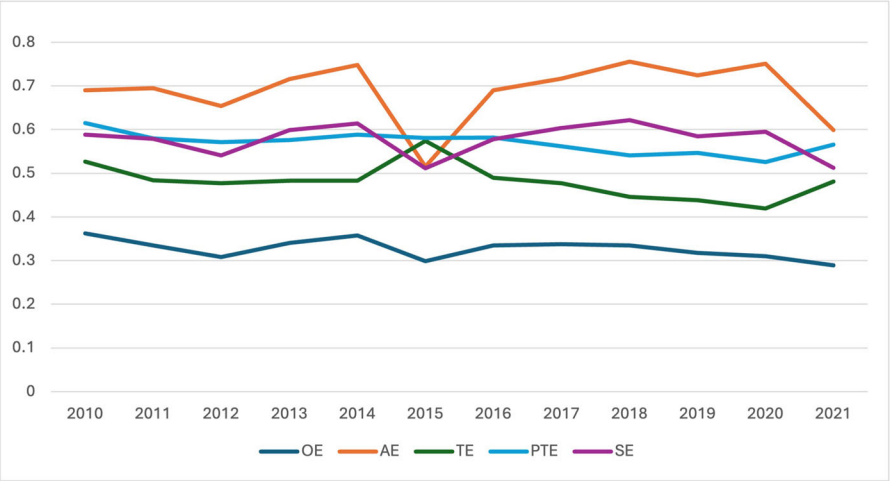

Figure 1. Efficieny measurs graph of Table 3.

Table 4. Summary statistics of efficiency measures of the pooled sample (2010–2021, TN = 10,495).

	OE	AE	TE	PTE	SE
Mean	0.2552	0.6723	0.3856	0.4775	0.5378
Min	0.0881	0.1770	0.0960	0.1740	0.0901
Max	1	1	1	1	1
STD	0.1148	0.1582	0.1480	0.1536	0.1522

OE = Overall Efficiency, AE = Allocative Efficiency, TE = Technical Efficiency, PTE = Pure Technical Efficiency, SE = Scale Efficiency, and TN = Total Number of observations.

together, the common frontier constructed by the pooled data also confirms that the main reason for the low OE of small banks has been the combination of higher pure technical and scale inefficiencies rather than allocative inefficiency.

The average efficiency measures obtained from the common efficient frontier of the pooled sample (Table 4) are lower than those obtained from the yearly efficient frontiers. This was expected because, with the single common efficient frontier obtained from the pooled sample, the efficiency measures of each bank are calculated relative to the most efficient bank(s) within the whole sample. However, with the yearly efficient frontiers, the efficiency measures of each bank for each year are calculated relative to the most efficient bank(s) from that year. This observation confirms Isik and Hassan's (2003) comment about the advantage of using yearly data rather than pooled data to mitigate the problem related to the random error in the pooled sample, as discussed in the data section. The observation also confirms Mester's (1997) comment about using a common cost function for all banks, as discussed in the methodology section.

Isik and Hassan (2003) outlined two advantages of this approach. Firstly, it is more flexible and, therefore, more appropriate than estimating a single multiyear frontier for the banks in the sample. Secondly, it partially mitigates the problems related to the lack of random error in DEA by allowing an efficient bank in one year to be inefficient in another year based on the assumption that errors due to luck or data problems are not consistent over time in a given year.

Mester (1997) argues that U.S. banks are too diverse for comparison with a common benchmark and rejects the hypothesis of a common cost function for all banks. We also posit that assuming all banks of all sizes have the same production technology is overly simplistic when measuring their cost efficiency using a single cost-efficient frontier

Table 5 shows the efficiency measures for small banks year by year, based on a combined sample. Figure 2 visually represents the same information. The table and the figure both indicate that small banks' OE has been consistently low over the 12 years following the 2008 GFC, ranging from a high of 27.72% in 2010 to a low of 23.51% in 2014. The main reason for this low OE is the low level of total efficiency (TE), which is, in turn, caused by low PTE and SE.

The findings from the annual efficient frontiers and the common efficient frontier clearly point to persistently low levels of technical inefficiency as the primary sources for small banks post the 2008 GFC

Table 5. Summary statistics of efficiency measures relative to the pooled sample frontier (2010–2021, TN = 10,495).

Eff. Measure	2010 (*N* = 878)	2011 (*N* = 877)	2012 (*N* = 875)	2013 (*N* = 879)	2014 (*N* = 878)	2015 (*N* = 867)	2016 (*N* = 878)	2017 (*N* = 879)	2018 (*N* = 895)	2019 (*N* = 895)	2020 (*N* = 865)	2021 (*N* = 829)
OE												
Mean	0.2758	0.2592	0.2433	0.2357	0.2351	0.2380	0.2441	0.2522	0.2659	0.2772	0.2709	0.2660
Max	0.893	0.850	0.9790	0.8628	0.8722	1	1	1	1	0.9800	1	1
MIN	0.0885	0.0895	0.0888	0.0882	0.0882	0.0906	0.0881	0.0886	0.0886	0.0896	0.0894	0.0882
STD	0.1143	0.1130	0.1119	0.1042	0.1064	0.1077	0.1120	0.1163	0.1170	0.1186	0.1186	0.1253
AE												
Mean	0.7020	0.6854	0.6692	0.6439	0.6354	0.6309	0.6330	0.6445	0.6698	0.7053	0.7253	0.7283
Max	0.9960	0.9970	0.9970	0.9970	0.9960	1	1	1	1	1	1	1
Min	0.2690	0.2380	0.2030	0.2440	0.2260	0.1860	0.1780	0.1800	0.2180	0.1770	0.2000	0.2110
STD	0.1398	0.1476	0.1542	0.1558	0.1565	0.1578	0.1572	0.1575	0.1575	0.1585	0.1593	0.1508
TE												
Mean	0.3974	0.3844	0.3699	0.3748	0.3779	0.3858	0.3914	0.3971	0.4021	0.3976	0.3779	0.3688
Max	1	1	1	1	1	1	1	1	1	1	1	1
Min	0.1050	0.0960	0.1050	0.1060	0.1030	0.1070	0.1070	0.1050	0.0990	0.1080	0.1110	0.1010
STD	0.1482	0.1503	0.1472	0.1467	0.1470	0.1492	0.1475	0.1502	0.1473	0.1441	0.1428	0.1513
PTE:												
Mean	0.4954	0.4815	0.4676	0.4694	0.4702	0.4771	0.4813	0.4864	0.4906	0.4863	0.4658	0.4566
Max	1	1	1	1	1	1	1	1	1	1	1	1
Min	0.1970	0.1890	0.1740	0.1830	0.1780	0.1810	0.1820	0.190	0.1870	0.1970	0.1910	0.1830
STD	0.1536	0.1545	0.1518	0.1504	0.1492	0.1527	0.1519	0.1552	0.1540	0.1506	0.1538	0.1617
SE												
Mean	0.5611	0.5427	0.5249	0.5073	0.5027	0.5024	0.5085	0.5201	0.5448	0.5733	0.5866	0.5834
Max	0.9399	0.9653	0.9790	0.9516	0.9682	1	1	1	1	0.9800	1	1
Min	0.1349	0.1367	0.1131	0.1160	0.1362	0.1280	0.1041	0.090	0.1300	0.1067	0.1168	0.1405
STD	0.1501	0.1482	0.1514	0.1441	0.1420	0.1421	0.1437	0.1461	0.1513	0.1577	0.1592	0.1544

OE = Overall Efficiency, AE = Allocative Efficiency, TE = Overall Technical Efficiency, PT = Pure Technical Efficiency, E = Scale Efficiency, N = Number of observations per year TN = Total number of observations in the pooled sample.

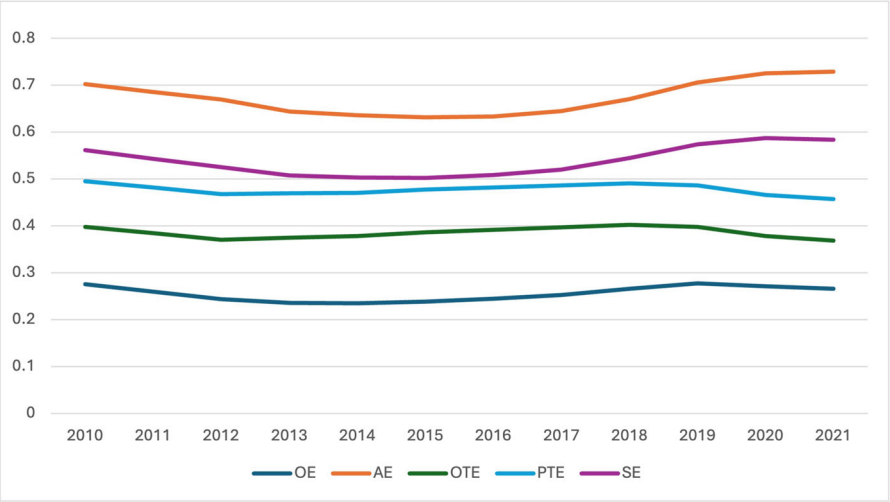

Figure 2. Efficieny measurs graph of Table 5.

rather than allocative inefficiency. This enduring technical inefficiency encompasses both pure technical and scale inefficiencies. When assessing banks' profit efficiency, Berger et al. (1993) caution that technical inefficiency is more widespread than allocative inefficiency across banks.

Berger and Humphrey (1997) in their comprehensive study of 130 bank efficiency papers, highlight the importance of understanding the sources of inefficiencies in the banking industry at both micro and macro levels. At the micro level, bank managers should clearly understand the origins of inefficiencies to improve bank performance. Most of the inputs banks use are either sticky or carry competitive market rates. For example, the rates charged by banks on different loans and rates paid by banks on different deposits and the other borrowed funds are highly competitive and market-oriented. Delis et al. (2011) also argue that banks' physical assets are sticky downward. Thus, the significant sources of improving bank productive efficiency are increasing output (scale of operation), reducing labor cost, or improving technology. At the macro level, the policymakers, and the regulatory authorities responsible for the banking system's safety and soundness should have a broader picture of the banking industry's performance. For example, the observed cost inefficiency shows the type of interventions needed to be implemented to minimize the extent of inefficiency in the small bank segment of the industry. The timely intervention of policymakers would reduce small banks' consolidation by reducing the possibility of small banks' acquisition by larger banks and reducing bank failure.

6. Conclusions

The results from this study have both micro and macro implications. At the micro level, the sustained low OE results from both the yearly and pooled frontier, accompanied by a wide range and high standard deviation, indicating cost-saving opportunities for many small banks. This cost-saving opportunity can be utilized by improving pure technical and scale efficiencies. At the macro level, the low efficiency of banks has been mentioned as one of the major reasons for bank failure (Amel et al., 2004; Isik & Hassan, 2003; Wheelock & Wilson 1995) and banking consolidation (Amel et al., 2004; Hughes et al., 1999; Kowalik et al., 2015). Improving the OE of small banks would mitigate small bank failure and their acquisition by larger banks, which would benefit regional economic growth.

7. Limitations and future direction of the study

Reflecting on our literature review and the process of writing our article has been enlightening. We have gained a deeper appreciation for the significance of our topic and, somewhat surprisingly, the scarcity of research in this area. We also recognize the critical importance of selecting the right methodology and sample for our study. Moving forward, we plan to expand our research in two key areas. Firstly, alongside cost efficiency, we intend to incorporate an analysis of small banks' profitability by utilizing

both profitability ratios and profit efficiency. Additionally, we aim to broaden our study to investigate how small banks responded to the 2008 GFC. This expansion will involve an analysis of the periods before, during, and after the 2008 GFC, exploring the relationship between cost efficiency and profitability during these distinct timeframes.

Notes

1. The Bank of International Settlement categorizes these actions into four categories: extending deposit insurance, capital injection, debt guarantees, and asset purchases. Please refer to BIS Quarterly Review, 2008, www.bs.org for detailed information.
2. In addition to size, the operational behavior of small banks may differ from that of large banks because of their differences in resource availability, lending behavior, organizational forms, risk-taking appetite, and available technology.
3. Around 78 percent of small banks make almost all their commercial and industrial loans to small businesses, compared with less than 12 percent of large banks (FDIC, 2020).
4. Akhigbe and McNulty (2003, 2005), Berger et al. (1993), Vander (2002), Wheelock and Wilson (1995) investigate the performance of small banks using profit efficiency.
5. For the related studies on the impact of the 1997, East Asia financial crisis on banking efficiency, please refer to studies by Krishnasamy et al. (2003), Chen (2005), Park and Weber (2006), Drake et al. (2006), Sufian and Habibullah (2009), Sufian (2010), Mahathanaseth and Tauer (2014). Studies by Isik and Hassan (2003) and Aysa et al. (2011) examine the 1994 Turkish financial crisis, and Fukuyama (1995) study examines Japan's financial shock.
6. For further information on comparing the input and output variables used in banking efficiency studies, please refer to Das and Ghosh (2006) and Sathye (2001).
7. The definition of a bank's size is typically based on its total assets or total deposits, which are closely related. Different studies use different thresholds to categorize small and large banks. For example, the FDIC's 2012 and 2020 Small Business Credit Survey (SBCS) questionnaire categorizes small banks as those with total deposits of $1 billion, while large banks have total deposits of $1 billion or more (FDIC, 2012, 2020). Meanwhile, Wiersch et al. (2022) defined small banks as those with total deposits of $10 billion, a definition also used by Gamble et al. (2020) and Bednarik and Marshall (2024). Some studies use total assets instead of total deposits to differentiate between small and large banks. For instance, a study by Akhigbe and McNulty (2003) defines small banks as those with total assets of $500 million or less. The Federal Deposit Insurance Corporation's FDIC Community Banking Study (2012) suggests that this threshold should be increased to $10 billion. Grochulski et al. (2018) define small banks as those within the bottom 95% of the size distribution of banks by assets.
8. The number of banks per year is slightly different because the number of banks with missing values differs from year to year.
9. Although the yearly samples consisted of almost the same banks, the mix and size of the portfolio of earning assets held by banks and the banks' size change from year to year.
10. Because of this, many researchers believe that the non-parametric approach over (under) estimates inefficiency (efficiency) measures.

Acknowledgements

We greatly appreciate the assistance provided by our graduate assistants, Laci Whiting from the School of Management at the University of Michigan-Flint and Kris Cumbers from the Cofrin School of Business at the University of Wisconsin-Green Bay, in this research project.

Authors' contributions

The paper is authored by Professors Rasoul Rezvanian, Seyed Mehdian, and Mussie Teclezion, who contributed equally to the conception, design, analysis, data collection, interpretation of the data, applied methodology, drafting the paper, critical revision for intellectual content and resubmission, and final approval of the version to be published. All authors agree to be accountable for all aspects of the work.

Disclosure statement

There are no interests to declare regarding this research.

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Data availability statement

The refined data used for efficiency estimations is available by authors upon request.

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