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Revisiting Efficiency Dynamics in Ghana's Rural and Community Banks: A Two-Step DEA and System GMM Analysis of Cost, Revenue, and Profit Efficiency

Stephen Banahene[1], Joyce Ama Quartey[2], Reindolph Osei-Anim[2*], Patricia Adutwumwaa[3], Samuel Nkansah[4]

[1]Department of Marketing, Logistics & Corporate Strategy, Christian Service University, Kumasi, Ghana
[2]Department of Accounting and Finance, Christian Service University, Kumasi, Ghana
[3]Audit Unit, Christian Service University, Kumasi, Ghana
[4]Finance Department, Christian Service University, Kumasi, Ghana
Email: *oseianim@rocketmail.com, snkansah@csuc.edu.gh

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Abstract

This study examines the efficiency dynamics and determinants of Rural and Community Banks (RCBs) in Ghana using a two-step Data Envelopment Analysis (DEA) and System Generalized Method of Moments (System GMM) framework. Specifically, the study estimates cost, revenue, and profit efficiency and investigates the bank-specific and macroeconomic factors influencing these efficiency measures. Secondary data were obtained primarily from the audited annual financial statements of Rural and Community Banks accessed through the ARB Apex Bank database. Additional governance-related information was verified from the published annual reports of the respective banks where necessary. The study covers the period from 2014 to 2019 and focuses on 20 of the 25 Rural and Community Banks operating in the Ashanti Region of Ghana. Banks with incomplete financial statements or missing observations during the study period were excluded to ensure a balanced panel suitable for DEA estimation and dynamic panel analysis. In the first stage, Data Envelopment Analysis was employed to estimate cost, revenue, and profit efficiency scores, while the second stage used the System GMM estimator to identify their determinants. The findings indicate that Rural and Community Banks exhibit relatively high cost efficiency but comparatively lower revenue and profit efficiency, suggesting that significant opportunities remain for improving income generation and profit performance. The empirical results further reveal that liabilities, loan-to-deposit ratio, non-performing loans, return on assets, and return on equity significantly

influence cost efficiency. Liabilities and non-performing loans are important determinants of profit efficiency, whereas loan-to-deposit ratio, investment-to-assets ratio, expenses-to-assets ratio, and liabilities significantly affect revenue efficiency. The study concludes that strengthening governance structures, improving credit risk management, enhancing resource allocation, and reinforcing regulatory oversight are critical to improving the operational efficiency and long-term sustainability of Rural and Community Banks in Ghana.

Keywords

Rural and Community Banks, Data Envelopment Analysis, System GMM, Cost Efficiency, Revenue Efficiency, Profit Efficiency, Ghana

1. Introduction

Ghana's economic development depends on several critical factors, including industrial growth, foreign trade expansion, agricultural modernization, and the improvement of domestic commerce. The financial sector, particularly the banking system, plays a central role in supporting these activities through financial intermediation, capital mobilization, and the effective transmission of monetary policy. The banking sector contributes significantly to national development by allocating financial resources to productive sectors in line with government economic planning and policy objectives. As noted by the Bank of Ghana (2024), a stable and efficient banking sector remains essential for macroeconomic stability and sustainable economic growth in Ghana. The performance of the banking sector is often regarded as a reflection of the broader economy because its efficiency directly influences investment, employment creation, and poverty reduction. While earlier studies such as Misra and Aspal (2012) viewed banking sector performance as a measure of economic effectiveness, more recent studies by International Monetary Fund (2024) and World Bank (2023) confirm that banking sector resilience is a major determinant of economic recovery and financial stability in developing economies, particularly in Sub-Saharan Africa. Rural and Community Banks (RCBs) serve as the backbone of rural financial intermediation in Ghana by providing essential banking services to rural households, farmers, traders, and small-scale enterprises. According to ARB Apex Bank (2024), RCBs continue to account for a significant share of banking outlets in Ghana and remain the primary source of formal financial services in many rural communities. Their contribution to financial inclusion, agricultural financing, and local economic development makes them central to Ghana's rural development agenda. Related Ghanaian evidence also emphasizes the importance of savings and credit intermediation by rural banks (Donkor & Duah, 2013; Appiah et al., 2015).

The efficiency of RCBs has a direct effect on their ability to provide banking products such as credit facilities, savings mobilization, and payment services. Re-

cent studies by Anwar et al. (2019) indicate that technical efficiency significantly improves loan delivery, deposit mobilization, and financial sustainability among rural banks. Similarly, improved operational efficiency enhances the ability of RCBs to support agricultural production, microenterprise development, and rural commercial activities. Studies on bank performance have traditionally focused on earnings quality, management efficiency, internal control systems, loan recovery, and asset quality. These indicators are essential because they determine the level of financial risk exposure and the long-term viability of banking institutions. Velliscig et al. (2022) emphasize that strong performance measurement systems are necessary for ensuring financial soundness and regulatory compliance. However, relying solely on accounting-based financial ratios may provide only a partial view of institutional performance, as such measures often fail to capture broader operational and governance dimensions. Recent literature increasingly supports the use of efficiency frontier techniques such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) as more comprehensive approaches to evaluating bank performance. These methods provide a broader assessment by incorporating multiple inputs and outputs simultaneously and are particularly useful in measuring the efficiency of RCBs where both financial and non-financial factors influence performance. Amenu-Tekaa (2022) argues that weak prudential regulations, inadequate governance structures, and excessive directed lending requirements have significantly contributed to the poor performance of many RCBs in Ghana. These institutional weaknesses reduce managerial flexibility and increase exposure to credit risk. Similarly, the Bank of Ghana (2025) identifies governance failures, high non-performing loans, and weak internal controls as major threats to the sustainability of rural banks. Even where legal and regulatory frameworks are well established, financial institutions may still fail due to poor management decisions, weak risk management systems, and adverse macroeconomic shocks. The failure of RCBs poses serious risks to rural communities because these institutions often serve as the only accessible formal financial service providers. Their collapse can negatively affect savings mobilization, local investment, and rural economic stability. Therefore, for RCBs to remain competitive and sustainable, they must allocate resources efficiently, maintain sound loan management practices, and ensure adequate capital maintenance (Anwar et al., 2020). The resource utilization capacity of many Rural and Community Banks in Ghana remains relatively weak. Efficiency performance can be assessed through factors such as bank size, profitability, liquidity strength, funding quality, and governance effectiveness. Recent studies by Adusei (2016) show that weak resource allocation and poor operational management continue to limit the financial sustainability of many RCBs. In addition, digital transformation and stronger supervisory mechanisms are increasingly recognized as important drivers of rural bank efficiency. Related evidence links electronic banking and business-intelligence-based performance assessment to bank performance and monitoring (Khrawish & Al-Sa'di, 2011; Massardi & Utama, 2018).

This study is motivated by the need to understand the financial strength, effi-

ciency, and sustainability of RCBs in Ghana. Given their significant role in supporting rural investment, poverty reduction, and community development, continuous performance evaluation is necessary to reduce the incidence of insolvency, operational losses, and institutional failure. A comprehensive performance measurement system is therefore required to assess the soundness of RCBs and provide evidence-based recommendations for policy reforms, management improvement, and long-term sector sustainability. Against this background, it becomes imperative to evaluate the rural banking sector using robust efficiency measurement approaches that go beyond traditional accounting ratios and capture the broader dimensions of institutional performance and resilience.

2. Literature Review

2.1. Overview of Bank Performance and Rural Banking in Ghana

The banking sector plays a fundamental role in economic development by mobilizing savings, allocating capital, facilitating investment, and supporting monetary policy transmission. In developing economies such as Ghana, the banking system is particularly important because it serves as the primary channel through which financial resources are directed toward productive sectors such as agriculture, trade, and small-scale enterprise development. According to the Bank of Ghana (2024), the stability and efficiency of the banking sector remain central to macroeconomic resilience, financial inclusion, and sustainable growth. Within Ghana's banking architecture, Rural and Community Banks (RCBs) occupy a strategic position by providing financial services to underserved rural populations. These institutions facilitate agricultural financing, microenterprise development, savings mobilization, and poverty reduction. Recent reports from ARB Apex Bank (2024) indicate that RCBs continue to dominate formal financial access points in many rural communities and remain critical to achieving Ghana's financial inclusion agenda. Despite their importance, many RCBs continue to experience weak operational efficiency, poor loan recovery, governance challenges, and high non-performing loans. The Bank of Ghana (2025) identifies weak internal controls, poor credit risk management, and governance failures as major threats to the sustainability of rural banks. These challenges necessitate a deeper examination of efficiency performance beyond conventional profitability indicators.

2.2. Theoretical Framework

2.2.1. Efficiency Structure Theory

This study is anchored primarily on the Efficiency Structure (ES) Theory, originally developed in banking performance literature by Demsetz (1973) and later expanded by Athanasoglou et al. (2008). The theory argues that superior firm performance is primarily driven by managerial efficiency and scale efficiency rather than market concentration alone. Under this theory, banks that operate with better management practices, stronger cost control systems, and efficient resource allocation achieve higher profitability and improved financial sustainability. Man-

agerial efficiency enables banks to minimize operating costs, optimize asset utilization, and improve loan portfolio quality, while scale efficiency allows larger institutions to benefit from economies of scale. The relevance of this theory to the current study lies in its direct connection to cost, revenue, and profit efficiency measurement using frontier approaches such as Data Envelopment Analysis (DEA). Since this study evaluates the operational efficiency of RCBs rather than simple profitability ratios, the Efficiency Structure Theory provides a stronger theoretical foundation.

2.2.2. Market Power Theory

The Market Power (MP) Theory explains bank performance from the perspective of market concentration and competitive advantage. According to Berger (1995), banks with greater market share may earn higher profits due to pricing power and reduced competition. The theory includes two major approaches: the Structure-Conduct-Performance (SCP) hypothesis and the Relative Market Power (RMP) hypothesis. The SCP approach suggests that highly concentrated markets improve profitability because dominant firms exercise monopoly power, while the RMP hypothesis argues that firms with superior products and larger market share earn higher returns. Although relevant, this study prioritizes the Efficiency Structure Theory because the focus is on operational efficiency rather than market dominance.

2.3. Approaches to Measuring Bank Performance

2.3.1. Traditional Accounting-Based Measures (CAMEL)

The CAMEL framework remains one of the most widely used traditional methods for evaluating bank performance. It assesses financial soundness using five dimensions: Capital Adequacy, Asset Quality, Management Efficiency, Earnings Quality, and Liquidity. Additional indicators such as Return on Assets (ROA), Return on Equity (ROE), and Net Interest Margin (NIM) are also commonly applied (Sufian & Habibullah, 2010). The major strength of CAMEL lies in its simplicity and regulatory usefulness. It is frequently used by central banks and supervisory institutions to identify financial distress and early warning signals. However, recent studies by Velliscig et al. (2022) argue that accounting-based ratios provide only partial measures of performance because they fail to account for multiple input-output relationships, input prices, and operational inefficiencies. This limitation is particularly important in rural banking where governance quality, institutional structure, and resource allocation significantly influence performance.

2.3.2. Frontier Methods: Data Envelopment Analysis (DEA)

Due to the limitations of traditional ratio analysis, recent banking studies increasingly employ frontier efficiency methods such as Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). DEA, introduced by Charnes, Cooper, and Rhodes (1978), is a non-parametric linear programming technique used to evaluate the relative efficiency of decision-making units (DMUs) with multiple inputs and outputs. DEA is particularly suitable for banking studies because banks simultaneously transform multiple inputs (deposits, labor, capital) into multiple outputs (loans, investments, income). Unlike CAMEL, DEA captures technical, al-

locative, scale, cost, revenue, and profit efficiency in a multidimensional framework. Recent studies by Simar and Wilson (1998) and Anwar et al. (2019) confirm that DEA provides more robust estimates of banking efficiency, especially for rural financial institutions where operational complexity extends beyond accounting performance. For this reason, DEA is considered more appropriate for evaluating RCB performance in Ghana. DEA cross-evaluation can also improve discrimination among efficient decision-making units (Doyle & Green, 1995), while cost and profit frontier applications provide complementary evidence on banking efficiency (Béjaoui Rouissi, 2011).

On the basis of the weaknesses and criticisms of the classical methods of measuring efficiency, most contemporary research has increasingly relied on frontier efficiency methods based on the Neoclassical Production Theory to estimate or assess the performance of financial institutions. Frontier Efficiency measures deviations in performance from that of ideal "best-practice firms" on the efficient frontier, controlling for the effect of a number of exogenous factors such as the prices faced in local markets. Frontier efficiency scores summarize firm performance in a single statistic that can account for the differences among firms in a sophisticated multidimensional framework that has its roots in economic theory (Cummins & Weiss, 2000). Therefore, frontier methods seem to be superior to classical performance ratios and ascertain better estimates of the underlying efficiencies of firms. In the Frontier approach, bank efficiency performance is evaluated by economic (cost), technical, or allocative efficiency under the assumption that they are economic units or firms converting inputs into outputs. Other dimensions of bank efficiency include profit, revenue, pure technical efficiency, scale efficiency, etc. Data Envelopment Approach (DEA) is the most commonly used non-parametric technique, which involves linear programming estimation of the observed data sets to construct a piecewise, quasi-convex hull around data points in an input space to create a frontier surface that can be used to evaluate the relative efficiency of firms by comparing output and input ratios relative to the surface. The DEA was developed by Charnes, Cooper and Rhodes (1978). The underpinning premise is that there exists an idealized production point that all producers aspire to reach. With heterogeneity across sets, the firms will position themselves at varying distances from the efficient frontier: the closest becomes the most efficient (Murillo-Zamorano, 2004; Coelli et al., 2005).

DEA offers important peer information about similar units working under common environmental conditions. This is captured by controlling for environmental factors during the estimation (Tahir, Bakar, & Haron, 2009). The main strength of DEA estimation is that it does not need any theoretical imposition of the manner in which the economic behaviour of observed units should take. However, it is criticized on the basis that it does not create room for the possibility of accounting for statistical noise or measurement errors in the model. The lack of statistical inference has been solved in the latest empirical literature through the technique of bootstrapping. The method of bootstrapping uses the efficiency scores produced

by DEA as an a priori for inefficiency in a hierarchical Bayes estimation of a stochastic frontier (Simar & Wilson, 1998; Greene, 1995). The advantage of DEA is that it can be employed for firms that produce multiple outputs from multiple inputs. The multiple inputs and outputs of each Decision Making Unit can be combined into an overall single measure of technical efficiency. In addition, DEA does not require input prices or output prices in order for a best practice production frontier to be identified. Therefore, if a researcher chooses to use the DEA technique, the researcher can decide to concentrate on measures of technical, pure technical, and scale efficiency of each bank, apart from concentrating on measures of cost, revenue, or profit efficiency alone. Since the output of rural banks is multiple based on multiple inputs, the DEA approach is the most suitable for this study. Again, due to the difficulty of obtaining financial input prices in the banking industry, the DEA approach is a feasible choice for measuring rural bank efficiency. Generally, the DEA as a linear programming technique for measuring efficiency of a DMU can be expressed as:

$$\text{Max}\, h = \frac{\sum_r U_r Y_{rjo}}{\sum_i V_i X_{ijo}} \quad \text{Subject to}$$

$$\frac{\sum_r U_r Y_{rj}}{\sum_i V_i X_{ij}} \le 1 \qquad j = 1, \cdots, n \left(\text{for all } j\right)$$

The U_r and V_i are assumed to be always equal to some small positive quantity of ε, just so that no input or output is being ignored in the computation of the efficiency of the firm.

$$U_r, V_i \ge \varepsilon$$

From the equation above, if $h = 1$, then the DMU is assumed to be efficient. But in the case where $h < 1$, then the DMU is considered to be inefficient. One major disadvantage of the DEA method is that it goes with the assumption that there is absence of random noise or measurement error in the data. In an attempt to get rid of this challenge, a stochastic version of DEA, which gives a statistical foundation for DEA methods, has been pursued (Simar & Wilson, 1998). One way to obtain empirical data on the true distribution underpinning the DEA efficiency estimates is through the use of a resampling technique such as bootstrapping. The bootstrap, in the simplest form, involves randomly selecting thousands of 'pseudo samples' from the observed set of sample data. These thousands of pseudo estimates become an empirical distribution for the estimator of interest, which is used as the approximation of the true underlying distribution. Once the approximation of the underlying distribution is conducted, statistical inference and hypothesis tests can be carried out.

2.4. Empirical Review of Rural Bank Performance

Most empirical studies on bank performance classify determinants into bank-spe-

cific (endogenous) and macroeconomic (exogenous) factors. Bank-specific factors include size, capital adequacy, liquidity, asset quality, deposit structure, and management efficiency, while macroeconomic factors include inflation, GDP growth, interest rates, and market concentration (Flamini et al., 2009). In Ghana, Owusu-Antwi, Antwi, and Crabbe (2014) found that investment-to-assets ratio, overhead cost, loan-to-assets ratio, and inflation significantly influence rural bank profitability. Similarly, Boadi, Li, and Lartey (2016) reported that capital adequacy, liquidity management, and funding risk are key determinants of RCB performance. More recent studies provide stronger evidence. Anwar et al. (2019) found that technical efficiency significantly improves loan delivery, deposit mobilization, and sustainability among RCBs. Amenu-Tekaa (2022) showed that weak prudential regulation, poor governance, and excessive directed lending requirements significantly reduce efficiency in Ghanaian rural banks. Adusei (2016) further established that weak resource allocation, poor operational discipline, and high non-performing loans continue to constrain the financial sustainability of many RCBs. Their findings also highlight the growing importance of digital banking transformation and stronger supervisory frameworks in improving rural bank performance. The Bank of Ghana (2025) similarly reports that governance failures, weak internal controls, and rising non-performing loans remain major drivers of institutional weakness among RCBs.

2.5. Empirical Evidence on Bank Performance

Drawing inferences from the above theories and concepts on the measurement bank performance, many researchers have carried out studies to measure bank profitability and its determining factors. These factors have been variously categorized as endogenous and exogenous (Aburime, 2008; Athanasoglou et al., 2008; Hassan Al-Tamimi, 2010). Characteristics that are specific to firms and can influence banks profitability are considered as endogenous factors and may include size and composition of credit portfolio, size of deposit liabilities, liquidity, interest rate policy, management quality, risk level, asset quality ratios, and state of information technology, labour productivity, and capital structure. Internal factors are affected by the internal decisions taken by managers and directors of the firm. Exogenous factors are those factors which are external to the bank but have an influence on its profitability. Examples of these external factors include market concentration, ownership, stock market development, inflation, interest rates, and other macroeconomic conditions (Athanasoglou et al., 2008; Flamini et al., 2009). External factors cut across the country and so are outside the domain of the firm. According to Flamini et al. (2009), macroeconomic factors also influence the profitability of banks. This study, however, used endogenous factors as these have the propensity to vary from bank to bank, while exogenous factors remain relatively the same across firms, albeit with the ability to affect all the firms in an aggregate manner. This is consistent with broader evidence that bank profitability responds to macroeconomic and bank-specific conditions (Naceur, 2003; Olweny & Shipho, 2011).

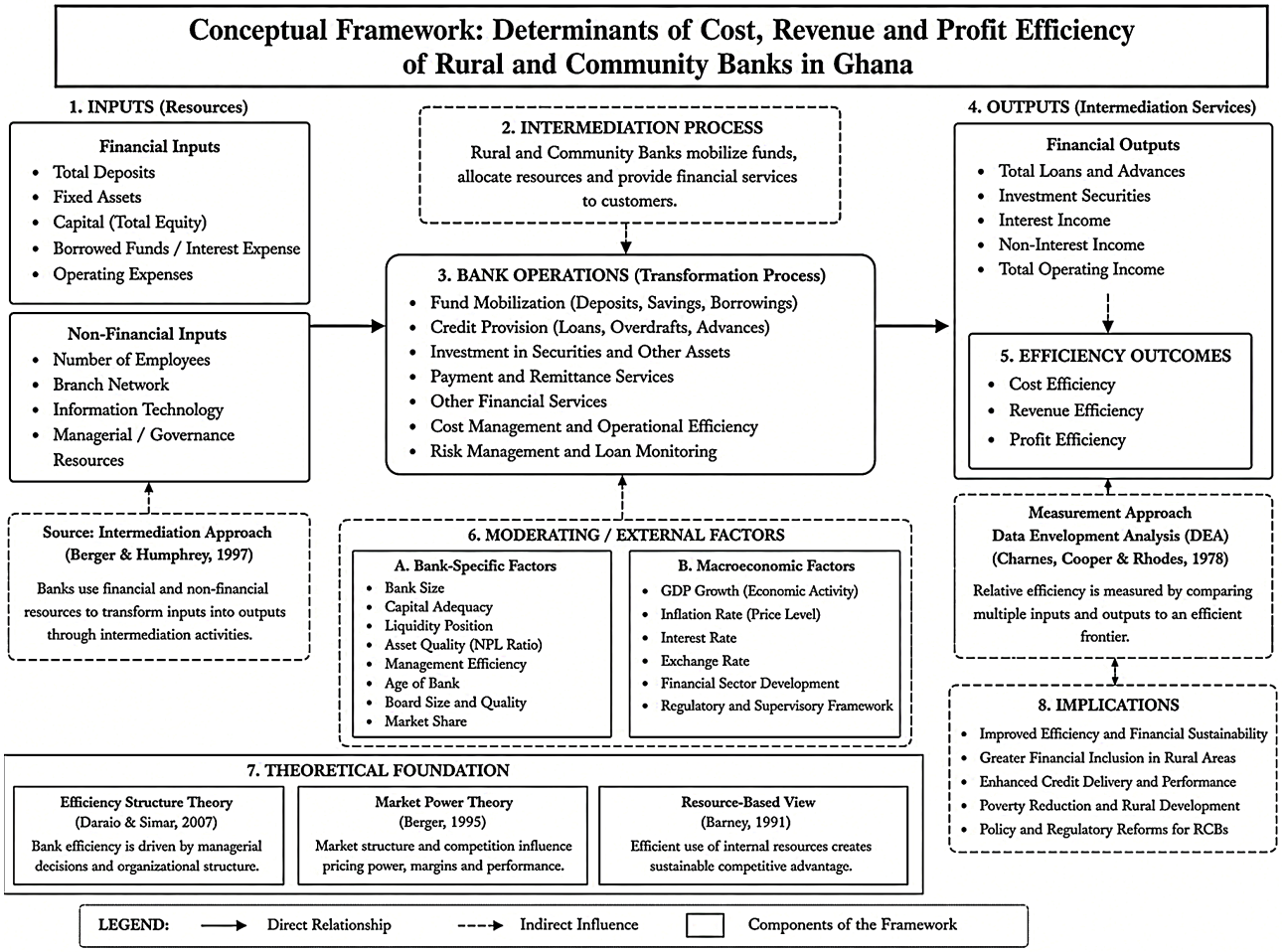
Researchers have identified the size of a bank as one of the endogenous factors that have been established as having a positive correlation with banks' profitability (Molyneux & Seth, 1998; Pilloff & Rhoades, 2002; Ramlall, 2009; Sufian, 2009). Despite the above research findings, some other researchers have conducted studies which have established that there is an inverse relationship between the size of a bank and its performance (Kosmidou, 2008; Spathis et al., 2002; Bouteska, 2020). According to Aburime (2008), the performance of banks is influenced by predicting, evading, and monitoring risks so that losses incurred as a result of risk are taken care of. Though it is critical for banks to hold liquidity, it has been noted that holding high liquidity incurs opportunity costs which could have been utilized in generating high returns (Kamau, 2009). Owusu-Antwi, Antwi and Crabbe (2014) carried out research that examined the key predictors of rural bank profitability using financial data from the Bank of Ghana and ARB Apex Bank annual reports, which covered all the existing 127 RCBs in Ghana from 2000-2012. Returns on assets were used as a proxy for profitability. A regression model was developed with return on assets as the dependent variable associated with six independent variables, which included both firm-level variables and macroeconomic factors. The findings of the study indicated that investment to total assets, the total overhead cost to total assets, loan to total assets, total assets, and inflation are the main drivers of rural banks' profitability measurement in Ghana. However, liquidity was found to have an insignificant impact on rural bank performance. Similarly, Boadi, Li and Lartey (2016) worked on the determinants of rural bank profitability. They used a fixed panel regression technique to assess the predictors of profitability using financial information of 114 rural banks in Ghana covering a period of 2005-2013. As an addition to the work done by Owusu-Antwi et al. (2014), Boadi et al. (2016) also focus on the impact of risk factors on profitability aside from the bank-specific and macroeconomic variables. In general, the results suggested that bank-specific factors such as capital adequacy, asset quality, liquidity management, and investment predict rural bank profitability. Moreover, the researchers also established that risk factors such as funding risk and bank resilience risk are also significant in determining the performance of rural banks. According to Boadi et al. (2016), the macroeconomic factors that influence the profitability of rural banks include GDP growth and inflation rate. They drew a conclusion by stating that continuous profitability performance of rural banks can curtail shortfalls in funding risk and increase the stability of rural banks. Again, Antwi and Apau (2015) also made an attempt to carry out an investigation into the factors that account for the performance of rural banks in Ghana. Using a panel data regression technique to analyse the performance of 30 rural banks in Ghana using financial data obtained from 2006-2010, the study indicated that credit risk, non-interest expense, bank's capital strength, GDP and inflation rate are significant determinants of rural bank profitability in Ghana. Similar to Boadi et al. (2016), the researchers showed that bank size is not a significant predictor of profitability.

2.6. Research Gap

Most previous studies on Rural and Community Banks in Ghana have focused primarily on profitability indicators such as ROA and ROE using traditional accounting-based approaches. While these measures are useful, they fail to capture broader operational efficiency dimensions such as cost, revenue, and profit efficiency. There is limited empirical evidence using frontier methods such as DEA combined with dynamic panel estimators such as System GMM to examine the determinants of cost, revenue, and profit efficiency among RCBs in Ghana. Furthermore, recent changes in prudential regulation, governance reforms, and macroeconomic shocks such as inflationary pressures require updated evidence. This study addresses this gap by employing a two-step DEA-System GMM approach to evaluate cost, revenue, and profit efficiency and identify their determinants among Rural and Community Banks in Ghana.

2.7. Conceptual Framework

See Figure 1.



Source: Author (2026).

Figure 1. The conceptual framework of the study.

3. Methodology

3.1. Data

This study relied on secondary data for the analysis. All the data were collected from the annual financial reports, sustainability reports, and reports from the websites of the selected RCBs in Ghana. Financial reports covering the periods from 2014-2019 were used because of their availability. This data covered a period of six (6) years for 20 RCBs. In sum, a panel dataset of 120 observations, which was well balanced, was used. Macroeconomic factors data employed in this study were taken from the website of the Ghana Statistical Service (GSS, 2014). The balanced panel of 120 bank-year observations was used for the first-stage DEA efficiency estimation. However, the effective sample employed in the second-stage System GMM estimation is smaller because the dynamic estimator requires lagged dependent variables and internally generated instruments, which reduce the number of usable observations during estimation.

3.2. Model Specification

3.3. First-Stage DEA Efficiency Estimation

The first stage of the analysis employs Data Envelopment Analysis (DEA) to estimate the cost, revenue, and profit efficiency of Rural and Community Banks (RCBs). Consistent with the banking literature, this study adopts the intermediation approach**,** which views banks as financial intermediaries that transform deposits, labour, and other operating resources into loans, investments, and other earning assets. The intermediation approach is particularly appropriate for Rural and Community Banks because their principal function is the mobilization of deposits and the allocation of financial resources to productive lending and investment activities. The efficiency analysis is estimated using an input-oriented Variable Returns to Scale (VRS) DEA model. An input orientation is appropriate because managers of Rural and Community Banks have greater control over the quantity of resources employed than over the demand for banking services. Consequently, the objective is to evaluate the extent to which each bank can minimize resource utilization while maintaining its observed level of financial outputs. The Variable Returns to Scale (VRS) specification proposed by Banker, Charnes, and Cooper (1984) is adopted instead of the Constant Returns to Scale (CRS) model because Rural and Community Banks differ substantially in size, operational capacity, market coverage, and managerial capability. The VRS model separates pure technical efficiency from scale efficiency and therefore provides more realistic efficiency estimates for institutions operating at different scales. This specification has become the preferred approach in banking efficiency studies involving heterogeneous financial institutions.

Following the intermediation approach, labour expenses, infrastructure expenditure, customer deposits, and total loans constitute the input variables used in the production process. Total cost, total revenue, and total profit represent the corresponding outputs for estimating cost, revenue, and profit efficiency, respectively. Input prices are incorporated in the estimation of cost and profit efficiency through

the observed prices of financial resources, while revenue efficiency is evaluated using observed output prices. The DEA framework therefore permits the simultaneous assessment of multiple inputs and outputs without imposing a specific functional form on the production technology.

For Cost Efficiency

It is assumed that all the n number of rural banks ($i = 1, 2, \cdots, n$) produce a vector of m outputs such that they are sold at r prices using a vector of v inputs for which they pay w input prices. The cost efficiency for the ith rural bank requires solving the following linear programming problems:

$$\text{Min} \quad \sum_v w_{jv} x_{jv}$$

$$\text{Subject to:} \quad \sum_i \lambda_i y_{im} \geq y_{jm} \quad \nabla m$$

$$\sum_i \lambda_i x_{iv} \leq x_{jv}$$

$$\sum_i \lambda_i = 1; \lambda_i \geq 0; i = 1, \cdots, n$$

For Revenue Efficiency

The revenue efficiency concerns the ability of the observed rural bank to maximise its revenue subject to the resource constraints. Again, it is based on the assumption that at all the n number of rural banks ($i = 1, 2, \cdots, n$) produce a vector of m outputs such that are sold at r prices using a vector of v inputs for which they pay w input prices.

The revenue efficiency for the ith rural bank requires solving the following linear programming problems:

$$\text{Max} \quad \sum_m r_j y_{jm}$$

$$\text{Subject to:} \quad \sum_i \lambda_i y_{im} \geq y_{jm} \quad \nabla m$$

$$\sum_i \lambda_i x_{iv} \leq x_{jv} \quad \nabla v$$

$$\sum_i \lambda_i = 1; \lambda_i \geq 0; i = 1, \cdots, n$$

For Profit Efficiency

Profit efficiency includes a more extensive concept than cost efficiency because it examines the effect of the production vector on both cost and revenue.

Profit efficiency is estimated by dividing observed profit of each DMU by the maximum profit that can be obtained with respect to the other efficient DMUs.

$$\text{Max} \quad \sum_m r_j y_{jm} - \sum_v w_{jv} x_{jv}$$

$$\text{Subject to:} \quad \sum_i \lambda_i y_{im} \geq y_{jm} \quad \nabla m$$

$$\sum_i \lambda_i x_{iv} \leq x_{jv} \quad \nabla v$$

$$\sum_i \lambda_i = 1; \lambda_i \geq 0; i = 1, \cdots, n$$

This solution is obtained from a linear combination of firms that produce at least as much of each of the outputs using the same or less amount of inputs. If this hypothetical firm were subject to the same input and output prices as the vir-

tual or best practice rural bank.

3.4. Second Stage Modelling: Determinants of Rural Bank Performance

Accordingly, while the DEA efficiency scores are computed using the complete balanced panel, the second-stage regression is estimated using the effective sample generated by the System GMM procedure. This distinction reflects the estimation requirements of dynamic panel models rather than missing observations in the original dataset. In the second stage, this study employs the two-step System Generalized Method of Moments (System GMM) estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998) to examine the determinants of bank efficiency. The choice of System GMM is motivated by the dynamic nature of bank efficiency, where current performance is influenced by previous efficiency levels. Furthermore, several explanatory variables, including profitability, liabilities, loan portfolio characteristics, and capital structure, may be endogenous because they are jointly determined with bank efficiency. Conventional estimators such as pooled Ordinary Least Squares (OLS), Fixed Effects (FE), and Random Effects (RE) may therefore produce biased and inconsistent estimates due to unobserved bank-specific heterogeneity, simultaneity, and reverse causality. System GMM addresses these econometric challenges by incorporating lagged dependent variables, controlling for unobserved heterogeneity through first differencing, and employing internally generated lagged instruments to mitigate endogeneity. The estimator is particularly appropriate for panels characterized by a relatively large cross-sectional dimension and a shorter time dimension, as is the case in this study. Consequently, System GMM provides consistent and efficient parameter estimates while preserving the dynamic behaviour of bank efficiency. Although the first-stage DEA analysis was conducted using a balanced panel of 120 bank-year observations (20 Rural and Community Banks observed over six years), the effective sample size for the second-stage System GMM estimation is smaller. The reduction in observations results from the dynamic specification of the model, which includes lagged dependent variables and internal instruments. The first-difference transformation used by the System GMM estimator removes the initial time period for each cross-sectional unit, while additional observations are excluded where valid lagged instruments are unavailable. Consequently, the estimation is based on the effective sample generated by the System GMM procedure rather than the original balanced panel. Among the main objectives of this study is to examine the factors that account for the performance of rural banks in Ghana. The use of the dynamic panel regression technique was to account for time persistence in the structure of rural bank performance. Dynamic panel data specification is generally given by:

$$y_{it} = \alpha + \delta y_{it-1} + \beta X_{it} + \delta G_t + u_i + \varepsilon_{it} \quad (1)$$

where y_{it} denotes the measures of rural bank performance (including cost efficiency, revenue efficiency and profit efficiency). X_{it} represent the vector of bank specific variables (including financial and non-financial variables) whiles

G_t denote the set of macroeconomic variables. α, β and δ denote the parameters to be estimated. The subscripts i and t denote the cross sectional and time dimension of the panel sample respectively. ε_{it} represent white noise. u_i is the unobserved heterogeneity across the banks. Equation (1) is consistently estimated using the System GMM technique.

3.5. Variable Selection

See Tables 1-3.

Table 1. Variables and Measurements for the Second Stage Modelling are shown in the table below.

Variable	Indicators	Measurement	Expected Sign
Dependent Variable			
Rural Bank Performance	Cost Efficiency (CE)	Computed using DEA-VRS approach	+(the higher, the better)
	Revenue Efficiency (RE)	Computed using DEA-VRS approach	+(the higher, the better)
	Profit Efficiency (PE)	Computed using DEA-VRS approach	+(the higher, the better)
Independent Variables			
Bank Specific Factors	Corporate Social Responsibility (CSR)	Expenditure on CSR	+/−
	Non-Performing Loans Ratio (NPLR)	Ratio of Non-performing loans to total loans	+/−
	Expenses to Total Assets (OE_TA)	Operating Expense divided by Total Assets	+/−
	Returns on Assets (ROA)	Ratio of Profits to Total Assets	+/−
	Returns on Equity (ROE)	Ratio of Profits to Total Equity	+/−
	Loan to Deposit ratio (Loan_Dep)	Total Loans divided by Total Customer Deposit	+/−
	Liabilities to Total Assets (Liab_Assets)	Total Liabilities divided by Total Assets	+/−
	Investment to Total Assets (Inv_TA)	Ratio of investment to Total Assets	+/−
Macroeconomic Variables	Gross Domestic Product (GDP)	Gross domestic product measured at constant price	+
	Inflation (Infl)	Annual inflation rate	−

Table 2. The variables used in the DEA efficiency estimation.

DEA Component	Variable	Measurement	Role in DEA Model
Inputs	Staff Salaries	Total staff salaries and employee-related expenses (GH¢)	Labour input used in the production of banking services
Inputs	Infrastructure	Expenditure on property, plant and equipment (GH¢)	Physical capital input

Continued

Inputs	Customer Deposits	Total customer deposits (GH¢)	Financial resources mobilized for intermediation
Inputs	Total Loans	Total loans and advances outstanding (GH¢)	Financial resources allocated in the production process
Outputs	Total Cost	Total operating expenditure (GH¢)	Output used in estimating cost efficiency
Outputs	Total Revenue	Total operating income (GH¢)	Output used in estimating revenue efficiency
Outputs	Total Profit	Net profit after tax (GH¢)	Output used in estimating profit efficiency
Input Price	Price of Loans	Net interest earnings divided by total loans	Proxy for the price of financial resources in the cost and profit efficiency models

Note: Following the intermediation approach, Rural and Community Banks are viewed as financial intermediaries that transform labour, physical capital, deposits, and loanable funds into financial outputs. The first-stage DEA employs an input-oriented Variable Returns to Scale (VRS) specification because bank managers exercise greater control over resource utilization than output demand, and the sampled banks differ considerably in operational scale and resource endowments. This specification enables the estimation of cost, revenue, and profit efficiency while accounting for scale heterogeneity among Rural and Community Banks. **Source**: Authors' compilation based on ARB Apex Bank financial statements and the DEA framework adopted in this study.

Table 3. The definition and expected effects of the explanatory variables.

Variable	Measurement	Expected Effect	Theoretical Justification
Loan-to-Deposit Ratio (LDR)	Total loans ÷ total deposits	+	Higher lending activity improves resource utilization and income generation, although excessive lending may increase risk.
Non-Performing Loans (NPL)	Non-performing loans ÷ total loans	−	Poor asset quality increases monitoring costs and reduces operational efficiency.
Return on Assets (ROA)	Net profit ÷ total assets	+	More profitable banks generally utilize resources more efficiently.
Return on Equity (ROE)	Net profit ÷ shareholders' equity	+	Higher shareholder returns reflect stronger managerial performance and operational efficiency.
Liabilities (LIAB)	Total liabilities	±	External financing can expand banking operations but may also increase financial costs if poorly managed.
Investment-to-Assets Ratio (IAR)	Investments ÷ total assets	+	Efficient investment allocation diversifies income sources and enhances revenue generation.
Expenses-to-Assets Ratio (EAR)	Operating expenses ÷ total assets	−	Higher operating costs generally reduce managerial and operational efficiency.
Inflation (INF)	Annual inflation rate (%)	−	Inflation increases operating costs and may weaken loan repayment capacity.
GDP Growth (GDPG)	Annual GDP growth (%)	+	Economic expansion improves business activity, loan demand, and bank performance.

Based on banking theory, profitability indicators such as ROA and ROE are expected to improve efficiency because profitable banks generally allocate resources more effectively. Conversely, non-performing loans and high operating expenses are expected to reduce efficiency by increasing credit risk and operational costs. Macroeconomic conditions, particularly inflation and economic growth, influence the operating environment within which Rural and Community Banks function, thereby affecting their efficiency performance. Including both bank-specific and macroeconomic variables enables a comprehensive assessment of the determinants of efficiency while reducing the risk of omitted-variable bias.

4. Results and Discussions

4.1. First Stage Analysis

Measurement and Benchmarking of Rural Bank Efficiency Based on the DEA Approach (Tables 4-6)

Table 6 presents the distribution of Rural and Community Banks across different efficiency score intervals for cost, revenue, and profit efficiency. The results indicate that 35% of the sampled banks achieved a cost efficiency score of 1.00, suggesting that seven institutions operated on the efficient frontier and utilized their resources efficiently. In contrast, only 25% of the banks attained full efficiency in both revenue and profit efficiency, indicating comparatively weaker performance in income generation and profitability. The majority of banks were concentrated within the 0.91 - 0.99 interval for cost efficiency and the 0.80 - 0.90 interval for revenue and profit efficiency. These findings suggest that while many Rural and Community Banks have achieved relatively high operational efficiency, considerable opportunities remain for improving revenue generation and profit performance through more effective resource allocation and operational management.

An examination of the kernel density plots (Figure 2, Figure 3, Table 7) shows that the efficiency scores of the RCBs are clustered at a high level around their mean. The overall cost, revenue, and profit efficiency of RCBs generally lies between 61% and 100%. From the density function, it is observed that the majority of RCBs have higher cost efficiency, with a mean of 96%.

Table 4. Cost, revenue and profit efficiency scores.

DMU	Cost Efficiency							Revenue Efficiency						
	2014	2015	2016	2017	2018	2019	Mean	2014	2015	2016	2017	2018	2019	Mean
1	0.987	1.000	1.000	1.000	1.000	1.000	0.998	0.871	0.653	0.620	0.643	0.766	0.703	0.709
2	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.875	0.807	0.802	0.784	0.841	1.000	0.852
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.733	0.895	1.000	0.886	0.920	0.864	0.883
4	1.000	0.987	1.000	1.000	0.966	0.969	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	0.950	1.000	1.000	1.000	1.000	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	0.813	0.775	0.804	0.789	0.912	0.912	0.834	1.000	0.846	0.890	0.814	0.848	1.000	0.900
7	0.724	0.694	0.674	1.000	1.000	1.000	0.849	1.000	0.886	0.862	0.696	0.747	0.783	0.829
8	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.994	0.926	0.930	0.936	0.969	0.959
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.781	0.898	0.991	0.945
10	1.000	1.000	1.000	0.999	0.969	1.000	0.995	0.914	0.800	0.878	0.869	0.910	0.877	0.875
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.832	0.889	0.789	0.918
12	0.999	0.905	0.878	0.895	0.910	0.877	0.911	0.610	0.676	1.000	1.000	1.000	1.000	0.881
13	1.000	1.000	1.000	1.000	1.000	0.923	0.987	0.865	0.910	0.949	1.000	1.000	0.973	0.950

Continued

14	1.000	1.000	1.000	1.000	1.000	0.972	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	0.903	0.870	1.000	0.949	0.796	0.866	0.897	0.959	0.951	1.000	1.000	0.959	0.986	0.976
16	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.724	0.632	0.743	0.647	1.000	0.786	0.755
17	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.949	0.957	0.984
18	0.782	0.825	1.000	0.886	0.920	0.864	0.880	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19	0.931	1.000	1.000	1.000	1.000	0.789	0.953	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	1.000	1.000	1.000	1.000	1.000	0.976	0.996	0.863	0.692	0.725	0.812	0.835	0.905	0.805

Table 5. Cost, revenue and profit efficiency scores-continuation.

DMU	Profit Efficiency						
	2014	2015	2016	2017	2018	2019	Mean
1	0.851	0.635	0.821	0.668	0.766	0.750	0.749
2	0.809	0.728	0.802	0.784	0.841	1.000	0.827
3	0.654	0.777	1.000	0.979	1.000	1.000	0.902
4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1.000	1.000	0.893	0.824	0.907	1.000	0.937
7	0.760	0.620	1.000	0.733	1.000	1.000	0.852
8	1.000	1.000	1.000	0.930	0.966	1.000	0.983
9	1.000	0.733	1.000	0.857	1.000	0.920	0.918
10	0.896	0.801	0.958	0.887	1.000	1.000	0.924
11	0.712	0.711	0.810	0.837	0.889	0.859	0.803
12	0.610	0.676	1.000	1.000	1.000	1.000	0.881
13	0.866	0.912	1.000	1.000	1.000	1.000	0.963
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000
15	0.965	0.965	1.000	1.000	0.959	1.000	0.982
16	0.740	0.629	0.656	1.000	0.709	0.675	0.735
17	1.000	1.000	1.000	1.000	0.949	1.000	0.992
18	1.000	1.000	1.000	1.000	1.000	1.000	1.000
19	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	0.875	0.705	0.907	0.863	0.981	0.953	0.881

Table 6. Distribution of rural and community banks by DEA efficiency scores.

Efficiency Score	Cost Efficiency No. of Banks	Cost Efficiency (%)	Revenue Efficiency No. of Banks	Revenue Efficiency (%)	Profit Efficiency No. of Banks	Profit Efficiency (%)
0.80 - 0.90	4	20.0	9	45.0	9	45.0
0.91 - 0.99	9	45.0	6	30.0	6	30.0
1.00 (Efficient Frontier)	7	35.0	5	25.0	5	25.0
Total	20	100.0	20	100.0	20	100.0

Note: DEA efficiency scores range from 0 to 1, where a score of 1.00 indicates that a Rural and Community Bank lies on the efficient frontier and is considered technically efficient relative to its peers. Scores below 1.00 indicate varying degrees of inefficiency, with lower scores reflecting greater potential for improving resource utilization. Source: Authors' computation using DEA results.

Table 7. Benchmarking of rural banks according to DEA-Efficiency scores.

	Benchmarking					
	DMU	Cost Efficiency	DMU	Revenue Efficiency	DMU	Profit Efficiency
Top Half	2	1.000	4	1.000	4	1.000
	3	1.000	5	1.000	5	1.000
	8	1.000	14	1.000	14	1.000
	9	1.000	18	1.000	18	1.000
	11	1.000	19	1.000	19	1.000
	16	1.000	17	0.984	17	0.992
	17	1.000	15	0.976	8	0.983
	1	0.998	8	0.959	15	0.982
	20	0.996	13	0.950	13	0.963
	14	0.995	9	0.945	6	0.937
Bottom Half	10	0.995	11	0.918	10	0.924
	5	0.992	6	0.900	9	0.918
	13	0.987	3	0.883	3	0.902
	4	0.987	12	0.881	12	0.881
	19	0.953	10	0.875	20	0.881
	12	0.911	2	0.852	7	0.852
	15	0.897	7	0.829	2	0.827
	18	0.880	20	0.805	11	0.803
	7	0.849	16	0.755	1	0.749
	6	0.834	1	0.709	16	0.735

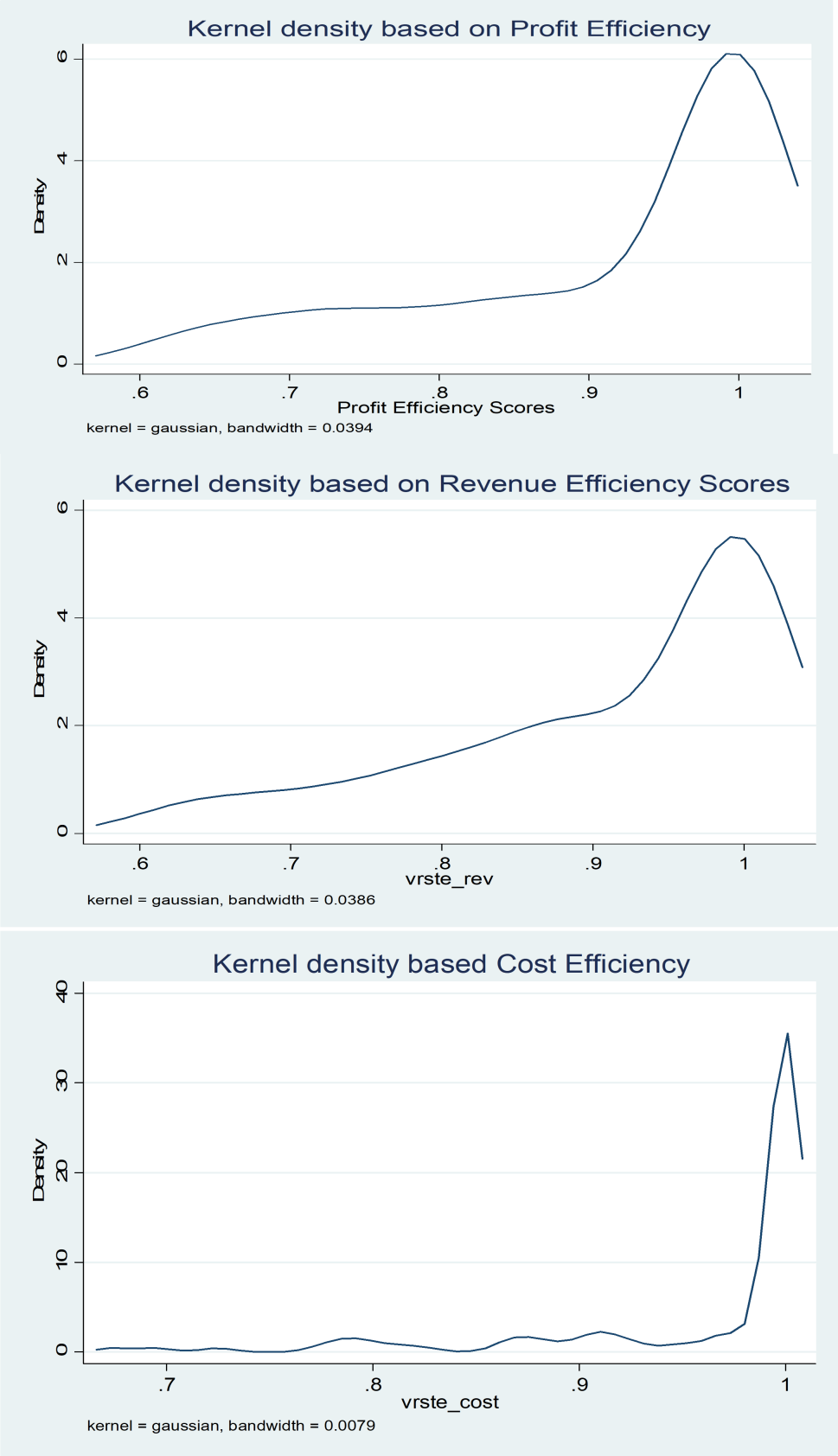


Figure 2. Kernel density function for cost, revenue and profit efficiency scores.

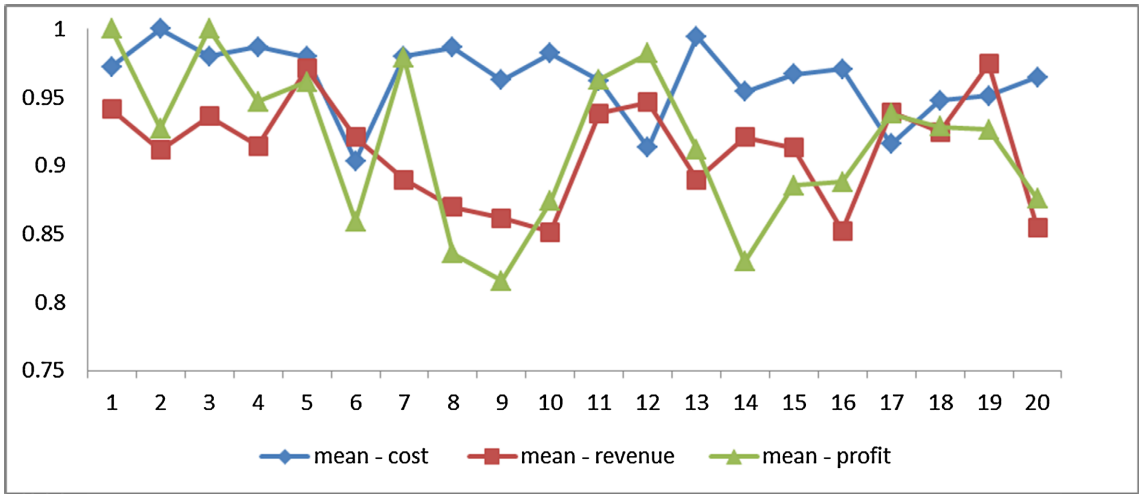


Figure 3. The overall average efficiency score of selected rural banks (2014-2019).

4.2. Second Stage Analysis: Determinants of Rural Bank Performance

The second stage analysis involves the investigation of the factors that determine the performance of rural banks over the sampled period. The study specifically explored the effect of bank specific variables which were largely financial variables as well as non-financial variables and macroeconomic factors on the level of rural bank efficiencies calculated in the previous section. The two-step system GMM approach is used to perform the estimations and the outcome of the analyses are presented in Tables 8-10. The study characteristically examined the determinants of cost efficiency, revenue efficiency and profit efficiency. Each estimation involved three (3) interconnected models.

4.2.1. Financial Performance and Bank Specific Variables

1 focuses on the effect of the financial bank specific variables. The variables used for this estimation are widely applied variables in extant studies under the CAMEL model. The reason for estimating Model 1 is not only to explore the effect of the widely used financial measures as predictors of performance but to also compare the results of the current study to the extant studies which have been largely based on the CAMEL model.

Model 2 then captures the effect of other bank specific variables which are likely to affect rural bank performance. The last model then introduces the macroeconomic factors to the estimation to capture their effects. Thus, the variables were added hierarchically. The purpose of adopting the hierarchical approach is to be able to track down any collinearity problems in the work; as this may affect the signs of the parameters and consequently lead to inconsistent results. Meanwhile, to curtail any potential biased results, the standard errors of the model results are corrected using Windmeijer (2005) finite-sample correction. The validity of the instruments used in the system GMM is checked using Sargan tests. First-order AR (1) and second-order AR (2) autocorrelation are also checked for each estima-

tion, as it is widely applied in the extant studies. The number of instruments was kept below 40 in all GMM specifications.

4.2.2. Determinants of Rural Bank Cost Performance

Table 8 displays the determinants of rural bank cost efficiency. The results indicate that in all the estimates, the instruments used are valid. This is suggested by the *p*-values of the Sargan test for over-identification restrictions. In addition, the tests for the presence of autocorrelation in the disturbance reported by both the AR (1) and AR (2) show that, excluding model 1 where a first-order autocorrelation was detected (without any evidence of second-order autocorrelation), no indication of autocorrelation existed either in the first or second order for models 2 and 3. It is therefore concluded that the models specified are robust and valid.

Table 8. Bank specific and macroeconomic determinants of cost efficiency. It is important to note that although the original dataset consists of a balanced panel of 120 observations, the System GMM estimator uses an effective estimation sample after applying the dynamic transformation and instrument construction. Consequently, the reported number of observations differs from the original sample size because the estimator excludes observations that cannot contribute valid lagged instruments. This reduction is an inherent feature of dynamic panel estimation and does not indicate missing data in the original dataset.

Variables	Cost Efficiency: Dependent Variable		
	MODEL 1	MODEL 2	MODEL 3
Cost_Eff (−1)	0.270 (0.069)***	0.204 (0.152)	−0.699 (0.738)
Cost_Eff (−2)	−0.429 (0.119)***	−0.498 (0.117)***	−0.517 (0.183)***
Liabilities	−0.108 (0.204)***	−0.135 (0.071)*	−0.034 (0.0189)*
Loans-to-Deposits	0.134 (0.002)***	0.012 (0.004)***	0.088 (0.006)***
Non-Performing loans	−0.770 (0.0682)***	−0.930 (0.503)*	−20.733 (0.889)***
Returns on Equity	0.092 (0.042)***	0.277 (0.076)***	0.392 (0.123)***
Investment-to-Assets	−0.008 (0.0181)	−0.037 (0.136)	−10.085 (0.362)***
Expenses-to-Assets	−0.147 (0.066)**	−0.289 (0.157)*	−0.249 (0.049)***
Returns on Assets	−0.104 (0.042)**	−0.292 (0.077)***	−0.417(0.127)***
Corporate Social Resp.		0.081 (0.083)	0.362 (0.208)*
Size		−0.105 (0.320)	0.386 (0.167)**
Age		−0.056 (0.103)	0.123 (0.053)**
Board size		−0.369 (0.533)	−0.449 (0.209)**
Market Share		0.135 (0.445)	−0.841 (0.269)**
Inflation Rate			0.812 (0.292)***
GDP Growth			0.501 (0.181)***
Year	−0.004 (0.005)	0.064 (0.168)	−0.005 (0.002)***
Constant	6.115 (9.161)	3.941 (3.520)	–

Continued

Diagnostic Test			
AR (1)	−2.2053	−1.1061	0.69022
p-value	0.0274	0.2687	0.4901
AR (2)	−0.3053	0.09598	1.1193
p-value	0.7601	0.9235	0.2630
Sargan Test	8.5552	7.0837	1.6056
p-value	0.6629	0.7926	0.9995
Prob > Wald chi^2	0.0000	0.000	0.000
Nos. Observations	64	64	64

*, **, *** denotes coefficients significant at 10%, 5% and 1%. **Note:** The reported observations represent the effective estimation sample used by the System GMM estimator after the inclusion of lagged dependent variables and internal instruments. The original dataset consists of a balanced panel of 120 bank-year observations.

4.2.3. Cost Efficiency and Bank Specific Variables

Starting from Model 1, the coefficient of the lag of cost efficiency indicates a strong persistence. The evidence shows that previous years' rural banks' performance has a strong positive effect on the current period performance. However, by the second period, such persistence is corrected. Focusing on the effect of the financial indicators, the results of Model 1 suggest that the growth in total liabilities has a detrimental effect on cost performance. It is also observed that the loans-to-deposit ratio has a statistically positive effect on cost efficiency. This confirms the proposition that the ability to convert customer deposits into loans yields better financial returns (Ayodeji Muyideen et al., 2025). Non-performing loans, an indicator of the quality of credit delivery is also observed to have a statistically negative influence on cost performance. This is an indication that rural banks that are able to ensure high loan quality achieve better performance. This result is consistent with the findings of Boadi et al. (2016), which identified a negative but statistically significant relationship between bank profitability and asset quality measured with non-performing loans. Indeed, a very interesting observation is made concerning the effects of profitability indicators of ROE and ROA on cost efficiency. Model 1 results show that while the effect of ROE on cost efficiency is positive and significant, ROA has a statistically strong negative effect on cost efficiency. This result is interesting, since ROE specifies the strength of the rural bank to generate returns for its shareholders; ROA indicates how management is efficiently utilizing its assets or resources to generate more income. The findings of Model 1 portray the notion that rural banks that provide higher returns to shareholders' equity perform better, thus confirming the bad management hypothesis. The implication of the negative effect of ROA on cost efficiency is that rural banks operate with higher costs in the use of their

resources to generate more income, so they are less profitable and therefore less cost efficient. The findings also support the "quiet life" hypothesis, where banks tend to hide behind high profit margins at the expense of low performance. The "Quiet Life Hypothesis (QLH)" posits that banks enjoy the advantages of market power in terms of foregone revenues or cost savings. Thus, cost and profits are negatively related to productivity and efficiency (Fiordelisi & Mare, 2014). This is quite the case among RCBs in Ghana, as the small banks tend to earn relatively smaller profit margins but are rated relatively more productive than their larger peers with large profit margins. This interpretation is also consistent with evidence that lending structure and credit conditions matter for bank performance (Hays et al., 2010).

Pertaining to Model 2, the other bank specific variables aside from the financial indicators are added to the estimation and their effects observed. In particular, the outlays on corporate social responsibility, size, age, board size and market share are added to the estimation, controlling for the financial indicators. It is observed that participation in CSR activities, age, board size, the size of the bank and market share did not have any statistically significant effect on cost performance. However, as observed in Model 1, growth in liabilities, loans-to-deposit ratio, non-performing loans ratio, ROE, and ROA have a significant effect on cost efficiency. The variables maintained their signs in the estimation of Model 2, an indication that collinearity is not a problem in this work. Another notable observation is the strong negative effect of second-period cost performance, while the previous period cost efficiency is positive but weak. The inclusion of CSR is also supported by banking evidence linking social-responsibility engagement to reporting and performance incentives (Grougiou et al., 2014).

Following the estimation of Model 2, the macroeconomic factors were subsequently added to the system GMM estimation to estimate Model 3. Thus, GDP growth and inflation rates were included in the specification while controlling for the bank specific variables.

The results of the Model 3 estimation show that both inflation and GDP growth have a positive and significant effect on cost efficiency. This finding corroborates the results of Boadi et al. (2016) who noted that the effect of GDP growth and inflation on banks' performance was both positive and significant. Meanwhile, the effects of banks' growth in liabilities, loans-to-deposit ratio, non-performing loans ratio, ROE, ROA and banks' leverage ratio have a significant effect on cost efficiency were further confirmed by the results in Model 3. Interestingly, it is observed that the size of the rural bank and market share both had a strong effect on cost performance. While the effect of size on cost performance is positive, the influence of market share on cost efficiency is negative and significant. The two reasons may account for this. It is possible that rural banks with strong market position may be experiencing scale diseconomies. It is also possible that due to their position and consequent expansion in total assets, rural banks with strong market position may resort to excessive risk-taking, such as increasing their leverage

above industrial average or engaging in high-cost-imposing activities. This therefore demonstrates a potential existence of moral hazard issues with large-sized rural banks in the region. The result also portrays that the age of the bank as well as the board size have a significant effect on cost performance. It is observed that while the age of the rural bank has a positive influence on cost efficiency, the size of the board has a negative relationship with cost performance. The result confirms the learning curve hypothesis, which stipulates that as the bank gains experience over time, it is able to reduce waste as it is able to learn from past experiences and best practices in the industry to inform future undertakings, thereby reducing potential losses and risks (Beck et al., 2013). Bouteska (2020) also shows that the large number of board members is detrimental to bank performance.

4.2.4. Determinants of Rural Bank Revenue Performance

Table 9 reports the dynamic panel regression analysis on the factors that account for variation of revenue efficiency among rural banks. The results suggest that in all the estimates, the instruments used are valid. This is suggested by the *p*-values of the Sargan test for over-identification restrictions. In addition, the tests for the presence of autocorrelation in the disturbance reported by both the AR (1) and AR (2) show no indication of autocorrelation in all the models. It is therefore concluded that the models specified are robust and valid. Beginning from Model 1, the coefficient of the lags of revenue efficiency suggests that shocks to rural bank performance are likely to correct in the second year. The evidence shows that second-period rural banks' performance has a strong negative effect on the current period performance.

With reference to the effect of the financial indicators, the results of Model 1 suggest that the loans-to-deposits ratio has a statistically positive effect on revenue efficiency, confirming the findings of Boadi et al. (2016). It is also observed that the investment-to-assets ratio has a positive impact on revenue efficiency, suggestive of the fact that rural banks that convert assets by investing in the capital markets perform better in revenue efficiency. Expense-to-assets ratio is also found to have a negative and significant effect on revenue performance.

Results of Model 2 show that the size of the rural bank contributes to the diminution of capital through revenue generation. It is observed that the effect of size on revenue performance is negative, confirming the proposition of a likely moral hazard in the operations of rural banks in the region. The findings suggest the potential of large-sized rural banks engaging in riskier portfolios under the presumption that any losses can be absorbed by the sheer size of the assets. Results of Model 2 present further confirmation of the fact that the loan-to-deposits ratio, investment-to-assets ratio and expenses-to-assets are strong determinants of rural bank performance in the region. Aside from these bank specific factors, it was found that the size of liabilities also influences revenue performance. The findings show that the size of liabilities has a statistically negative effect on revenue generation efficiency.

Table 9. The bank specific and macroeconomic determinants of revenue efficiency.

Variables	Revenue Efficiency: Dependent Variable		
	MODEL 1	MODEL 2	MODEL 3
Revenue_Eff (−1)	0.081 (0.094)	0.037 (0.196)	0.192 (0.2404)
Revenue_Eff (−2)	−0.268 (0.0742)**	−0.195 (0.0241)***	−0.364 (0.1163)***
Liabilities	0.127 (0.2280)	−0.059 (0.017)***	−0.126 (0.043)***
Loans-to-Deposits	0.026 (0.003)***	0.042 (0.019)***	0.042 (0.019)**
Non-Performing loans	−0.650 (0.8776)	−0.887 (20.218)	−0.708 (0.453)
Returns on Equity	−0.168 (0.1561)	−0.053 (0.163)	−0.050 (0.335)
Investment-to-Assets	0.117 (0.033)***	0.351 (0.037)***	1.244 (0.558)**
Expenses-to-Assets	−0.652 (0.3141)**	−1.081 (0.444)**	−2.172 (1.702)**
Returns on Assets	0.142 (0.153)	−0.091 (0.165)	0.020 (0.334)
Corporate Social Resp.		0.125 (0.219)	0.360 (0.208)
Size		−0.465 (0.099)***	−0.548 (0.293)*
Age		0.091(0.144)	0.099 (0.232)
Board size		−0.003 (0.052)	−0.004 (0.133)
Market Share		−0.268 (0.612)	−0.017 (0.119)
Inflation Rate			−0.0.327 (0.101)***
GDP Growth			−0.339 (0.178)**
Year	0.013 (0.0347)	−0.001 (0.004)	−0.002 (0.074)
Constant	−7.571 (6.327)	100.685 (9.948)	60.212 (4.707)
Diagnostic Test			
AR (1)	−1.0891	−0.83059	−1.7938
p-value	0.2761	0.4062	0.0728
AR (2)	0.48392	0.66181	−0.11551
p-value	0.6284	0.5081	0.9080
Sargan Test	8.212	7.5101	1.60491
p-value	0.694	0.7564	0.9995
Prob > Wald chi^2	0.0000	0.000	0.000
Nos. Observations	64	64	64

*, **, *** denotes coefficients significant at 10%, 5% and 1%. **Note:** The reported observations represent the effective estimation sample used by the System GMM estimator after the inclusion of lagged dependent variables and internal instruments. The original dataset consists of a balanced panel of 120 bank-year observations.

In Model 3, the macroeconomic factors were subsequently added to the system of GMM estimation, controlling for the bank specific variables. The results of the Model 3 estimation show that both inflation and GDP growth have a negative

effect on revenue efficiency. The striking implication of this result is that a decline in economic growth contributes to revenue performance among the sampled rural banks. This may be due to the fact that during recession, management is more careful with risks, thereby holding "safe" portfolios such as investing in government bonds and securities, which attract higher interest rates during periods of economic downturn. In contrast, the findings show that during periods of low inflation, the rural banks are more revenue efficient than in periods of high inflation. This suggests possible countervailing effects between inflation and GDP growth on rural bank performance. Alimi (2014) argued that a high rate of inflation worsens the efficiency of the financial sector through financial market frictions and slows down economic performance. In fact, market frictions entail the rationing of credit, which reduces intermediary activity and capital formation. The reduction of capital investment impacts negatively both on long-term economic growth and equity market activity.

Concerning the effects of bank specific factors, Model 3 results confirm earlier findings from Models 1 and 2 that loan-to-deposits ratio, investment-to-assets ratio, liabilities-to-assets and expenses-to-assets are strong determinants of rural bank performance in the region. Aside from these bank specific factors, it is found that the size of liabilities also influences revenue performance.

4.2.5. Determinants of Rural Bank Profit Efficiency

The bank specific and macroeconomic determinants of rural bank profit efficiency are displayed in **Table 10** below. Again, just like the previous models, the general robustness of the models estimated was confirmed by the Sargan test of over-identification and tests for autocorrelation. Following the general procedure, three models are also estimated to explore the determinants of rural bank profit efficiency. For model 1, the financial indicators are included in the modelling and results show that non-performing loans significantly contribute to the build-up of profit inefficiency. This confirms the earlier reports by Boadi et al. (2016) who identified a negative but statistically significant relationship between bank profitability and asset quality measured with non-performing loans. Interestingly, it is shown that the size of liabilities rather has a positive effect on profit efficiency. The conclusion that can be drawn is that while increases in liabilities are profit enhancing, the level and size of assets present a constraint to how much liabilities a rural bank can afford to maximise profits. At some point, the rural bank must strike a balance between liabilities and assets that will optimize profits; although the effect of the size of liabilities is positive, increasing liabilities without recourse to the asset size is bad business for the incumbent rural bank.

In Model 2, the other bank specific variables are also included in the estimation and the results show that none of the variables has a statistically significant impact on profit efficiency. In particular, participation in CSR activities, age, board size, the size of the bank and market share did not have any statistically significant effect on profit efficiency. However, as observed in Model 1, growth in liabilities and non-performing loans ratio have a significant effect on profit efficiency.

Table 10. Bank specific and macroeconomic determinants of profit efficiency.

Variables	Profit Efficiency: Dependent Variable		
	MODEL 1	MODEL 2	MODEL 3
Profit_Eff (-1)	−0.114 (0.1719)	−0.007 (0.1768)	−0.291 (0.271)
Profit_Eff (-2)	0.160 (0.075)**	0.175 (0.086)**	0.403 (0.096)***
Liabilities	0.051 (0.0203)**	0.085 (0.018)***	0.100 (0.014)***
Loans-to-Deposits	0.005 (0.004)	0.029 (0.011)***	0.213 (0.022)***
Non-Performing loans	−0.800 (0.174)***	−10.648 (0.905)*	−20.245 (1.174)*
Returns on Equity	−0.131 (0.157)	−0.358 (0.280)	−0.265 (0.133)**
Investment-to-Assets	0.120 (0.0975)	0.069 (0.132)	0.646 (0.249)***
Expenses-to-Assets	−0.377 (0.451)	−0.936 (0.706)	−10.761 (0.612)***
Returns on Assets	0.097 (0.153)	0.325 (0.278)	0.236(0.132)*
Corporate Social Resp.	0	0.092 (0.121)	0.207 (0.090)**
Size		−0.152 (0.158)	−0.136 (0.219)
Age		0.045 (0.072)	−0.004 (0.081)
Board Size		−0.047 (0.079)	−0.032 (0.068)
Market Share		0.054 (0.281)	0.330 (0.362)
Inflation Rate			−0.182 (0.047)***
GDP Growth			−0.184 (0.061)***
Year	0.032 (0.025)	0.007 (0.041)	0.003 (0.002)
Constant	−4.914 (4.398)	–	–
Diagnostic Test			
AR (1)	−0.7233	−0.13622	1.4809
p-value	0.4695	0.8916	0.1386
AR (2)	−1.4508	0.1340	−0.33081
p-value	0.1468	0.8934	0.7408
Sargan Test	4.952	6.7979	1.4261
p-value	0.9335	0.4502	0.997
Prob > Wald chi^2	0.0000	0.000	0.000
Nos. Observations	64	64	64

*, **, *** denotes coefficients significant at 10%, 5% and 1%. **Note:** The reported observations represent the effective estimation sample used by the System GMM estimator after the inclusion of lagged dependent variables and internal instruments. The original dataset consists of a balanced panel of 120 bank-year observations.

Meanwhile, it is observed that loans to deposit ratio has a strong positive influence on rural bank's profit efficiency. In Model 3, the macroeconomic factors were subsequently added to the system GMM estimation, controlling for the bank specific variables. The results of the Model 3 estimation show that both inflation and GDP growth have a negative effect on profit efficiency. The negative effect of GDP growth shows that periods of economic recession are commensurate with high profit efficiency among the rural banks.

As explained earlier, this may be due to the fact that during recession, management is more careful with risks, thereby holding "safe" portfolios such as investing in government bonds and securities which attract higher interest rates during periods of economic downturn. In contrast, the findings show that during periods of low inflation, the rural banks are more profit efficient than in periods of high inflation. Concerning the effects of bank specific factors, Model 3 results confirm earlier findings from Models 1 and 2 that liabilities and the non-performing loans ratio are strong determinants of rural bank performance in the region. Other bank specific factors that were found significant on profit performance are corporate social responsibility, investment to assets, returns to assets and loans to deposit ratio have a positive effect on profit performance. Moreover, returns to equity and expenses to assets have a detrimental effect on profit performance.

4.3. Discussion of Results

The aim of this study is to assess the performance of Rural and Community Banks (RCBs) in Ghana, particularly RCBs in the Ashanti Region of Ghana, and identify the macroeconomic and bank specific factors that influence rural banks' performance. A total of 20 rural banks out of the target group of 25 rural banks in Ashanti region have been used for this study. Financial information was gathered from the sampled rural banks focusing on 2010-2015 financial years. Rural bank performance was evaluated from three main dimensions including cost efficiency, revenue efficiency and profit efficiency using the widely applied non-parametric DEA approach. The purpose of focusing on rural banks in Ghana was specifically due to the fact that in spite of the economic contributions of rural banks to economic growth and development, their operations are met with serious challenges threatening their sustainability and ability to perform their core functions. Unfortunately, literature has not dealt adequately in terms of research into the factors that account for their operational challenges that rural banks face. Most of the studies have relied overly on accounting ratios as a means of evaluating performance. However, such an approach is limited in terms of the ability to capture the true performance of the rural banks performance. The need to adopt modern approaches to evaluating rural bank performance was emphasized and inspired the execution of this current work.

The study findings portray that the sampled rural banks perform better under cost efficiency compared to profit efficiency and revenue efficiency, respectively. The DEA efficiency scores reveal that the average efficiency scores are 96.4%,

91.1% and 91.6% for cost efficiency, revenue efficiency and profit efficiency, respectively. The implication is that the rural banks can obtain input savings of about 3.6% in terms of cost performance; 8.9% for revenue mobilization and 8.4% for profit efficiency. Pertaining to the benchmarking, the findings of the study reveal that a significant number of rural banks that were profit efficient were also relatively revenue efficient; however, profit and revenue efficiency did not necessarily imply cost efficiency. This result is interesting given the fact that profit efficiency indicates the ability of the rural bank to optimise profit given revenue and cost conditions, whereas revenue efficiency illustrates the ability of the rural to efficiently generate revenue from its revenue generation sources. Conversely, cost efficiency demonstrates the ability of the rural bank to maximize output using the least cost approach.

Concerning the determinants of rural bank performance, the findings of the study reveal that bank specific factors and macroeconomic variables are the predictors of rural bank performance in Ghana. First, the results of the study show that whilst shocks to rural bank performance are usually corrected in the second period, previous years' performance can have a strong influence on current period performance especially relating to cost performance. Focusing on financial bank specific indicators (CAMEL based indicators) of rural bank performance, the study findings show the bank specific factors have a varying effect on different bank performance components—revenue, cost and performance.

For example, pertaining to bank specific determinants of cost performance, it is found that banks' growth in liabilities, loans to deposits and non-performing loans ratio, as well as ROE and ROA have a significant effect on cost efficiency. On the other hand, loan-to-deposits ratio, investment-to-assets ratio, and expenses-to-assets and the size of liabilities also influence revenue performance. For profit efficiency, the findings show the strong influence of growth in liabilities and non-performing loans. Meanwhile, the effect of expense-to-assets ratio and investment to assets were found to be mixed on cost performance; whiles growth in liabilities was also estimated to have a mixed influence on revenue performance. Likewise, loans to deposit ratio and returns on equity were found to provide mixed effect on profit performance. The implication of the study findings is that bank specific financial indicators do not draw a homogenous impact on dimensions of rural bank performance in terms of effect size and direction of influence. The findings of the study show some variations in terms of the impact on cost efficiency, revenue and profit efficiency.

The findings of this study, however, extend empirical support to the findings of Tesfai (2015), Ongore and Kusa (2013), Sangmi and Nazir (2010), and Ongore and Kusa (2013), while also aligning with more recent empirical studies such as Boadi et al. (2016). The result of this work corroborates the extant literature and concludes, however, that the earnings quality—illustrated by the influence of expenses-to-assets; management efficiency as well as bank liquidity—illustrated by the influence of loans-to-deposits; and asset quality measures—given by the effect of non-performing loans ratio have a statistically strong effect on rural bank per-

formance. This implies that rural banks that are able to control operational expenses, maintain prudent liquidity management, and ensure effective loan portfolio quality are more likely to achieve stronger efficiency outcomes in terms of cost, revenue, and profit generation. In particular, the negative effect of non-performing loans reinforces the importance of credit risk management and loan recovery systems, while the positive contribution of loans-to-deposit ratio suggests that efficient financial intermediation remains central to rural bank sustainability. Similarly, the effect of expenses-to-assets ratio confirms that earnings quality remains a major predictor of operational efficiency, as excessive operating costs directly reduce profitability and weaken institutional resilience. The need for management to focus on these areas to ensure improved performance in the credit market is therefore highly emphasized, particularly within the context of Rural and Community Banks (RCBs) where credit delivery and financial inclusion remain core institutional mandates.

Relating the effect of non-financial bank-specific indicators on rural bank performance, the findings of this study portray that whereas the size of the rural bank may have an influence on both cost efficiency and revenue performance, the market share of the rural bank affects only the cost performance. A notable observation from the study results is that there is a potential existence of moral hazard issues with large-sized rural banks in the region. The findings suggest the potential of large-sized rural banks engaging in riskier portfolios under the presumption that any losses can be absorbed by the sheer size of the assets. This situation may arise because larger banks tend to enjoy stronger market confidence and easier access to funds, which may encourage management to undertake aggressive lending strategies, excessive leverage, or high-cost expansion decisions that eventually reduce operational efficiency. It is essential to stress that the age of the rural bank as well as the number of board members and corporate social responsibility—indicators of bank governance—have a significant effect on cost performance. It is observed that while the age of the rural bank has a positive influence on cost efficiency, the size of the board has a negative relationship with cost performance. The result supports the learning curve hypothesis, which stipulates that as a bank gains experience over time, it is able to reduce waste, improve operational processes, and adopt more efficient managerial practices. Older banks are therefore more likely to benefit from institutional memory, accumulated managerial knowledge, and stronger stakeholder trust, all of which improve efficiency performance (Beck et al., 2013). Meanwhile, the negative influence of board size on cost performance is consistent with Pathan et al. (2007) and Staikouras et al. (2007), who report an adverse association between larger boards and bank performance. Bouteska (2020) further confirms that board characteristics are important determinants of bank performance. Mang'ana et al. (2017), and Bouteska (2020) also show that the large number of board members is detrimental to bank performance. This may be explained by coordination difficulties, slower decision-making processes, increased agency problems, and weaker monitoring efficiency associated with excessively large boards.

In terms of macroeconomic indicators of rural bank performance, the findings of this current work reveal that the effect of macroeconomic variables on rural bank performance is mixed. Accounting for cost efficiency, the study results show that both inflation and GDP growth have a positive and significant effect on cost efficiency. This finding corroborates the results of Mirzaei, Liu, and Moore (2011), Pasiouras and Kosmidou (2007), as well as more recent studies by Boadi et al. (2016) who noted that the effect of GDP growth and inflation on banks' performance was both positive and significant. This suggests that during periods of economic expansion, improved household income, stronger business activities, and enhanced repayment capacity improve banking operations and reduce cost inefficiencies. Explaining the variations in profit efficiency and revenue efficiency, the findings of the current study show that both inflation and GDP growth have a negative effect on revenue efficiency. The striking implication of this result is that there is a possible countervailing effect between inflation and GDP growth on rural bank performance. A decline in economic growth is revealed to contribute to revenue performance, whereas low level of inflation is associated with high revenue efficiency. This may be due to the fact that during recession, management is more careful with risks, thereby holding "safe" portfolios such as investing in government bonds and securities, which attract higher interest rates during periods of economic downturn. Such defensive portfolio adjustments may improve short-term revenue efficiency despite weaker macroeconomic growth. However, under conditions of low inflation rates, the slow rise in general price levels is conducive for banks to generate higher revenue because stable prices reduce uncertainty, improve repayment discipline, and lower the cost of financial intermediation. High inflation, on the other hand, increases market friction, weakens savings mobilization, reduces real returns, and worsens financial sector efficiency (Alimi, 2014). Azariadis and Smith (1996) on the other hand emphasize the importance of threshold level of inflation in the relationship between inflation and financial sector performance, and recent studies continue to support the argument that inflation exerts both direct and indirect effects on banking sector productivity depending on the macroeconomic environment and the level of financial market development.

5. Conclusion and Recommendation

5.1. Conclusion

This study sought to examine the macroeconomic and bank specific determinants of rural bank performance in Ghana, focusing on Ashanti Region. Rural bank performance was evaluated in terms of cost, revenue and profit efficiency. Generally, the findings of the study show that there is room for RCBs in Ghana to improve their performance. The findings of the study suggest that rural banks can obtain input savings of about 3.6% in terms of cost performance, 8.9% for revenue mobilization and 8.4% for profit efficiency. Again, while not many RCBs were identified as fully efficient in terms of cost, revenue or profit, there is strong evidence to suggest that the sampled rural banks perform better in cost efficiency compared

to revenue and profit efficiency. Moreover, the findings of the study revealed that the banks that are profit-efficient are also relatively revenue efficient. However, profit and revenue efficiency did not necessarily imply cost efficiency. Pertaining to the determinants of rural bank performance, the findings collectively suggest that both bank-specific factors and macroeconomic environments have diverse significant impacts on RCBs' performance. The results of this work corroborate with the extant literature and conclude, however, that earnings quality—illustrated by the influence of expenses-to-assets; management efficiency as well as bank liquidity—illustrated by the influence of loans-to-deposits; and asset quality measures—given by the effect of non-performing loans ratio; have a statistically strong effect on rural bank performance. The need for management to focus on these areas to ensure improved performance in the credit market is highly emphasized. Another notable observation from the study results is that there is a potential existence of moral hazard issues with large-sized rural banks in the region. The findings suggest the potential of large-sized rural banks engaging in riskier portfolios under the presumption that any losses can be absorbed by the sheer size of the assets. The evidence provided by this study also shows that there is a possible countervailing effect between inflation and GDP growth on rural bank performance.

5.2. Recommendations

Based on the findings of this study, the following recommendations are suggested:

The overall findings of the study, generally, suggest that there is room for RCBs in Ghana to improve their cost, revenue, and profit efficiency. The findings, collectively, also suggest that both bank-specific factors and macroeconomic environments have diverse significant impacts on RCBs' performance. By inference to the totality of the RCBs industry, these findings provide important policy implications for individual RCBs and industry stakeholders (regulators) to improve the performance of RCBs if RCBs must succeed in undertaking their core mandates. It is therefore recommended that RCBs should improve their managerial efficiency so they can make crucial decisions that will lead to improved financial performance of the banks. It is expedient for RCBs to increase their efforts in generating non-interest income through commissions, net earnings from the sale of investment securities, and guarantee fees, as these would contribute immensely to the profitability of RCBs.

Furthermore, it is also vital for the management of RCBs to pay due attention to the effective management of their assets in order to improve the asset earnings quality—illustrated by the influence of expenses-to-assets; management efficiency as well as bank liquidity—illustrated by the influence of loans-to-deposits; and asset quality measures—given by the effect of non-performing loans ratio. The need for management to focus on these areas to ensure improved performance in the credit market is highly emphasized. This means that the core banking activities of RCBs, which include lending, should be improved in order to boost the quality of earnings of the banks, as it determines the earning power of RCBs. This study therefore

recommends that management of RCBs should create internal policies which will improve the liquidity position of the banks through the identification, measurement, monitoring and control of liquidity risks in RCBs.

5.3. Limitations and Future Research Direction

The following are the limitations within which this study was conducted. First, this study utilized data from twenty (20) selected RCBs in Ashanti Region, and this scope is a major constraint on the ability of the researcher to generalize the findings for all RCBs in Ghana. Future studies should be conducted using more RCBs and compared with other financial institutions that operate in rural areas. Another major limitation of this study involves the use of a six-year financial data on the selected RCBs. The data used covers the period of 2014 to 2019. Hence, any uneven trend before or beyond the set period will be a limitation of the study. It is recommended that further studies be carried out on RCBs using data that spans more than five years in order to improve the quality of the findings. The analysis of this study was only based on monetary data; hence, non-monetary factors were not considered in this study. Other researchers could factor non-monetary factors into their studies on RCBs.

Author Contributions

All authors contributed to the conception and design of the study, data acquisition/curation, analysis and interpretation of the findings, drafting of the manuscript, and critical revision of the manuscript for important intellectual content. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the work.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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