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ORIGINAL RESEARCH

Determinants of bank efficiency in developed (G7) and developing (E7) countries: role of regulatory and economic environment

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Abstract
Efficiency is one of the key factors promoting the long-term performance and sustainability of the banking industry. In this context, this paper investigates the implications of the regulatory environment, macroeconomic factors, monetary conditions, and uncertainty for the banking sectors' operating as well as investment efficiencies. Using data from G7 and E7 countries from 2001 to 2020, we employ a set of empirical techniques, including Fixed Effects, Random Effects, Panel Fully Modified Least Squares, Panel Dynamic Least Squares and Generalized Method of Moments. Our key findings show that leverage, capital adequacy, monetary conditions, economic growth, price stability as well as exchange rate stability and uncertainty have substantial effects on bank efficiency, with notable differences between impact on operational and investment efficiencies and developed (G7) and developing (E7) economies.

Keywords Bank efficiency · Operational efficiency · Investment efficiency · Capital adequacy · Leverage · Monetary policy · Uncertainty · Financial regulations · Economic growth · G7 · E7

JEL Classification E52 · E58 · G18 · G21

1 Introduction

The banking sector plays a critical role in the development and functioning of the economy. An efficient banking sector is a key driving force for economic activity and, as such, the banking sector remains under the special attention of policymakers and regulators. Through financial intermediation, the banking sector serves two core purposes—the

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creation of liquidity and the mitigation of risks. Thus, banks are essentially pools of investment capital looking for returns, whilst the banking system aims to provide a framework to attract more capital and allocate it as efficiently as possible, and in doing so maximise profits.

In the context of a more financially integrated world, the global financial system remains vulnerable to numerous potential risks (Nasir and Du 2018). The profound importance of the banking sector for the domestic and global economy has led to many studies focusing on the factors that may affect the performance of the banks (Le et al. 2020; Huynh et al. 2020a, b), yet measures of efficiency are relatively underexplored. Following the emergence of globally coordinated financial sector reforms since 1990s under the Basel framework (See BIS 2022; Goodhart 2011), there has been a significant shift in the banking environment, and these reforms have had a notable impact on the operations of commercial banks. One of the key goals of these reforms was to increase the resilience of the banking system and evidence suggests that regulatory reforms have indeed had some implications for the banking sector's performance in terms of both profitability (Le et al. 2020) and efficiency (Barth et al. 2013a). In this study, we specifically focus on the efficiency of the banking sector. The notion of efficiency as an overall performance measure for all types of businesses was first articulated in the early works of Edgeworth (1881) and Pareto (1927), and its empirical implementation was documented by Shephard (1953). Efficiency generally refers to the optimal utilization of scarce resources, minimizing costs while maximizing results. As with any sector of the economy, the efficiency of the banking sector is profoundly important (Ullah et al. 2023). Banks that generate higher yields from a fixed amount of input are identified as efficient institutions. Thus, employing a resource-based perspective, we can assess bank efficiency by examining their input and output resources. As such, one of the most important tasks in measuring efficiency is the identification and measurement of inputs and outputs (Kao and Liu 2014).

In this regard, this study employs measures of both operational efficiency and investment efficiency. Operational efficiency is narrowly defined as the ability to deliver products and services cost-effectively without sacrificing quality. It can also be defined as what occurs when the right combination of people, processes, and technology come together to enhance the productivity and value of any business operation while driving down the cost of routine operations to a desired level. Investment efficiency, as defined by Hodgson et al., (2000), is a function of the risk, return and total cost of investment management, subject to the constraints within which investors must operate. The stability and consistency of relative returns reduce active risk at the overall level and could improve active returns and lower net costs through stock lending (See Hodgson et al., (2000) for details). As one of the contributions to the literature is to measure both types of efficiencies, we employ the Data Envelope Analysis (DEA) method, as used by Phan et al. (2018) and Banna et al. (2018). This is an effective approach to assess cost, technical, and scale efficiencies. Despite disagreements about the most appropriate methodological approach, it is widely agreed that focusing on a single aspect of firm-level efficiency is not sufficient. Instead, the efficiency should be assessed from numerous angles since measurements of efficiency are more convincing if estimates are consistent across multiple approaches.

Improving efficiency has proven to be challenging for the banking industry, with evidence suggesting that the efficiency of the banking sector is influenced by both internal and external factors (Athanasoglou et al. 2008; Dietrich and Wanzenried 2011; Defung et al. 2016). Indeed, bank efficiency is likely to be affected by numerous other factors, including monetary conditions (and thus monetary policy), financial conditions (and thus financial policy), as well as macroeconomic factors influencing banks both directly and indirectly.

For instance, favourable macroeconomic conditions can lead to the growth of the banking industry, while an unstable and uncertain macroeconomic environment can affect banks' credit and market risk, resulting in poor banking efficiency. Furthermore, ripple effects from macroeconomic crises, particularly in developed markets, can impede bank efficiency both domestically as well as in other countries around the world.

Economic and financial uncertainty can also impact banking efficiency through its impact on businesses, households and wider society (Nasir and Morgan 2018; Huynh et al. 2020b; Nasir 2020; Tiwari et al. 2021; Makarem et al. 2023; Yu et al. 2023). For instance, economic policy uncertainty can have an impact on bank loan portfolios as banks often respond to high economic policy uncertainty by raising interest rates and reducing the amount of credit extended to borrowers, which could also have implications for the real economy (Bordo et al. 2016). Increased economic uncertainty can also raise firms' credit risk and transfer more risk to the banking sector. Furthermore, increased economic uncertainty makes it difficult to predict the profits of investment projects consequently reducing banks' revenues. Decision-making under uncertainty is particularly difficult, with implications for all aspects of the economy—including the financial sector (see Stokey 2008; Bloom 2009; Nasir 2020). Therefore, it is cogent to expect a significant nexus between uncertainty and bank efficiency and, given the lack of existing evidence on this issue, it is important to further analyse this relationship which the subject study aims for.

This study provides numerous contributions to the existing literature on the topic of banking efficiency. First, it employs an inclusive approach that accounts for various factors affecting bank efficiency, including macroeconomic variables, economic policy uncertainty, the regulatory environment as well as monetary and credit conditions. Second, this study uses capital adequacy as well as leverage to capture various aspects of bank regulation. Third, unlike previous work that focused solely on operational efficiency (e.g., Barth 2013), this study employs measures of both operational efficiency and investment efficiency. Fourth, unlike Barth et al., (2013a, b) who focused on the pre-Global Financial Crisis (GFC) period, this study employs data from 2000 to 2020 which encompasses both the pre- and post-crisis period, a valuable addition given the profound changes in the banking system over this period (Barth 2013b). In particular, we use a dataset that includes 12 years after the GFC during which BASEL-III and regulatory frameworks have been updated. Fifth, we also argue that the empirical approaches we employed are more novel and better account for issues of endogeneity. Sixth, we also analysed the implications of uncertainty for operational and investment efficiency, to the best of our knowledge, no study has done this before. Seventh, we also analysed the implications of monetary policy and credit conditions for banking efficiency, including the recent move towards monetary or Quantitative Tightening (Q.T) by many central banks across the world. Last but not least, we employed a comprehensive set of control variables, including economic growth, unemployment, inflation and the exchange rate for both measures of bank efficiency in the underlying economies and performed a comparative analysis.

As a corollary to the above-claimed contributions, this study also contributes to the literature by examining and comparing the developed and developing countries' banking sector efficiencies. While some previous studies (details in the literature review section) have examined the impact of some of the factors we are incorporating (e.g., macroeconomic variables) on bank efficiency, they are either limited to a single country/region or focused on a limited number of factors. In this regard, Cull et al (2017) have argued that the banks in developed and developing countries may vary in terms of their efficiency. Consequently, by focusing on banks in the G-7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) as well as the E-7 (Brazil, Russia, India and China plus Mexico, Indonesia, and Turkey) countries, this study adds to the existing literature on banking efficiency by considering a group of developed and developing countries and a large variety of relevant factors. This allows us to see if there are disparities in the effect of numerous factors on bank efficiency across developed and developing countries which may then lead to a different set of policy implications under the notion that the one size may not fit all!

Employing the DEA approach to account for both the operational and investment efficiencies of banks in 14 (G7 and E7) economies over 20 years, we analyse the effects of numerous factors, including macroeconomics (e.g., economic growth, inflation, unemployment, exchange rate, economic policy uncertainty and monetary policy) as well as financial (e.g., regulatory environment, credit conditions) on the efficiency of the banking system. The analysis employs several estimation techniques including Fixed Effects, Random Effects, Panel Fully Modified Least Squares, Panel Dynamic Least Squares and Generalized Method of Moments. Our key findings suggest that the leverage, capital adequacy, monetary conditions, and economic outlook (i.e., growth and employment, price stability as well as exchange rate stability and uncertainty) have substantial effects on the operational and investment efficiencies of the banking sector. There are crucial differences in the impact of these factors on the two forms of efficiency between developed and developing countries. Under the effects of the regulatory and economic environment, uncertainty and monetary regime, the banking sector efficiencies of developed and developing economies differ substantially. The findings have profound implications for policymakers and stakeholders of the banking sector and financial stability in the context of bank efficiency.

The remainder of the paper is organized in the following manner. The literature on banking efficiency is discussed in Sect. 2. The definitions of inputs, outputs, and variables are revealed, while the methodology is introduced in Sect. 3. Section 4 reports and discusses empirical findings. Section 5 concludes and draws policy implications.

2 Literature review

The GFC revived interest in prudential regulations and their effectiveness for banking sector growth, performance, and stability (Barth et al., 2004, 2008). While several studies on bank efficiency have focused on various aspects such as the function of management, institutional ownership, and policy reforms and their effects on banking efficiency, by analysing how banking regulations, macroeconomic factors, uncertainty and monetary policy affect banks' operational efficiency and investment efficiency, this study contributes to the existing literature. This section critically discusses the existing evidence and caveats in the body of knowledge on the subject.

2.1 Macroeconomic environment and bank efficiency

Some studies have focused on the macroeconomic determinants of bank efficiency. For instance, Berger and Mester (1997) in their review study, argue that no consensus has been formed on the sources of inefficiency in the financial system. Several subsequent studies on bank efficiency have been conducted in the European context. For instance, Dietsch and Vivas (2000) discovered that disparities in cost-effectiveness between French and Spanish banks are explained by the macroeconomic environment. Similarly, Grigorian and Manole's (2006) assessment of bank efficiency in emerging markets found a significant link between bank efficiency and economic growth. This is mostly attributable to bankers' terms of attracting more depositors and building a greater income stream in high-income countries. However, Almaqtari et al. (2019) showed that GDP growth has an inverse relationship with bank performance in India. This contrast suggests that the effects on the economic environment may vary among countries in their impact on banking sector efficiency.

Recently, there has been a sharp increase in inflation which could have implications for the performance of the banking sector, including efficiency (Farah et al. 2022). However, the implications of inflation for the efficiency of the banking sector are somewhat uncertain. An increase in inflation reduces the real value of long-term profits by applying costs in the form of damages, lowering the real value of the fund holdings. Additionally, because of increased inflation, the true worth of a bank's customer deposits and investments diminishes. Expected increases in the rate of inflation can also impair the financial sector's capacity to allocate resources efficiently. Previous research on this issue has highlighted the importance of imperfect information in bank credit to show how higher inflation can negatively impact bank lending, resulting in negative consequences for the banking industry (see Huybens and Smith 1998 and 1999). Demirgüç-Kunt and Maksimovic (1998) found that inflation can influence the firms' financial decision-making, with implications for the banks' efficiency. Perry (1992) argued that unexpected increases in inflation pose cash flow problems for borrowers, which can lead to the termination of loan agreements and a wave of bad debts. Furthermore, if banks are slow to alter their lending rates, bank expenditures may climb higher than bank earnings. In their study on European banks, Abreu and Mendes (2002) argued that the impact of inflation and bank performance is dependent on banks' efficiency. However, the overall effect of inflation on bank efficiency remains uncertain and requires further investigation.

Unemployment, as a key measure of labour market performance, has implications for the banks' performance and hence potentially for bank efficiency. For instance, the unemployment rate could potentially have implications for banks operating costs and thus efficiency. In their study on Singapore, Clair (2004) documented that regional banks' sustainability is impacted by the unemployment rate. Similarly, Heffernan and Fu (2010) argued the unemployment rate negatively impacts bank performance. The likelihood of default is determined by current earnings and the rate of unemployment, which is connected to the uncertainty of future earnings and lending rates. The theoretical literature on life-cycle spending frameworks, such as Lawrence (1995) which expressly integrates the possibility of default, can also be related to the macroeconomic causes of non-performing loans. According to these models, creditors with low earnings have a greater probability of bankruptcy since they are more likely to lose their jobs and be unable to pay their debts (see e.g., Skarica 2014; Messai and Jouini 2013; Louzis et al. 2012). Given the above, we can see the potential for a significant impact of unemployment on banking sector efficiency.

The exchange rate has important implications for both emerging and developed economies (Nasir and Simpson 2018; Nasir and Jackson 2019; Nasir et al. 2020; Pham et al. 2023). Volatility in foreign exchange rates affects banks having assets and obligations denominated in international currencies. The foreign exchange market is a crucial part of banking operations and has a big impact on how much money banks lend and how much they keep in reserve (Negrbo 2012; Javaid and Alalawi 2018). Some studies have suggested that the exchange rate dynamics can harm banks' profitability and performance (Almaqtari et al. 2019). To protect themselves from exchange rate fluctuation s, banks must also be careful when investing in foreign currency. The vulnerability of bank earnings has a significant impact on bank rate and currency rate risks through typical on-balance-sheet banking activities. According to Allen et al. (2002), international investors typically hedge their currency rate risk by lending domestically in foreign currency. This evidence on the exchange rate and bank performance implies that significant exchange rate dynamics may affect bank inefficiency. Hence, in addition to other factors discussed above, we include the exchange rate among the macroeconomic determinants of banks' investment and operational efficiency. We have formulated the following hypotheses that will be tested against the empirical results in light of the statistical level of significance.[1]

H_0 The macroeconomic environment (economic growth, inflation, unemployment, exchange rate) has no statistically significant effect on banks' (operational/ investment) efficiency.

H_1 The macroeconomic environment (economic growth, inflation, unemployment, exchange rate) has a statistically significant effect on banks' (operational/investment) efficiency.

2.2 Regulatory environment and bank efficiency

Banking regulation remains an important and highly controversial topic. A strong regulatory and oversight structure can reduce moral hazards and deter excessive risk-taking (Ayadi et al. 2016). Ensuring banks have sufficient capital requirements is a particularly contested area, as a bank that has too little capital raises its risk of failure, whereas one that has too much capital pressures banks and their clients with additional costs and may decrease the effectiveness of the banking system (Merton and Perold, 1993a, b). A similar tension exists with liquidity requirements. Central banks have played a key role in the supervision of the financial sector in many countries. While it is generally acknowledged that the primary task of the central bank should be price stability, the delegation of other responsibilities to central banks, such as the duty of overseeing and regulating the banking industry, remains the topic of much discussion (Fischer 1997).

The regulatory environment of the financial system has seen tremendous change over the last few years, as banking regulations evolved in response to the uncertainty, instability and growth in the industry. According to Casu et al., (2017) focus has shifted from deregulation to re-regulation to strengthen the banking sector. Following the GFC, concerns were raised about the adequacy of the existing regulatory environment, with numerous studies highlighting regulatory flaws as one of the major factors contributing to the complexity and depths of the financial meltdown (Merrouche and Nier 2014). The crisis demonstrated how credit risk and market risk, exacerbated by systemic risk, can spread swiftly, together with the worry of adequate asset values, dispersing funding mechanisms, and capital adequacy. Banks have since been under pressure to maintain adequate capital levels in order to avoid another global financial meltdown, and capital adequacy has become the central criterion of the new regulatory framework (Basel Committee on Banking Supervision 2010). Consequently, it has become critical to determine the adequate relationship between risk susceptibility and bank capital levels needed to cushion expected losses, whilst ensuring that banks' efficiency is not unnecessarily hindered.

It is challenging to pin down the precise effects of the regulatory environment on banking performance as the supervision of financial markets differs among nations. The

[1] As the empirical convention, we choose 1%, 5% and 10% level of significance that implies 99%, 95% and 90% levels of confidence in our estimates.

existing literature reports contradictory results regarding how regulatory and supervisory policies affect bank performance (e.g., Barth et al., 2004, 2008; Haque and Brown 2017; Triki et al., 2017). While there have been numerous studies on the impact of regulations on bank performance, the impact of regulation on banking efficiency has received much less attention. Furthermore, there is no evidence of how regulation has affected the different aspects of efficiency in transition countries during the last two decades. Djalilov and Piesse (2019) have highlighted the importance of regulations in the banking sector, whereas Barth et al. (2004) have stated that regulations and capital adequacy requirements do not impact bank efficiency. According to Koutsomanoli-Filippaki et al. (2009), banking reforms are crucial for bank profitability as they increase bank profit efficiency. Similarly, Goddard et al. (2004) reported a positive impact of capitalisation on European banks' profitability. Pasiouras et al. (2009) focused on a limited time horizon (2000–2004) and reported that capital requirements can affect banks' profits and efficiency. According to Barth et al. (2004), tighter financial regulations are related to fewer non-performing loans, although not significantly linked with bank failures, bank growth and efficiency. Whilst Goddard et al. (2013) found that although the efficiency of banks contributes to profitability, higher capitalisation has a negative impact on profitability. It is therefore clear that the effects of the regulatory environment on bank efficiency remain uncertain, and as such, further research on this issue is required.

H_0 The regulatory environment (capitalisation and leverage) has no statistically significant effect on banks' (operational/ investment) efficiency.

H_1 The regulatory environment (capitalisation and leverage) has a statistically significant effect on banks' (operational/ investment) efficiency.

2.3 Monetary policy and bank efficiency

Monetary policy affects the value, supply and cost of money in an economy through the manipulation of the cost and supply of credit money. It also has implications for the banking sector (Bernanke and Gertler 1995). Changes in monetary policy cause banks' credit flow patterns to fluctuate as banks are obliged to shift sources of finance whenever the monetary authority restricts liquidity in the financial system. Rajan (2005) has argued that increasing market-based pricing and interactions between banks and financial markets intensify the rewards system that drives banks, possibly resulting in stronger relationships between monetary policy and financial soundness. It is recognised that changes in interest rates caused by changes in monetary policy have a significant impact on bank profitability, with a primary focus on net interest margins (Cruz-García, 2020). Long ago, Samuelson (1945) argued that falling interest rates may result in lower net interest income since earnings from loans decline while interest costs on deposits do not. Some studies have also drawn attention to the potential relationship between accommodating monetary policy and the performance of banks. Overall, the evidence suggests that monetary policy easing hurts profitability (Alessandri and Nelson 2015; Varlik and Berument 2017), with magnifying impacts in low and long-term interest rate settings.

During the period of Great Moderation and particularly since the GFC, monetary policymakers across the world have taken a very expansionary approach, with interest rates being lowered to near-zero for many years (Nasir 2021). There have been numerous studies assessing the impact of this environment on the performance of the banking sector, but generally seen through the lens of profitability rather than efficiency (see e.g., Altavilla et al. 2019; Goodhart and Kabiri 2019; Cruz-García, 2020; Nguyen et al. 2022; Dang and Huynh 2022). Moreover, with many key central banks—including the Fed, ECB, and Bank of England—now tightening up monetary policy, it is particularly important to get a clear understanding of the impact of monetary policy on bank efficiency. Therefore, as a contribution to the literature, this study analyses the impact of monetary policy on the investment and operational efficiency of banks.

H_0 The monetary policy has no statistically significant effect on banks' (operational/investment) efficiency.

H_1 The monetary policy has a statistically significant effect on banks' (operational/investment) efficiency.

2.4 Uncertainty and bank efficiency

Uncertainty is another crucial factor with important implications for both the economy and the financial system. Uncertainty is particularly important for banks as it has implications for risk analysis, which is central to the banks' role. Banks could be impacted by economic uncertainty through a decrease in credit availability and loan re-pricing. Throughout periods of increased economic uncertainty, banks might prefer to restrict lending criteria and levy interest rates to adjust for increased default risk, and/or look for ways to increase non-interest earnings and lower operating expenses. Furthermore, unexpected changes in the macroeconomic climate could have a direct impact on banks' business programs and techniques, including administrative expenditures and profit.

There are several measures of uncertainty in use. This study employs the economic policy uncertainty (EPU) index, which has been used extensively since its creation by Baker et al. (2016). Several studies have found that the EPU is a key factor influencing the economy. For instance, according to Al-Thaqeb and Algharabali (2019), uncertainty has a detrimental impact on business revenues, economic activity and growth. More recently, a growing number of studies have also looked at how EPU affects financial markets including stock, oil, bonds and crypto markets (Nasir and Morgan 2018; Huynh et al. 2020b). When it comes to studies on bank efficiency, we can observe that the main transmission channels through which uncertainty may affect the banking system are bank credit supply and loan pricing (Claus 2011; Ciccarelli et al. 2015; Wulandari 2012). A study by Nguyen (2022) reported that the EPU can adversity affect European banks' stability. However, there is relatively little research into the effects of economic uncertainty on bank efficiency. It is therefore important to further investigate the effects of uncertainty on banks' operational and investment efficiency.

H_0 The uncertainty has no statistically significant effect on banks' (operational/ investment) efficiency.

H_1 The uncertainty has a statistically significant effect on banks' (operational/ investment) efficiency.

3 Methodology

To measure the banks' operational and investment efficiencies, we employ the Data Envelopment Analysis (DEA). This approach is a useful tool for assessing cost, technical and scale efficiencies without having direct knowledge of factor input costs. Its benefits include simplicity and effectiveness in handling numerous outputs, which makes it an appropriate tool for application in this context. Some studies have used the parametric technique (e.g., Berger and Mester 1997), while others prefer the non-parametric approach (e.g., Seiford and Thrall 1990). Despite disagreements about the appropriate methodological approach, the developing opinion shows that agreement on a single (best) frontier methodology for assessing firm-level efficiency is not crucial. Instead, the efficiency measurements produced from multiple methodologies should meet a set of consistency constraints. These measures will be compelling if efficiency estimates are consistent across multiple approaches. As a result, regulators need accurate and convincing projections, similar to other decision-makers (Bauer et al. 1997). We utilized the constant returns to scale, BCC (Banker, Charnes and Cooper) model by Banker et al. (1984) for input orientation. This involves the minimization of inputs while holding outputs constant, to assess efficiency, as recommended by Defung et al. (2016). This approach is appropriate because changing inputs is easier for banks than changing outputs (such as capitalization or revenue), which are subject to 3rd judgments (Goswami et al. 2019). As a result, according to Banna et al. (2019), is therefore aimed to reduce the following indicators:

$$\text{Minimize}\ \ \text{OP} \sum_{k=1}^{t} \sigma \kappa ¡\, \kappa \leq \kappa ¡\, o Effi, \sum_{k=1}^{t} \sigma \kappa \acute{L} \kappa \leq \acute{L} ¡\, o \sum_{k=1}^{t} \sigma \kappa = 1,$$

where k = 1, 2,..., N; t = 1, 2,..., I; Ĺ = 1, 2,..., Ĺ; Effi is the operational efficiency of decision-making unit (DMU) k; κĹκ is the output j of the DMU k: κ¡κ is the input j of the DMU k; ϕk is a constant vector denoting the intensity levels at which the t observations are conducted (Delis and Papanikolaou 2009). The input and output of each DMU are the basic building blocks of efficiency, and DEA is a measure of efficiency. Therefore, the efficiency measurement is directly influenced by the choice of the input–output indices. The assets and equity methods are applied in this paper to choose the input and output indicators. We chose capital, leverage and Bank rate as the inputs. The operational and investment efficiency of the bank makes up the output index. It is assumed that the inputs and outputs are not negative; the total inputs are given as i and outputs by Ĺ.

The ratio of output and input factors, or investment efficiency, is the ratio of effective outputs achieved by enterprises' investments to the amount of input components. Assume that there are n DMUs to be assessed in terms of m inputs and s outputs, using the standard DEA terminology. DMUj's ith input and y_r output are referred to as it and r, respectively.

$$\text{Maximize}\ \ \text{Invest}\quad \Sigma_{k=1}^{t} = 1\beta_{\llcorner} W_{¡} = \eth_{e}^{t}\ (q_r^t\, Y_r^t)$$

$\eth_{e}^{t}\ (q_r^t\, Y_r^t)$ is the best outcome of the above model, which displays DMUd's performance over time using a (Charnes et al. 1978) CCR model.

The nexus between banking efficiency, both in terms of operational and investment efficiencies, and their determinants can be specified in the form of the following models:

$$Operational\ efficency = \beta_o + \beta_1 GDP_t + \beta_2 inflation_t + \beta_3 unemployment_t + \beta_4 leverage_t + \beta_5 uncertainity_t + \beta_6 capitalisation_t + \beta_7 ExchangerRate_t + \beta_8 bankrate\ _t + \Lambda_i + \varepsilon_t \tag{1}$$

$$Investment\ Efficiency = \beta_o + \beta_1 GDP_t + \beta_2 inflation_t + \beta_3 unemployment_t + \beta_4 leverage_t + \beta_5 uncertainity_t + \beta_6 capitalisation_t + \beta_7 ExchangeRate_t + \beta_8 bankrate\ _t + \Lambda_i + \varepsilon_t \tag{2}$$

where $\beta_{1,}\ \beta_{2,}\ \beta_{3,}\ \beta_{4,}\ \beta_{5,}\ \beta_{6,}\ \beta_7$ and β_8 are the coefficients of explanatory variables, t represents time subscript and ε are stochastic error terms which are independent and identically distributed (i.i.d). Λ_i are the induvial specific effects that will be incorporated into the individual effect models (e.g., fixed effect and random effect) to account for the unobserved heterogeneity.

The nature of the associations in the two models of efficiency is determined using a set of estimation approaches. These include Fixed Effect (FE), Random Effect (RE), Fully Modified OLS (FMOLS), Dynamic OLS (DOLs), and Generalized Method of Moments (GMM). We employed alternative approaches for the robustness of estimates. There are differences in the underlying assumptions of these estimation approaches. For example, under FE the regressors and heterogeneous time-invariant individual effects are correlated while that is not the case under RE (see Bell et al. 2019 for debate on FE and RE). These approaches capture the individual-specific heterogeneity and hence overcome the issue of endogeneity. In the case of the banking sector, it is important to account for the bank-specific effects (Luu et al. 2023; Zhai et al. 2023). However, the DOLS and FMOLS also have many advantages due to which some studies have considered them superior. For instance, the convergence of OLS could be low in small samples. The OLS may suffer from serial correlation and heteroskedasticity leading to a situation where the inferences are not valid even asymptotically. The DOLS on the other hand can tackle these issues and the issue of endogeneity by adding the leads and lags. Furthermore, the white heteroskedasticity robust standard errors are employed. The FMOLS yields unbiased estimates of the long-run relationship when the underlying data is non-stationary. It keeps valuable information concerning long-run properties inherent in the levels of time-series data. These approaches account for the effects of potential endogeneity that could be in the OLS residuals and coefficient estimates that are asymptotically biased (see, Arize et al. 2015). Following the first differencing of all variables, the four-panel estimate methodologies were used to establish consistency and reliability of results. Panel estimations are carried out for the developed and developing countries (G-7 and E-7) for Model I, which used operational efficiency as the dependent variable, and Model II, which used investment efficiency as the dependent variable. The diagnostic testing is carried out to check the robustness of our estimates and includes autocorrelation and heteroscedasticity diagnostic tests. In addition to the Lagrange Multiplier (LM) test for heteroscedasticity, the Breusch-Godfrey serial correlation LM test for autocorrelation was manually calculated. Model I's D-W statistic for FE and RE was within the permissible range of 1.5–2.5, however, Model II's RE had no heteroscedasticity. The models were re-estimated using the period weights (PCSE) in the coefficient covariance Operational efficiency for the FE and RE to address heteroscedasticity issues. Operational efficiency re-estimations have been like the original forecasts (statistical significance and sign of coefficients). As previously stated, the FMOLS and DOLS estimations can respectively address autocorrelation by employing Newey-West and independent variable leads and lags with first variations. To solve the endogeneity issue, we also use GMM as the GMM is more advantageous (see, Ullah et al. 2018, 2021 for a detailed discussion on GMM usage to address endogeneity problem).

3.1 Data

The sample includes data from 109 major banks occupying a large share of each banking sector over the period 2001–2020. Among these, 62 are from developed (G7) while 47 are from developing (E7) economies. We ensured the chosen banks from each country constitute at least 80% of the market capitalisation. All banks with complete data for at least twenty years are included in the analysis which is a requirement for second-order correlation estimation (Arellano and Bond 1991). As GMM assumes second-order correlation, and this will be the estimation method employed, this correlation must be tested (Neves 2018; Vieira et al. 2019). So, in essence, we needed a balanced sample and we have it.

The World Bank and DataStream databases provide readily available data on key variables.

Bank efficiency measurement is a crucial task and various studies have defined investment efficiency from different perspectives. The selection of a suitable approach, as well as input and output elements, is the most significant aspect of evaluating efficiency (Sufian and Habibullah 2010; Sufian 2011). The paper employs loans/finance to follow the intermediation strategy and is compatible with previous research (Kumar and Gulati 2009; Shawtari et al. 2015a, b). We choose three inputs (capital, leverage and bank rate) and three outputs (operational efficiency, yield and investment) using the intermediation approach. In true essence, investment efficiency can be defined as the maximum profit generated by the investment**.** Operational efficiency is one of the variables that most influence bank performance, traditionally, the cost–benefit ratio (CIR) has been used to gauge operational efficiency in the banking industry, with the greater the CIR, the more inefficient the bank. To improve financial institution performance as evaluated by profitability, operational efficiency must be improved (Athanasoglou et al. 2008; Dietrich and Wanzenried 2011) i.e., costs must be reduced. Lowering costs while increasing revenues, resulting in a high level of bank profitability. Knezevic and Dobromirov (2016) and Trujillo-Ponce (2013) found a negative association between CIR and profitability. However, it must be highlighted that because it is designed to examine performance based on efficiency, it cannot be utilized as an explanatory variable as it is an operational efficiency variable itself. As a result, CIR is only utilized to determine profitability. The equity-to-assets ratio was used, taking into account the notion that well-capitalized banks should be more cautious, resulting in higher efficiency scores.

Data on macroeconomic factors were gathered from a variety of sources. Operational and investment efficiency are used as measures of bank efficiency. Macroeconomic factors include GDP, exchange rate, inflation rate and unemployment rate, while the regulatory environment is depicted by capital and leverage ratios, monetary policy by bank rate and economic uncertainty by economic policy uncertainty (Table 1).

4 Analysis and findings

We start with the descriptive statistics which are provided in Table 2. The mean values of investment efficiency and operational efficiency are (0.008 > 0.007 or 0.8% > 0.7%) respectively, indicating that investment efficiency is higher. The standard deviation for efficiency measures is 0.024 and 0.038, respectively, indicating that efficiency measures are not highly varied over the period of study. Macroeconomic factors (GDP, unemployment,

Table 1 Dataset information

Variables	Measurement	Code	Source
Efficiency	Investment Operational	Invest OPE	DEA Analysis
GDP	Annual GDP growth rate	GDP	World Economic Outlook database
Inflation	Consumer price index (CPI)	Inf	World Economic Outlook database
Unemployment	Annual unemployment rate	Ump	Macrotrend
Uncertainty	Uncertainty rate	Uncertain	Uncertainty index
Exchange rate	Exchange rate Annual fluctuation	Exchange	World Economic Outlook database
Capital adequacy	Capital adequacy ratio Tier I and2	Cap	Thomson Reuters
Leverage	Leverage ratio	Lev	Thomson Reuters
Bankrate	Interest rate	Bart	State bank database

Table 2 Descriptive statistics

Variables	Mean	Median	Maximum	Minimum	Std. Dev	Skewness	Kurtosis	JarquE−Bera
GDP	0.280	0.028	3.779	−3.486	0.916	1.314	8.872	3760.644***
Inflation	0.375	0.034	4.550	−0.356	0.885	2.584	8.707	5385.267***
Unemploy-ment	0.949	0.061	9.630	0.024	2.245	2.418	7.649	4089.217***
Uncertainty	155.979	123.620	791.860	21.620	109.960	2.396	11.031	7945.931***
Exchange rate	94.456	95.330	128.110	10.200	16.269	−0.961	7.408	2100.615***
Bank rate	0.046	0.032	0.699	−0.019	0.063	4.734	40.566	135,895.7***
Capital adequacy	0.156	0.146	11.230	−0.474	0.241	44.488	2042.982	3.78E+08***
Operational efficiency	0.007	0.003	0.700	−0.005	0.024	15.159	344.816	10,127,138***
Investment efficiency	0.008	0.003	1.400	0.000001	0.038	25.176	869.589	64,990,445***
Leverage	2.646	1.481	1023.000	−0.023	22.021	45.666	2116.112	4.06E+08***

***, **, * 10%,5%, 1% statistical significance

inflation, and exchange rate) mean and standard deviation show high fluctuations indicating the dynamics of the macroeconomy.

4.1 Panel unit root tests

To analyse the order of integration of our variables we tested for the presence of a unit root as non-stationarity could result in inaccurate estimation outcomes. We utilize the Fisher- test for the investigation of stationarity, complimented by the Levin et al. (2002) test that assumes homogeneity in a common unit root test. Finally, we applied Pesaran (2016), which is an individual unit root test that assumes heterogeneity and compensates for cross-sectional dependency that may be present in our data. In this regard, Pesaran (2016) has argued that the weak and strong cross-sectional dependence can have implications for the unit-root testing, therefore we employed alternative approaches for robustness and the results are presented in Table 13 (Appendix). The results of unit-root testing showed that most of the variables were non-stationary at the level whereas all variables became stationary after first differencing. It implied that we could proceed with further analysis.

4.2 Panel cointegration tests

To analyse the presence of a long-term relationship between bank efficiency and its determinants, we performed cointegration testing. In this regard, we performed Kao residual cointegration test as well as Pedroni Residual Cointegration. According to Gutierrez (2006), Kao's tests are more powerful when we have homogeneous panels with a small number of time periods (T), however, where we have panels with large T, Pedroni's tests perform best (See Pesaran 2016). In the subject study, we have a fairly large (T), however, we still employ both tests to obtain robust estimates. The Kao residual cointegration test and the results are presented in Table 14 (Appendix). The null hypothesis (no cointegration) for the Kao test was rejected for Model-I and Model-II at the 1% significance level, indicating the existence of a long-term relationship or cointegration.

4.3 Pedroni residual cointegration test for efficiency

We also performed Pedroni's panel cointegration test. First, we employed the test focusing on operational efficiency and the results are shown in Table 15 (Appendix). The findings show that panel ADF and Rho statistics, ADF and PP reject the null hypothesis of no cointegration, indicating that determinants of bank operational efficiency are co-integrated and there is a long-term relationship. Next, we come to the investment efficiency and Pedroni's panel cointegration results are shown in Table 16 (Appendix). The findings show that panel Rho, panel ADF and PP statistics, reject the null hypothesis of no cointegration, indicating that bank efficiency and its determinants are co-integrated. Among Pedroni's test statistics, group statistics have the best ability to judge cointegration (1999). Therefore, it is concluded that the variables under consideration exhibit a valid long-run relationship.

4.4 Correlation analysis

The correlation analysis is performed to analyse the association between the variables. The results are presented in Table 3.

The GDP, capital, leverage, uncertainty and unemployment, leverage and capitalisation have a negative correlation with operational efficiency. It might imply that well-capitalized banks have higher margins and profitability, which is congruent with ideas highlighting that highly capitalized banks can demand more now for lending and pay less to depositors. Investment efficiency has an inverse correlation with economic growth, uncertainty, bank rate and capital adequacy. The uncertainty and capital ratios seem to have a negative correlation with both measures of efficiency.

Table 3 Correlation analysis

	OPE	Invest	GDP	Inflation	Unemployment	Uncertainty	Exchange rate	Bank rate	Leverage	Capital adequacy
OPE	1.000									
Invest	0.022	1.000								
GDP	−0.034	−0.014	1.000							
Inflation	−0.004	0.049	0.638	1.000						
Unemployment	−0.012	0.030	0.515	0.703	1.000					
Uncertainty	−0.017	−0.016	−0.221	−0.161	−0.1204	1.000				
Exchange rate	0.024	0.224	0.055	0.091	0.175	0.024	1.000			
Bankrate	0.049	−0.002	−0.229	−0.095	−0.222	0.025	−0.334	1.000		
Leverage	−0.006	0.022	−0.007	−0.010	−0.012	−0.015	0.021	−0.011	1.000	
Capital adequacy	−0.014	−0.018	−0.004	−0.001	0.041	0.151	−0.073	0.147	−0.001	1.000

Table 4 Panel estimations determinants of bank operational efficiency

Variables	FE	RE	FMOLS	DOLS
GDP	(−0.0013)* 0.071	(−0.0013)* 0.082	(−0.027) *** 0.000	(−0.049)*** 0.000
Inflation	(0.0007) 0.431	(0.00068) 0.486	(−0.147) *** 0.000	(−0.051) 0.408
Unemployment	(−5.38E−06) 0.987	(2.65E−05) 0.943	(−0.073)** 0.015	(−0.401)*** 0.001
Uncertainty	(−5.52E−06) 0.276	(−5.28E−06) 0.312	(3.21E−05) *** 0.000	(3.02E−05)*** 0.004
Capital adequacy	(−0.01014) 0.463	(−0.0089) 0.549	(0.083) *** 0.000	(0.00762) 0.894
Exchange rate	(5.93E−05) 0.108	(6.85E−05)* 0.0702	(0.00021) *** 0.000	(0.00028)*** 0.001
Bank rate	(0.0283)*** 0.011	(0.0328)*** 0.0065	(0.08840)*** 0.003	(0.0860) 0.1881
Leverage	(−7.55E−06) 0.753	(−9.96E−06) 0.678	(0.00085) 0.320	(0.0053)** 0.0275
R-square	0.006	0.006	−162.124	−1958.59
Adj. R-squre	0.002	0.002	−162.685	−2075.88
F statistic	1.574	1.726		
Prob	0.127	0.087		
D W test	1.481	1.518		
H test	2.6715	2.69205	1947.93	1958.87

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16.07; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 5% significance is = 16.07. FMOLS estimator uses adjustments for the long-run variances and covariances

4.5 Estimation of models efficiency

The determinants of efficiency were analysed using a set of panel estimation approaches including the FE, RE, FMOLS and DOLS. These estimation techniques were used to take a broader approach to empirical results. The findings of Model I, which used operational efficiency as the dependent variable, and Model II, which used investment efficiency as the dependent variable, are summarized in Table 4 and 5.

The findings suggest inflation and unemployment and GDP all have a negative impact on the operational efficiency of banks. The null hypothesis of no impact was rejected in the alternative hypothesis of a significant impact was accepted. That inflation and unemployment could reduce bank efficiency is to be expected, but the latter result is somewhat surprising and contrasts somewhat with the findings of Martins et al. (2019), who reported that GDP has a positive influence on banks' profitability. However, it could be the case that when the economy is growing well, banks' efficiency falls even though profitability increases, as banks may use their resources less efficiently during boom periods. In terms of the size of the effects, if we focus on the effects of GDP under the FE model, it shows a 1% increase in GDP leads to − 0.0013 or 0.13% decrease in operational efficiency, a mild but still notable effect. We can also see that the Bank rate, exchange rate and economic uncertainty all show a significant positive relationship under some models. The null

Table 5 Panel estimations for bank investment efficiency

Variables	FE	RE	FMOLS	DOLS
GDP	(− 0.0045)*** 0.001	(− 0.0032)*** − 0.006	(− 0.0256)*** 0.004	(− 0.0265) 0.160
Inflation	(0.0031)* 0.062	(0.0041)*** 0.006	(− 0.0712)** 0.0138	(− 0.0570) 0.314
Unemployment	(− 0.0023)* 0.089	(3.55E−05) 0.947	(0.0386) 0.430	(0.0844) 0.379
Uncertainty	(− 1.5E−06) 0.870	(− 5.91E−06) 0.450	(4.32E−05) 0.7232	(1.25E−05) 0.658
Capital	(− 0.00031) 0.990	(− 0.0149) 0.495	(− 0.0724) *** 0.000	(0.0766)* 0.0553
Exchange rate	(2.80E−05) 0.668	(4.71E−05) 0.408)	(0.00012) *** 0.000	(8.44E−05) 0.207
Bank rate	(0.02562) 0.328	(0.00479) 0.780	(0.293) *** 0.000	(0.301560)** 0.031
Leverage	(6.09 − E−06) 0.874	(1.55E−06) 0.966	(0.001211) 0.2465	(0.001386) 0.556
R-square	0.0594	0.0068	− 3.427	− 17.897
Adj. R-squre	0.003	0.003	− 3.442	− 17.961
F statistic	1.058	1.775		
D.W test	2.126	2.018		
H-test	9.80623	9.334269	779.563	1769.82

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16.07; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 5% significance is = 16.07. FMOLS estimator uses adjustments for the long-run variances and covariances

hypothesis of no impact was rejected, and the alternative hypothesis was accepted. This latter result is also somewhat surprising, as we generally expect uncertainty to have a negative effect on both the economy and the financial system. However, here it implies that the banks become more efficient with the increase in uncertainty which is intuitive as in uncertain times one shall become more prudent in resource usage and hence more efficient. The two regulatory variables—capital adequacy and leverage—also showed a positive and significant impact under some models. Therefore, we reject the null hypothesis and accept the alternative hypothesis. This suggests bank regulation can potentially be used to increase bank efficiency (or at least, it doesn't necessarily impede it). An important finding given the heated debates over the costs and benefits of banking regulation in recent years. Next, we come to the analysis of investment efficiency and the results are presented in Table 5.

One again we find evidence that GDP, inflation, and unemployment have a negative effect on bank efficiency under some of the models. The null hypothesis was rejected and the alternative hypothesis was accepted. Uncertainty shows mixed results and is insignificant this time hence we could not reject the null hypothesis at the required statistical level of significance. As was the case for operational efficiency above, we find some evidence that bank rate and exchange rates have a positive effect on investment efficiency. In terms of the two regulatory variables, capital adequacy showed a negative and significant impact on investment efficiency under the FMOLS model, whilst leverage is insignificant this time. This adds to the findings of Kosmidou (2008) who, when assessing factors influencing the performance of Greek banks, found that profitability

Table 6 GMM: banking operational and investment efficiency

	OPE. efficiency	Invest efficiency
GDP	(− 0.002417) *** 0.000	(0.002213) *** 0.000
Inflation	(− 0.002809) *** 0.000	(− 0.001609) *** 0.000
Unemployment	(6.05E−05) 0.197	(3.40E−05) *** 0.000
Uncertainty	(− 2.80E−06)*** 0.000	(2.54E−06) *** 0.000
Leverage	(− 0.000731) *** 0.000	(0.002694) *** 0.000
Bankrate	(0.073348) *** 0.000	(0.151295) *** 0.000
Exchange rate	(− 0.000220) *** 0.000	(0.000229) *** 0.000
Capital	(− 0.027461) *** 0.000	(0.035533) *** 0.000
Hansen J-Stat	107.1460	106.3768
Prob(J-Stat)	0.3189	0.3125
Instrument rank	110	109
AR (1)	− 0.705	− 1.417
AR (2)	− 0.147	− 0.586
Observations	1833	1842

Estimations were made in the system utilising the GMM dynamic model estimate. * Significance at 10%; ** Significance at 5%; *** 1 percent. Under the null hypothesis of no serial correlation, the Arellano-Bond test is distributed asymptotically as N (0.1). The AR test indicates that there are no issues with serial correlation

is linked to well-capitalized banks, reduced cost-to-income ratios, strong economic growth and negatively linked to inflation. Our study adds to these findings by looking at the two forms of efficiency rather than profitability (Table 6).

4.6 Determinants of efficiency employing GMM

Our findings in the previous section are now verified using the Generalized Method of Moments (GMM) approach. To control for the issue of correlation between the lagged dependent variable and the error term, GMM models are used in a two-step system. According to Chowdhury and Rasid (2017), GMM could only alleviate ’fixed effect’ issues by finding a solution of correlation among a dependent variable’s lagged and the error term, as well as the endogeneity problems. Furthermore, the GMM system attempts to address instrument deficiencies by supplementing instruments.

The results employing the GMM approach show that uncertainty, capital adequacy, leverage, exchange rate and GDP have a negative relationship with bank operational efficiency, but they have a positive impact on investment efficiency, while inflation has a negative effect on both forms of efficiency. While the size of these effects may be somewhat modest in many cases, they are still worthy of consideration. For instance, for GDP, a 1% increase leads to a − 0.2417% decrease in operational efficiency but a 0.2213% increase in investment efficiency. The GMM results show that there is no order correlation in the error.

Table 7 Panel estimations for bank operational efficiency G7

Variables	FE	RE	FMOLS	DOLS
GDP	(− 0.00649) 0.543	(− 0.001472) 0.116	(− 0.0323) *** 0.000	(− 0.030776)** 0.0208
Inflation	(0.000958) 0.576	((0.000318) 0.834	(− 0.217087) *** 0.000	(− 0.191873)** 0.049
Unemployment	(0.001170) 0.254	(9.4E−05) 0.844	(− 0.041691) 0.243	(− 0.035567) 0.599
Uncertainty	(1.06E−05) 0.441	(2.23E−06) 0.842	(4.61E−05) *** 0.000	(4.35E−05)*** 0.007
Capital adequacy	(0.041068) 0.171	(0.014290) 0.568	(− 0.090547) *** 0.000	(− 0.081140) 0.124
Exchange rate	(9.59E−05) 0.100	(1.48E−05) 0.777	(0.000191) *** 0.000	(0.000165)* 0.078
Bank rate	(0.245647) 0.001	(0.189318)*** 0.001	(0.150498)*** 0.001	(0.119815) 0.191
Leverage	(− 1.83E−05) 0.499	(− 1.33E−05) 0.613	(0.003902)*** 0.006	(0.004660) 0.123
R-square	0.08400	0.0135	− 231.741	− 191.511
Adj. R-square	0.0415	0.0067	− 233.161	192.677
F statistic	1.7304	1.9898		
Prob	0.0002	0.0445		
D W test	1.684	1.587		
H test	7.650	7.922	1135	1149

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16.07; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 5% significance is = 16.07

The *p* value of the Arellano and Bond second-order correlation test indicates that in both specifications i.e., operational and investment efficiency model, there is no significant order correlation and hence our results are robust. These findings also have a crucial empirical implication, it is vital to address the endogeneity problem in the studies on banking efficiency by employing approaches like GMM that can bring meaningful results.

4.7 Determinants of bank efficiency in developed economies

After the joint analysis of emerging and developed countries, we analysed the determinants of banking sector efficiency in emerging and developed economies in seclusion. We started with the developed economies. Like the previous section, unit-root testing, cointegration testing, correlation and descriptive statistical analysis were performed. We did find evidence of cointegration and stationarity at the level or at least at the first difference.[2]

4.7.1 Estimation of models—banking efficiency in developed economies

The association between bank efficiency and its determinants in developed economies was analysed using the same set of estimation approaches as we employed in the previous section. The results are presented in Table 7.

[2] Those results have been concealed to save the space but are available upon request.

Table 8 Panel estimation tests for bank investment efficiency G7

Variables	FE	RE	FMOLS	DOLS
GDP	(− 0.00392)** 0.034	(− 0.000962) 0.580	(− 0.0740) *** 0.000	(− 0.0864) *** 0.000
Inflation	(0.004478) 0.129	(0.004109) 0.145	(− 0.0191) 0.683	(0.0167) 0.837
Unemployment	(− 0.00125) 0.4769	(− 0.00038) 0.655	(0.0685)* 0.080	(0.2254) *** 0.010
Uncertainty	(− 2.52E−05)	(− 4.95E−08) 0.998	(6.57E−07) 0.973	(5.77E−06) 0.877
Capital adequacy	(0.03666) 0.477	(− 0.00058) 0.989	(− 0.114) *** 0.000	(0.0035) 0.522
Exchange rate	(8.26E−05) 0.410	(3.72E−05) 0.698	(0.000159) *** 0.000	(0.00017) 0.337
Bank rate	(0.2679) 0.043	(0.1585) 0.147	(0.4421) *** 0.000	(0.7762) *** 0.003
Leverage	(7.34E−08) 0.998	(− 4.24E−06) 0.931	(0.0013) 0.450	(− 0.0023) 0.522
R-square	0.0682	0.0078	− 14.476	− 288.122
Adj. R-square	0.009	0.000	− 14.570	− 306.258
F statistic	1.1678	1.141		
D W test	2.224	2.147		
H-test	8.19	8.96	962.8	804.96

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16.07; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 5% significance is = 16.07

Results of our analysis focusing on banks' operational efficiency in developed economies reveal that GDP, inflation, and capital adequacy have a negative impact. Other factors, such as uncertainty, leverage, bank rate and exchange rate have a positive impact on operational efficiency. The only variable that showed insignificant negative results was unemployment. Next, we estimated the impact of determinants of investment efficiency for developed economies and the results are presented in Table 8.

In line with previous estimations, the analysis of investment efficiency in the G7 reveals a negative impact from GDP, whilst the impact of bank rate and the exchange rate was found to be positive, in both cases, results were only significant in some of the models. In terms of the regulatory variables, capital adequacy once again has a negative effect on investment efficiency, whilst leverage is insignificant. Considering that well-capitalized banks are deemed stronger since they assume less hazard, and so, as per financial models, make lower yields, an unfavourable link between profitability and the high capital ratio should be expected.

4.7.2 Determinants of banking efficiency in developed economies employing GMM

In our analysis of determinants of banking efficiency in developed economies, we now employ the Generalized Method of Moments (GMM) approach. The results are presented in Table 9.

Table 9 Banking efficiency GMM results for the G7

Variable	Operational. efficiency	Investment efficiency
GDP	(− 0.00165) *** 0.000	(0.00079) *** 0.000
Inflation	(− 0.001163) *** 0.000	(− 0.00212) *** 0.000
Unemployment	(0.000473) *** 0.000	(0.00513) *** 0.000
Uncertainty	(3.4E−05) *** 0.000	(3.28E−05) *** 0.000
Leverage	(− 0.00097) *** 0.000	(− 0.00440) *** 0.000
Bankrate	(− 0.31725) *** 0.000	(0.9463) *** 0.000
Exchange rate	(− 0.000253) *** 0.000	(0.000519) *** 0.000
Capital	(− 0.00599) *** 0.000	(0.03297) *** 0.000
Hansen J-Stat	60.6605	(60.2468)
Prob(J-Stat)	0.248	0.230
Instrument rank	63	62
AR(1)	NA	(− 1.306)
AR(2)	NA	(0.221)
Observations	1036	1035

Estimations were made in the system utilising the GMM dynamic model estimate. * Significance at 10%; ** Significance at 5%; *** 1 percent. Under the null hypothesis of no serial correlation, the Arellano-Bond test is distributed asymptotically as N (0.1). The AR test indicates that there are no issues with serial correlation

The results of the GMM analysis for the developed economies confirmed that the coefficients of all determinants remained the same in terms of the sign as the overall analysis. Specifically, it showed that inflation and leverage can negatively impact operational efficiency and investment efficiencies. Whereas, the GDP, bank rate, exchange rate and capital adequacy negatively impact operational efficiency and their impact on investment efficiency is positive. There is a significant impact of these variables on banking efficiency in terms of magnitude. For instance, if we take capital adequacy, a 1% increase in the capital ratio can lead to a reduction of − 0.599% (− 0.00599) in operational efficiency and an increase of 3.297% (0.03297) in investment efficiency. As compared to the other estimation approaches, the GMM yielded results which were statistically more significant and meaningful. This suggests that the estimates are robust.

4.8 Determinants of banking efficiency in emerging economies

After analysing the determinants of banking sector efficiency in the developed economies, we focused on the emerging economies' banking sector. Once again, we started with unit root testing and cointegration analysis. The results showed that all the

Table 10 Panel estimation for bank operational efficiency in the E7

Variables	FE	RE	FMOLS	DOLS
GDP	(0.000441) 0.984	(−0.025072) 0.179	(−0.02058) 0.668	(−0.02327) 0.366
Inflation	(−0.0030)** 0.033	(−0.0020) 0.134	(−0.0553)*** 0.000	(−0.0546) 0.161
Unemployment	(−0.0739) 0.329	(−0.0834)* 0.060	(−0.1146)** 0.0273	(−0.0817) 0.510
Uncertainty	(−1.2E−06) 0.846	(−3.41E−06) 0.550	(1.36E−05)** 0.0278	(1.32E−05) 0.318
Capital adequacy	(−0.015990) 0.438	(−0.021741) 0.202	(−0.0744) *** 0.000	(−0.071783) 0.117
Exchange rate	(0.000111)* 0.101	(9.92E−05)* 0.107	(0.00024) *** 0.000	(0.000226)*** 0.003
Bank rate	(0.4247)*** 0.005	(0.0501) *** 0.000	(0.0063) *** 0.000	(0.019626) 0.791
Leverage	(−0.00207)*** 0.002	(−0.00144)*** 0.003	(−0.00317) *** 0.000	(−0.00324)** 0.011
R-square	0.0865	0.0288	−2.306	−2.162
Adj. R-square	0.0276	0.0200	−2.3325	−2.187
F statistic	1.4691	3.2822		
Prob	0.0175	0.001		
D W test	1.384	1.328		
H test	4.81	13.20	558.92	550.36

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16.07; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 5% significance is = 16.07

variables were stationary at level or at least first difference and there was significant evidence of cointegration.[3]

4.8.1 Estimation of models—banking efficiency in emerging economies

We estimated the impact of determinants of banks' operational and investment efficiencies in emerging economies. The results for the operational efficiency are reported in Table 10.

The results show that GDP, inflation, unemployment, capital ratio and leverage all have a negative impact on operational efficiency in the E7, although GDP is no longer significant. Other factors, such as uncertainty, bank rate and exchange rate have a positive impact on operational efficiency, with the FMOLS model generally providing more significant estimates. Next, we move onto the results for investment efficiency in the E7. Results are reported in Table 11.

The estimates of bank investment efficiency in developing economies were somewhat mixed and mostly insignificant, except in the case of inflation, GDP, Bank rate and leverage.

[3] These results, which have been concealed to save space, can be provided upon request.

Table 11 Panel estimation for bank investment efficiency in the E7

Variables	FE	RE	FMOLS	DOLS
GDP	(0.020691) 0.429	(0.0074) 0.729	(0.0362)** 0.036	(0.0154) 0.6983
Inflation	(−0.001366) 0.411	(−0.0010) 0.483	(09.1400) *** 0.000	(−0.1948) *** 0.000
Unemployment	(0.019998) 0.8200	(0.0032) 0.948	(−0.00069) 0.994	(−0.5346) 0.114
Uncertainty	(−1.3E−06) 0.854	(−6.05E−06) 0.357	(9.14E−06) 0.377	(3.55E−05) 0.113
Capital adequacy	(−0.004922) 0.837	(−0.015637) 0.423	(−0.01754) 0.523	(0.0684) 0.286
Exchange rate	(2.87E−05) 0.713	(3.82E−05) 0.591	(5.65E−05) 0.310	(9.20E−05) 0.493
Bank rate	(0.011783) 0.509	(0.0059) 0.722	(0.0980)** 0.036	(0.2008)** 0.032
Leverage	(0.000455) 0.0564	(−7.26E−05) 0.895	(0.00108) 0.180	(0.00471)*** 0.015
R-square	0.045936	0.002829	−9.896383	−339.796
Adj. R-square	−0.015616	−0.006205	−9.98286	−361.783
F statistic	0.764292	0.313186		
D W test	1.673	1.601		
H-test	5.93	5.47	952.54	65.38

Coefficients are in brackets; *, ** and *** = 10%, 5% and 1% significance levels respectively; D-W statistic = Durbin Watson statistic; A. test statistic = Autocorrelation test statistic where Chi-square Distribution at 5% significance level is 16; H. test statistic = Heteroscedasticity test statistic where Chi-square Distribution at 0.05% significance is = 16.07

4.8.2 Determinants of E7 bank efficiency employing GMM

Lastly, we employed the Generalized Methods of Moments (GMM) estimation approach to analyse the determinants of banks' operational and investment efficiencies in emerging economies and the results are presented in Table 12.

The results from the GMM approach for the determinants of bank efficiency in the E7 show a high degree of statistical significance. In this sub-sample, we can see that GDP now has a positive impact on both forms of bank efficiency. A 1% increase in economic growth leads to a 0.63% (0.0063) increase in operational efficiency and a 2.09% (0.0209) increase in investment efficiency in the banking sector of emerging markets. As one might expect, our results reveal a negative impact of both inflation and uncertainty on bank efficiency. We also find that the bank rate has a negative impact on operational efficiency but a positive impact on investment efficiency, whilst the opposite holds for the exchange rate. Surprisingly, unemployment appears to have a positive impact on both forms of efficiency. In terms of the regulatory variables, capital adequacy has a positive impact on both operational (4.26%) and investment efficiency (0.80%), whilst leverage has a negative impact on operational efficiency and a positive effect on investment efficiency. Financial institutions in emerging economies with higher capital ratios are not only safe and more secure, they are also more efficient.

Table 12 Banking efficiency GMM results for the E7

Variable	OPE. efficiency	Investment efficiency
GDP	(0.0063) *** 0.000	(0.0209) *** 0.000
Inflation	(− 0.0013) *** 0.000	(− 0.00063) *** 0.000
Unemployment	(0.0413) *** 0.000	(0.0142) *** 0.000
Uncertainty	(− 9.56E−06) *** 0.000	(− 6.71E−06) *** 0.000
Leverage	(− 0.0028) *** 0.000	(0.0018) *** 0.000
Bankrate	(− 0.0162) *** 0.000	(0.0397) *** 0.000
Exchange rate	(4.74E−05) *** 0.000	(− 2.91E−05)** 0.012
Capital	(0.0426) *** 0.000	(0.0080)** 0.011
Hansen J-Stat	41.645	39.274
Prob(J-Stat)	0.315	0.412
Instrument rank	47	47
AR(1)	− 3.008	− 1.927
AR(2)	− 1.291	0.606
Observations	1945	1944

Estimations were made in the system utilising the GMM dynamic model estimate. * Significance at 10%; ** Significance at 5%; *** 1 percent. Under the null hypothesis of no serial correlation, the Arellano-Bond test is distributed asymptotically as N (0.1). The AR test indicates that there are no issues with serial correlation

5 Conclusion and implications

Banking efficiency is a key factor affecting the long-term performance of the financial system and with it the wider economy. In this context, we investigated the impact of macroeconomic factors, regulatory environment, monetary policy and economic uncertainty on the operational and investment efficiencies of major banks in the G7 and E7 countries. We undertook an extensive empirical exercise employing various estimation approaches which led us to conclude that the GMM approach, which accounts for key problems such as endogeneity, delivers more meaningful results. We found evidence that a healthy economy with a high economic growth rate has a negative impact on operational efficiency, as does uncertainty, exchange rate, leverage, and high capital ratios. This contrasts with investment efficiency, which is positively affected by these factors. Furthermore, we found that inflation erodes both forms of efficiency.

Disaggregated analysis shows there are notable differences between developed and developing countries. We found that economic growth had a negative impact on the operational efficiency of developed economies' banking sector but a positive impact on its investment efficiency. Yet, in the case of developing economies, economic growth had a positive impact on both operational and investment efficiencies. This suggests that the developed economies' banks may become operationally less efficient when the economy is booming and there is a state of euphoria. The analysis of the impact of economic uncertainty on bank efficiency reveals some surprising results. We found that uncertainty had a positive impact on both forms of bank efficiency in developed economies whereas it had a negative impact in developing countries. Our result reveals the negative impacts of inflation for both developing and developed economies banking sectors efficiencies which further highlights the importance of price stability.

The impact of leverage on the developed economies' banking sector's efficiency is concluded to be negative. In the case of developing economies, only the operational efficiency is negatively affected by high leveraging. Capital adequacy showed very interesting results which lead us to conclude the high capital ratios are not necessarily a bad thing for the banking sector's efficiency, particularly in developing economies. While the operational efficiency of the developed economies' banking sector may have a negative impact from the high capital ratios, investment efficiency is positively affected. Furthermore, both forms of efficiency in the developing countries' banking sector are positively affected by capital adequacy. These findings validate the notion of encouraging banks to increase the minimum capital to absorb losses, curb banks' excessive risk-taking and promote banking sector stability as well as efficiency. In the context of monetary policy tightening, our study results lead us to conclude a negative impact on operational efficiency but a positive effect on investment efficiency in both developed and developing economies. This is consistent with the argument that when liquidity and savings are plentiful and interest rates are low, investors will be eager to invest, and banks will step in to fill the void. It implies that increased investment efficiency is expected.

Our findings have far-reaching policy and financial implications for banks, policymakers and stakeholders of financial stability, specifically in the context of the banking sector. First, while strictly limited capital improves operating performance, it could affect banks' efficiency, in developed as well as developing economies. However, the results may vary between the two groups as well as between the measures of efficiency in the developed countries. While capital can absorb losses and is an important component of resilience to adverse shocks, it is more expensive than other forms of funding because investors expect additional compensation for the higher risk they bear. However, there are definitely gains, particularly in emerging economies and also for investment efficiency in developed economies. It also implies that the banks may encourage diversifying their lending activities, such as housing lending, capital-intensive and lower-return lending, loan repricing, deposit liability repricing, a general lengthening of the maturity of liabilities, and a continued shift toward more stable sources of funding. As a result, all modified lending activities are likely to require more capital, which will have a direct impact on banks' efficiency. Furthermore, in terms of strategy, the banks must be vigilant regarding macroeconomic environment changes and have a keen eye on economic policy uncertainty. Economic uncertainty is found to have deteriorating effects on the bank's efficiency in developing economies. Policymakers' roles include not only implementing post-crisis capital requirements but also monitoring for any unexpected effects of the reforms and being alert to new risks that emerge to ensure that the resilience we injected into the banking system post-crisis stands the test of time.

The findings also imply that macroeconomic and bank-level factors are crucial to bank efficiency. To make the best use of their resources, banks are to ensure efficient and effective supervision and related services. The equitable allocation of resource gains from various investments, such as bond yield and collateralized debt obligations, prudent strategic planning to prevent elevated amounts of financial distress, enhanced supervision to prevent excessive levels of non-performing loan ratios, assurance of a healthy competitive environment, and excellence in services to maintain competitive banking are some examples of this. Additionally, as financial policy implications, banks need to look for increasing bank capital adequacy levels, use creative methods to lower the percentage of non-interest-bearing assets and invest resources in stocks and capital markets, which are less risk-free projects for the banking industry, to increase efficiency. Regarding the implications of changing macroeconomic variables, such as economic growth and inflation, among others, on bank efficiency, the bank must also be considerate of these risks. This would imply that to promote financial intermediation, policies targeted at stabilizing inflation and GDP growth should take precedence. In times of high economic growth, the developed economies' banking sector should remain focused on efficiency and avoid complacency. The monetary policy tightening which has been recently on the agenda of many central banks also has implications for the banks' operational efficiency, although there are gains through increased investment efficiency. It will require banks to watch out for their operations and rising operational costs.

Like any study, the scope of this paper has a limit. There could be further research which may consider additional factors, such as corporate governance or ownership structure. This study focused only on G7 and E7, future studies can be conducted on other countries and regions. Digital currencies, fintech, and blockchain are also posing new challenges to the banking system. All these aspects are beyond the scope of the subject study but incorporating them into further analysis could provide more insights into the efficiency of the banking sector in the twenty-first century. Furthermore, it would be interesting to extend the analysis of operational and investment efficiency into technological and allocative efficiencies in future research.

Appendix

See Tables 13, 14, 15, 16.G-7 and E-7 Banks

Table 13 Unit root tests

Variable	Test	Individual intercept		Individual intercept and trend		Conclusion
		Level	1st Difference	Level	1st Difference	
GDP	LLC	(−9.949) 0.0000**	(−34.057) 0.0000**	(−8.9075) 0.0000**	(−28.915) 0.0000**	Stationary at level
	IPS	(−12.729) 0.000**	(−33.561) 0.000**	(−8.147) 0.000**	(−28.050) 0.000**	Stationary at level
	F-ADF	(610.141) 0.000**	(1338.65) 0.000**	(481.705) 0.000**	(1009.93) 0.0000**	Stationary at level
Inflation	LLC	(−24.544) 0.000**	(−56.641) 0.000**	(−21.522) 0.000**	(−51.599) 0.000**	Stationary at level
	IPS	(−19.495) 0.000*	(−49.426) 0.000*	(−18.569) 0.000**	(−40.603) 0.000**	Stationary at level
	F-ADS	(777.423) 0.000**	(2442.93) 0.000**	(717.93) 0.000**	(1219.22) 0.000**	Stationary at level
Unemployment	LLC	(−2.459) 0.070	(−9.471) 0.0000**	(−0.023) 0.4908	(−5.730) 0.0000**	Stationary after 1st difference
	IPS	(−7.076) 0.000**	(−13.571) 0.000**	(−4.792) 0.000**	(−4.028) 0.000**	Stationary at level
	F-ADS	(372.119) 0.000**	(576.781) 0.000**	(306.359) 0.000	(322.539) 0.000***	Stationary after 1st difference
Uncertainty	LLC	(4.540) 1.000	(−26.278) 0.000**	(−4.581) 0.000**	(−17.878) 0.000**	Stationary after 1st difference
	IPS	(3.919) 1.000	(−24.765) 0.000**	(−0.693) 0.244	(−19.052) 0.000**	Stationary after 1st difference
	F-ADS	(221.029) 0.430	(1008.29) 0.000***	(295.872) 0.000***	(756.673) 0.000***	Stationary after 1st difference

Table 13 (continued)

Variable	Test	Individual intercept		Individual intercept and trend		Conclusion
		Level	1st Difference	Level	1st Difference	
Exchange rate	LLC	(− 3.271) 0.000***	(− 37.019) 0.000**	(− 14.229) 0.000**	(− 32.045) 0.000**	Stationary after 1st difference
	IPS	(− 5.335) 0.000**	(− 37.029) 0.000**	(− 9.189) 0.000**	(− 33.1549) 0.000**	Stationary at level
	F-ADS	(376.755) 0.000**	(1465.75) 0.000**	(449.853) 0.000**	(1192.66) 0.000**	Stationary at level
Bank rate	LLC	(− 9.577) 0.000**	(− 28.272) 0.000**	(− 12.310) 0.000**	(− 22.175) 0.000	Stationary at level
	IPS	(− 5.723) 0.000**	(− 27.543) 0.000**	(− 10.838) 0.000**	(− 17.607) 0.000***	Stationary at level
	F-ADS	(358.322) 0.000**	(1049.69) 0.000**	(495.312) 0.000**	(678.599) 0.000**	Stationary at level
Capital adequacy	LLC	(674.808) 0.000***	(− 783.987) 0.000**	(− 853.725) 0.000**	(− 621.122) 0.000**	Stationary at level
	IPS	(− 101.417) 0.000***	(− 111.106) 0.000**	(− 105.134) 0.000**	(− 97.207) 0.000**	Stationary at level
	F-ADS	(614.643) 0.000**	(1916.45) 0.000**	(452.399) 0.000**	(1108.02) 0.000**	Stationary at level
Operational efficiency	LLC	(− 113.048) 0.000***	(− 43.1856) 0.000***	(− 114.858) 0.000***	(− 33.7339) 0.000***	Stationary at level
	IPS	(− 52.5783) 0.000***	(− 51.5529) 0.000***	− (48.9411) 0.000***	(− 46.5996) 0.000***	Stationary at level
	F-ADS	(2736.61) 0.000***	(2423.54) 0.000***	(961.904) 0.000***	(1412.80) 0.000***	Stationary at level

Table 13 (continued)

Variable	Test	Individual intercept		Individual intercept and trend		Conclusion
		Level	1st Difference	Level	1st Difference	
Investment efficiency	LLC	(− 118.902) 0.000***	(− 143.215) 0.000***	(− 204.583) 0.000***	(− 99.3678) 0.000***	Stationary at level
	IPS	(− 43.8949) 0.000***	(− 68.5175) 0.000***	(− 59.7825) 0.000***	(− 51.9654) 0.000***	Stationary at level
	F-ADS	(1673.55) 0.000***	(2594.65) 0.000***	(955.657) 0.000***	(1351.53) 0.000***	Stationary at level
Leverage	LLC	− 4.42955 0.0000**	− 40.2966 0.0000**	− 10.1158 0.0000**	1.78433 0.9628	Stationary at level
	IPS	− 7.94340 0.0000**	− 38.1379 0.0000**	− 7.49142 0.0000**	− 31.8291 0.0000**	Stationary at level
	F-ADS	474.593 0.0000**	1559.68 0.0000**	420.633 0.0000**	1144.56 0.0000**	Stationary at level

Table 14 Kao residual cointegration test

Operational efficiency	(−16.02856)	0.000***
Investment efficiency	(−27.18995)	0.000***

Test Stats. is in brackets; *** = 1% significance level

Table 15 Pedroni residual cointegration test for banks' operational efficiency

Variables	Test statistics	I.I	I.I and I. T	No, I or T
OPE. GDP	Panel v statist	(11.95668) 0.000***	(2.019628) 0.0217	(22.88198) 0.000***
	Panel rho statistic	(−20.68690) 0.000***	(−13.34580) 0.000***	(−26.33849) 0.000***
	Panel PP statistic	(−22.81781) 0.000***	(−29.25395) 0.000***	(−25.82040) 0.000***
	Panel ADF statistic	(−23.88170) 0.000***	(−27.92434) 0.000***	(−25.70306) 0.000***
OPE, GDP, inflation	Panel v statist	(6.666923) 0.000***	(−0.314709) 0.000***	(12.03456) 0.000***
	Panel rho statistic	(−10.96929) 0.000***	(−5.458869) 0.000***	(−14.10038) 0.000***
	Panel PP statistic	(−23.98698) 0.000***	(−22.37093) 0.000***	(−22.95743) 0.000***
	Panel ADF statistic	(−22.62702) 0.000***	(−19.08485) 0.000***	(−22.75755) 0.000***
OPE.GDP inflation unemployment	Panel v statist	(2.571125) 0.005*	(−1.707251) 0.9561	(5.341274) 0.000***
	Panel rho statistic	(−4.615429) 0.000***	(−1.748070) 0.040	(−8.156765) 0.000***
	Panel PP statistic	(−17.62489) 0.000***	(−19.46717) 0.000***	(−21.84722) 0.000***
	Panel ADF statistic	(−17. −9271) 0.000***	(−21.38657) 0.000***	(−20.46988) 0.000***
OPE. GDP inflation unemployment Bank rate	Panel v statist	(0.760357) 0.223	(−3.260006) 0.999	(3.309078) 0.000***
	Panel rho statistic	(−2.135002) 0.016	(0.786055) 0.784***	(−5.188702) 0.000***
	Panel PP statistic	(−22.64651) 0.000***	(−23.24410) 0.000***	(−26.74115) 0.000***
	Panel ADF statistic	(−22.84044) 0.000***	(21.38582) 0.000***	(−25.74200) 0.000***
OPE. GDP inflation unemployment Bank rate Uncertainty	Panel v statist	(−2.153818) 0.984	(−4.439040) 1.000	(0.229288) 0.409
	Panel rho statistic	(1.135242) 0.871	(2.286803) 0.988	(−2.016377) 0.0219
	Panel PP statistic	(−20.60763) 0.000***	(−26.70040) 0.000***	(−24.92149) 0.000***
	Panel ADF statistic	(−20.89681) 0.000***	(−25.93451) 0.000***	(−25.40131) 0.000***

Table 15 (continued)

Variables	Test statistics	I.I	I.I and I. T	No, I or T
Operational efficiency GDP inflation unemployment Bank rate uncertainty leverage	Panel v statist	(− 4.380652) 1.000	(− 5.909725) 1.000	(− 2.362099) 0.099
	Panel rho statistic	(4.506653) 1.000	(5.620034) 1.000	(1.542031) 0.938
	Panel PP statistic	(− 18.55471) 0.000***	(− 25.34106) 0.000***	(− 23.03139) 0.000***
	Panel ADF statistic	(− 18.18970) 0.000***	(− 22.52389) 0.000***	(− 23.54881) 0.000***
OPE. GDP inflation unemployment Bank rate leverage exchange rate	Panel v statist	(− 1.179848) 0.881	(− 4.874030) 1.000	(− 0.667443) 0.747
	Panel rho statistic	(3.899753) 1.000	(6.967394) 1.000	(1.177174) 0.880
	Panel PP statistic	(− 22.41421) 0.000***	(− 20.88681) 0.000***	(− 24.36925) 0.000***
	Panel ADF statistic	(− 19.49930) 0.000***	(− 16.78153) 0.000***	(− 27.12622) 0.000***
OPE. GDP inflation uncertainty Bank rate leverage exchange rate	Panel v statist	(− 2.333734) 0.990	(− 5.094791) 1.000	(− 2.538231) 0.994
	Panel rho statistic	(3.121724) 0.999	(6.136509) 1.000	(1.400640) 0.919
	Panel PP statistic	(− 25.79748) 0.000***	(− 24.45517) 0.000***	(− 23.22865) 0.000***
	Panel ADF statistic	(− 24.88745) 0.000***	(− 20.51004) 0.000***	(− 25.37484) 0.000***
OPE. GDP inflation uncertainty Bank rate leverage capital	Panel v statist	(− 2.212158) 0.986	(− 5.630853) 1.000	(− 1.758763) 0.960
	Panel rho statistic	(2.883859) 0.998	(5.431501) 1.000	(1.386399) 0.917
	Panel PP statistic	(− 25.53299) 0.000***	(− 27.45368)) 0.000***	(− 23.76620) 0.000***
	Panel ADF statistic	(− 24.79734) 0.000***	(− 21.13347) 0.000***	(− 25.61392) 0.000***
OPE. GDP inflation unemployment Bank rate leverage capital adequacy	Panel v statist	(− 3.033738) 0.998	(− 6.551580) 1.000	(− 2.704734) 0.996
	Panel rho statistic	(3.792475) 0.999	(6.344102) 1.000	(1.932400) 0.973
	Panel PP statistic	(− 21.84400) 0.000***	(− 23.33037) 0.000***	(− 24.19594) 0.000***
	Panel ADF statistic	(− 20.57944) 0.000***	(− 20.89824) 0.000***	(− 23.65897) 0.000***

Significant *p* values at 1% (***), 5% (**), & 10% (*) levels

Table 16 Pedroni residual cointegration test for bank investment efficiency

Variables	Test statistics	I.I	I.I & I. T	No, I or T
Invsteffi, GDP	Panel v statist	(7.900644) 0.000***	(− 2.551135) 0.994	(19.15411) 0.000***
	Panel rho statistic	(− 26.43381 0.000***	(− 17.32051) 0.000***	(− 34.39826) 0.000***
	Panel PP statistic	(− 32.63882) 0.000***	(− 34.47969) 0.000***	(− 29.27452) 0.000***
	Panel ADF statistic	(− 32.22450) 0.000***	(− 34.39531) 0.000***	(− 28.78757) 0.000***
Invest, GDP, inflation	Panel v statist	(7.019037) 0.000***	(− 1.357454) 0.912	(12.74296) 0.000***
	Panel rho statistic	(− 17.59282) 0.000***	(− 10.87151) 0.000***	(− 19.74068) 0.000***
	Panel PP statistic	(− 33.68192) 0.000***	(− 34.32354) 0.000***	(− 28.87382) 0.000***
	Panel ADF statistic	(− 33.44977) 0.000***	(− 34.04346) 0.000***	(− 27.48736) 0.000***
Invest, GDP, inflation, capital	Panel v statist	(3.233787) 0.000***	(− 3.233912) 0.999	(7.141897) 0.000***
	Panel rho statistic	(− 10.69000) 0.000***	(− 5.938713) 0.000***	(− 13.14912) 0.000***
	Panel PP statistic	(− 30.44255) 0.000***	(− 31.68936) 0.000***	(− 29.00609) 0.000***
	Panel ADF statistic	(− 30.05117) 0.000***	(− 31.38383) 0.000***	(− 28.91493) 0.000***
Invest, GDP, inflation, capital unemployment	Panel v statist	(− 1.617488) 0.947	(− 6.705227) 1.000	(1.442396) 0.074
	Panel rho statistic	(− 5.740403) 0.000***	(1.731183) 0.041	(− 9.012406) 0.000***
	Panel PP statistic	(− 27.77699) 0.000***	(− 31.13248) 0.000***	(− 30.73075) 0.000***
	Panel ADF statistic	(− 27.57770) 0.000***	(− 30.14950) 0.000***	(− 30.52848) 0.000***
Invest, GDP, inflation, capital Unemployment bank rate	Panel v statist	(− 4.129427) 1.000	(− 8.486315) 1.000	(− 2.487144) 0.993
	Panel rho statistic	(− 1.462366) 0.071	(1.852026) 0.968	(− 3.449727) 0.000***
	Panel PP statistic	(− 34.38272) 0.000***	(− 37.52983) 0.000***	(− 31.97596) 0.000***
	Panel ADF statistic	(− 20.81357) 0.000***	(− 18.71400) 0.000***	(− 29.69351) 0.000***
Invest, GDP, inflation, capital Unemployment bank rate, exchange rate	Panel v statist	(− 4.695967) 1.000	(− 7.634303) 1.000	(− 4.910713) 1.000
	Panel rho statistic	(4.547841) 1.000	(7.381043) 1.000	(1.764917) 0.961
	Panel PP statistic	(− 15.03235) 0.000***	(− 15.41637) 0.000***	(− 20.24296) 0.000***
	Panel ADF statistic	(− 14.81700) 0.000***	(− 15.06669) 0.000***	(− 19.66989) 0.000***

Table 16 (continued)

Variables	Test statistics	I.I	I.I & I. T	No, I or T
Invest. GDP, inflation, capital Uncertainty, bank rate, exchange rate	Panel v statist	(− 5.507916) 1.000	(− 9.707574) 1.000	(− 4.083191) 0.000***
	Panel rho statistic	(3.650093) 0.999	(7.051006) 1.000	(1.39522) 0.918
	Panel PP statistic	(− 18.21609) 0.000***	(− 16.03442) 0.000***	(− 22.11231) 0.000***
	Panel ADF statistic	(− 17.64169) 0.000***	(− 15.10837) 0.000***	(− 21.19861) 0.000***
Invest, GDP, inflation, capital Uncertainty, unemployment, exchange rate	Panel v statist	(0.142828) 0.443	(− 4.487932) 1.000	(2.137129) 0.016
	Panel rho statistic	(3.070780) 0.998	(6.452666) 1.000	(0.272511) 0.607
	Panel PP statistic	(− 23.18484) 0.000***	(− 22.28803) 0.000***	(− 26.82182) 0.000***
	Panel ADF statistic	(− 21.50420) 0.000***	(− 20.40086) 0.000***	(− 25.28392) 0.000***
Invest, GDP, inflation, capital Uncertainty, unemployment, leverage	Panel v statist	(0.142828) 0.443	(− 4.487932) 1.000	(2.137129) 0.0163
	Panel rho statistic	(3.070780) 0.998	(6.452666) 1.000	(0.272511) 0.607
	Panel PP statistic	(− 23.18484) 0.000***	(− 22.28803) 0.000***	(− 26.82182) 0.000***
	Panel ADF statistic	(21.50420) 0.000***	(− 20.40086) 0.000***	(− 25.28392) 0.000***
Invest, GDP, inflation, capital Bankrate, unemployment, leverage	Panel v statist	(1.034413) 0.150	(− 2.002507) 0.977	(1.628414) 0.051
	Panel rho statistic	(1.813695) 0.965	(6.173914) 1.000	(0.100954) 0.540
	Panel PP statistic	(− 34.12062) 0.000***	(− 24.30926) 0.000***	(− 30.85165) 0.000***
	Panel ADF statistic	(− 30.29953) 0.000***	(− 22.19347) 0.000***	(− 28.53452) 0.000***
Invest, GDP, inflation, capital Bankrate, uncertainty, leverage	Panel v statist	(0.879099) 0.189	(− 1.927007) 0.973	(2,081696) 0.018
	Panel rho statistic	(1.464011) 0.928	(5.651418) 1.000	(− 0.325155) 0.372
	Panel PP statistic	(− 31.38175) 0.000***	(− 25.49490) 0.000***	(− 32.65330) 0.000***
	Panel ADF statistic	(− 28.67314) 0.000***	(− 23.58125) 0.000***	(− 29.99950) 0.000***
Invest, GDP, Inflation, capital Bankrate, exchange rate, leverage	Panel v statist	(− 2.292893) 0.989	(− 4.871097) 1.000	(− 1,401,499) 0.919
	Panel rho statistic	(4.049821) 1.000	(8.115980) 1.000	(1.63159) 0.948
	Panel PP statistic	(− 18.48647) 0.000***	(− 11.55018) 0.000***	(− 22.03426) 0.000***
	Panel ADF statistic	(− 17.53298) 0.000***	(− 10.92735) 0.000***	(− 20.94831) 0.000***

Significant *p* values at 1% (***), 5% (**), & 10% (*) levels

US	UK	Japan	Germany	Italy	France	Canada
Wells Fargo & Co	Barclays Plc	Bank Of Nagoya Ltd	Landesbank Baden-Württemberg	Credito Emiliano	Banque Populaire SA	Bank Of Nova Scotia
Bank Of New York Mellon	Standard Chartered Plc	Chiba Bank	Deutsche Bank AG	Banca Monte Dei Paschi di Siena SPA	BNP Paribas Sa	Canada Western Bank
PNC	HSBC Bank	Towa Bank Ltd	Commerzbank AG	Banca Popolare Di Sondrio Scpa	Aareal Bank AG	Laurentian Bank of Canada
Capital One	Lloyds Banking Group Plc	Fukui Bank Ltd	DNB Bank	Banca Popolare Dell'emilia Romagna S.C	Byblos Bank Sal	Imperial Bank
Cathay General Bancorp	NatWest Group Plc	Hachijuni Bank Ltd	Aareal Bank	Intesa Sanpaolo SPA	Caisse Regionale De Credit Agricole Mutuel De Paris Et D Ile De France	Bank Of Montreal
Charles Schwab	Santander UK Plc	Hyakujushi Bank Ltd	Bayernlb, Munich	Mediobanca Banca Di Credito Finanziario Spa	Axa Sa Bank	National Bank of Canada
Citi Group	Close Brother	Iyo Bank Ltd	Deutsche Bank, Frankfurt	UniCredit Bank	Société Bank	Royal Bank of Canada
Fifth Third Bancorp		Keiyo Bank Ltd				Toronto Domino
Goldman Sachs Bank USA		Shinsei Bank Ltd				Desjardins Group
JP Morgan Chase and Co		Yamanashi Chuo Bank Ltd				
U.S. Bancorp						
SVB Financial Group						
Truist Bank						
State Street Corp						
Td Bank						
Wintrust Financial Corp						

China	Turkey	India	Mexico	Brazil	Indonesia	Russia
Bank Of East Asia Ltd	Ak Bank	Axis Bank Ltd	Banco Santander Sa	Banco Bradesco	Access Bank Plc	Alfa-Bank
China Merchants Bank Co Ltd	Denizen bank	Bank Of Baroda Ltd	Bank Of Nova	Banco Do Brasil Sa	Bank Cimb Niaga Tbk PT	Moskovskiy Kreditnyi Bank
Agriculture Bank of China	Finansbank	Bank Of India	Banorte Bank	Banco Do Estado Do Rio	Bank Danamon Indonesia TBK PT	Promsvyaz'bank PAO
China Minsheng Banking Corp Ltd	Turkiye Garanti Bankasi AS	HDFC Bank Ltd	HSBC Bank	Banco Do Nordeste Do Brasi	Bank Mandiri (Persero) Tbk Pt	Rossel'khozbank AO
Commercial Bank of China	Turkiye Is Bankasi As	ICICI Bank Ltd	Inbursa Bank	Banco Santander Brasil SA	Bank Negara Indonesia (Persero)	Sberbank Rossii PAO
Ping An Bank	Turkiye Vakiflar Bankasi Tao	IDBI Bank Ltd	BBVA Bancomer Bank		Bank Rakyat Indonesia (Persero) Tbk Pt	Uralsib Bank
Hua Xia Bank Co Ltd	Ziraat Bank	Kotak Mahindra Bank Ltd			Bank Woori Saudara Indonesia 1906 TBK PT	VTB Bank
ICBC China						

Declarations

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