INTERNATIONAL MONETARY FUND

Estimation and Determinants of Cost Efficiency: Evidence from Central Bank Operational Expenses

Romain Veyrune and Solo Zerbo

WP/23/195

2023
SEP

WORKING PAPER

 WP/23/195

IMF Working Paper
Monetary and Capital Markets Department

Estimation and Determinants of Cost Efficiency: Evidence from Central Bank Operational Expenses
Prepared by Romain Veyrune and Solo Zerbo*

Authorized for distribution by Jihad Alwazir
September 2023

ABSTRACT: The finances of central banks is a topic of renewed interest: many central banks are posting significant losses due to the cost of monetary policy, over which central banks have no control. Conversely, operational expenses, over which the central banks have more control, is a subject of less attention. We use public income statement data from central banks to calculate a score for operational expense efficiency based on a stochastic frontier analysis. In addition, we offer potential explanations for the observed variations in efficiency levels across central banks. Our analysis reveals significant heterogeneity across countries and income groups. Central banks with a single objective demonstrate higher efficiency compared with those with multiple objectives. Regarding the output of price stability, central banks in low-income developing countries exhibit lower efficiency compared with central banks in emerging markets and advanced economies. Factors such as central bank independence, the depth of the financial system, and the degree of openness play a role in influencing efficiency levels. Our findings underscore the significance of well-defined objectives, the operating environment, and concentration on core activities in reducing inefficiency.

JEL Classification Numbers:	E5, O1, F1
Keywords:	operational efficiency; stochastic frontier analysis; operating independence; trade; financial depth

Authors' Email Addresses:	RVeyrune@imf.org; SZerbo@imf.org

* The authors would like to thank Robin Darbyshire, Vern McKinley, Ashraf Khan, Maria Oliva, and participants at the MCM Policy Forum for their comments and insights.

WORKING PAPERS

Estimation and Determinants of Cost Efficiency

Evidence from Central Bank Operational Expenses

Prepared by Romain Veyrune and Solo Zerbo[1]

[1] The authors would like to thank Robin Darbyshire, Vern McKinley, Ashraf Khan, Maria Oliva, and participants at the MCM Policy Forum for their comments and insights.

Contents

I. Introduction

A primary focus of measuring the cost efficiencies of financial institutions has been placed on commercial banks.[1] By contrast, central banks do not have a profit maximization objective (Goncharov et al. (2021)).[2] Instead, central banks are accountable for meeting their policy objectives, which are ideally limited to price and financial stability, because central banks have tools to directly pursue these goals by respectively influencing financial conditions and providing liquidity backstop to banks and the market. In practice, they often also have multiple objectives related to public services on which central banks are expected to have specific expertise. Operational expenses include staff costs, currency expenses, professional charges (e.g., fees), and equipment maintenance that the central banks incur as part of their activities. These typically include monetary policy design and implementation; financial supervision (if in the remit of the central bank); account management services provided, for instance, to the government; foreign reserve management; and all other costs related to other peripheral activities. Against this backdrop, central bank operational expense efficiency came across as secondary in comparison with their effectiveness in achieving their "policy" objectives. As a result, studies on cross-central banks' operational efficiencies, as well as their drivers, are limited. In this paper, we fill the gap, and our goal is twofold: (i) measure cost efficiency of central banks; and (ii) investigate the determinants of efficiency.

As a matter of principle, central banks should care about their operational expense efficiency. While not subject to profitability, central banks should use their—public—resources efficiently. A relative lack of budget constraint due to: (i) the absence of liquidity constraint; and (ii) the steady flow of seigniorage could divert the attention from cost efficiency in normal times. However, at the time of losses, operational expenditures, over those central banks have direct control, are grabbing more attention, especially when fiscal backstops are not immediately available.

There are other arguments in favor of improving a central bank's efficiency. First, efficiency (rational use of resources) could help effectiveness (capacity to reach one's objective). The two concepts are different but not inconsistent. For instance, streamlining noncore activities would improve effectiveness in reaching policy goals, by reducing conflicts between objectives and distractions from core tasks, and cost efficiency. Second, central banks, while independent, remain accountable to oversight institutions, for example, national parliaments, and perceived inefficiency could undermine central banks' reputation and, in turn, their independence (McKinley and Banaian, 2005).

Significant factors that limit analyzing efficiency within central banks lie in data availability and the multiplicity of activities of some central banks. Additionally, the plurality of objectives assigned to central banks varies among economies, making cross-comparisons of central banks challenging. That said, compared with other industries, the range of services and products provided by central banks is relatively limited. Some will be found in almost all central banks; these include price stability, issuing means of retail payment (bank notes), issuing instruments for interbank settlement (banks' reserve at the central bank), maintaining a stock of foreign assets, and lending to (or absorbing from) monetary counterparties (for example, banks). Findings would be mixed on whether the central bank fixes the exchange rate, supervises banks (versus a separate banking supervisor with its own budget), is mandated to advance economic development or assist the government, or is allowed to finance the government.

To address this difficulty, we have constructed a new dataset that includes 90 central bank income statements, objectives, and staffing information from 2008 to 2021. Accounting standards may be different from country to country. Out of the 90, 30 central banks apply International Financial Reporting Standards (IFRS) standards,

[1] See, for example, Ben Naceur (2016) and Chuling Chen (2009) for a detailed review of commercial bank efficiency analysis.

[2] In difficult situations (with high inflation and low interest rates), central banks become reluctant to recognize a loss.

and the others apply generally accepted local standards. The estimate attempts to control for the difference in accounting standards. Furthermore, the panel features of the data allow us to control for observed heterogeneity across central banks and their operating environments. Our paper represents the first empirical attempt to measure central bank operational cost efficiency using stochastic frontier analysis and study the determinants of efficiency.

We find significant variation among central banks. On average, central banks with a single objective tend to be more cost efficient than those with multiple objectives. This result suggests that focusing on core activities reduces inefficiency. When considering the price stability objective as output, we find that operational efficiencies tend to be lower in low-income countries (LICs) than in emerging markets (EMs) and lower in EMs than in advanced economies (AEs). Specifically, we observe that financial depth and central bank independence have a positive impact on the operational efficiency of central banks, while the impact of trade openness is negative.

To the best of our knowledge, only McKinley and Banaian (2005) attempted to measure efficiency at the institutional central banking level and measure empirically central banks' operational efficiency based on 2001 data from 32 central banks. Several central banks have implemented efficiency reviews (Bank of England, 2018). These exercises are idiosyncratic, completed by business lines and work processes for a given central bank, with benchmarking implemented at the level of the different products. For example, Bauer and Hancock (1993) investigated the efficiency and productivity growth of check processing operations at 47 Federal Reserve offices over the period of 1979–90. Similarly, Bauer and Ferrier (1996) examined the Federal Reserve's costs of processing three payment services—checks, automated clearinghouse transfers, and wire transfers of funds—over the period of 1990–94. They found a significant dispersion in the operating performances of the various sites of processes for all three payment services. Further, Bohn et al. (2001) considered another type of central banking activity, namely currency distribution. The authors estimated scale and cost efficiency for 37 Federal Reserve currency processing and handling facilities over the period of 1991–96 using a translog and a hybrid-translog cost function.

The rest of the paper is organized as follows: Section II presents the methodology. Section III provides an overview of the data and conducts the cost-efficiency analysis. Section IV explores the determinants of bank efficiency levels. Section V concludes.

II. Measuring Central Bank Operational Efficiency

Stochastic Frontier Analysis

Over the past decades, efficiency analysis using frontier methods has become widespread. Stochastic frontier analysis (SFA) allows multiple homogeneous types of inputs and outputs in the efficiency estimation. The efficiency of any production process is calculated directly from its outputs, which have functional form with its inputs and have strongly depended on the available structural relationship of its inputs and outputs.

There are two main modeling techniques for estimating the operational efficiency of firms: SFA[3] and data envelopment analysis (DEA). SFA is a parametric approach that provides benchmark information against which competitors can identify best practices and "worst practices" associated with high and low efficiency. The standard SFA model allows for statistical noise and can be used to compute measures of reliability (for example, standard errors) for efficiency estimates. DEA is a nonparametric approach and can be used to

[3] SFA was introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977).

identify efficient firms (peers), which inefficient firms should study to become more efficient. A weakness of the DEA analysis model is that it does not allow for measurement errors. The stochastic frontier method has three principal advantages compared with the nonparametric DEA method. First, SFA allows for separating random error from the production unit inefficiency and considers the existence of exogenous shocks. Second, SFA allows for measurement errors. Third, stochastic frontier analysis is less sensitive to outliers. Hence, in this paper, we employ SFA.

Let's consider the following cost function, which represents the bank's desire to minimize its operational expenses (personnel, currency, and others) and expenses arising from noncore operations concerning its input and output. The cost of monetary policy (interest rate expense) is exogenous, because it is determined by the price stability objective. Per our definition of operating expenses, we model the cost function as follows:

$$C_{it} = F(Y_{it}, Z_{it})\xi_{it}\exp(v_{it}) \qquad (1)$$

C_{it} is the total operating expenses bank *I* incurs at time *t; F* (,) is the production function; Y is the vector of outputs, such as assets and income; and Z is a vector of inputs, such as labor and equity. The cost function is assumed to be subject to two types of shocks: v_{it} is a random shock and ξ_{it} is the level of efficiency for central bank *i* at time *t*.

A fundamental element of stochastic frontier analysis is that each firm potentially produces less than it might, because of a degree of inefficiency. If ξ_{it} = 1, the bank is expending the minimal cost, with the technology embodied in the production function *F*(.). When ξ_{it}< 1, the bank is not making the most of the input, given the technology embodied in the production function *F* (,). Because the cost is assumed to be strictly positive, the degree of technical efficiency is assumed to be strictly positive (that is, ξ_{it} > 0).

Assuming a Cobb Douglass production function *F*(.) and taking the natural log of both sides yields:

$$\log(C_{it}) = cte + \sum_{j=1}^{p} \alpha_j \log(y_{jit}) + \sum_{j=1}^{q} \beta_j \log(z_{jit}) + v_{it} + \mu_{it} \qquad (2)$$

Where $\mu_{it} = \ln(\xi_{it})$ represents the inefficiency factor pertaining to bank *i*. *p* and *q* represent the total number of inputs and outputs, respectively, from the central bank operations. $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$ are unknown parameters to be estimated.

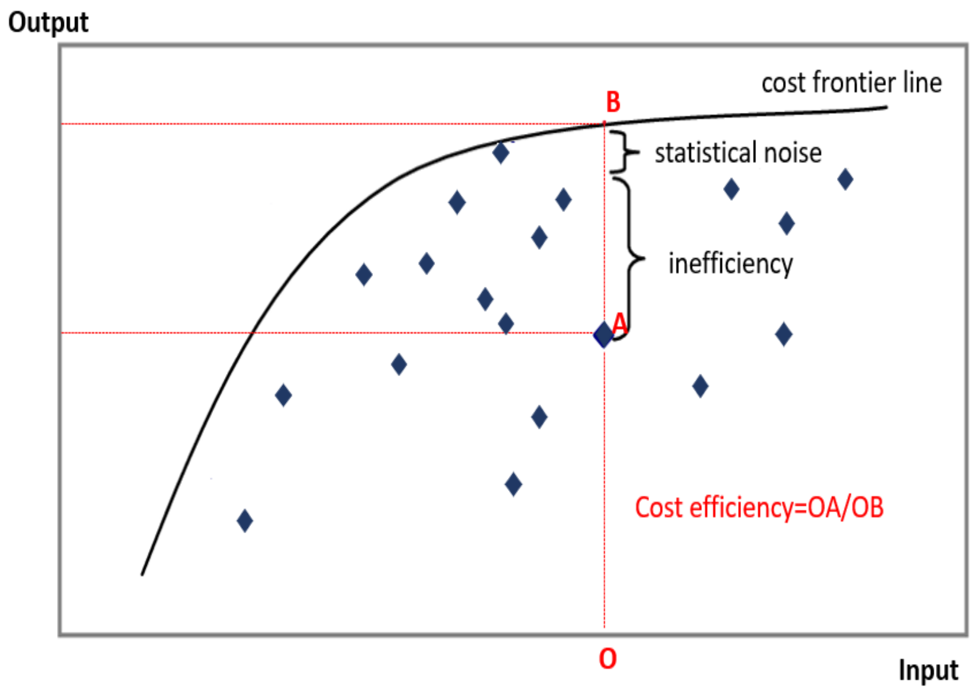
We assume that v_{it} are independently and identically distributed $N(0, \sigma_v)$ and μ_{it} are independently distributed inefficiency effects and follow $N^{+}(m_{it}, \sigma_\mu)$.

In equation (2), the cost efficiency can be explained as the percentage of cost that was used efficiently and is estimated as follows:

$$\text{Cost efficiency Score}_{it} = \frac{\widehat{Cost}_{frontier}}{\widehat{Cost}_{it}} = \exp(-\widehat{\mu_{it}}) \qquad (3)$$

Alternatively, the cost efficiency can be defined by the ratio between the cost needed to produce the same output mix as the best-practice bank in the sample and the actual cost. The frontier value is usually unobservable, and for most studies, the relative efficiency is more important than absolute efficiency. Since the objective is to measure efficiency, we want a model where most of the variation in the error term is explained by the inefficient term rather than the noise. We also control for countries' characteristics to account for local idiosyncrasies.

Figure 1. Stochastic Frontier Analysis Representation



Source: Authors' illustration.

Determination of Central Banks' Input and Output Factors

A cautious selection of input and output variables must be undertaken to conduct an efficiency analysis of any organizational unit. This is crucial in order to get a reliable, relevant, and interpretable result. To specify central banks' operation function,[4] we follow the literature on the production approach, where a firm uses labor and capital to produce services. Here, we consider two inputs. In addition to the number of staff, we include equity, because it could be an important item for monetary policy formulation, as shown by many studies (Klüh and Stella (2008), Berriel and Bhattarai (2009), Del Negro and Sims (2015), Archer and Moser-Boehm (2013)).

We use two types of output: tangible and intangible. Tangible output includes total assets and interest income. Mandate types of output, such as price stability and financial stability, are more challenging to incorporate, due to their intangible nature. The most important function of a central bank, monetary policy, requires multiple economists and models, which do not themselves generate revenue.

[4] An alternative specification of the cost function is the intermediation approach—a bank's production process is one of financial intermediation; that is, it borrows funds from savers and provides those funds to investors in the form of loans or other investments. However, central banks do not specialize in financial intermediation as do commercial banks.

III. Data and Results

Data

Our primary analysis is based on central bank profit-and-loss accounts extracted from their income statements. We collect information on net interest income, noninterest income, operating expenses, total assets, equity, and the number of staff. Initially, our sample consists of 90 central banks, of which 24 are in low-income developing countries (LIDCs), 42 are in emerging markets, and 24 are in advanced economies. The panel data cover the period 2008–21, although the data are unbalanced. We retain observations with at least three staffing information data points, resulting in a final sample of 75 central banks with 712 observations, resulting in an average of eight observations per central bank. There could be several potential confounding variables that may introduce bias to our estimates, particularly due to the systematic correlation between individual inefficiency and country characteristics. To address these issues, we include a common set of control variables representing key country characteristics, such as GDP per capita (which also controls for labor costs), population, and country size. Macroeconomic variables are sourced from the World Bank and IMF databases. Table 1 provides descriptive statistics, offering an overview of our sample for analysis.

Table 1. Descriptive Statistics

	Mean	Median	Standard Deviation	Kurtosis	Skewness	Observations
			Central Bank Income Statements			
Net interest income	5.4E+09	7.6E+07	2.1E+10	38.0	5.5	749
Noninterest income	2.0E+09	6.4E+07	7.8E+09	50.9	6.2	746
Operating expenses	1.7E+09	8.8E+07	6.3E+09	33.4	5.6	749
Asset	6.3E+11	1.9E+10	2.5E+12	63.9	7.1	749
Equity	2.2E+10	8.4E+08	8.7E+10	25.5	5.1	749
Number of staff	1848	679	3261	14.1	3.6	749
			Macroeconomic Variables			
GDP per capita	2.5E+04	2.0E+04	2.2E+04	2.8	1.3	749
Population	2.9E+07	7.4E+06	5.3E+07	12.9	3.3	749
Inflation	3.9	2.4	5.3	30.0	4.4	749
Country size	3.5E+07	1.08E+05	1.76E+08	30.9	5.7	749

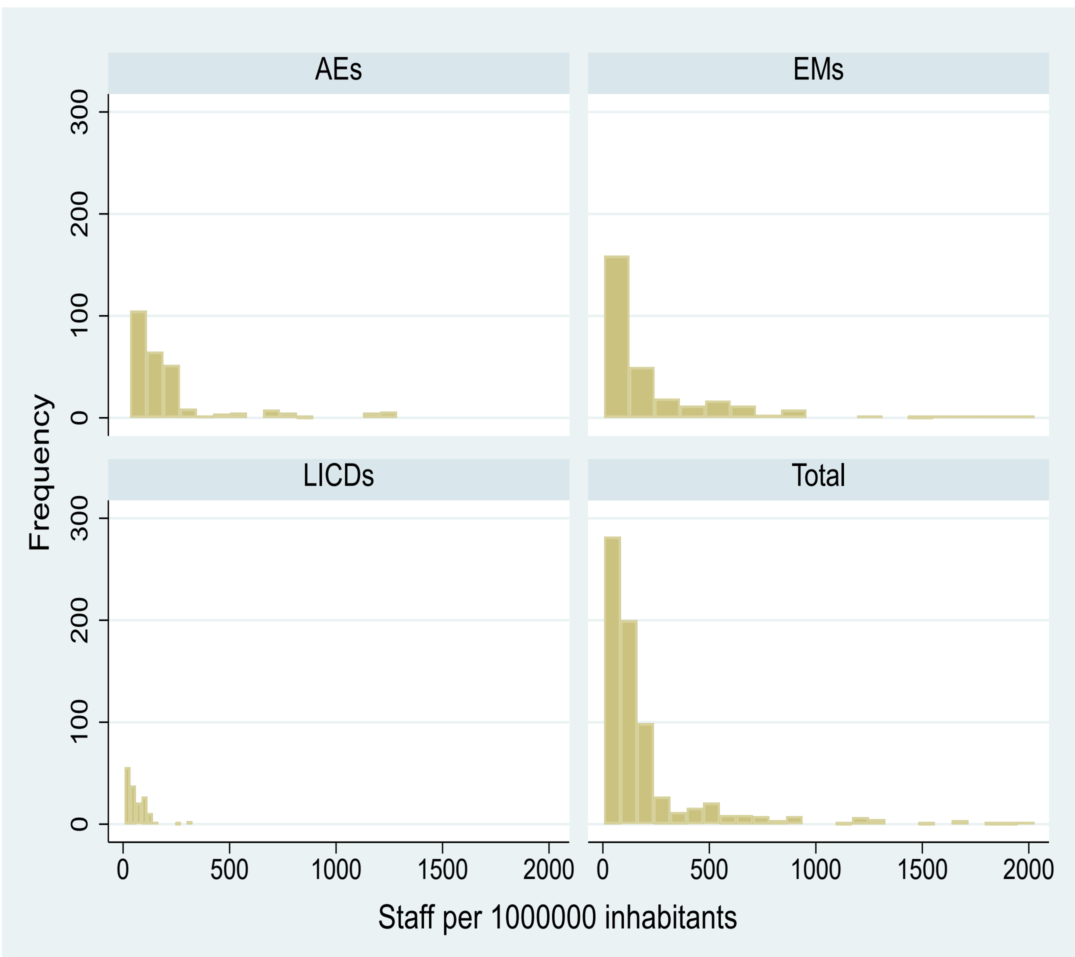
Source: Authors' calculations.

Note: The table presents the descriptive statistics. All values are in USD excluding number of staff, population, inflation, and GDP per capita.

Despite the form and presentation of central bank balance sheets' varying around the world because of different accounting practices, some items, such as such as total asset, equity, number of staff, and operational expenses, can be generalized to a common form. Also, in our paper, we test whether these items differ between IFRS and non-IFRS, and the differences in accounting do not lead to statistically different average operational expenditures between central banks using IFRS and those using other reporting standards (Table A.6). In any case, the fixed effect would capture accounting differences if they could be linked to an unobserved constant heterogeneity, that is, if they did not change dramatically during the period.

Figure 2 displays the distribution of the number of central bank employees per 1 million inhabitants across income groups and the total sample. The figure indicates that the number of central bank employees varies significantly across regions. Among the countries in our sample, emerging markets exhibit the highest number of staff per million inhabitants. One possible explanation for the substantial differences observed across income groups is that central banks' roles and responsibilities differ from country to country, leading to variations in the range of activities they undertake.

Figure 2. Histogram of the Size of Central Banks' Staff and Overall Contributions (by Income Group)

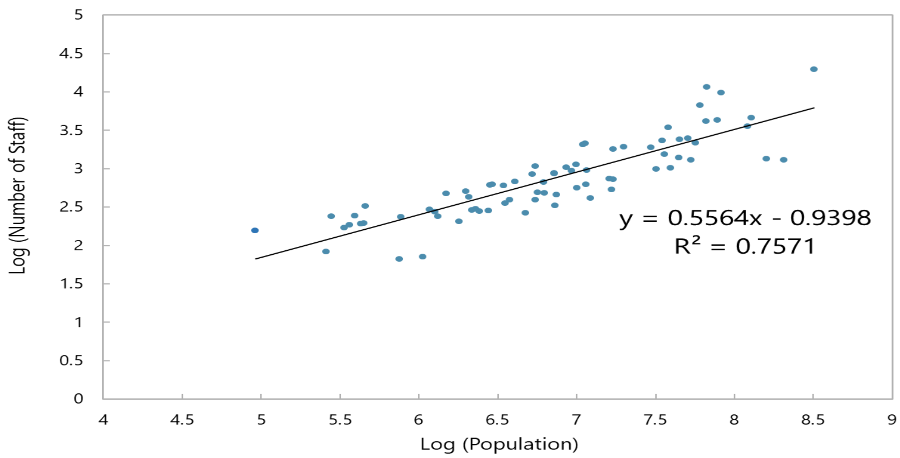


Source: Authors' estimates.

Notes: The height of the bars reflects the number of countries. Sample data include 712 observations of 75 central banks over the period of 2008–21. AE = advanced economy; EM = emerging market; LIDC = low-income developing countries.

Figure 3 presents the relationship between staffing and population. While the result is correlational rather than causal, it shows a positive link between the size of the population and the number of staff. A similar result holds for the relationship between a central bank's average salary per headcount and the country's GDP per capita, as shown in Figure 4. Both representations allow the positioning of a central bank compared with others with similar country populations and average incomes.

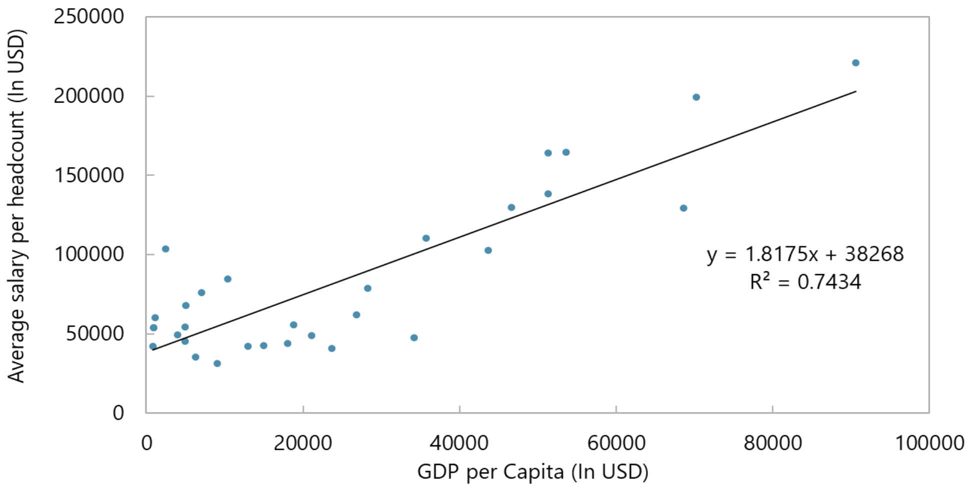
Figure 3. Staffing and Population



Source: Authors' estimates based on central banks' annual reports .

Note: Each blue dot represents a central bank.

Figure 4. Average Salary per Headcount and GDP per Capita

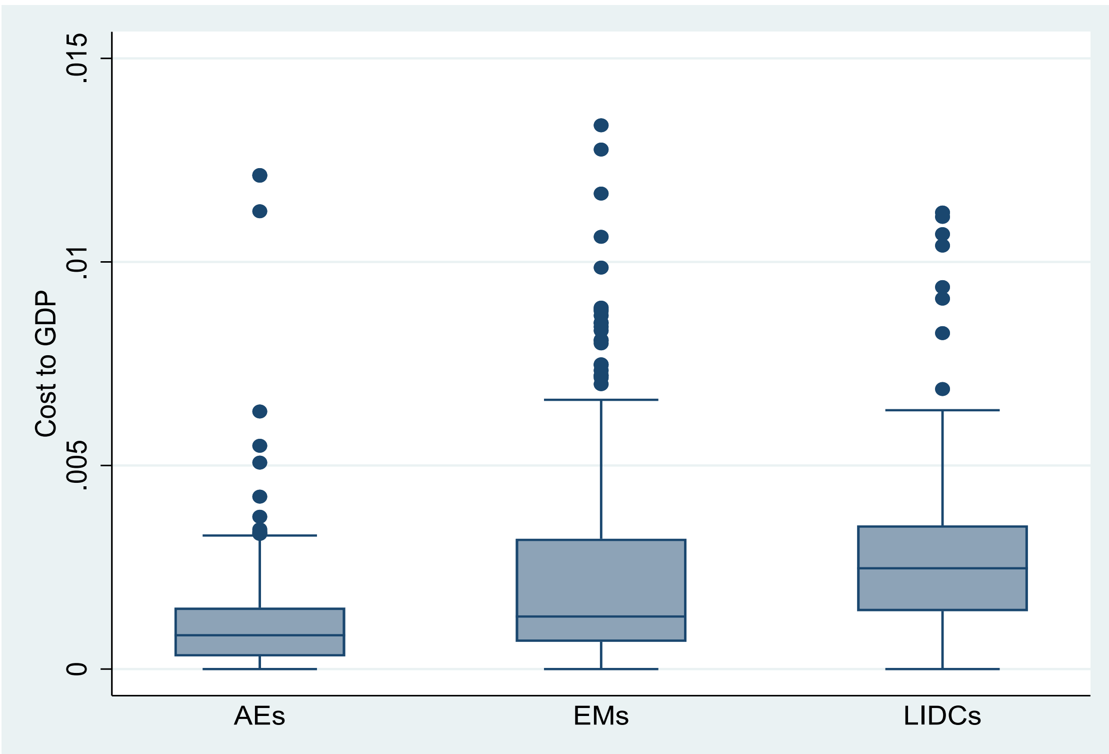


Source: Authors' estimates based on central banks' annual reports.

Note: Each blue dot represents a central bank.

Plotting the distribution of operational expenditures to GDP, Figure 5 shows differences across income groups over the sample period. Operational expenses in terms of GDP tend to be higher in low-income developing countries (LIDCs) than in emerging markets and higher in emerging markets than in advanced economies. Central banks in developing countries provide the public with a range of services beyond price and financial stability, leading to higher operational expenditures. The extra cost is explained by the central banks' providing services and undertaking developmental initiatives that tend to be more in the general government's area of responsibility than at the core of central banking activities. This reflects the budgetary constraint of the general government.

Figure 5. Distribution of Cost to GDP (by Income Group)



Source: Authors' estimates.

Note: Figure 2 presents the distribution of cost to GDP by income group over the sample period. The central line in each box corresponds to the median, and the box edges correspond to the 25th and 75th percentiles. Sample data include 712 observations of 75 central banks over the period of 2008–21. AE = advanced economy; EM = emerging market; LIDCs = low-income developing countries.

Results

a) Baseline Specification

In this subsection, we report our baseline results solely based on tangible output, that is, without including central bank objectives as an output. We start with a simple ordinary least squares (OLS) and fixed effect regressions. We perform the following regression like equation (2) in Section II but with a single error term.

$$\log(C_{it}) = cte + \sum_{j=1}^{p} \alpha_j \log(y_{jit}) + \sum_{j=1}^{q} \beta_j \log(z_{jit}) + \varepsilon_{it}$$

Table 2 presents the results from the estimation. Column 1 reports our estimate without any control. Column 2 reports the estimate after including country and year fixed effects. Estimates of inputs and outputs coefficients are statistically significant at conventional levels except for equity in column 2. The results show that both our selected inputs and outputs are positively correlated with operational expenses. Put differently, central banks with higher outputs and inputs tend to have high operational expenses.

Table 2. Operational Expenses

	(1)	(2)
VARIABLES	Pooled OLS	Fixed Effects
Log (asset)	0.385***	0.333***
	(0.0315)	(0.0481)
Log (interest income)	0.303***	0.206***
	(0.0240)	(0.0367)
Log (staff)	0.182***	0.539***
	(0.0458)	(0.0993)
Log (equity)	0.0919***	0.0463
	(0.0289)	(0.0311)
Constant	0.237	-1.228
	(0.353)	(0.870)
Observations	712	712
R-squared	0.886	0.681
Country FE	No	Yes
Number of central banks	75	75

Source: Authors' estimates.

Note: Table 2 displays the results of the model estimation using OLS and panel fixed effect regression. Sample data are for 75 central banks over the period 2008–21. The dependent variable is the log of operational expenses. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. FE = Fixed Effects; OLS = ordinary least squares.

Next, we turn to the stochastic frontier analysis, which accounts for two different error terms (inefficiency and noise). We operationalize this estimation in four ways, as reported in columns 1 and 2 of Tables 3 and 4. Specifically, Tables 1 and 2 provide the estimates from a model with tangible assets only, while Table 3 and 4 summarize our estimate that considers both tangible and intangibles assets. Table 5 provides descriptive statistics of the efficiency estimates for each model.

Column 1 of Table 1 reports our estimate with time fixed effects, to control for unobserved time-dependent variation in costs. Column 2 reports the estimate after including time fixed effects and controlling for the specific features of each country. For each specification, we report the corresponding share of inefficiency explained by each model. Overall, the results show that individual inefficiency can explain a large part of the variance we see in the production process of the central banks. The underlying inefficiency of the central banks explains the

72 percent and 73.3 percent of the variations of the overall inefficiency observed in columns 1 and 2, respectively.

Table 3. Stochastic Frontier Estimates with Tangible Assets Only

	(1) Model 1	(2) Model 2
Log (asset)	0.3692***	0.4860***
	(0.0383)	(0.0401)
Log (interest income)	0.2187***	0.2355***
	(0.0328)	(0.0335)
Log (number of staff)	0.3196***	0.4479***
	(0.0624)	(0.0831)
Log (equity)	0.0551***	0 .0600***
	(0.0279)	(0.0276)
Log (GDP per capita)		-0.1315***
		(0.047)
Log (population)		-0.1514***
		(0.0759)
Log (country size)		0.0053
		(0.0436)
Dummy (AE)		-0.1423
		(0.2412)
Dummy (LIDCs)		0.4836***
		(0.1785)
Constant	-2.386 ***	-0.35422
	(0.5031)	(0.8606)
Observations	712	712
Time FE	Yes	Yes
Wald chi2	1824	3033
σ_μ	0.533	0.549
σ_v	0.191	0.2
Share of inefficiency	72%	73.3%

Source: Authors' estimates.

Note: Table 3 displays the results of model estimation using stochastic frontier analysis. Sample data are for 75 central banks over the period of 2008–21. The corresponding share of inefficiency explained by each model is obtained by $\frac{\sigma_\mu}{\sigma_\mu+\sigma_v}$. The dependent variable is the log of operational expenses. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. AE = advanced economy; FE = Fixed Effects; LIDCs = low-income developing countries.

Using equation (3) from Section 2, we compute the cost efficiency score based on the model. The overall efficiency levels range from 0.15 to 0.8, meaning 20–85 percent of operational costs could be saved if banks were operating efficiently.[5] The estimated average inefficiency for the whole sample is 0.4, suggesting that an average central bank could improve its cost efficiency by 60 percent, thus matching its performance with the best-performing central bank.

[5] Quader et al. (2020) estimate technical efficiency value ranging from 0.24 to 0.82 using a sample of 17 central banks in Asia.

b) Central Bank Mandate as Intangible Assets: Price Stability Output

In this section, we consider a central bank's "policy" objective as an output. We investigate central bank mandates and objectives using the IMF's Central Bank Legislation Database (CBLD).[6] We focus on central banks with a price stability objective—the objective of 95 percent of central banks in our sample. Price stability is also typically considered the objective most at the core of the central bank mandate. We re-estimate the frontier analysis by adding price stability as an output. We use inflation as a price stability output while controlling for the cost of monetary policy proxied by interest expenses and the monetary policy framework (inflation targeting versus non-inflation targeting). Table 4 shows the estimates and the share of inefficiency explained by the models.

Table 4. Stochastic Frontier Estimates with Tangible and Intangible Assets

	(1) Model 3	(2) Model 4
Log (asset)	0.4684***	0.4580***
	(0.034)	(0.0346)
Log (interest income)	0.2515***	0.3033***
	(0.0399)	(0.0344)
Log (inflation)	0.0051	0.0101
	(0.0277)	(0.0283)
Log (number of staff)	0.4757***	0.4953***
	(0.0349)	(0.0727)
Log (equity)	0.0843***	0.0762***
	(0.0285)	(0.0278)
Dummy (inflation targeting)		0.3535**
		(0.1457)
Log (interest expense)		-0.0357***
		(0.0116)
Log (population)	-0.2958***	-0.2618***
	(0.0655)	(0.0606)
Log (country size)	0.0740*	0.0271
	(0.0375)	(0.0351)
Constant	0.4513	0.2230
	(0.6320)	(0.6152)
Observations	673	673
Time FE	No	No
Wald chi2	2829	2257
σ_μ	0.998	0.780
σ_v	0.21	0.20
Share of inefficiency	83%	81%

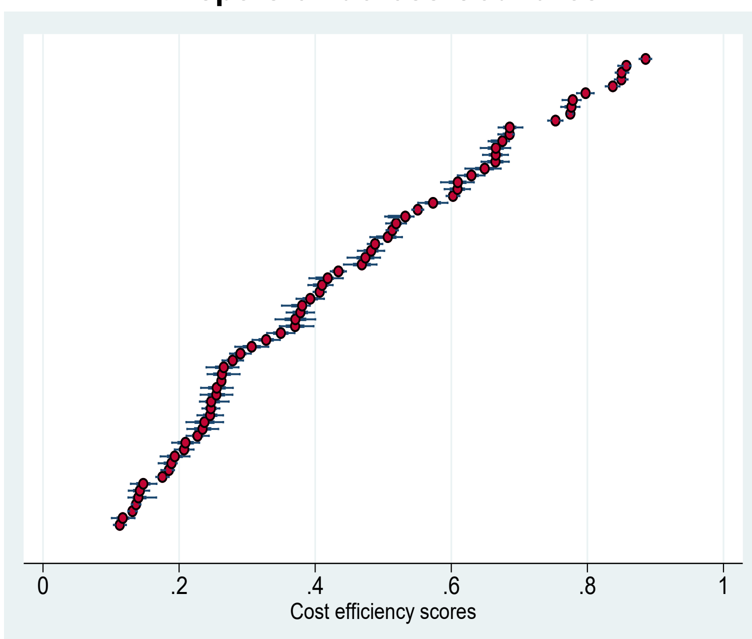
Source: Authors' estimates.

Note: Table 4 displays the results of model estimation using stochastic frontier analysis. Sample data are for 60 central banks over the period 2008–21. The corresponding share of inefficiency explained by each model is obtained by $\frac{\sigma_\mu}{\sigma_\mu+\sigma_v}$. The dependent variable is the log of operational expenses. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. FE = Fixed Effects.

[6] We complement the CBLD database with two other papers on central bank mandates and objectives (Central bank mandates, sustainability objectives and the promotion of green finance and The role of central banks in societal development in emerging countries).

Coefficients for the baseline input and output variables remain statistically significant. The coefficient for inflation is positive but not statistically significant, while the monetary policy framework and the monetary policy cost are statistically significant. The estimated values of the cost function parameters enable us to calculate the gap of each observation compared with the frontier of best practices. Relative to the baseline model, the share of inefficiencies explained by the model with price stability output increased by 10 percentage points. Similarly, the average and median cost efficiencies are higher in the model with intangible output. This result suggests that factors pertaining to price stability output are important drivers of central bank operational efficiency. Perhaps it is not surprising that, after controlling for country effects, the average efficiency levels are higher, but the dispersion of the efficiency is also greater, which indicates that country-specific factors play an important role in determining central bank efficiency levels. The overall operational efficiency levels range from 0.15 to 0.89, as shown in Figure 6, where each box illustrates country-level cost efficiency. There is a large dispersion across central banks, with only a few countries at an efficient frontier level. Moreover, there is little variation in cost efficiency over time at the central bank level. The estimates also show consistency in terms of ranking the central banks across the different SFA specifications.

Figure 6. Efficiency Estimates with Tangible and Intangible Assets: Dispersion across Countries

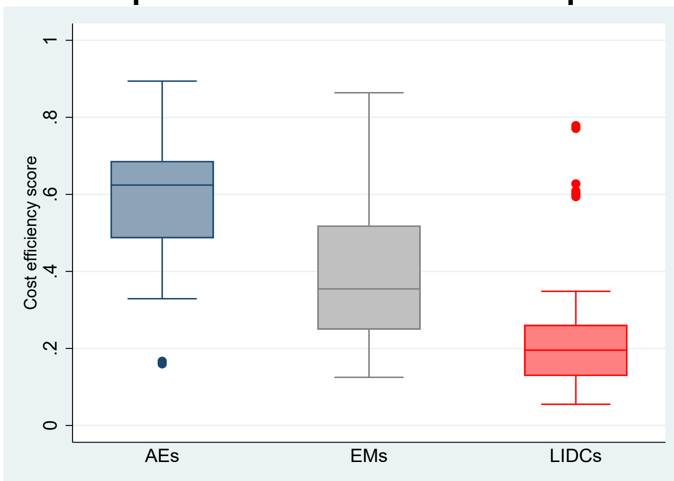


Source: Authors' estimates.

Note: The figure shows cost efficiency scores by country. The red circle measures the median, and the legs capture operational efficiency variation over time. Cost efficiency scores are estimated using stochastic frontier analysis.

Analyzing cost efficiency according to income group (Figure 7), we observe a pattern by level of economic development. Indeed, operational expense efficiencies tend to be lower in LIDCs than in emerging markets and lower in emerging markets than in advanced economies. Currency unions in LIDCs display a higher cost efficiency compared with peers in the region. The median cost-efficient scores for AEs, EMs, and LIDCs are respectively 0.63, 0.38, and 0.2. A possible explanation of this result could be correlated with the degree of central bank autonomy, degree of focus in terms of mandatory objective, shock absorption capacity, management, and supervisory practices.

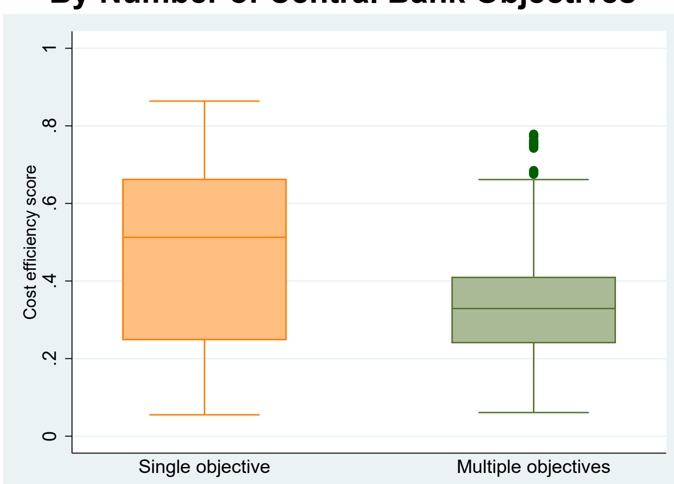
Figure 7. Efficiency Estimates with Tangible and Intangible Assets: Dispersion across Income Groups



Source: Authors' estimates.
Note: Cost-efficiency scores underlying these calculations are derived from model 4 in Table 4. The center line in each box corresponds to the median, and the box edges correspond to the 25th and 75th percentiles. Estimations are based on a common cost frontier with country-specific environmental variables, including population, country size (area), and a dummy variable if the central bank has additional objectives. Sample data include 536 observations for 62 central banks over the period of 2008–21. AE = advanced economy; EM = emerging market; LIDC = low-income developing country.

Next, we investigate the dispersion of the efficiencies across the number of objectives by classifying central banks into two groups: central banks with a single objective and central banks with multiple objectives. As shown in Figure 8, there is likely a difference between these groups. Central banks with a single objective tend to be, on average, more efficient than those with multiple objectives. This result suggests that focusing on core activities reduces inefficiency.

Figure 8. Efficiency Estimates: By Number of Central Bank Objectives



Source: Authors' estimates.
Note: Cost-efficiency scores underlying these calculations are derived from model 4 in Table 4. The center line in each box corresponds to the median, and the box edges correspond to the 25th and 75th percentiles. Cost-efficiency scores are estimated using a stochastic frontier analysis. Estimations are based on a common cost frontier with country-specific environmental variables. Central bank objectives include price stability, macroeconomic development, financial system stability, and monetary stability. Sample data include 712 observations for 75 central banks over the period of 2008–21; 60 percent of central banks in our sample have a single objective, representing 465 observations.

IV. Determinants of Central Bank Efficiency

Overall, the SFA revealed intriguing efficiency patterns across income groups and the number of central banks' objectives (single versus multiple), raising questions about the drivers of operational efficiency. Table 5 summarizes the distribution of the estimates from different SFA models. Having obtained the individual central banks' operational efficiency, we next investigate its drivers by looking at three key factors with significant implications for policymakers: operational independence, international trade, and financial depth. To do so, we use the efficiency estimates from Model 4.

Table 5. Summary Statistics of Efficiency Estimates

Model 1: Efficiency scores based on SFA with time fixed effects and no control variables.

Model 2: Efficiency scores based on SFA with time fixed effects and control variables.

Model 3: Efficiency scores based on SFA with price stability as an output and control variables.

Model 4: Efficiency scores based on SFA with price stability as an output and control variables, including cost of monetary policy.

	Model with Tangible Assets only		Model with Tangible and Intangible Assets	
	Model 1	Model 2	Model 3	Model 4
N	712	712	673	673
Mean	0.42	0.45	0.50	0.55
Sd	0.23	0.20	0.26	0.25
Median	0.47	0.44	0.53	0.63
Max	0.90	0.92	0.91	0.92
Min	0.05	0.08	0.03	0.04
Share of inefficiency	75%	73%	83%	82%

Source: Authors' estimates.

Numerous studies have demonstrated the detrimental effects of poor governance and corruption on central banks' efficiency in service provision, and a similar argument can be applied to central banks' operations, as central banks operate in an environment that can impact their independence. To measure central bank independence, we employ the monetary freedom index obtained from the Index of Economic Freedom database.[7] This index focuses on essential aspects of the economic environment, over which governments typically exert policy control. It combines measures of price stability (inflation) with assessments of price controls. Further, the functioning of central banks may depend on a country's economic and international trade strategy. Therefore, factors such as trade openness and exchange rate arrangements can profoundly impact the efficiency of central banks, as these factors will act as shock drivers.

We also examine the impact of capital account openness as a driver of financial shock, such as the external interest rate environment and the business cycle. We use the Chinn-Ito index, which is a de jure measure of financial openness based on the information compiled in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions.

Lastly, the depth of the financial system can influence the effectiveness of central banks' operations by affecting overall financial transaction costs within the system. To capture cross-country differences in financial depth, we use the financial system deposit-to-GDP ratio.

Having obtained individual central banks' cost efficiency, we next investigate whether the efficiency levels can be explained by the factors listed above. For this purpose, we perform the following regression.

$$CostEfficiency_{it} = \alpha_0 + \alpha_1 CB\ independence_{it} + \alpha_2 \left(\frac{X+M}{GDP}\right)_{it}$$

$$+ \alpha_3 RGDP\ growth_{it} + \alpha_4 \left(\frac{Total\ Deposit}{GDP}\right)_{it} + \alpha_5 Capital\ Account\ Openess_{it} + \varepsilon_{it} \qquad (4)$$

Table 6 reports the estimates. The first column shows the result using the full sample and the other columns report the estimates for each income group.

The level of financial development is also crucial to central bank efficiency. Our findings reveal a positive relationship between cost efficiency and bank deposits to GDP, particularly for EMs and LIDCs. Higher levels of financial depth contribute to improved efficiency levels of central banks. The result indicates that more financial intermediation tends to help reduce the overall transaction cost in the financial system. Chilling (2019) also finds a positive impact of financial intermediation in the form of bank deposits on commercial banks' operational efficiency.

Moving to trade openness, we find negative and statistically significant coefficients, as reported in column 1. The finding indicates that countries could be prone to external shocks through their trade openness, leaving central banks less margin to maneuver the adverse effects of external shocks. We do not find a statistically significant role for capital account openness and real GDP growth in shaping central bank cost efficiency.

Finally, the analysis consistently reveals that central bank independence has a positive and statistically significant impact across all specifications, indicating that central banks with higher independence tend to have

[7] https://www.heritage.org/index/monetary-freedom. The score for a central bank's independence is based on two factors: the weighted average inflation rate for the most recent three years and price controls. The weighted average inflation rate for the most recent three years serves as the primary input into an equation that generates the base score for monetary freedom. The extent of price controls is then assessed as a penalty of up to 20 points subtracted from the base score.

$$Central\ bank\ independence = 100 - \alpha\sqrt{(Weighted\ Avg.Inflation)} - PC\ penalty$$

higher operational efficiency. These estimates underscore the importance of central bank independence in enhancing efficiency.

Table 6. Determinants of Central Bank Operational Efficiency

VARIABLES	(1) ALL	(2) AEs	(3) EMs	(4) LIDCs
(X+M)/GDP	-0.000762***	-0.000842***	-0.00649	-0.0110
	(0.000128)	(0.000134)	(0.00460)	(0.00883)
Central bank independence	0.00118***	0.000652	0.00126***	0.000957**
	(0.000165)	(0.000386)	(0.000238)	(0.000443)
Real GDP growth	-0.000276	0.000226	-6.31e-05	-3.21e-05
	(0.000226)	(0.000440)	(0.000289)	(0.000241)
Financial system deposit/ GDP	0.000480**	0.000350	0.000798***	0.00113**
	(0.000225)	(0.000253)	(0.000164)	(0.000408)
Capital account openness	-0.00351	0.00780	-0.0120	0.0204
	(0.0105)	(0.0197)	(0.00829)	(0.0240)
Constant	0.339***	0.517***	0.300***	0.143***
	(0.0198)	(0.0444)	(0.0188)	(0.0309)
Observations	528	196	221	111
R-squared	0.288	0.185	0.463	0.368
Number of central banks	63	20	28	15
Country FE	Yes	Yes	Yes	Yes

Source: Authors' estimates.

Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. AE = advanced economy; EM = emerging market; FE = Fixed effects. LIDC = low-income developing country .

To test the robustness of the effect of central bank independence, we use an alternative measure: the index of central bank independence, developed by David Romelli (2022). The index covers a wide range of central bank characteristics based on their charters. It is a dynamic measure of de jure central bank independence that allows for a more precise determination of the timing and magnitude of reforms in central bank design. The index includes 42 criteria of central bank institutional design across five dimensions: (i) governor and central bank board; (ii) monetary policy and conflict resolution; (iii) objectives; (iv) financial independence; and (v) limitations on lending to the government. All indexes take values between 0 (no independence) and 1 (fully independent).

The results pertaining to the panel regression in equation (4) for the de jure central bank independence index (column 1) and each dimension of the index (column 2) are presented in Table 7 for the full sample. While the effect of the other covariates remains robust, the de jure central bank index is statistically significant and positive, and the central bank impendence indexes are statistically significant and positive except for the central bank independence index on monetary policy and conflict resolution.

Table 7. Central Bank Operational Efficiency and De Jure Central Bank Independence

VARIABLES	(1)	(2)
CBI	0.180***	
	(0.0288)	
CBI board		0.0253***
		(0.00765)
CBI policy		-0.0519
		(0.0321)
CBI objective		0.0399***
		(0.00411)
CBI finances		0.00853
		(0.0206)
CBI lending		0.315***
		(0.0882)
Constant	0.295***	0.179***
	(0.0288)	(0.0332)
Observations	329	321
R-squared	0.189	0.259
Number of central banks	53	52
Controls	yes	yes
Country FE	yes	yes

Source: Authors' estimates.

Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. CBI = central bank independence; FE = Fixed Effects.

V. Concluding Remarks

Central banks play a crucial role in regulating the economy through their assigned mandates. In this paper, we use central bank-level data to analyze operational efficiency levels in 75 countries. Using stochastic frontier analysis, we observe significant disparities in operational efficiencies among central banks and across income groups. Generally, central banks with a single mandate exhibit higher efficiency compared with those with multiple mandates. When focusing on the price stability mandate as an output, operational efficiencies tend to be lower in LIDCs than emerging markets and lower in emerging markets than advanced economies. Several factors impact efficiency levels, including central bank independence, the depth of the financial system, and trade openness.

Our findings underscore the significance of well-defined objectives, the operating environment, and concentration on core activities in reducing inefficiency. In fact, research and practical experience show that a concentration on core activities is a prerequisite for good performance. Moreover, regularly assessing the scope of their operations through external reviews could help central banks identify sources of inefficiency. This type of review would also enhance central bank transparency and thus improve the decision-making process.

While our study provides an entry point for policy discussions on central bank operational efficiency, we acknowledge that there are significant disparities in the operating environment and operational practices among countries, such as number of divisions, staffing by divisions, disclosure rules, and management and supervisory practices. For example, a central bank is a combination of a university (monetary policy), a government department (supervision and other regulation), a clearing bank (government and commercial bank accounts), and an investment bank (foreign reserve management). Future research should delve into these sector-specific efficiencies. Additionally, exploring more fine-grain efficiency measures by employing meta frontier analysis to measure efficiency gaps between different groups could be a promising avenue for further investigation.

Appendix I

a. Robustness Tests

The appendix includes a set of robustness exercises to examine the determinants of central bank efficiencies by testing the robustness of our three factors using alternative specifications and samples. First, we divide our sample into two groups: countries with a free-floating exchange rate regime and those with other exchange rate regimes. The coefficients for central bank independence, real GDP growth, and financial system depth exhibit the same signs as in the previous results. When analyzing the impact of trade balance on operational efficiency, we find a positive (albeit close to zero) and statistically significant coefficient for floating exchange rate countries, while fixed exchange rate countries show a negative and statistically significant coefficient (Table A.1).

Second, we introduce additional control variables to account for the operating environment, such as control of corruption, the rule of law, and financial freedom. Our results remain unchanged, reinforcing the robustness of our findings (Table A.2).

Third, we consider an alternative measure of financial depth by using the public international debt-to-GDP ratio instead of the financial system deposit-to-GDP ratio. The results, presented in Table A.3, are similar, and the economic insights discussed in Section IV remain valid.

Finally, we further investigate the trade channel by dividing the sample into two subsets: countries with trade surpluses and countries with trade deficits. We then re-estimate the model to examine the impact of trade deficit and surplus on efficiency. Also, one can see the impact of the trade surplus as an aggregate demand channel, while the impact of the trade deficit could be considered an imported inflation channel. Table A.4 presents the estimates, and the results provide additional support for our previous analysis, which examines the effect trade balance in LIDCs versus AEs have on central bank operational efficiency.

Table A.1. Determinants of Central Bank Operational Efficiency: By Exchange Rate Regimes

	(1)	(2)
VARIABLES	Floats	Nonfloats
(X+M)/GDP	-0.000808***	-0.0100**
	(0.000198)	(0.00457)
Central bank independence	0.000723*	0.00132***
	(0.000415)	(0.000180)
Real GDP growth	0.000135	-0.000161
	(0.000611)	(0.000148)
Financial system deposit/GDP	0.000381	0.000592***
	(0.000389)	(9.33e-05)
Capital account openness	0.00589	-0.00400
	(0.0534)	(0.00802)
Constant	0.479***	0.277***
	(0.0584)	(0.0127)
Observations	178	350
R-squared	0.181	0.394
Number of central banks	18	45
Country FE	Yes	Yes

Source: Authors' estimates.

Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. FE = Fixed Effects.

Table A.2. Determinants of Central Bank Operational Efficiency: Controlling for Additional Operating Environment

VARIABLES	(1) ALL	(2) AEs	(3) EMs	(4) LIDCs
(X+M)/GDP	-0.000693***	-0.000743***	-0.00585	-0.0118
	(0.000121)	(0.000129)	(0.00424)	(0.00830)
Central bank independence	0.00125***	0.000848**	0.00136***	0.000961**
	(0.000164)	(0.000382)	(0.000224)	(0.000422)
Real GDP growth	-0.000166	0.000313	1.75e-06	-3.70e-05
	(0.000208)	(0.000412)	(0.000286)	(0.000234)
Financial system deposit/GDP	0.000543**	0.000441*	0.000812***	0.00107**
	(0.000214)	(0.000228)	(0.000149)	(0.000416)
Capital account openness	0.00375	0.00728	-0.00442	0.0135
	(0.00935)	(0.0139)	(0.00934)	(0.0276)
Control of corruption	-0.0144**	-0.0224	-0.00843	-0.00494
	(0.00708)	(0.0150)	(0.00708)	(0.0136)
Rule of law	-0.00943	-0.0112	-0.0189**	0.0207*
	(0.00839)	(0.0182)	(0.00807)	(0.0115)
Financial freedom	-7.64e-06	-0.000185	0.000382	9.59e-06
	(0.000347)	(0.000504)	(0.000490)	(0.000757)
Constant	0.338***	0.553***	0.273***	0.156***
	(0.0253)	(0.0628)	(0.0279)	(0.0484)
Observations	520	196	213	111
R-squared	0.332	0.259	0.549	0.406
Number of central banks	63	20	28	15
Country FE	Yes	Yes	Yes	Yes

Source: Authors' estimates.

Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. AE = advanced economy; EM = emerging market; FE = Fixed Effects; LIDCs = low-income developing countries.

Table A.3. Determinants of Central Bank Operational Efficiency: Alternative Measure of Financial Depth

VARIABLES	(1) ALL	(2) AEs	(3) EMs	(4) LIDCs
(X+M)/GDP	-0.00103***	-0.00103***	-0.00117	-0.0110
	(4.10e-05)	(4.12e-05)	(0.00314)	(0.00792)
Central bank independence	0.00122***	0.000767**	0.00147***	0.000642
	(0.000208)	(0.000341)	(0.000240)	(0.000478)
Real GDP growth	-0.000209*	1.94e-05	-0.000249	-7.94e-05
	(0.000123)	(0.000321)	(0.000219)	(0.000153)
Capital account openness	0.00899	0.0583***	-0.0158	0.0273
	(0.0168)	(0.0154)	(0.0203)	(0.0266)
Public debt/GDP	0.000422***	0.000598***	0.000470***	0.000363**
	(9.60e-05)	(0.000159)	(0.000147)	(0.000128)
Constant	0.326***	0.439***	0.285***	0.185***
	(0.0211)	(0.0354)	(0.0267)	(0.0349)
Observations	511	197	207	107
R-squared	0.326	0.277	0.467	0.433
Number of central banks	59	19	26	14
Country FE	Yes	Yes	Yes	Yes

Source: Authors' estimates.
Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. AE = advanced economy; EM = emerging market; FE = Fixed Effects; LIDCs = low-income developing countries.

Table A.4. Determinants of Central Bank Operational Efficiency: Aggregate Demand vs. Imported Inflation

VARIABLES	(1) Trade Deficit Group	(2) Trade Surplus Group
(X-M)/GDP	0.0791***	-0.000989***
	(0.0150)	(0.000112)
Central bank independence	0.00102***	0.000623**
	(0.000227)	(0.000246)
Real GDP growth	0.000180	0.000214
	(0.000135)	(0.000167)
Financial system deposit/GDP	0.000531***	0.000294
	(0.000140)	(0.000242)
Constant	0.419***	0.571***
	(0.0168)	(0.0306)
Observations	279	176
R-squared	0.358	0.216
Number of central banks	46	29
Country FE	Yes	Yes

Source: Authors' estimates.
Note: The table reports the regression coefficients. The dependent variable is the operating expense efficiency. Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1. FE = Fixed Effects.

b. Additional Tables and Figures

Table A.5. Summary Statistics of Central Bank Operating Environment

	Mean	Median	Standard Deviation	Kurtosis	Skewness	Observations
Central bank independence	77.10	77.70	6.67	3.59	-1.18	688.00
Control of corruption	0.44	0.26	1.04	-1.23	0.29	714.00
Rule of law	0.42	0.30	0.97	-1.27	0.16	714.00
Financial freedom	57.59	60.00	16.18	-0.55	-0.22	677.00

Source: Authors' estimates.

Table A.6. Testing for a Difference Between IFRS and Non-IFRS Group Means of Operational Expenses

Group	Obs.	Mean	Std. err.	Std. dev.	(95% conf. Interval)	
0 (non-IFRS)	425	19.30	0.11	2.30	19.07914	19.51801
1 (IFRS)	291	17.66	0.10	1.73	17.46306	17.86335
Combined	716	18.63	0.08	2.24	18.46973	18.79811
diff		1.64	0.16		1.32317	1.947563

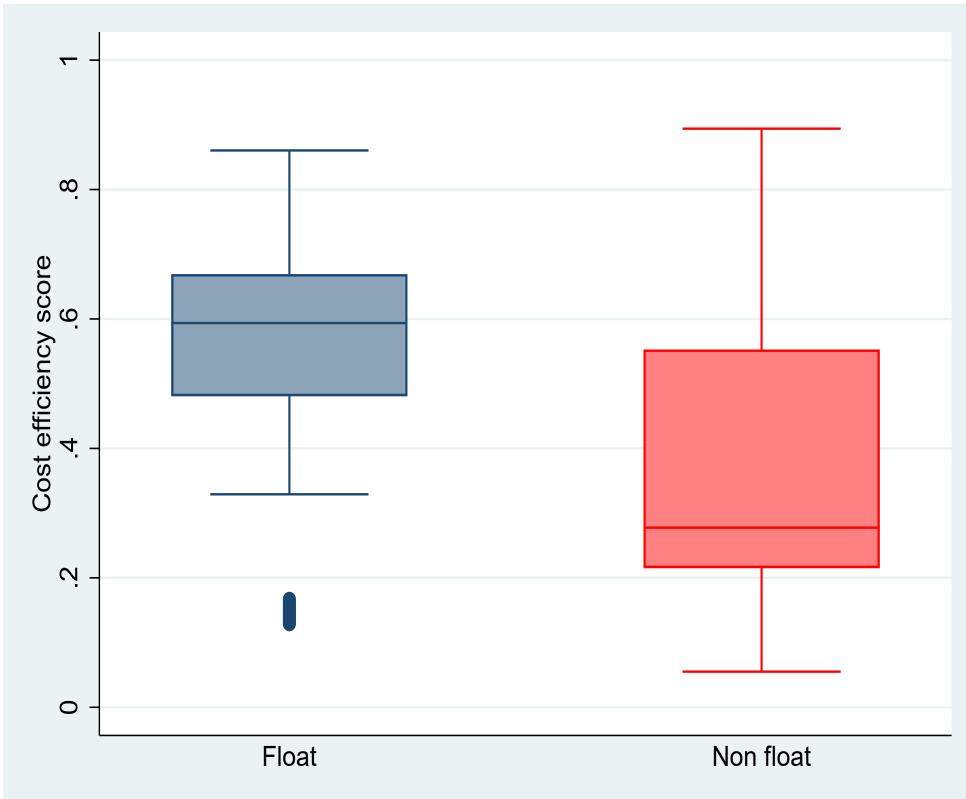
diff = mean(0)-mean(1) t = 10.2842
H0: diff = 0 Degrees of freedom = 714

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0
Pr(T < t) = 1.0000 Pr(T > t) = 0.0000 Pr(T > t) = 0.0000

Source: Authors' estimates.

Note: IFRS = International Financial Reporting Standards.

Figure A.1. Efficiency Estimates with Price Stability Output: Dispersion Across Exchange Rate Regime



Source: Authors' estimates.

References

Archer, D., and P. Moser-Boehm. 2013. “Central Bank Finances.” BIS Papers 71. Bank for International Settlements, Basel.

Bauer, P.W., and D. Hancock. 1993. “The Efficiency of the Federal Reserve in Providing Check Processing Services.” *Journal of Banking & Finance,* Special Issue on the Efficiency of Financial Institutions 17, 287–311. https://doi.org/10.1016/0378-4266(93)90033-A.

Bauer, P.W., and G.D. Ferrier. 1996. “Scale Economies, Cost Efficiencies, and Technological Change in Federal Reserve Payments Processing.” *Journal of Money, Credit and Banking* 28, 1004–39. https://doi.org/10.2307/2077938.

Ben Naceura, Sami, Hichem Ben-Khedhiriband, and Barbara Casu. 2011. “What Drives the Performance of Selected MENA Banks? A Meta-Frontier Analysis.” IMF Working Paper 11/34. International Monetary Fund, Washington, DC.

Berriel, Tiago C., and Saroj Bhattarai. 2009. "Monetary Policy and Central Bank Balance Sheet Concerns," *The B.E. Journal of Macroeconomics* 9, Issue 1.

Bohn, J., D. Hancock, and P. Bauer. 2001. “Estimates of Scale and Cost Efficiency for Federal Reserve Currency Operations.” *Economic Review, Federal Reserve Bank of Cleveland* 37, 2–26.

Carrière-Swallow, Yan, Nelnan Fidèle Koumtingué, and Sebastian Weber. 2023. “Inflation and Monetary Policy in a Low-Income and Fragile State: The Case of Guinea,” IMF Working Paper 23/84. International Monetary Fund, Washington, DC.

Chen, Chuling. 2009. “Bank Efficiency in Sub-Saharan African Middle-Income Countries.” IMF Working Paper 09/14. International Monetary Fund, Washington, DC.

Chinn, Menzie D., and Hiro Ito. 2006. ”What Matters for Financial Development? Capital Controls, Institutions, and Interactions,” *Journal of Development Economics,* Volume 81, Issue 1, 163-92. October.

Eickmeier, Sandra, and Boris Hofman. 2022. “What Drives Inflation? Disentangling Demand and Supply Factors.” BIS Working Papers 1047. Bank for International Settlements, Basel.

Goncharov, et al. 2021. “(Why) Do Central Banks Care about Their Profits?” *Journal of Finance,* forthcoming.

Klüh, Ulrich, and Peter Stella. 2008. "Central Bank Financial Strength and Policy Performance: An Econometric Evaluation." IMF Working Paper 08/176 International Monetary Fund, Washington, DC.

McKinley, Vern, and K. Banaian. 2005. “Central Bank Operational Efficiency: Meaning and Measurement.” Central Banking Publications.

Peery, James, Walter Enders, and C. James Hueng. 2006. “Using the Aggregate Demand-Aggregate Supply Model to Identify Structural Demand-Side and Supply-Side Shocks: Results Using a Bivariate VAR.” *Journal of Money Credit and Banking*.

Romelli, David. 2022. “The Political Economy of Reforms in Central Bank Design: Evidence from a New Dataset.” *Economic Policy*, Volume 37, Issue 112, 641–88. October.

Sheremirov, Viacheslav. 2022. "Are the Demand and Supply Channels of Inflation Persistent? Evidence from a Novel Decomposition of PCE Inflation." Federal Reserve of Boston Working Paper.

United Kingdom National Audit Office. 2018. "Managing the Bank of England's Central Services." Report by the Comptroller and Auditor General.

PUBLICATIONS

Estimation and Determinants of Cost Efficiency: Evidence from Central Bank Operational Expenses
Working Paper No. WP/2023/195