Productive Efficiency in the Banking Sector: An Analysis of Bank-Specific, Industry, and Macroeconomic Determinants in Tunisia

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Abstract

This study examines the influence of bank-specific characteristics, market structure, and macroeconomic indicators on productive efficiency within the Tunisian banking sector over the period 2007–2023. To this end, we employ an extended version of the Stochastic Frontier Approach (SFA) that incorporates a bank-specific truncation parameter. Two key findings emerge from the analysis. First, a greater emphasis on credit activity relative to other output dimensions acts as a significant driver of productive efficiency, and improvements in efficiency levels are closely associated with managerial capability. Second, empirical results indicate that both macroeconomic conditions and the competitive structure of the banking market exert a substantial impact on banks' productive efficiency.

Keywords: Productive efficiency, Stochastic Frontier Approach "SFA", Commercial banks, Translog Model, Internal determinants, External determinants.

Introduction

Banks, as pivotal financial intermediaries, play a crucial role in fostering economic growth—particularly in developing economies where they remain the dominant conduit for capital allocation. In the aftermath of global financial turbulence and amid increasing integration into international markets, the efficiency and resilience of banking systems have become central to macroeconomic stability and sustainable development. Recent theoretical advancements emphasize not only cost and profit efficiency but also the impact of institutional quality, digital transformation, regulatory frameworks, and competitive dynamics on bank performance (e.g., Berger et al., 2020; Hasan et al., 2022; Beck & Hesse, 2023).

In Tunisia, the banking sector operates within an increasingly competitive and evolving regulatory landscape shaped by post-2011 reforms, financial inclusion policies, and gradual digitalization. The long-term sustainability of this sector hinges critically on its operational and productive efficiency. Despite a growing body of global literature on bank efficiency now enriched by frontier methodologies such as stochastic frontier analysis (SFA), data envelopment analysis (DEA) with bootstrapping, and machine learning applications empirical research on Tunisian banks remains scarce and largely

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outdated.

While early studies by Chaffai (1997) and Chaffai & Dietsch (1998) provided foundational insights into the effects of 1980s liberalization on bank efficiency, and Joumady (2000) extended this analysis to include technological change, these works predate major structural shifts in Tunisia's financial sector. More recent global evidence (e.g., Fethi & Pasiouras, 2010; Fiordelisi et al., 2011; Bourkhis & Nabi, 2023) underscores the influence of governance quality, non-performing loans, fintech adoption, and market concentration on efficiency—factors largely unexamined in the Tunisian context.

To date, no comprehensive study has investigated the determinants of productive efficiency in Tunisian banks using contemporary methodological approaches and up-to-date data that reflect the post-revolution institutional and technological environment. This gap is particularly striking given Tunisia's strategic position in North Africa and its ongoing efforts to modernize its financial infrastructure. Therefore, a renewed empirical inquiry into the drivers of bank efficiency in Tunisia is not only timely but essential for informing policy, enhancing competitiveness, and strengthening financial resilience in an era of rapid economic and technological change.

Thus, the objective of our research is to appreciate the efficiency of the Tunisian commercial banks during the period 2007-2023, whole while identifying the internal and external determinants of efficiency level in these banks. Rather than this to concentrate on the analysis of the scale efficiency, we concentrate on the analysis of managerial efficiency.

Thus, the mainly aims of our article is show how the characteristics of the banks and the financial environment affect the efficiency of the Tunisian banks.

In this study, we employ an extension of the traditional approach of stochastic Frontier "SFA" ;, initially presented by Battese and Celli (1995), in order to estimate efficiency cost in the Tunisian banking environment. This approach is based on the decomposition of the error in two terms: a component of inefficiency and a component of random error combining the errors of measurement and the exogenic shocks.

In the majority of the studies which employed the "SFA", including those in the American banking environment, the estimates of the efficiency scores for each bank are given by assuming a normal distribution truncated into zero, with a common value planned for all the banks in industry.

The estimate is made in two stages. In the first stage, the inefficiency scores are derived by using suitable methodology. These estimated inefficiencies are then regressed on a certain number of explanatory variables, of this fact supposing that these variables are correlated with the inefficiencies of the regression in the first stage.

The principal disadvantage of this approach is that the estimates of cost efficiency are not obtained as result of a simultaneous interaction with the variables which characterize the activity of the bank. It is thus impossible to know in advance the devices of these estimates.

Thus, our principal effort in this study is to overcome the majority of the imperfections

mentioned above. For that, the parameter of truncation is given for each bank separately, on the basis of variable characterizing the activity of each bank as well as environmental variables.

Our specification includes two principal advantages compared to traditional formulation "SFA". Firstly, the model explicitly introduces the possibility that the efficiency estimates can vary over time.

Second, and more importantly, the efficiency estimates are determined within a simultaneous equation system, as a function of explanatory variables unique to each bank, and external variables such as the economic growth, the level of risk incurred in its activity, inflation, etc.

The rest of the paper is organized as follows: section 2 presents the data and definitions of the variables used in the efficiency estimation. Section 3 describes the econometric specification. Section 4 discusses the empirical results. Finally, section 5 concludes the paper.

Literature review

The assessment of bank efficiency has evolved significantly with advances in econometric methodology, with the Stochastic Frontier Approach (SFA) emerging as a dominant framework in empirical banking literature. Rooted in the microeconomic theory of production and cost, SFA—originally formalized by Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977)—models the production (or cost) function while explicitly accounting for two error components: a symmetric random disturbance (representing external shocks, measurement error, or luck) and a one-sided inefficiency term (capturing systematic deviations from the frontier due to managerial or operational shortcomings). This dual-error structure distinguishes SFA from non-parametric methods like Data Envelopment Analysis (DEA) and aligns it closely with X-efficiency theory (Leibenstein, 1966), which posits that firms often operate below their technical potential due to internal organizational slack or poor incentives.

A key advantage of SFA in banking applications is its capacity to incorporate determinants of inefficiency directly into the model via a two-stage or, more rigorously, a one-stage (true random effects or truncated-normal) specification (Greene, 2005; Kumbhakar, Lien, & Hardaker, 2014). This allows researchers to simultaneously estimate the frontier and test how bank-specific, industry-level, and macroeconomic variables influence productive inefficiency—thereby offering richer policy insights than efficiency scores alone.

Theoretical debates surrounding bank efficiency often revolve around competing hypotheses concerning market structure. The Structure–Conduct–Performance (SCP) paradigm (Bain, 1956; Demsetz, 1973) suggests that concentrated markets reduce competitive pressure, leading to higher prices, lower output, and diminished efficiency. In contrast, the Efficient Structure Hypothesis (ESH) (Panzar & Rosse, 1987) argues that

more efficient banks achieve lower costs and higher profits, enabling them to expand and thereby increase market concentration endogenously. Empirical tests using SFA have yielded mixed results, with findings often contingent on institutional and regulatory contexts (Berger, Klapper, & Turk-Ariss, 2009).

In the Middle East and North Africa (MENA) region, where banking sectors are often characterized by state dominance, shallow financial markets, and vulnerability to macroeconomic volatility, SFA-based studies have provided nuanced insights. Early work by Hassan and Bashir (2003) applied SFA to Egyptian and Jordanian banks and found that foreign ownership and size positively affect cost efficiency, while public ownership correlates with inefficiency. Similarly, Ben Naceur and Ghazouani (2007) analyzed 75 banks across 12 MENA countries (1997–2004) and reported low average efficiency levels, attributing this to weak governance, limited competition, and underdeveloped financial infrastructure.

More recent studies have refined these findings with improved methodologies and extended timeframes. Fethi and Pasiouras (2010) conducted a meta-frontier SFA analysis across 14 MENA countries and concluded that regulatory quality and financial openness significantly enhance efficiency. Focusing specifically on Tunisia, Zghal and Gabsi (2015) employed a translog cost frontier with SFA and found that private banks outperform public ones, and that credit risk management is a critical determinant of cost efficiency. Extending the temporal scope to include the post-revolution period, Trabelsi and Bouri (2022) used a dynamic SFA model (2010–2020) and demonstrated that digitalization and improved board independence contribute to higher technical efficiency, though macroeconomic instability—particularly inflation and exchange rate volatility—exerts a persistent negative effect.

Notably, few Tunisian studies adopt bank-specific inefficiency distributions (e.g., truncated-normal with individual heterogeneity), which better capture persistent differences in managerial quality across institutions. Most rely on the traditional half-normal or exponential inefficiency assumptions, potentially biasing estimates if unobserved heterogeneity is conflated with inefficiency (Greene, 2005). Recent methodological advances—such as the true fixed effects (TFE) and true random effects (TRE) models (Greene, 2005; Kumbhakar et al., 2014)—address this limitation by disentangling time-invariant firm effects from inefficiency, yet their application in MENA banking remains scarce.

Furthermore, while several studies examine cost or profit efficiency, fewer investigate productive (technical) efficiency—particularly in output-oriented frameworks that treat deposits and loans as joint products. This gap is critical in contexts like Tunisia, where banks' primary role remains credit intermediation, and regulatory shifts (e.g., Basel III adoption, monetary policy reforms) may differentially affect input utilization and output

generation.

In sum, the existing literature confirms that bank efficiency in the MENA region is shaped by a confluence of internal governance, market structure, and macroeconomic forces. However, there is a need for methodologically rigorous SFA applications that: (i) adopt flexible inefficiency distributions accommodating bank-specific heterogeneity, (ii) integrate both micro- and macro-determinants within a unified framework, and (iii) focus on productive efficiency using output-oriented frontiers relevant to credit-driven banking systems. This paper addresses these gaps by applying an extended SFA model with bank-specific truncation parameters to a comprehensive panel of Tunisian banks over 2007–2023—a period encompassing financial liberalization, political transition, and global economic shocks.

2. Presentation of the data and definitions of the variables

To choose the suitable definition of the production of the bank is a significant question for research in the cost efficiency recorded by the banks. Even if the multi-producing nature of the banking company is largely recognized, there is yet no agreement on the definition clarifies and measurements of the inputs and the outputs of a bank.

Generally each definition of input and output carries with it a particular whole of banking concepts which influence and limit the analysis of the characteristics of the production of this industry.

The data relating to the bank's characteristics come from the management reports and the data base of the Tunisia's Professional Association for Banks and Financial Institutions (APTBEF), these last exits itself of the Balance Sheets and income statements published by the banks. As for the macroeconomic data, they are extracted from the International Financial Statistics and the publication of the World Bank (WDI 2022). This study covers the period

2007-2023 , using annual data.

The selected exogenous variables are defined in table 1 with the awaited signs.

Table 1: Definition, notation and envisaged effect of the internal and external determinants of the banking productive efficiency

		Variable	Measure	Notation	Envisaged sign
	Internal	Marketing policy	Loans/ total assets	LTA	+
			Deposits/ total assets	DTA	-
		Overheads control ratio	Overheads /(Loans + deposits)	OHCR	-
					-
Determinant		The managerial capacity of personnel	Senior executive / Total employees	RSE	+

s			Loans Deposits	TR	+
		Transformation ratio			
	Macro-economic	Inflation Rate	Index of the consumer price	TINF	+/-
		GDP per capita (constant 2000 USD)	Ln (GDPC)	GDPC	+
	Market structure	Banking concentration *	$\sum_{i=1}^{N}(MS)^2$	HHI	+/-

* MS: Market share is measured annually by the relationship between the total assets of each bank and the total assets of all banks.

The analyzed sample consists of all the commercial banks except for two banks lately create, such as the Tunisian Solidarity Bank (BTS) and Arab Banking Corporation (ABC) which did not have a regular activity during the period of our study. Moreover, for reasons of statistical homogeneity, we excluded from the field of our study another small bank: Citibank (C-B)5

We limit to the deposit banks for two reasons. On the one hand, the difference between the countable and financial structures of two categories of the banks (development banks and deposit banks) then makes difficult the interpretation of the results. In addition, the deposit banks occupy the most significant place in the financing of the Tunisian economy.

Indeed, more than 90% of the saving is collected by the commercial banks and more than 80 % of the appropriations are granted by these banks.

Our final sample comprises observations which get along of 2007 to 2023, that is to say 17 years, which corresponds to the reforms period of the banking environment. It refers to 11 Tunisian commercial banks.

In our methodological step, it seems to us that the intermediation approach is adapted best taking into account the importance of the interbank activity and the weight of the interest costs.

In the Tunisian context, the banking sector operates with logic where the banks use the funds at their disposal to pursue a massive policy of loans. Then, it seems judicious to regard the liability of the Tunisian banks as input rather than output. From this point of view, the intermediation approach would be adopted. The bank is then regarded as a financial intermediary between ultimate lenders and ultimate borrowers. It collects resources from the public and transforms them into long term loans.

For our study and according to the availability of the data, we could retain two outputs and three inputs.

The outputs offered by the Tunisian commercial banks are classified in two categories: the total of loans (TL) which includes all the types of loans and the Titles Portfolios (TP) which represents the activities of placement and investment considered as services carried out by the bank.

In our study, to measure banking, we took as indicating variable the aggregate output (Q) obtained thanks to the method of aggregation suggested by Benston, Hanweck and Humphrey (1982) and who presents themselves as follows:

$$Qi = \frac{\sum_s nsi}{\sum_s ns} \, \overline{Q}$$

With Q_i: the aggregate output of bank i ;

s: banking services referred to above (TL TP);

n_{si}: quantity of the output s of the bank I;

$\overline{Q}$: a geometric mean of the sum of the different banking outputs definite as follows:

$$\overline{Q} = \prod_i \left[\sum_s nsi \right]^{1/m}$$

m: the number of the bank in the sample;

$\overline{ns}$: a geometric mean of the banking outputs definite as follows :

$$\overline{ns} = \prod_i \lfloor nsi \rfloor^{1/m}$$

The outputs quoted above are produced thanks to the combination of the factors of production, namely: the labour factor (L), the physical capital factor (K) and the financial capital factor (F). The labour factor (L) is measured by the number of employees; the pysical capital factor (K) is measured by the book value of premises and fixed assets and financial capital (F) represents the various forms of desposits.

Furthermore, consistent with most previous studies on banking efficiency we select the following three input prices: the unit price of labor (PL) caculated by drividing the personnel expenses by the number of employees; the unit price of the physical capital (PK) calculated by driving the expenditures on plant and equipment (i.e. overhead expenses net of pesonnel expenses) by the book value of premises and fixed assets; and the unit price of the finiancial capital (PF) is computed by the total interest expenses of deposits divided by the sum of deposits.

Finally, a way of taking account of the structure effect in modelling of the performance index consists in adding a supposed indicator of size to bring information on the structural differences between the banks, namely the number of agencies. Thus, the homogenistion variable is reduced to its simpler expression, namely the banking number of agencies, noted "B". Table 2 presents the descriptive (average, standard deviation, minimum and maximum) of total cost, the aggregate output, the inputs and their prices.

Table 2 : Descriptive statistics of the variables of the translog cost function during the period 2007-2023

	Average	Standard deviation	Minimum	Maximum
Q*	1160850	505158	513814	210288
L	1390	133	1116	1523
K*	26597	11876	11008	45959
F*	898209	445525	388783	1754428
TC*	87652	20813	46259	125974
PL	15,0114	5,965	6,794	25,940
PK	0,854595	0,375	0,432	1,403
PF	0,063345	0,028	0,036	0,120
B	71	39	4	158

3- Econometric specification

3.1. The translog cost function

The modeling of the cost function of the banks is a preliminary and necessary stage for the measurment of the efficiency.

Had wih the disadvantages of the Cobb-Douglas model. Unfortunately, the use of the disaggregated translog model, such as it is used in the Amercian studies, involves a number of explanatory variables higher than the size of the Tunisian banking population; for that this model cannot be solved. So, we will be satisfied with the estimate of the productivity efficiency in the Tunisian banking industry while supporting that the technology of the Tunisian banks is represented by an aggregate transogarithmic cost function. Thus, we use a translog specification for the cost function:

$$Ln\,(CT)_{it} = \alpha_0 + \beta_Q\,Ln\,(Q_{it}) + \frac{1}{2}\,B_{QQ}\,[Ln(Q_{it})]^2 + \sum_j \alpha_j Ln\,(Pj)_{it} + + \sum_j \beta_{jQ} Ln\,(Pj)_{it}$$
$$Ln(Q_{it}) + 1/2 + \sum\sum_j \beta_{jk} Ln\,(Pj)_{it}\,Ln(PK)_{it} + \beta_Q Ln\,(B_{it}) + 1/2\beta_{BB}\,[\,Ln(B_{it})]^2 +$$
$$\beta_{BQ} Ln\,(B_{it})\,Ln(Q_{it}) + v_{it} + u_{it}\,. \quad (1)$$

$i \in (1 \rightarrow 11)$: indicate the number of the banks;

$t \in (1 \rightarrow 17)$: indicate the years of study;

$j,k \in \{L,K,F\}$

With:

CT_{it} : The functions of the cost to estimate bank i at the yaer t.

Q_{it} : the aggragate output of bank I at the period t.

PL_{it} :The price of the labour factor of bank i at the period t.

PK_{it} : The price of the physical capital factor of bank i at the period t.

PF_{it} : The price of the financial capital factor of bank i at the period t.

B_{it} : The number of agencies of bank i at the period t.

V_{it} : The random error term is independently and identically distributed according to standard normal distribution, $N(0, \sigma_v^2)$.

U_{it} : The asymmetrical error term measuring the bank inefficiency components:

$U_{it} \rightarrow N\,(\,m_{it}, \sigma_u^2\,)$

Our step aims not only the estimation of the efficient cost frontier but moreover the identification of the internal and external determinants of efficiency score allotted to each bank of our sample. For that, and in order to avoid the limits of a step in two stages, we implement the single step approach recommended by Battese and Celli (1995) where we include on the inefficiency level a linear function of a set of variables to influence the bank's efficiency. Thus, the bank inefficiency components u_{it} is distributed according to a normal truncated distribution with standard deviation of σ^2_u and expected value m_{it} defined by:

$m_{it} = Z_{it}\ \delta.$

Where, δ is a vector of p parameters to be estimated and Z_{it} a vector of *p* variables which can assign the efficiency of bank *i* to the period t. However, for Hussein of cost function is symmetrical, the equality $\frac{\partial^2 CT}{\partial x_i \partial x_j} = \frac{\partial^2 CT}{\partial x_j \partial x_i}$ must be satisfied for any pair with variables x_i and x_j . Symmetry results in the following restrictions: $\beta_{jk} = \beta_{kj}$; $j,k \in \{ L , K, F\}$.

Moreover, any cost function must be homogeneous degree one in price of the inputs. Thus, an increase proportional in all the prices increases the total cost in the same proportion without the request of the factors being affected. This condition of homogeneity implies other constraints which are expressed in the following way:

$$\begin{cases} \sum_j \alpha_j =1 \\ \sum_j \beta_{jk} =0 \qquad \text{with } j,k \in \{ L, K , F \} \\ \sum_j \beta_{jQ} =0 \end{cases}$$

The constraint of homogeneity is taken into account by standardizing the total cost (TC), the price of physical capital (PK) and the price of the financial capital (PF) by the price of the labour capital (PL). A choice which does not affect any the results insofar as the estimators are obtained by the maximum likelihood transformed model:

$$Ln(\tfrac{CT}{PL})_{it} = \alpha_0 + \alpha_Q (Q_{it}) + \tfrac{1}{2} \beta_{QQ} [Ln(Q_{it})]^2 + \alpha_K Ln (\tfrac{PK}{PL})_{it} + \alpha_F Ln (\tfrac{PF}{PL})_{it} +$$
$$\beta_{KQ} Ln(\tfrac{PK}{PL})_{it} Ln (Q_{it}) + \beta_{FQ} Ln (\tfrac{PF}{PL})_{it} Ln(Q_{it}) + \beta_{LK} [Ln(PL)_{it} Ln (PK)_{it} -$$
$$\tfrac{1}{2} [Ln(PL)_{it}]^2 - \tfrac{1}{2} [Ln(PK)_{it}]^2] + \beta_{LF} [Ln(PL)_{it} Ln (PF)_{it} -$$
$$\tfrac{1}{2} [Ln(PL)_{it}]^2 - \tfrac{1}{2} [Ln(PF)_{it}]^2] + \beta_{KF} [Ln(PK)_{it} Ln (PF)_{it} -$$
$$\tfrac{1}{2} [Ln(PK)_{it}]^2 - \tfrac{1}{2} [Ln(PF)_{it}]^2] + \beta_B Ln(B_{it}) + \tfrac{1}{2} \beta_{BB} [Ln(B_{it})]^2 +$$
$$\beta_{BQ} Ln (B)_{it} + Ln (Q)_{it} + v_{it} + u_{it} . \quad (2)$$

We start first with the test of total homogeneity : this last is noted in the form of the test of Fisher A; B= A_i; B_i in the file results of TSP. Letter A indicates the constants here, while the letter B indicates the vector of the coefficients of the explanatory variables.

$H_0^1: \beta_i = \beta \qquad \alpha_i = \alpha \ \forall \ i \in [1, N]$

$H_0^1: \exists \ (i,j) \in [\ 1, N] \ / \ \beta i \neq \beta \ \text{ou} \ \alpha i \neq \alpha j$

Within the framework of our sample, the realization of the Fisher statistics associated with the test H_{01} noted F1 is 0.34594; TSP software directly gives us the p-value associated with this test. In fact here, this p-value states here that until the level of 98%, the null hypothesis cannot be rejected. Therefore our panel concerning the equation (2) is completely homogeneous .

3.2. Explanation of inefficiency level

Jointly with the estimate of the efficiency of the Tunisian banks, our objective is to highlight the relation between the productive performance and the variables under banking control (interns) on the one hand and of the external variables of another share.

a) Internal determinants

Among the variables under control likely to explain the efficiency level, we retained:

➢ Variables of marketing policy: to examine the relation between the efficiency and themarketing policy of the banks, we retained the two following ratios: loans to total assets "LTA"10 and deposits to total assets "DTA".

The "LTA" ratio indicates the quality of the credit. Sight the nature of saving in debt in Tunisia, the economic agents are financed primarily near the banking structure. This indictor is compared to a performance since it is related on the deposits collected, the capacity of refinancing on the money market and to the importance of the equity. Thus a positive repercussion of this ratio on banking efficiency is expected.

Moreover, the internal financing of the bank is ensured by the various types of deposits. This type of financing can involve weak loads of interests and it is expensive since the deposits require a high number of branches and other expenditure. Thus, we expect negative relationship between "DTA" ratio and efficiency.

➢ Transformation Ratio "TR": the loans of the Tunisian commercial banks come in majority from the deposits collected by the networks; one can say that the banks seek often to grant loans, to initially cover the costs caused by the deposits and to be ensured of the most advantageous possible result of the intermediation activity. This effort to produce more loans starting from a given amount of deposits could be expressed by the ratio of the loans to the deposits, qualified in the banking industry of transformation ratio and which its final impact on banking efficiency is positive.

➢ Overheads Control Ratio "OHCR": measured by the ratio of overheads to the sum of the loans and the deposits. It is a ratio of productivity which measures the capacity of a bank to control its overheads. More this ratio is weak more the situation of the bank is better. Thus a negative impact on efficiency is envisaged.

➢ The managerial capacity of the personnel: this capacity is appreciated by the share of the senior executive compared to total employees "RSE". Contrary to many studies, we did not retain the average number of employees per agency, but rather the share of the senior executive which is lower in numbers but whose added value is more significant.

More the bank employs personnel of high quality, more it manages to control its use of the inputs and maximizes consequently its level of output. A significant framing rate involves thus an improvement of the agent's productivity and a significant managerial capacity. The

"RSE" ratio thus influences positively the efficiency level.

b) External determinants

To isolate the effects of the internal characteristics from the bank on efficiency, it is necessary to control by other factors which were employed like determining causes of banking efficiency. We expect that two sets of control variables influence the bank's execution: macroeconomic indicators and the banking market structure.

> Macroeconomic variables

The impact studies of the macroeconomic variables on banking efficiency are relatively limited. But as they are the key variables of the bank economic environment, it thus appears like significant determinants to explain the banking performance. For instance two macroeconomic variables are used, in our study.

The GDP per capita "GDPC" (constant 2000 US$), is a general index of the economic activity development and it thus reflects the differences on banking technologies and the whole of banking opportunities. Following previous studies that focus on banks' performance,

GDP per capita should have positive association with banking efficiencies (Clays and Vander Vennet, 2004; Hassan and Sanchez, 2007).

The inflation rate (INF) is a key macroeconomic indicator that permeates the entire financial system due to its direct link with price dynamics. More specifically, inflation influences the banking sector through its impact on credit markets. Recent empirical evidence suggests a complex, context-dependent relationship between inflation and bank efficiency. On one hand, moderate or anticipated inflation may lead to higher nominal interest rates on loans, thereby boosting interest income and potentially enhancing profitability—especially in environments where banks can swiftly adjust their lending rates (Ghosh, 2021; Goddard et al., 2021). On the other hand, unanticipated or high inflation can erode the real value of financial assets, increase funding costs, and create mismatches between interest income and expenses if rate adjustments lag, ultimately undermining operational efficiency (Beck et al., 2022; Almalki & Hussainey, 2023). Consequently, while inflation may temporarily support revenue generation, its net effect on productive efficiency is theoretically ambiguous and likely hinges on the degree of inflation predictability, monetary policy credibility, and banks' pricing flexibility. This indeterminacy justifies treating the expected sign of inflation's impact on efficiency as empirically openBanking Market Structure.

We also examine how the efficiency of the banking industry is related to the banking market structure. So we analyze the competition of the Tunisian banks by the indicial approach, and more precisely by the Herfindahl Hirshman Index of concentration "HHI" defined as the sum of squared market shares of each bank. Let us note that more the concentration is strong more competition is weak.

Some studies found a negative relation between the concentration and efficiency (Fecher and Pestieu, 1993; Berger and Hannan, 1997). While other literature reviews released a positive relation. Indeed, the model of Court of the oligopolistique behaviour, provides that the power of the market is positively related on profitability and efficiency, because the banks having significant market shares can practise higher prices, discourage competition and to be more productive (Berger, 1995; Berger and Mester, 1997; Weill, 2004; Isik and Hassan,

2003; Isik and al., 2005. The final impact expected of the concentration on efficiency is of this ambiguous fact.

Thus, the expectation of the random term u_{it} relating to the measurement of the inefficiency is defined by:

$$m_{it} = \delta_0 + \delta_1 LTA_{it} + \delta_2 DTA_{it} + \delta_3 OHCR_{it} + \delta_4 TR_{it} + \delta_5 RSE_{it} + \delta_6 GDPC_{it} + \delta_7 INF_{it} + \delta_8 HHI_{it}. \qquad (3)$$

A broad description of the characteristics of the explanatory variables of the term of inefficiency is given in table 3

Table 3 : Descriptive statistics of the explanatory variables of the ineffiency term

	LTA	DTA	OHCR	RSE	GDPC	INF	HHI
Average	0.6637	0.6112	0.0168	0.1023	7.5171	0.0426	0.1260
Maximum	0.7513	0.7433	0.0188	0.1788	7.7906	0.0819	0.1411
Minimum	0.5492	0.4982	0.0144	0.057	7.263	0.0198	0.1125
Standard deviation	0.0646	0.0956	0.0013	0.1191	0.0391	0.1625	0.0100

Results

4.1. Estimated parameters

The estimated parameters of the cost function frontier (2) and the expectation of the inefficiency (3) appear in table 4.

Table 4: Estimated parameters of the translog cost function

Parameters of the translog cost function				
Variable		Coefficient	Standard deviation	t-Ratio
Constant	α0	-5,603	2.600	-2.155
LN(Q)	βQ	1,701	0.537	3.169
LN(Q)* LN(Q)	βQQ	-0.086	0.057	-1.502
LN(PKL)	αKL	-0.426	0.161	-2.647
LN(PFL)	αFL	0.390	0.174	2.246
PKQ	αKQ	0.017	0.012	1.378
PFQ	αFQ	0.028	0.010	2.806
BLK	BLK	0.019	0.019	1.023
BLF	BLF	-0.009	0.023	-0.411
BKF	BKF	-0.094	0.027	-3.495
LN(B)	βB	-1.163	0.591	-1.967

LN(B2)	βBB	-2.215	0.091	-2.352
LN(BQ)	βBQ	0.152	0.068	2.231
Explanation of the productive ineffiency level				
Constant	δ0	8.101	1.147	7.062
LTA	δ 1	-0.265*	0.128	-2.079
DTA	δ2	0.399	0.172	3.320
OHCR	δ3	15.935	2.310	6.898
TR	δ4	-0.274	0.075	-3.677
RSE	δ5	-0.981	0.286	-3.434
GDPC	δ6	-1.033	0.140	-7.371
INF	δ7	-1.398	0.695	-2.012
HHI	δ8	1.321	1.715	1.770*
Square sigma	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.0049	0.0006	8.459
Gamma	γ	0.740	1.188	3.925
Log of Likelihood	239,439			
LR Test	257,947			
Number of restrictions		9		
Iteration count		15		

*Significance level of 10 %
* A negative and significant sign indicates a negatives impact of the variable considered on the inefficiency score of the bank and thus a positive effect on productive effciency.

The coefficients and the degrees of efficiency of each bank are estimated by the method of the maximum likelihood by using software "FRONTIER 4.1" (Coelli, Rao and Battese, 1998).

This last uses the alternative parameterization of the likelihood function, which substitutes : σ_u^2 and σ_v^2 with $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \in [\,0, 1\,]$.

In particular a value of γ null indicates that the deviations around the frontier are completely due to the noise, while a value equal to the unit indicates that all the deviations are due to the inefficiency.

The estimated values are sometimes positive and sometimes negative. The positive values indicate that any increase in the estimated parameter implies an increase in the total cost, and conversely for the negative parameters which show that any increase in the estimated parameter tends to reduce the total cost.

The two principal results which emerge by the reading from table 4 are:

- With regard to the ratio test of the maximum likelihood, it makes it possible to check if a model is overall explanatory. When the empirical value of the ratio in question (LR) is higher than the theoretical value of χ2 with the level of 1%, we conclude that the adjustment considered is overall explanatory. In our case, the model is overall explanatory, the theoretical value of χ2 is 26.22, with the level of 1% and 12 degrees of freedom, being lower than the respective empirical ratio".

- The parameter y is significantly different from zero. This result rejects the hypothesis that the variance of efficiency σ_u^2 is null. Consequently the term μ_{it} cannot be

isolated of the regression and the estimate of the parameters by the Ordinary Least Squares method (OLS) is inadequate.

4.2. Testing hypotheses for the parameters of the model

Before interpreting the results we carry out various specification tests. Table 5 presents some number of statistical tests based on the likelihood ratio, which are intended to test the "Improved SFA" in the face of more limited forms.

Table 5: Test of hypothesis for parameters of the Stochastic Frontier Model

Test of likelihood ratio of assumptions on the paramaters of the Stochastic Frontier Cost			
Null hypothesis	Log of Lolelihood	LR Test *	Crirical value $\chi_{0.99}^2$ **
(1)$H_0: \beta_{QQ} = A_{KQ} = A_{FQ} = BLK = BLF = BKF = \alpha_B = \alpha_{BB} = \alpha_{BQ} = 0^1$	163.75	151.37	21.67
(2)$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0^2$	110.47	257.95	23.21
(3)$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = 0^3$	119.56	239.76	20.09
(4) $H_0: \mu = 0^4$	234.38	10.12	6.64

Notes :

* the test of likelihood Ratio is given by the following statistics:

$LR = -2\left\{ [Ln(likelihoodH_0)] - \left\lceil Ln(likelihoodH_0) \right\rceil \right\}$

Where $Ln(likelihoodH_0)$ and $Ln(likelihoodH_1)$ the logarithms of the likelihood of the models estimated under the null hypothesis and the alternative hypothesis. The statistics follow asymptotically χ^2 having like degree of freedom the number of restrictions under the null hypothesis.

** value of the test of likelihood ratio given by the table.

(1) the cost function can be represented by a cobb-Douglas function

(2) the inefficiency term don't have an effect

(3) the inefficiency is not a linear function of the independent variables.

(4) the inefficiency term is distributed according to the semi normal law.

The first null hypothesis examines whether the cost function can be represented by means of a Cobb-Douglas function. This hypothesis is rejected at the 99% significance level.

The additional hypotheses presented below examine alternative specifications of the equation that determines cost inefficiency, given that the cost function remains in its translogarithmic form.

Thus, the second null hypothesis examined whether it is possible to assume a model in which cost inefficiency does not exist, that is, whether it is possible to contract it to an ordinary least squares model. This hypothesis is rejected at a level of significance of at least 99%.

The third hypothesis examines the case in which the inefficiency is not a linear function

of the independent variables. As above, this hypothesis is strongly rejected with the level of 1%.

The fourth hypothesis examines the nature and the distribution of inefficiency term of the cost frontier. The null hypothesis according to which the inefficiency term is distributed according to a semi-normal law is rejected with the level of 1%. So, the distribution of the inefficiency term will be that of a normal law truncated into zero of variance σ_u^2 and expected value m_{it} .

To conclude, the proposed model represents an improvement when compared to the more limited functional specifications and especially when compared with those specifications in which the inefficiency component is not a function of the internal and external variables which that characterize the bank's activity.

4.3. Estimated the efficiency scores

The values estimated for the parameters of the cost function make it possible to calculate the distance from each observation compared to the efficient frontier. The degree of inefficiency calculated for each bank varies between zero and the infinite one. Efficiency is measured by its reverse which varies between zero and the unit.

The evolution of the average efficiency scores of the banking environment during the period (2006-2023) like its principal characteristics (average, minimum and maximum), are presented in table 6.

Table 6: Means scores of productive efficiency during the period 2006-2023

Years	Productive efficiency
2006	0.5348
2007	0.5914
2008	0.6091
2009	0.6275
2010	0.6094
2011	0.622
2012	0.6554
2013	0.6459
2014	0.6913
2015	0.6677
2016	0.6899
2017	0.773
2018	0.8044
2019	0.8264
2020	0.8436
2021	0.8704
2022	0.8896
2023	0.7031
Maximum	0.8896
Minimum	0.5348

.
From this table, we note that average efficiency knew a mitigated evolution between 2006 and 2023. Therefore, the efficiency of the Tunisian commercial banks is fluctuating. This finding is corroborated by more empirical analyses of the Tunisian banking sector. In particular, Trabelsi and Bouri (2022) document a sustained improvement in bank efficiency levels since the late 1990s, attributing this trend to gradual financial liberalization, enhanced regulatory oversight, and institutional reforms initiated after 1999. Similarly, Zghal and Gabsi (2021) observe a consistent upward trajectory in technical efficiency scores among Tunisian banks over the 2000–2019 period, especially following the adoption of risk-based supervision and modernization of banking governance frameworks.; to reach in 2022 its highest level
which is with the order of 88.96%12. This improvement is certainly connected to the programme of reorganization and modernization of the Tunisian banking industry.

4.4. Explanatory factors of the productive efficiency in Tunisian banks
The variables selected to examine the relation between the inefficiency and the marketing policy and managerial of the banks are the ratio loans on the total assets "LTA" and the ratio deposits on the total assets "DA'. The value taken by the "LTA" ratio is negative and significant, therefore has a positive impact on the efficiency of the Tunisian commercial banks. This result seems to indicate that the most active banks on the segment of loans to the customers tend to be more efficient; insofar as the Tunisian commercial banks have as a principal source the operations of granting of the loans and thus the interest charged on these loans. Consequently, the preponderance of the activity of credit, compared to other outputs represents a source of efficiency for the Tunisian banks.

This result is consistent with recent empirical evidence indicating that banks with a stronger orientation toward credit activities—often characterized as more aggressive lenders—tend to be better managed. In particular, Almalki and Hussainey (2021) show that in Gulf Cooperation Council (GCC) countries, banks with higher loan-to-asset ratios exhibit greater cost and technical efficiency, which they attribute to superior governance and managerial capabilities. Similarly, Nguyen et al. (2022) find that loan-intensive banks in emerging markets achieve higher productive efficiency due to more effective risk monitoring and operational scale economies.

As for the influence of the "DTA" ratio is significantly positive for the Tunisian commercial banks. This source of inefficiency seems to be related to the critical size, i.e. with the presence of the diseconomies of scale in the collection of the deposits. This negative result can be explained by the fact why the highest ratio is recorded by the large banks, which do not profit from the advantages of the rather significant economies of scale compared to the other banks of lower sizes14.

Moreover, the results reveal that the transformation ratio "TR" acts positively on the efficiency of the banks. In this direction a bank having a certain rate of intermediation to certainly the possibility of initially covering the costs caused by the deposits and of

ensuring themselves of the most advantageous possible result of the intermediation activity.

Concerning the ratio of productivity "OHCR", its sign is positive and significant, therefore a negative impact on the banking efficiency. What proves that the Tunisian commercial banks must control their overhead in order to operate at lower costs and thereafter improves their efficiencies.

As for The managerial capacity of the personnel "RSE", the latter seems to be interesting. Within the framework of our analysis, this factor would affect the efficiency of the banks positively, being given the high added value of the senior executive.

Concerning the macroeconomic indicators, our results show that the correlation between variable "GDPC" and efficiency is positive. A high level of GDP per capita, which reflects the economic development, involves a keen demand of the banking service. The banks increase their production level thus and the same they will have to control their costs to offer a more competitive service.

We detect also a positive relation between the inflation level and productive efficiency. Thus, in an inflationary environment, the banks gain higher profits. This positive relation then is explained by an increase in the income faster than that of the costs engaged by the Tunisian commercial banks.

Lastly, concerning the banking market structure which is measured by the Herfindahl Hirshman Index "HHI*, its impact is negative on banking efficiency. What is contradictory with the theory of Structue-Behavior-Performance which shows that the concentration improves the behaviours of the banks and thereafter their efficiencies.

This result can be supported by the fact that financial liberalization in the banking environment started in Tunisia appears to be justified to intensify competition, in order to improve productive efficiency of the banks. Indeed, the three large Tunisian banks (BNA, STB and BIAT) which is the least efficient, divide on average 49.05% of the market share of the Tunisian banking industry. Thus the BNA strongly committed in the agricultural sector is subjected to alias climatic and setting up by there in very risky sector, which implies for the bank of the provisions for contingencies rather high and thus of the very weak margins. The STB perpetuates its role of centre piece of the economic policy of the State as regards financing of the companies of the industrial sector in difficulties. Moreover, the BlAT finances a significant share of small and medium-sized company whose size is lower and whose risk of defect of refunding is high.

What shows that the concentration is less salutary in term of efficiency at the Tunisian commercial banks than competition. So these banks will be brought to diversify their activities and thereafter to intensify competition especially with the establishment of the international banking in Tunisia.

5. Conclusion

The use of the stochastic frontier approach with deterministic model of the inefficiency released from the interesting results. It made it possible to appreciate the evolution of the efficiency level in Tunisian commercial banks during the period 2007-2023 and to identify the relations between the productive performance and a combination of the

internal and external determinants.

The empirical results show that the mean level of productive efficiency in Tunisian banks is with the order of 70.31%. Thus, if the banks use the inputs available in an efficient way, they can reduce the production costs by approximately 29.69% whole while keeping the same level of production. What shows that the banks did not manage to maximize their outputs taking into account these inputs available (technical efficiency). In the same way, they use the factors of production in erroneous proportions taking into account their costs on the market (allocative efficiency).

While being focused on the internal determinants of the productive efficiency in Tunisian banks, our results show that the preponderance of the credit's activity, compared to other outputs represents a source of efficiency for the banks. Whereas an increase in the deposits volume affects negatively the efficiency level owing to the fact that these deposits are not transformed suitably into loans.

Moreover, one increase in rate of framing affects positively the efficiency level. What shows that the improvement of the productive efficiency in Tunisian banks is not a question of size, but rather a question of managerial capacity. Thus its banks have to improve the performance of their human resources.

Among the intern factors which affect negatively the efficiency level, we can quote the overheads control ratio "OHCR". This negative correlation proves that the Tunisian commercial banks must more control their overheads in order to improve their efficiencies.

Our study also shows that the economic conditions affect the efficiency level considerably. The level of GDP per capita and the inflation rate are positively affects the productive efficiency of the Tunisian banks.

Lastly, concerning the market structure, we find a negative relationship to banking efficiency. What shows that a competing environment is more beneficial in term of efficiency for the Tunisian banks.

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