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DEA Window Approach to Analyze Trends in Efficiency of Angolan Insurance Companies

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ABSTRACT

The objective of this study is to analyze trends in scale efficiency scores in the insurance sector in Angola, related to its ability to minimize resources to maximize results. The methodology followed was the DEA window analysis, which allowed, on the one hand, to compare the efficiency scores recorded with their average, allowing to section in time, periods of analysis of the trend in the efficiency scores of eleven Angolan insurers. From the analysis carried out, it was possible to identify the least efficient insurers in the period (2019-2023). Despite a slight downward trend, it was also possible to verify that between the first and second windows (2019-2022), the insurers presented homogeneous efficiency scores, indicating efficiency averages, for this period, quite similar for the set of insurers that were part of the sample. Finally, it was possible to determine that none of the insurers analyzed recorded, in the period (2019-2023), an efficient average score.

1. INTRODUCTION

In an environment where market uncertainty and volatility are increasingly a risk with an impact on both people's lives and companies, the existence of entities with the capacity to offer financial protection against risks and events of an uncertain nature is of utmost importance.

The current international context is characterized by the prevalence of events that increase uncertainty regarding the outcome of goals at various levels. These events, such as global wars, energy transition, and the slowdown in the globalization process (with the increase in barriers to free trade), allow us to foresee the central role of insurers in identifying, assessing, managing, and mitigating risk with multiple origins.

Thus, insurers, in their different functions, promote economic and financial stability, protecting people and companies from events with adverse financial impacts, on the one hand, and contributing to the generation of resources for investment, which they capture from their policyholders.

At an international level, according to the insurance activity in the period between (2022-2023), the evolution of the insurance activity registered distinct developments, in Asia and the Pacific there was a record of a decrease in the production of insurance, having settled at 0.3%, in North America there was a trend of stability with a record of an increase of 8.3% in the production of insurance premiums, and the African region with levels of issuance of insurance premiums, still below the averages of both Asia and North America (ARSEG & EY, 2024).

In 2023, the insurance sector in Angola showed a growth of 21.4% in total insurance production, driven by the life branch. Another relevant indicator for business in the sector is the financial solidity of insurers, which in the same period recorded an overall solvency margin of over 200% (ARSEG, 2023).

The main objective of this study is to analyze trends in the scale efficiency scores of Angolan insurers, related to their ability to minimize resources to maximize results.

2. LITERATURE REVIEW

2.1 Efficiency of non-bank financial institutions

Non-banking financial institutions, such as insurance companies, play an important role in the consolidation and stability of any financial system. However, traditionally, greater attention has been devoted to understanding the dynamics that lead to superior performance in the banking financial system. Most studies on the determinants of the performance of entities operating in the financial system focus their analysis on commercial banks and very few on non-banking financial institutions, which may be due to the fact that the banking sector is more developed and has a wide distribution (Imtiaz, Mahmud, & Faisal, 2019).

Non-bank financial institutions comprise a broad group of entities with diverse business models, including different types of investment funds, insurance companies and pension funds (Emter, Killeen, & McQuade, 2021).

Non-financial institutions, in their fundraising and investment and risk management functions, once accompanied by appropriate supervisory mechanisms, can directly, for better or for worse, play an important role in the efficiency of the financial market, similar to that of banking financial institutions, so much so that, according to Liang & Reichert (2011), there is empirical evidence that non-bank financial institutions, such as investment banks and insurance companies, can have a statistically significant negative impact on economic growth, stemming from flexible regulation.

However, for the financial ecosystem, there are several benefits arising from the activity of non-banking financial institutions, namely ranging from multi-risk management to the capture and application of funds, with repercussions on the financial system and the economy in general.

As far as insurance companies are concerned, they originated during the Renaissance, to respond to the various forms of risk, transferring them to themselves, being able to assume them technically and financially, in exchange for remuneration, leaving the insured free from this concern (Vieira, 2012). By doing so, insurance companies contribute to the efficient mobilization of capital in economies, contribute to the physical and patrimonial integrity of their insured, stimulate investment in risk capital, ensuring more dynamic economies.

The insurance sector is one of the most important areas of activity for sustainable economic development, ensuring protection and fostering the formation of long-term provisions and reserves (Carvalho, Flores, & Valdez, 2022). The above highlights the role and importance of insurers as risk managers and fund mobilizers, whose dynamics in efficiency between 2019 and 2023, in the Angolan context, will be the subject of this study.

2.2 DEA Window Technique and DEA VRS Model: An Overview

The DEA window technique has its operational part based on the principle of moving averages, which in the presence of panel data, allows capturing the dynamic effect present in the trends of DMU efficiency over time. The technique allows comparing the trend in efficiency scores in a given period of time, and between different time periods.

Several authors have studied the procedures to follow to set an optimal window size that would allow this same dynamic effect to be faithfully captured. However, there is no single formulation, and the most common in the DEA literature is that formulated by (Cooper, Seiford, & Tone) (2007), and which appears in Table 1.

Table 1. DEA windows

Indicators	**Formulas**
Number of windows	w = k - p +1
Number of DMUs in each window	(n) (p)
Number of different DMUs	(n) (p) (w)
Variation in the number of DMUs	n (p - 1) (k - 1)

Source: Cooper, Seiford, & Tone(2007)

According to Asmild , Paradi , Aggarwall , & Schaffnit (2004), assuming that the technological change within each window is insignificant, the input and output matrices in each window, aiming at their formalization, are fixed considering N DMUs (n = 1… N), which are observed in T periods (t = 1…T) and that use *r* inputs to produce s outputs, so the window with start k, $1 \leq k \leq t$; number of windows (w), $1 \leq w \leq t - k$, is denoted byk_w and n (w)therefore, the matrices result as shown below:

input matrix:

$$X_{k_w} = \left(x_k^1, x_k^2, \ldots, x_k^N, x_{k+1}^1, x_{k+1}^2, \ldots, x_{k+1}^N, \ldots, x_{k+w}^1, x_{k+w}^2, \ldots, x_{k+w}^N\right) \quad (1)$$

output matrix:

$$Y_{k_w} = \left(y_k^1, y_k^2, \ldots, y_k^N, y_{k+1}^1, y_{k+1}^2, \ldots, y_{k+1}^N, \ldots, y_{k+w}^1, y_{k+w}^2, \ldots, y_{k+w}^N\right) \quad (2)$$

The matrices presented thus represent the distribution of the analysis moments over a set of reference periods. One of the advantages of this technique is that, since each DMU is treated as a different DMU in each analysis window, the technique allows the number

of DMUs to be increased. This feature is particularly useful in cases where the number of DMUs is relatively close to the sum of the number of inputs and the number of outputs.
DEA, as a methodology adopted for the evaluation of DMUs, has supported numerous studies that aim to identify, analyze and evaluate the different nuances of the productive efficiency of companies. DEA models are based on mathematical programming and are divided into radial and non-radial. Radial models (CRS and VRS) are those that, in their variable optimization process, seek one of two goals: maximizing results or minimizing resources. In turn, non-radial models (Additive, SBM and ERM) have a composite or mixed orientation.
The adoption of DEA models in studies on the evaluation of DMU efficiency is, in the view of Olfati , *et al.* , (2022)related to the possibility of admitting several inputs and outputs simultaneously, enabling the obtaining of individualized efficiency scores for each of the DMUs, which may have different units of measurement, as well as allowing the identification of inefficiencies, important for the decision-making process in DMUs.
Considering the existence of differences, albeit residual, between DMUs, in their process of optimizing both resources and results, even among those inserted in the same area of activity and in the same productive context, the assumption that the scale of returns resulting from their activity is not constant appears to be the most feasible.
The VRS model measures the resulting combination of observed values for inputs and outputs, under the condition that, since returns to scale are variable, they assume increasing, constant or decreasing conditions (Fernandes, Minori, & Morais, 2017).
The mathematical formulation of the input-oriented VRS model, considering the maximum and minimum constraints, is as follows:

$$\text{Maximize } h_k = \sum_{r=1}^{m} u_r y_{rk} \, u_k \tag{3}$$

Subject to:

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{4}$$

$$\sum_{i=1}^{m} u_r y_{rj} - \sum_{i=1}^{n} v_i x_{ij} - u_k \leq 0 \tag{5}$$

$$u_r , v_i \geq 0 \tag{6}$$

Where:
y: inputs; x: outputs; u e v: weights; r: 1,…, m; i: 1,…, n; j: 1,…, N.

3. METHODOLOGY

In summary, Table 2 presents the specifications of the model used, which will be detailed *later* in points 3 and 4, respectively.

Table 2. Model specification

Model	DEA VRS
Guidance	Input
Homogeneity of DMUs	Only Angolan insurers
Choice of variables	Value-added approach

In order to capture the trend in the dynamics of the efficiency of the insurance companies analyzed, the input-oriented VRS model was used. The choice of the model was based on the premise that both the size and scale of operations of financial institutions in general and insurance companies in particular are quite diverse, with a greater possibility that the scale of returns from their activities is not constant.
The orientation given to the model derives from the objective of the study, therefore, the justification for its adoption is the intention of understanding what has been the trend in the process of minimizing costs in the results of the insurance companies targeted by the study, taking into account the result variables analyzed.
The balance between the number of variables and the number of insurers analyzed followed the principle that the number of DMUs analyzed must be at least twice the total number of inputs and outputs selected (Cooper, Seiford, & Tone, 2007)and (Golany & Roll, 1989). In this sense, based on the assumptions stated for setting DEA windows, the configuration shown in Table 2 was considered. Based on the mathematical formulations shown in Table 1, the width of the analysis windows was set at three periods, since this allows obtaining the maximum number of different DMUs (in this case 99), meeting the goal of including the largest number of different DMUs in the analysis, seeking to increase the discriminatory power of the efficiency scores, at the obtained frontier. Another factor that justifies the set window width, and corroborated by the empirical work carried out, was the finding that it is in the situation in which the width of the analysis window is three periods, that the number of DMUs registers a smaller value in its variation, indicating greater stability regarding the results to be obtained, in the condition, where: k: number of periods, w: number of windows, p = width of the window in the condition (p ≤ k) and n: number of DMUs. Thus, considering eleven DMUs, five periods

to which the data refer, a window width of three periods, and also a number of three windows, the configuration of the DEA windows obtained is the one shown in Table 2.

Table 2. Analysis windows

Periods	1	2	3	4	5
Window 1	2019	2020	2021		
Window 2		2020	2021	2022	
Window 3			2021	2022	2023

The criterion for including the insurers analyzed in the sample was the score in the ARSEG ranking (2023, p. 80), which considers the volume of gross premiums issued as a relevant indicator. However, only insurers with complete data published in the period analyzed were included in the sample, so both the cut-off line in time and the order in which they appear in the classification in Table 3 followed this criterion. Therefore, the following insurers were left out of the sample: PRUDENCIAL, VIVA, FORTALEZA, CONFIANÇA, SUPER, ROYAL, UNISAÚDE TREVO and BONWS.

Taking into account the inclusion criteria in the sample, the following insurance companies were analyzed: (ENSA), (NOSSA), (FIDELIDADE), (BIC), (TRANQUILIDADE), (ALIANÇA), , (MUNDIAL), (STAS), (PROTTEJA), (SOL), (GIANT)and (ARSEG).

Table 3. Classification of insurance companies analyzed

Classification	Insurance companies	Branch	Established
1st	ENSA SEGUROS, S.A.	Life and non-life	1978
2nd	NOSSA SEGUROS, S.A.	Life and non-life	2005
3rd	FIDELIDADE SEGUROS, S.A.	Life and non-life	2010
4th	MUNDIAL SEGUROS, S.A.	Life and non-life	2006
6th	ALIANÇA SEGUROS, S.A.	Life and non-life	2017
7th	BIC SEGUROS, S.A.	Life and non-life	2014
10th	PROTTEJA SEGUROS, S.A.	Non-life	2012
11th	SOL SEGUROS, S.A.	Life and non-life	2016
13th	TRANQUILIDADE SEGUROS, S.A.	Life and non-life	2010
14th	STAS SEGUROS, S.A.	Life and non-life	2016
17th	GIANT SEGUROS, S.A.	Life and non-life	2018

Source: ARSEG(2023, p. 36)

4. DATA AND VARIABLES

Given the availability of data from the insurance entities targeted by this study, on their official online pages, the supporting data refer to the period between 2019-2023.

The selection of variables followed the assumptions of the value-added approach of (Micajkova, 2015), with the aim of including those more specifically related to the specificities of the insurance business. From this perspective, and based on the literature reviewed, the following variables were used:

- Input variables (commissions: amounts paid to brokers or agents to attract clients and generate premiums; claims costs: proxy used to capture the effect of efficiency in process management);
- Output variables (gross premiums issued: result of the insurer's operations, in terms of payments made to cover claims; investment income: capital reserves to cover future claims).

In order to provide a general overview of the data, Table 4 presents a summary of its status, thus creating preconditions for modeling the variables.

Table 4. Descriptive statistics of variables

Variables	Minimum	Maximum	Average	Standard deviation
Commissions	1	5848440919	515547350	1015047532
Claims costs	61575	20105201375	2993015906	4225155048
Gross premiums written	1985633	97769436627	13165108245	20892806071
Investment income	1	7895619354	787511357	1452239382

In order to ensure a selection of variables with the lowest degree of association between them, and therefore with the greatest explanatory capacity between them, a correlation test was carried out, the results of which appear in Table 5. The test results suggest a relatively weak correlation between the variables, both input and output, so none were removed.

Table 5. Correlation matrix between variables

Variables	Commissions	Claims costs	Gross premiums written	Investment income
Commissions	1,000			
Claims costs	0.531	1,000		
Gross premiums written	0.304	0.292	1,000	
Investment income	0.327	0.695	0.194	1,000

5. RESULTS AND DISCUSSION

Table 6 presents a summary of the main results obtained, namely the efficiency scores for each insurer and for each year, which were used for all subsequent analysis. It is worth highlighting the low standard deviation (6%) compared to the average efficiency score (42%), i.e. a standard deviation approximately seven times lower than the average. These indicators, to a certain extent, minimized initial concerns regarding the presence of outliers in two of the variables included in the model (commissions and investment income).

Table 6. Table of efficiency scores obtained

Insurers	2019	2020	2021	2022	2023	Mean	St. Dev.
FIDELIDADE SEGUROS, S.A.	15%	12%	0%	9%	21%	11%	8%
BIC SEGUROS, S.A.	100%	26%	20%	20%	15%	36%	36%
NOSSA SEGUROS, S.A.	37%	31%	51%	100%	100%	64%	34%
ENSA SEGUROS, S.A.	100%	89%	100%	16%	28%	67%	41%
TRANQUILIDADE SEGUROS, S.A.	25%	95%	75%	100%	100%	79%	32%
ALIANÇA SEGUROS, S.A.	100%	78%	66%	71%	100%	83%	16%
MUNDIAL SEGUROS, S.A.	16%	7%	21%	20%	100%	33%	38%
PROTTEJA SEGUROS, S.A.	0%	0%	7%	21%	16%	9%	9%
STAS SEGUROS, S.A.	8%	2%	9%	6%	10%	7%	3%
SOL SEGUROS, S.A.	1%	4%	9%	6%	16%	7%	6%
GIANT SEGUROS, S.A.	100%	100%	21%	21%	13%	51%	45%
Mean	46%	40%	34%	35%	47%	41%	6%

The positioning of the different insurers in Chart 1 corresponds to their classification according to the average of their efficiency scores, i.e. none achieved the maximum score (100%). This indicates that none of them were efficient in the period (2019-2023). However, given that an average efficiency of 41% was recorded for all insurers, it can be seen that around half of them achieved scores above this value, with ALIANÇA Seguros, S.A. being the least inefficient.

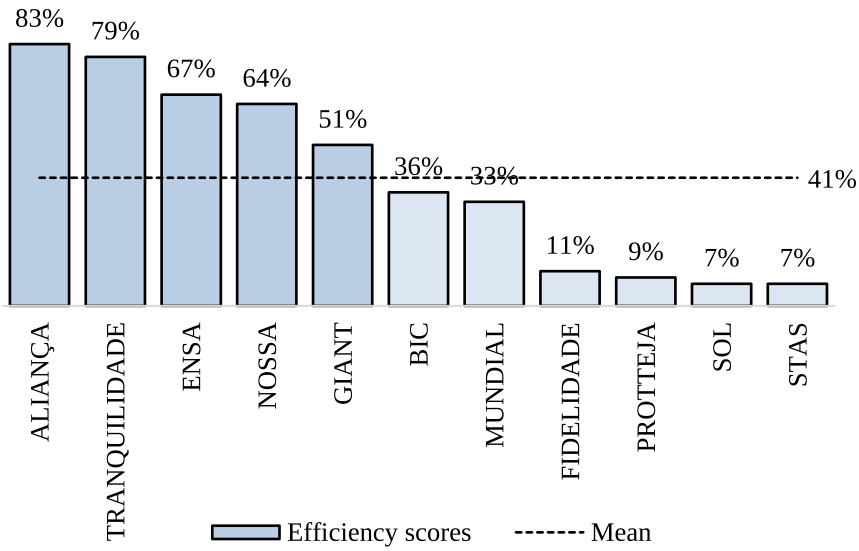
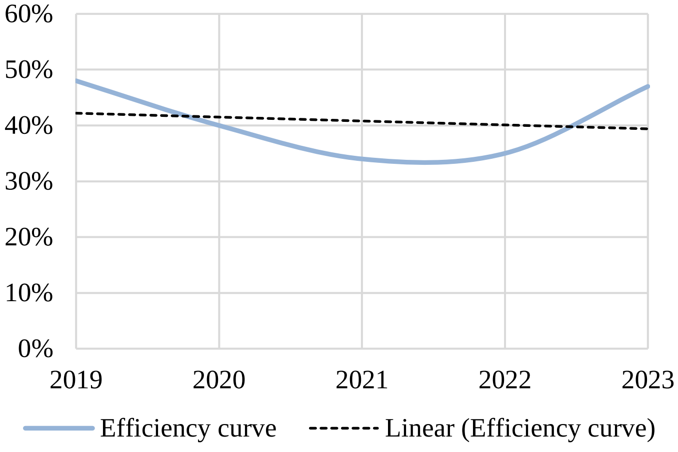
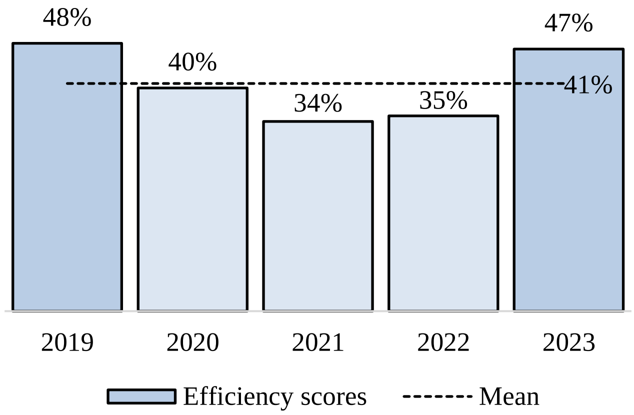


Chart 1. Efficiency Scores vs. Average Efficiency

Graph 3 shows the efficiency score curve for the set of insurers analyzed in the reference period and their respective trend line. As can be seen, by comparison with Graph 4, its configuration is quite similar to the score curve of ALIANÇA Seguros, S.A. A visual inspection of Graphs 2 and 3 shows that, overall, it was in the period between 2021 and 2022 that the lowest level of efficiency was recorded, with the period of decrease beginning in 2019, with an increase again from 2022 onwards.

The trend in efficiency scores for all insurers is slightly downward, a finding that is reinforced by the comparative analysis between the average efficiency scores recorded in each analysis window and the respective standard deviations, as shown in Graph 5.

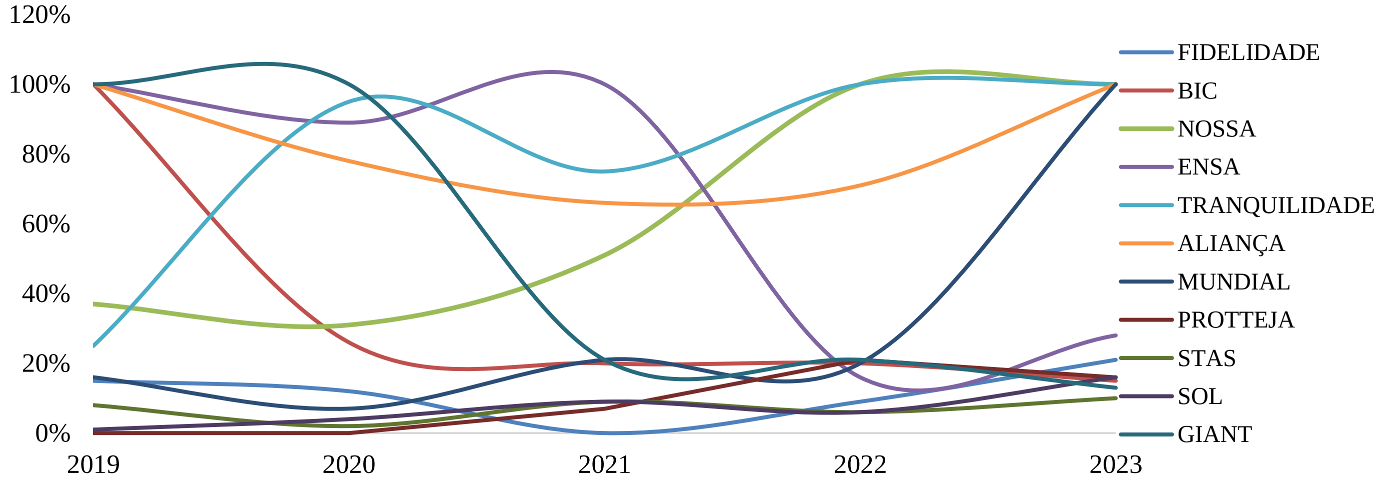




Graph 3. Curve vs. Trend in efficiency scores Graph 2. Efficiency vs. Average efficiency

Graph 4 shows the behavior of the efficiency score curves of each insurer in the period analyzed. From this, it is possible to identify that the insurer with a more constant trajectory, and the only one always with scores above the average, was MUNDIAL Seguros, S.A. Although in overall terms the trend in efficiency scores for the sample is slightly downward, as shown in Graph 3, it can be seen that two groups of insurers have presented distinct trends, from the last year of the period analyzed. The first constituted by: MUNDIAL Seguros, S.A., ALIANÇA Seguros, S.A., TRANQUILIDADE Seguros, S.A. and NOSSA Seguros, S.A., which despite sharp fluctuations between values above the average and close to the minimums, in the last year of the period analyzed (2023) recorded scores above the average and close to the maximums recorded.

The second group, consisting of: STAS Seguros, S.A., SOL Seguros, SA, PROTEJA Seguros, S.A., GIANT Seguros, S.A., ENSA Seguros, S.A., FIDELIDADE Seguros, S.A. and BIC Seguros, S.A., had a low level of variation in efficiency scores, always close to the minimum scores. In this group, the exception can be pointed out to BIC Seguros, SA, which from 2019 to 2020 registered a sharp decrease in efficiency scores, remaining there until 2023, as well as ENSA Seguros, S.A., which registered a sharp decrease in its scores from 2021 onwards.



Graph 4. Individualized behavior of efficiency score curves

Graph 5 shows the results comparing the efficiency scores in each window and their respective standard deviations. Thus, it can be seen that window three has an average score higher than the average standard deviation value, indicating that most of the insurers analyzed operate at similar efficiency levels. However, it can be seen that between windows one and two, the average and standard deviation are more than close, they are perfectly aligned, indicating that the insurers presented homogeneous efficiency scores between these two windows, that is, in the period between 2019 and 2022. However, since in the period under analysis, the trend in efficiency scores was downward (Graph 3), and none of them were efficient, the aforementioned homogeneity can be seen as an opportunity for optimization, through innovation that leads to productive specialization.

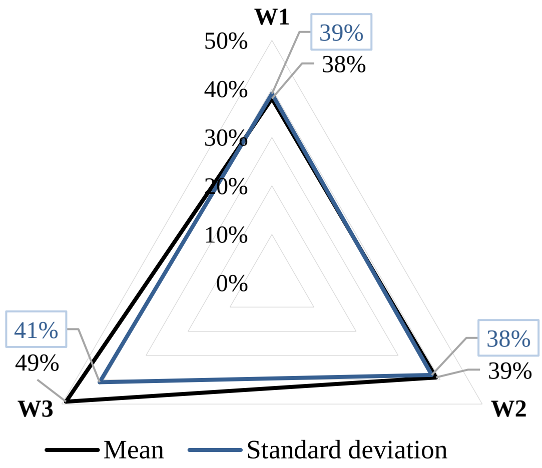


Chart 5. Trend in efficiency scores vs. Standard deviation

6. CONCLUSIONS AND OBSERVATIONS

Despite efficiency records in some years and fairly homogeneous results in some periods by some insurers, none of them recorded an average efficient score in the period (2019-2023), the least inefficient being ALIANÇA Seguros, SA. This record is even more evident when, based on the records of the average scores for each year, compared to the global average, which is still less than 50%. Although slight, the trend recorded in the efficiency scores for all eleven insurers analyzed is downward, which may indicate a market performance that is also decreasing, with an impact on the reduction of market shares.

The values found for the standard deviation are significantly lower than the average efficiency scores for the set of insurers analyzed, which indicates that, in general, they operate at very similar efficiency levels, which does not make it possible to carry out benchmarking within the sample, if the reference scores are the global efficiency averages obtained by each insurer.

In preparing this study, two constraints were obstacles to empirical procedures, namely: the need for greater standardization in the criteria adopted for reporting financial statements by insurers. This would ensure greater reliability of the results obtained. Another constraint in this regard is the illegibility of documents containing relevant information, posted on the official websites of some insurers targeted by the study, with repercussions on the sample size of twenty-three in the ARSEG ranking, compared to eleven.

The inference of the results of this study, for contexts external to it, may produce results with sampling or extrapolation bias, since they were obtained within the strict scope of the DMUs that make up its sample, and in the referenced period.

Thus, in order to better reflect the panorama of the trend in the relative efficiency of DMUs operating in the insurance sector in Angola, once the aforementioned constraints have been overcome, both the sample and its time horizon should be expanded.

APPENDIX

Insurers	2019	2020	2021	2022	2023	Mean	St Dev
	15.39%	13.35%	0.20%			10%	8%
FIDELIDADE, S.A.		10.78%	0.55%	9.63%		7%	6%
			0.56%	8.26%	21.04%	10%	10%
Mean	15%	12%	0%	9%	21%	12%	8%
	100.00%	28.58%	23.64%			51%	43%
BIC, S.A.		22.80%	19.25%	21.26%		21%	2%
			16.43%	18.11%	14.83%	16%	2%
Mean	100%	26%	20%	20%	15%	36%	36%
	36.95%	22.09%	18.72%			26%	10%
NOSSA, S.A.		39.25%	34.78%	100.00%		58%	36%
			100.00%	100.00%	100.00%	100%	0%
Mean	37%	31%	51%	100%	100%	64%	34%

	100.00%	77.90%	100.00%			93%	13%
ENSA, S.A.		100.00%	100.00%	10.37%		70%	52%
			100.00%	21.80%	27.69%	50%	44%
Mean	100%	89%	100%	16%	28%	67%	41%
	24.77%	100.00%	88.15%			71%	40%
TRANQUILIDADE, S.A.		89.10%	74.58%	100.00%		88%	13%
			63.63%	100.00%	100.00%	88%	21%
Mean	25%	95%	75%	100%	100%	79%	32%
	100.00%	55.45%	47.56%			68%	28%
ALIANÇA, S.A.		100.00%	50.68%	42.11%		64%	31%
			100.00%	100.00%	100.00%	100%	0%
Mean	100%	78%	66%	71%	100%	83%	16%
	16.30%	5.21%	33.02%			18%	14%
MUNDIAL, S.A.		8.70%	15.38%	19.64%		15%	6%
			15.17%	19.72%	100.00%	45%	48%
Mean	16%	7%	21%	20%	100%	33%	38%
	0.17%	0.09%	8.30%			3%	5%
PROTTEJA, S.A.		0.41%	6.45%	22.50%		10%	11%
			5.97%	19.48%	16.41%	14%	7%
Mean	0%	0%	7%	21%	16%	9%	9%
	8.01%	2.36%	10.26%			7%	4%
STAS, S.A.		2.13%	9.26%	5.76%		6%	4%
			8.41%	5.29%	9.72%	8%	2%
Mean	8%	2%	9%	6%	10%	7%	3%
	0.82%	0.54%	10.26%			4%	6%
SOL, S.A.		7.58%	9.26%	5.76%		8%	2%
			8.41%	5.29%	16.41%	10%	6%
Mean	1%	4%	9%	6%	16%	7%	6%
	100.00%	100.00%	14.96%			72%	49%
GIANT, S.A.		100.00%	13.40%	16.61%		43%	49%
			33.58%	26.09%	13.47%	24%	10%
Mean	100%	100%	21%	21%	13%	51%	45%
#							
Mean	46%	40%	35%	35%	47%		
St Dev	44%	41%	33%	37%	42%		

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