Chapter 2

Financial Performance of the US Deposit Banks: The Entropy Based PARIS Method

Naci Yilmaz[1]

Abstract

The financial performance of banks can be regarded as one of the most significant topics in financial markets. It is very important by everyone. In this study, a comparison was made among the bank groups in FDIC system by evaluating their financial data. For this study, the PARIS (**P**reference **A**nalysis for **R**eference **I**deal **S**olution) method, one of the novel multi-criteria decision- making (MCDM) techniques was employed together with the ENTROPY method. PARIS was used as a ranking method and ENTROPY was applied as a weighting method. Five bank groups were classified regarding to their asset sizes were evaluated. The performance analysis is based on ten criteria. According to the ENTROPY weighting method, the most important criterion was Equity Capital to Assets. Net Interest Margin and Net Loans & Leases to Total Deposits ratios follow it respectively. The least important criterion was Return on Assets. According to the PARIS method, the bank group with the average asset of between $100 million - $1 billion performed the best between 2018-2022. The worst performing bank group was the one with assets over $250 billion.

1.Introduction

The contagiousness effect of the crisis in the financial system, which includes banks, is very important and public authorities have been sensitive to this issue since the 2008 crisis. With the two bank failures (Silicon Valley Bank and Signature Bank) in 2023, investors and financial experts have focused on the financial performance and soundness of the deposit banks operating in the United States and also in the world. Not only investors and financial experts but also other bank stakeholders (customers, employees, managers, partners, suppliers, government etc.) are curious about the

1 Assoc.Prof., Doğuş University, Economics. ORCID: 0000-0003-0107-6448. E-mail:nyilmaz@dogus.edu.tr

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financial soundness of the banks whose deposits were insured by Federal Deposit Insurance Corporation (FDIC). They want to understand the financial soundness of the banks by comparing them with each other in the FDIC system. This study was conducted in order to compare the financial performance of the bank groups classified by the asset size and to find the most successful group in the period between 2018-2022. In this study, a comparison was made among the bank groups in FDIC system by evaluating their financial data. For this study, the PARIS (**P**reference **A**nalysis for **R**eference **I**deal **S**olution) method, one of the novel multi-criteria decision-making (MCDM) techniques was employed together with the ENTROPY method. PARIS was used as a ranking method and ENTROPY was applied as a weighting method. In this analysis, five bank groups classified according to asset size were evaluated.

2.Literature Review

Since the PARIS method is still very new, a study applied in the banking sector has not been found in the literature. The method has had some applications in the aerospace and steel industry. These studies are given below.

Ardil (2020a) implemented the PARIS and TOPSIS (the **T**echnique for **O**rder of **P**reference by **S**imilarity to **I**deal **S**olution) methods to solve aircraft selection process problem. He used the mean weight (MW) and the entropy weight (EW) methods to determine the weights of criteria. The ranking results indicated that the A321 (neo) (3 *a*) aircraft had the best performance among other alternatives.

Ardil (2021) applied the PARIS and TOPSIS methods to solve airline quality rating problem. The selected multiple performance criteria were determined as on-time arrivals, mishandled baggage, involuntary denied boardings, and consumer complaints. The research results showed that the alternative (a2) airline is the best-rated airline

Le (2022) implemented the PARIS method to solve the milling steel selection process problem. SR and MRR are selected as the output parameters of the milling process. He used the average weight (AW), the mean weight (MW) and the entropy weight (EW) methods to determine the weights of criteria. In the study, 27 alternatives (experiments) are analyzed. In order to see stability of ranking alternatives the GINI index was used.

Ardil (2023) applied the PARIS method to solve the unmanned combat aircraft (UCA) selection problem. In the study, a case study was considered to evaluate and compare the quality of twenty unmanned combat aircrafts.

The research result showed that in complicated problems requiring uncertain decision making, the PARIS technique produces consistent decision solutions.

3. Methodology

3.1. ENTROPY Method

For the first time physicist R. Clausius used the concept of ENTROPY in 1865 by writing that "all systems were left to their own devices and natural conditions in the universe", which was defined as "disorder and distortion". It was later redefined by Shannon in 1948 as "a measure of uncertainty" in the field of communication. In this method, which is used to determine the weight coefficients of the criteria, it is possible to calculate the weight of the criteria based on the available data. In this respect, the personal judgments and thoughts of the decision-makers are departed. Thus, the decision-making process is calculated objectively. The method consists of five steps (Zhang et al., 2011; Karami and Johansson, 2014; Ömürbek et al. 2017; Light, 2019; Aydin, 2020).

Step 1. Building the decision matrix.

$$X = [x_{ij}]_{mxn} \qquad \text{Equation (1)}$$

In the first step of the method, the decision matrix is built. In Equation (1), m indicates the alternatives and n indicates the criteria. Xij indicates the performance value of the alternative i according to the criterion j.

Step 2. Normalizing the decision matrix.

If criterion j is the benefit criterion that means the bigger is the better, Equation (2) is used.

$$r_{ij} = \frac{x_{ij}}{x_{ij}max} \qquad \text{Equation (2)}$$

If criterion j is the cost criterion that means the smaller is the better, then Equation (3) is used.

$$r_{ij} = \frac{x_{ij}min}{x_{ij}} \qquad \text{Equation (3)}$$

Step 3. Calculation of the Entropy value for the criteria.

Entropy values ej are calculated with the help of Equation 4 using the entropy coefficient of the normalized values.

$$e_j = -k \sum_{j=1}^{n} (r_{ij}) \text{ x } \text{In } (r_{ij}) \qquad \text{Equation (4)}$$

ej shows the entropy value and k (= $\text{In}(n)^{-1}$) denotes entropy coefficient.

Step 4. Calculation of the information variance degree dj.

With the help of Equation 5, d_j is calculated, which indicates the distance from the ideal.

$$d_j = 1 - e_j \qquad \text{Equation (5)}$$

Step 5. Finding the entropy weights for criteria.

In the final stage, the criterion weights w_j are calculated with the help of Equation 6 below.

$$w_j = \frac{d_j}{\sum_{i=1}^{n}(d_j)}, \quad \sum_{j=1}^{n} w_j = 1 \qquad \text{Equation (6)}$$

3.2. PARIS Method

In this study, the PARIS (**P**reference **A**nalysis for **R**eference **I**deal **S**olution) method was applied. It was introduced by Ardil (2020). Even if it is a member of the MCDM family, it employes three different normalization technics. Also, for each normalization, the ranking of the alternatives is performed in three steps. For this reason, when employing the method, nine different ratings are obtained for the alternatives. The application steps of the PARIS are explained below (Ardil, 2020a; Ardil,2020b; Ardil, 2020c; Ardil, 2023; Le, 2022).

Step 1. Building the decision matrix.

In the first step of the PARIS method, the decision matrix with m units alternative and n units criteria is created as seen below.

$$X = [x_{ij}]_{mxn} \qquad \text{Equation (7)}$$

Step 2. Threefold normalization of the matrix.

i. The first way of normalization is called as "vector normalization":

If criterion j is the benefit criterion that means the bigger is the better, Equation (8) is used. If criterion j is the cost criterion that means the smaller is the better, then Equation (9) is used.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad \text{Equation (8)}$$

$$r_{ij} = 1 - \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad \text{Equation (9)}$$

ii. The second way of normalization is called as "linear normalization":

If criterion j is the benefit criterion that means the bigger is the better, Equation (10) is used. If criterion j is the cost criterion meaning that the smaller is the better, Equation (11) is used.

$$r_{ij} = \frac{x_{ij}}{x_{ij}^{max}} \quad \text{Equation (10)}$$

$$r_{ij} = \frac{x_{ij}^{min}}{x_{ij}} \quad \text{Equation (11)}$$

iii. The third way of normalization is called as "max - min linear normalization":

If criterion j is the benefit criterion that means the bigger is the better, Equation (12) is used. If criterion j is the cost criterion meaning that the smaller is the better, Equation (13) is used.

$$r_{ij} = \frac{x_{ij} - x_{ij}^{min}}{x_{ij}^{max} - x_{ij}^{min}} \quad \text{Equation (12)}$$

$$r_{ij} = \frac{x_{ij}^{max} - x_{ij}}{x_{ij}^{max} - x_{ij}^{min}} \quad \text{Equation (13)}$$

Step 3: Calculation the weighted normalized values.

$$z_{ij} = w_j \cdot r_{ij} \quad \text{Equation (14)}$$

Step 4. Summarizing the weighted normalized values:

$$\pi_i^{\omega} = \sum_{j=1}^{n} w_j \cdot r_{ij} \quad \text{Equation (15)}$$

Step 5. Ranking alternatives according to π_i^{ω} values:

The alternative with the largest value of π_i^{ω} is the best alternative.

Step 6. Determining the components of the ideal solution:

$$z_j^* = \in \{ z_1^*, \dots, z_j^* \} = \langle (max_i z_{ij} \mid j \in B), (min_i z_{ij} \mid j \in C) \rangle \quad \text{Equation (16)}$$

In Equation (16), *B* indicates the possible largest criterion and *C* shows the possible smallest criterion.

Step 7. Determining the distance from the ideal solution:

$$\pi_i^* = \sum_{j=1}^{n} (z_j^* - z_{ij}) \qquad \text{Equation (17)}$$

Step 8. Ranking the alternatives according to the π_i^* values.

The smaller value of π_i^* is the better.

Step 9. Finding the distance from the ideal for each alternative:

$$R_i = \sqrt{(\pi_i^{\omega} - \pi_i^{\omega,\max})^2 + (\pi_i^* - \pi_i^{*,\min})^2} \qquad \text{Equation (18)}$$

Step 10. Ranking the alternatives based on their *Ri* values with the ascending order.

The alternative with the smallest value of *Ri* is accepted as the best alternative.

4. Application of the Method

The goal of the study is to rank and to evaluate the financial performances of the FDIC insured bank groups. These bank groups were built on their average asset size. For this goal, ENTROPY and PARIS methods were employed. Both of them are among the MCDM methods. By using these methods, financial performances of five different bank groups in the FDIC system were evaluated depending upon the ten financial ratios selected as the decision-making criteria.

The data set of the research was obtained from the web page of FDIC. The bank groups (alternatives) to be compared and the criteria to be used for ranking can be seen Table 1 and Table 2:

Table 1. Alternatives

Bank Asset Size Group (2022/Q4)	Code	Bank Numbers	Asset Share
Assets > $250 Billion	Group 1	13	55.45
Assets $10 Billion - $250 Billion	Group 2	145	30.05
Assets $1 Billion - $10 Billion	Group 3	823	9.65
Assets $100 Million - $1 Billion	Group 4	2,964	4.65
Assets < $100 Million	Group 5	761	0.20
Total		**4,706**	**100.00**

Source: FDIC Quarterly Banking Profile, QBP Time Series Spreadsheets. https://www.fdic.gov/analysis/quarterly-banking-profile/index.html.

According to the table, the total number of deposit banks operating in the FDIC system is 4706 at the end of 2022. The most populous group is group 4 with 2964 banks. The share of Group 1 is 0,01 percent, Group 2 is 3 percent, Group 3 is 18 percent, Group 4 is 63 percent and Group 5 is 16 percent in the total. The table above and the graph below show the share of these groups in total assets. The group with the largest share is Group 1 with a share of 55.45 percent. It is followed by Group 2 with a share of 30.05 percent.

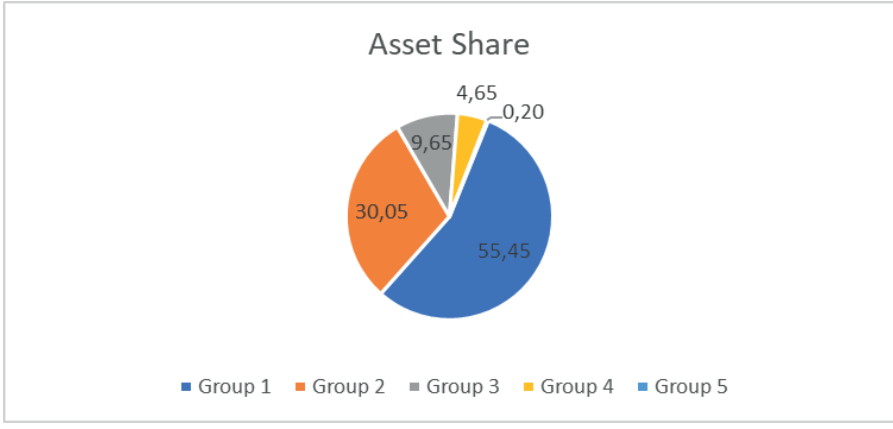

Figure 1. Asset Share of The Five Bank Groups. Source: FDIC Quarterly Banking Profile, QBP Time Series Spreadsheets. https://www.fdic.gov/analysis/quarterly-banking-profile/index.html.

The research was based on ten financial ratios (criteria) of these banking groups. Criteria name, criteria code, optimum and criteria weight can be read by looking to the table below:

Table 2. Types of Criteria

Criteria Name	**Code**	**Optimum**	**Weight**
Return on Assets	ROA	Max	0.0999
Return on Equity	ROE	Max	0.0990
Net Interest Margin	NIM	Max	0.1006
Percent of Loans and Leases Noncurrent	NPL	Min	0.1000
Equity Capital to Assets	ECA	Max	0.1007
Core Capital (Leverage) Ratio	LEVR	Max	0.1003
Total Risk-Based Capital Ratio (PCA)	PCA	Max	0.1000
Net Loans & Leases to Total Deposits	LTD	Max	0.1004
Insured Deposits as a Percent of Total Deposits	ID	Max	0.0996
Liquidity Ratio	LR	Max	0.0994

Percent of Loans and Leases Noncurrent (NPL) criterion is cost-oriented because it produces cost for banks. The other 9 criteria are benefit-oriented criteria. The knowledge about how the criterion weights to be found and how to interpret them will be explained later.

The FDIC bank groups' financial ratios are shown in the decision matrix below. The numbers in the matrix are the arithmetic average between 2018-2022. Financial ratios of the five FDIC insured bank groups in the USA can be seen in Table 3.

Table 3. Initial Decision Matrix-FDIC Insured Banks' Financial Ratios between 2018-2022

	ROA	**ROE**	**NIM**	**NPL**	**ECA**	**LEVR**	**PCA**	**LTD**	**ID**	**LR**
Group Code	Max	Max	Max	Min	Max	Max	Max	Max	Max	Max
Group 1	1.07	10.80	2.65	1.00	9.91	8.40	14.95	53.99	44.37	38.21
Group 2	1.32	12.04	3.53	0.98	10.92	9.72	14.74	74.89	55.99	26.18
Group 3	1.31	11.99	3.62	0.72	11.08	10.55	15.08	82.19	66.70	19.99
Group 4	1.22	11.30	3.63	0.70	10.97	11.12	16.86	75.79	73.85	24.19
Group 5	0.78	5.79	3.56	1.09	13.43	13.62	23.55	65.72	83.39	33.46
Max	***1.32***	***12.04***	***3.63***	***1.09***	***13.43***	***13.62***	***23.55***	***82.19***	***83.39***	***38.21***
Min	***0.78***	***5.79***	***2.65***	***0.70***	***9.91***	***8.40***	***14.74***	***53.99***	***44.37***	***19.99***

Source: FDIC Quarterly Banking Profile, QBP Time Series Spreadsheets. https://www.fdic.gov/analysis/quarterly-banking-profile/index.html. The numbers are the arithmetic average of the four years between 2018-2022.

At first, the matrix numbers must be normalized. Thus, the numbers or values of different criteria units can be reduced to the 0-1 scale. For this, as the first stage of the PARIS method, the initial decision matrix elements were normalized by using Equation 10 or Equation 11. The selection of these equations depends on whether the optimum of the criterion is cost-oriented or benefit-oriented. In this application, only the second way was selected and used from the three different normalization ways of the method (Ardil, 2021). The results of normalization are presented in Table 4.

Table 4. Normalized Decision Matrix (rij)

	ROA	**ROE**	**NIM**	**NPL**	**ECA**	**LEVR**	**PCA**	**LTD**	**ID**	**LR**
Group	*Max*	*Max*	*Max*	*Min*	*Max*	*Max*	*Max*	*Max*	*Max*	*Max*
Group 1	0.811	0.897	0.730	0.697	0.738	0.616	0.635	0.657	0.532	1.000
Group 2	1.000	1.000	0.972	0.711	0.813	0.714	0.626	0.911	0.671	0.685
Group 3	0.997	0.996	0.998	0.969	0.825	0.774	0.640	1.000	0.800	0.523
Group 4	0.929	0.938	1.000	1.000	0.817	0.816	0.716	0.922	0.886	0.633
Group 5	0.590	0.481	0.982	0.640	1.000	1.000	1.000	0.800	1.000	0.876

In the second stage, the weighted normalized values z_{ij} should be calculated using Equation 14. Before doing so, the criterion weights wj must be determined by the ENTROPY method. Since the first two stages of the ENTROPY method are identical to the PARIS method, the third stage has been continued. At this stage, Share in Total Matrix was arranged in Table 5.

Table 5. Share in Total Matrix

	ROA	**ROE**	**NIM**	**NPL**	**ECA**	**LEVR**	**PCA**	**LTD**	**ID**	**LR**
Code	Max	Max	Max	Min	Max	Max	Max	Max	Max	Max
Group 1	0.19	0.21	0.16	0.17	0.18	0.16	0.18	0.15	0.14	0.27
Group 2	0.23	0.23	0.21	0.18	0.19	0.18	0.17	0.21	0.17	0.18
Group 3	0.23	0.23	0.21	0.24	0.20	0.20	0.18	0.23	0.21	0.14
Group 4	0.21	0.22	0.21	0.25	0.19	0.21	0.20	0.21	0.23	0.17
Group 5	0.14	0.11	0.21	0.16	0.24	0.26	0.28	0.19	0.26	0.24
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Then the ENTROPY weight values of each criterion in the matrix in Table 5 are calculated by using Equation 4, 5 and 6 respectively. The results can be seen in Table 6.

Table 6. Criterion Weights (w)

	ROA	ROE	NIM	NPL	ECA	LEVR	PCA	LTD	ID	LR	
Code	Max	Max	Max	Min	Max	Max	Max	Max	Max	Max	
Group 1	-0.508	-0.477	-0.564	-0.532	-0.527	-0.562	-0.528	-0.570	-0.604	-0.399	
Group 2	-0.445	-0.444	-0.477	-0.526	-0.498	-0.517	-0.533	-0.470	-0.533	-0.513	
Group 3	-0.446	-0.445	-0.469	-0.432	-0.493	-0.492	-0.526	-0.442	-0.480	-0.595	
Group 4	-0.467	-0.463	-0.469	-0.422	-0.497	-0.476	-0.492	-0.467	-0.449	-0.537	
Group 5	-0.605	-0.666	-0.474	-0.557	-0.435	-0.415	-0.390	-0.510	-0.412	-0.439	
AVR	-0.4941	-0.4988	-0.4907	-0.4937	-0.4901	-0.4924	-0.4937	-0.4917	-0.4957	-0.4967	SUM Dj
dj= (1-cj)	0.5059	0.5012	0.5093	0.5063	0.5099	0.5076	0.5063	0.5083	0.5043	0.5033	5.0625
cj= (1-dj)	1.5059	1.5012	1.5093	1.5063	1.5099	1.5076	1.5063	1.5083	1.5043	1.5033	
wj	0.0999	0.0990	0.1006	0.1000	0.1007	0.1003	0.1000	0.1004	0.0996	0.0994	1.0000
RANK	7	10	2	6	1	4	5	3	8	9	

According to Table 6, we see that the difference in importance among the criteria is not very big and that the criteria used in the analysis have almost equal weight. The most important criterion showing the financial performance of the bank groups is ECA. NIM, LTD ratios follow it respectively. ECA has the biggest weight with 10,07 percent. NIM has the second big weight with 10,06 percent and LTD has the third biggest weight with 10,04. The least important criterion is ROE with its 9,90 percent. We can also see from the table that the total of the criterion weights is equal to 1.

After determining the weights, weighted decision matrix was formed according to the PARIS method. Equation 14 is used for this purpose. The results obtained are shown in Table 7.

Table 7. Weighted Decision Matrix (zij) ve π_i^{ω} values

	ROA	ROE	NIM	NPL	ECA	LEVR	PCA	LTD	ID	LR	Sum (π_i^{ω})	Rank
Code	*Max*	*Max*	*Max*	*Min*	*Max*	*Max*	*Max*	*Max*	*Max*	*Max*		
Weight (w)	*0.100*	*0.099*	*0.101*	*0.100*	*0.101*	*0.100*	*0.100*	*0.100*	*0.100*	*0.099*		
Group 1	0.081	0.089	0.073	0.070	0.074	0.062	0.063	0.066	0.053	0.099	0.731	**5**
Group 2	0.100	0.099	0.098	0.071	0.082	0.072	0.063	0.091	0.067	0.068	0.810	**4**
Group 3	0.100	0.099	0.100	0.097	0.083	0.078	0.064	0.100	0.080	0.052	0.852	**2**
Group 4	0.093	0.093	0.101	0.100	0.082	0.082	0.072	0.093	0.088	0.063	0.866	**1**
Group 5	0.059	0.048	0.099	0.064	0.101	0.100	0.100	0.080	0.100	0.087	0.837	**3**
min/max (zj*)	0.100	0.099	0.101	0.064	0.101	0.100	0.100	0.100	0.100	0.099		

According to Table 7, Group 4 was the group that received the highest score and ranked first in the ranking formed by the horizontal sum of the weighted matrix values (π_i^{ω}) of each group from largest to smallest. The

total score of this group is 0.866 points. The second best group was Group 3 with 0.852 points. Group 5 took third place. Group 1 was in last place after Group 2 in ranking.

According to the PARIS method, this ranking must be confirmed by the other two rankings. One of them is sorted according to π_i^* values of the bank groups and the other is ranking made by R_j values. These rankings are shown in Table 8 and Table 9 below, respectively.

Table 8. π_i^* *Values and Ranking*

	πj^*	Rank
Group 1	0.021	**5**
Group 2	0.012	**4**
Group 3	-0.015	**2**
Group 4	-0.018	**1**
Group 5	0.000	**3**

Table 9. R_j *Values and Ranking*

	Ri	Rank
Group 1	0.140	**5**
Group 2	0.063	**4**
Group 3	0.014	**2**
Group 4	0.000	**1**
Group 5	0.033	**3**

The rankings in Table 8 and Table 9 are the same as in Table 7 (ranking of π_i^{ω}) and confirm it. In these two tables ranking from best to worst is realized as Group 4 > Group 3 > Group 5 > Group 2 > Group 1. In other words, Group 4 had the lowest score in Table 8 (ranking of π_i^*) and Table 9 (ranking of R_j) and had the best place in both rankings. In general, in all three rankings made according to the PARIS method, the following result emerged.

Table 10. Final Ranking

Bank Asset Size Groups in FDIC System	**Code**	**Ranking**
Assets $100 Million - $1 Billion	Group 4	1
Assets $1 Billion - $10 Billion	Group 3	2
Assets < $100 Million	Group 5	3
Assets $10 Billion - $250 Billion	Group 2	4
Assets > $250 Billion	Group 1	5

According to the table above, the bank group in FDIC system with assets "between $100 Million - $1 Billion" performed the best in the period of 2018-2022 based on the selected 10 criteria such as Return on Assets, Return on Equity, Net Interest Margin, Percent of Loans and Leases Noncurrent, Equity Capital to Assets, Core Capital (Leverage) Ratio, Total Risk-Based Capital Ratio, Net Loans & Leases to Total Deposits, Insured Deposits as a Percent of Total Deposits and Liquidity Ratio. The worst performing bank group was the bank group in FDIC system with assets over $250 Billion. According to this result, it is understood that the banks with large assets in the US banking system have not performed well for the last 4 years. This result can be interpreted as an indication that systematic risk has increased and the state budget may deteriorate.

5. Conclusion

With two bank failures in the United States in 2023, investors and financial experts have focused on the financial performance and soundness of the deposit banks operating in the country. In this study, a comparison was made among the bank groups in FDIC system by evaluating their financial ratios (criteria). For this study, the ENTROPY method was used to determine the criterion weight and the PARIS method was used to rank bank groups classified by the asset size. Both methods are types of the multi-criteria decision- making techniques (MCDM). The performance analysis is based on ten criteria such as Return on Assets, Return on Equity, Net Interest Margin, Percent of Loans and Leases Noncurrent, Equity Capital to Assets, Core Capital (Leverage) Ratio, Total Risk-Based Capital Ratio, Net Loans & Leases to Total Deposits, Insured Deposits as a Percent of Total Deposits and Liquidity Ratio. According to the ENTROPY weighting method, the most important criterion was Equity Capital to Assets (ECA). Net Interest Margin (NIM) and Net Loans & Leases to Total Deposits (LTD) ratios follow it respectively. However, there were not much difference in significance among the criteria. The least important criterion was ROE. According to the PARIS method, the bank group in FDIC system with assets "between $100 Million - $1 Billion" performed the best in the period of 2018-2022. The worst performing bank group was the bank group in FDIC system with assets over $250 Billion. Naturally, It is possible to say that result of research may change depending on the method used.

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